Forest Ecology and Management 403 (2017) 79–95

Contents lists available at ScienceDirect

Forest Ecology and Management

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

Early white spruce regeneration treatments increase birch and reduce aspen after 28 years: Toward an integrated management of boreal post-fire salvaged stands

Andrew C. Allaby[a], Glenn P. Juday[a,*], Brian D. Young[b]

[a] Department of Forest Sciences, University of Alaska Fairbanks, Fairbanks, AK 99775, USA
[b] Department of Natural Science, Landmark College, Putney, VT 05346, USA

ARTICLE INFO

Keywords:
Salvage harvest
Alaska
Picea glauca
Betula neoalaskana
Assisted regeneration
Site preparation

ABSTRACT

Post-harvest regeneration failure of white spruce (*Picea glauca* Moench [Voss]), has led to concerns of "de-coniferization" on productive site in the Alaskan boreal forest. Forest management in the region sought historically to increase spruce composition after harvest through silvicultural practices such as site preparation and assisted regeneration; however, successful reforestation requires the effects of these practices to persist over time and control non-target tree species. In order to identify the enduring effects of silvicultural regeneration practices, we sampled a large (26.7 ha) white spruce regeneration trial established immediately following a stand-replacing wildfire and subsequent salvage harvest in a productive upland forest. The original regeneration treatments followed a split-split plot experimental design on two landform types (LF), four ground scarification treatments (GST) plus a non-scarified control, and five artificial white spruce regeneration treatments (WSRT) plus a natural seedfall control (Densmore et al., 1999). Here we analyze the total biomass, stand density, and basal area for all tree species within each of the regeneration treatments 28 years post-establishment, and calculate seed dispersal distances. Our results show that compared to natural seedfall control plots, white spruce basal area was six times greater in planted seedling plots, and white spruce stem density (dbh ≥ 1.0 cm) was nearly three times greater in broadcast seeding plots. White spruce stem density from natural seedfall averaged 944 stems ha^{-1}, but was dependent on both topographic position and distance to wind-dispersed seed sources. Our results also indicate that GST had few significant effects on white spruce basal area or stem density. However, scarification nearly doubled Alaska birch (*Betula neoalaskana* Sarg.) stem density and basal area compared to non-scarified control plots. Planted white spruce plots supported 19% less birch basal area, except in the most intensive scarification treatments in which birch basal area did not differ. Intensive scarification reduced quaking aspen (*Populus tremuloides* Michx.) basal area by half on slope plots. Our results demonstrate that early regeneration practices profoundly influence stand development beyond the stem initiation stage, but pre-fire stand type, post-fire configuration of unburned seed sources, and topographical variation play a mediating role in determining species assemblages and competitive relationships. A fire-killed stand must be considered within its ecological and landscape context to determine the probable success of a management action such as salvage and tree regeneration.

1. Introduction

Silvicultural practices employed in slow-growing northern forests aim to influence future forest composition by emulating typical post-disturbance successional processes (Drever et al., 2006). Stand-replacing wildfire, the principal disturbance in the boreal forest, kills most sexually mature trees and initiates secondary succession (Heinselman, 1981). Boreal forest communities have adapted to particular fire frequencies, sizes, and severities (Weber and Flannigan, 1997), and individual tree species display reproductive strategies suited to post-wildfire conditions (Greene et al., 1999). Wildfires combust forest floor organic layers that hinder seedling establishment (Johnstone and Chapin, 2006), remove competing vegetation (Zasada et al., 1992), and leave a heterogeneous burn mosaic that permits remnant trees and legacy rootstocks to reproduce (Greene et al., 2006). Following a disturbance, seedling recruitment is especially constrained by propagule availability and seedbed receptivity to a short period of time (Zasada, 1986). Successful reforestation, whether natural or actively managed,

---

* Corresponding author.
E-mail address: gpjuday@alaska.edu (G.P. Juday).

http://dx.doi.org/10.1016/j.foreco.2017.07.047
Received 10 March 2017; Received in revised form 18 July 2017; Accepted 27 July 2017

