Forest Ecology and Management 312 (2014) 117–128

Contents lists available at ScienceDirect

Forest Ecology and Management

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

Forest regeneration in gaps seven years after partial harvesting in riparian buffers of boreal mixedwood streams

Azim U. Mallik [a,*], David P. Kreutzweiser [b], Cristina M. Spalvieri [a]

[a] Department of Biology, Lakehead University, Thunder Bay, Ontario P7B 5E1, Canada
[b] Canadian Forest Service, Natural Resources Canada, 1219 Queen St. East, Sault Ste. Marie, Ontario P6A 5E2, Canada

ARTICLE INFO

Article history:
Received 16 August 2013
Received in revised form 5 October 2013
Accepted 9 October 2013
Available online 7 November 2013

Keywords:
Selective harvesting
Gap regeneration
Conifers
Hardwoods
Natural disturbance
emulation (END) principles

ABSTRACT

Partial harvesting in boreal forest riparian buffers has been proposed as a management tool to emulate natural disturbance (END) along streams and lakes to increase shoreline habitat complexity through ensuing forest regeneration. We investigated the effect of partial harvesting in stream-side riparian buffers on regeneration of canopy species (*Abies balsamea*, *Betula papyrifera*, *Picea glauca*, *Picea mariana* and *Populus tremuloides*) by testing the hypothesis that juvenile trees would be more abundant, species-rich, and larger in gaps than in non-harvested buffers, and that those differences would be proportional to gap size. Our main objective was to determine what gaps sizes are conducive to promote tree and woody shrub regeneration in stream-side riparian areas of boreal mixedwood forests. We compared woody plant regeneration among harvest gaps varying in size (small, 10–20 m^2; medium, 21–100 m^2; and large, >100 m^2), and contrasted with regeneration under closed canopy in unharvested buffers and undisturbed reference forests. We found that woody plant communities in partial harvesting gaps were denser and more diverse than unharvested buffers. They were more so in medium to large gaps and consisted of shade-intolerant and early successional species. Favorable light and soil temperature in the large gaps appear to be responsible for this. We concluded that intentional shoreline disturbance aiming to achieve increased riparian habitat complexity and early successional forest community is possible by partial harvesting at up to 50% basal area removal. However, as END principles are increasingly applied to riparian forest management, it will be necessary to test and monitor the effectiveness and longer-term ecological responses of riparian communities to such management at catchment and landscape levels.

1. Introduction

Forest management practices in North America are increasingly including the emulation of natural disturbance (END) as a guiding principle to sustain natural forest structure and processes (Long, 2009), and this applies to riparian (shoreline) as well as upland forests (Macdonald et al., 2004). In managed boreal forests, riparian buffers (shoreline bands of undisturbed riparian forests, also called riparian reserves) are maintained along margins of streams and lakes to protect stream water quality, fish and other aquatic biota (Lee et al., 2004). But these riparian buffers devoid of natural disturbance such as wildfire are considered unnatural (Buttle, 2002). To emulate natural disturbances along lake- and stream-side forests, varying levels of harvesting, including partial harvesting and variable retention in riparian buffers have been suggested as riparian forest management options (OMNR, 2001, 2010; Macdonald et al., 2004).

In the boreal forest, wildfire is the predominant natural disturbance that affects forest patterns (McCarthy, 2001), and while fires do not avoid riparian forests (Lamb et al., 2003; Braithwaite and Mallik, 2012), they do tend to burn more patchily as they approach water bodies (Nitschke, 2005). It has been suggested that partial harvesting in riparian buffers may emulate this riparian forest patchiness thereby producing more natural shoreline forests than conventional no-harvest buffers (Kardynal et al., 2009; Holmes et al., 2010; Sibley et al., 2012).

Intentional shoreline disturbance by harvesting is intended to emulate natural shoreline disturbances that produce a range in riparian forest structure and composition (Palik et al., 2000; Kreutzweiser et al., 2012). This is particularly applicable in landscapes where forest harvest rotation times can approximate natural disturbance such as fire return intervals in the North American central boreal forest. One of the goals of intentional shoreline harvesting is to increase shoreline habitat complexity by creating areas of disturbance sufficient to promote early-successional regeneration in riparian forests to support biodiversity (Naylor et al., 2012). As in upland forests, natural recovery following disturbances through secondary succession also occurs in riparian

* Corresponding author. Tel.: +1 807 343 8927; fax: +1 807 346 7797.
E-mail address: amallik@lakeheadu.ca (A.U. Mallik).

0378-1127/$ - see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.foreco.2013.10.015

areas (Swanson et al. (2011). But it is currently unknown if intentional disturbance such as partial harvesting in riparian buffers of boreal mixedwood forests can emulate those regeneration processes and produce shoreline patches of early successional forest.

Partial harvesting creates canopy gaps, and gap sizes are important determinants of forest structure, particularly in the absence of stand replacing disturbance (McCarthy, 2001; Dobrowolska and Veblen, 2008). Senescence or natural disturbances such as windthrough, ice damage, insect defoliation and wildfire produce a range of gap sizes from the death of single to many trees creating growing space for newly recruited or suppressed seedlings. Small-scale canopy disturbances only affect a few trees at a time. These disturbances often result in uneven-aged stand structure and greater species diversity (Forcier, 1975; Runkle, 1982; Grushecky and Fajvan, 1999). Although tree regeneration in forest gaps has been widely studied in temperate and boreal forests (Runkle, 1982; Kneeshaw and Bergeron, 1998; Pham et al., 2004; Hill et al., 2005; Dobrowolska and Veblen, 2008; Brais et al., 2013) little is known about the effect of canopy gaps created by partial harvesting in riparian buffers.

We assessed woody plant communities in gaps created by partial harvesting at up to 50% basal area removal in riparian buffers and compared them to nearby reference (no-harvest) buffer plots. We previously reported riparian understory plant responses to the partial harvesting at three years post-harvest (Mallik et al., 2013). Here we report on the response of shrubs and commercially desirable juvenile trees in the harvested gaps seven-year post-harvest across a gradient of canopy gap size. Our main objective was to determine what gaps sizes are conducive to promote early successional regeneration in stream-side riparian areas of boreal mixedwood forests.

We hypothesized that woody plants would be taller, more abundant and species-rich in gaps in partially harvested buffers than in non-harvested buffers, and that those differences would be proportional to gap sizes and their characteristic microenvironment. This was based on the well-established understanding that the removal of canopy trees and resultant increased light penetration to forest floors generally stimulate tree seedling and sapling growth, especially among shade-intolerant species (McCarthy, 2001). However, these potential effects are less well known in riparian areas of boreal forest streams, and in particular, it is not known if gaps created by partial harvesting in riparian areas of boreal forests are sufficient to induce these regeneration effects. Specifically, we intended to determine the size of gaps required to promote early-successional forest regeneration in stream-side riparian areas of boreal mixedwood forests.

2. Materials and methods

2.1. Study area

The study area was located about 60 km south of White River, Ontario on the boreal shield of central Canada, 75 km inland from the northeastern shore of Lake Superior (latitude 48°19′35″N, longitude 85°21′01″W) (Fig. 1). The forest in the study area is boreal mixedwoods with varying proportions of white spruce (*Picea glauca* (Moench) Voss), black spruce (*Picea mariana* (Miller) B.S.P.), balsam fir (*Abies balsamea* (L.) Miller), jack pine (*Pinus banksiana* Lamb.) trembling aspen (*Populus tremuloides* Michx.), and white birch (*Betula papyrifera* Marshall). The dominant understory vegetation includes *Cornus canadensis* L., *Vaccinium angustifolium* L., *V. myrtilloides* L., *Clintonia borealis* (Ait.) Raf., and *Pleurozium schreberi*

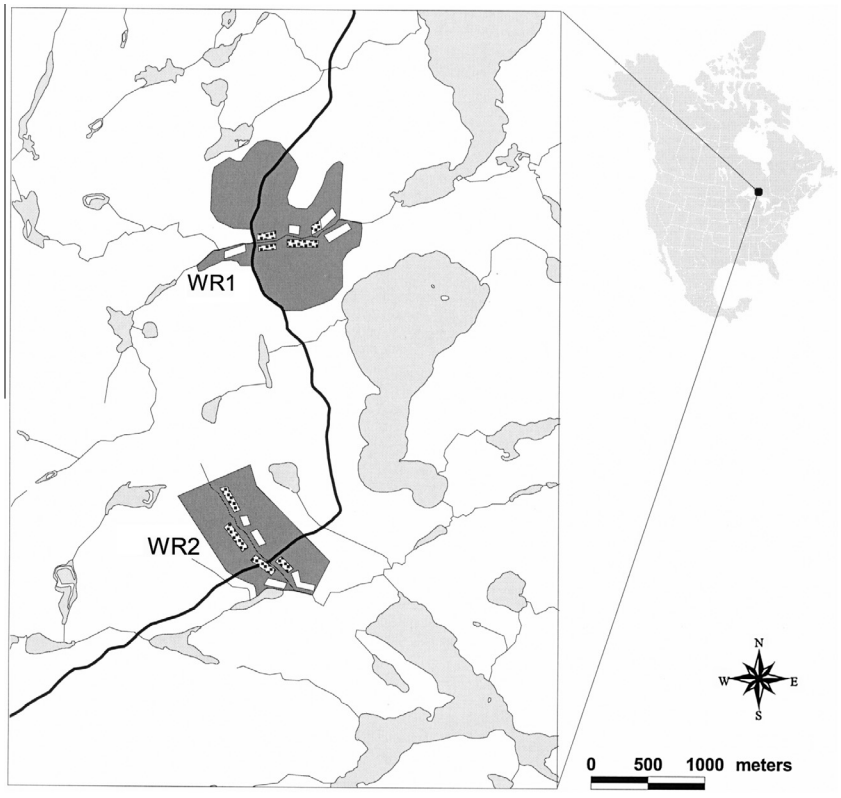

Fig. 1. The two study areas in the White River Riparian Harvesting Impacts Project, near White River, Ontario, in the central North American boreal zone. Dark shading indicates the total harvest area, light shading indicates lakes and ponds. The heavy dark line is a logging road, the lighter lines are streams. Areas in riparian (stream-side) buffers that were partially harvested and included assessment gaps are indicated by dotted rectangles. Areas in non-harvested riparian buffers in which reference plots were established are indicated by open rectangles.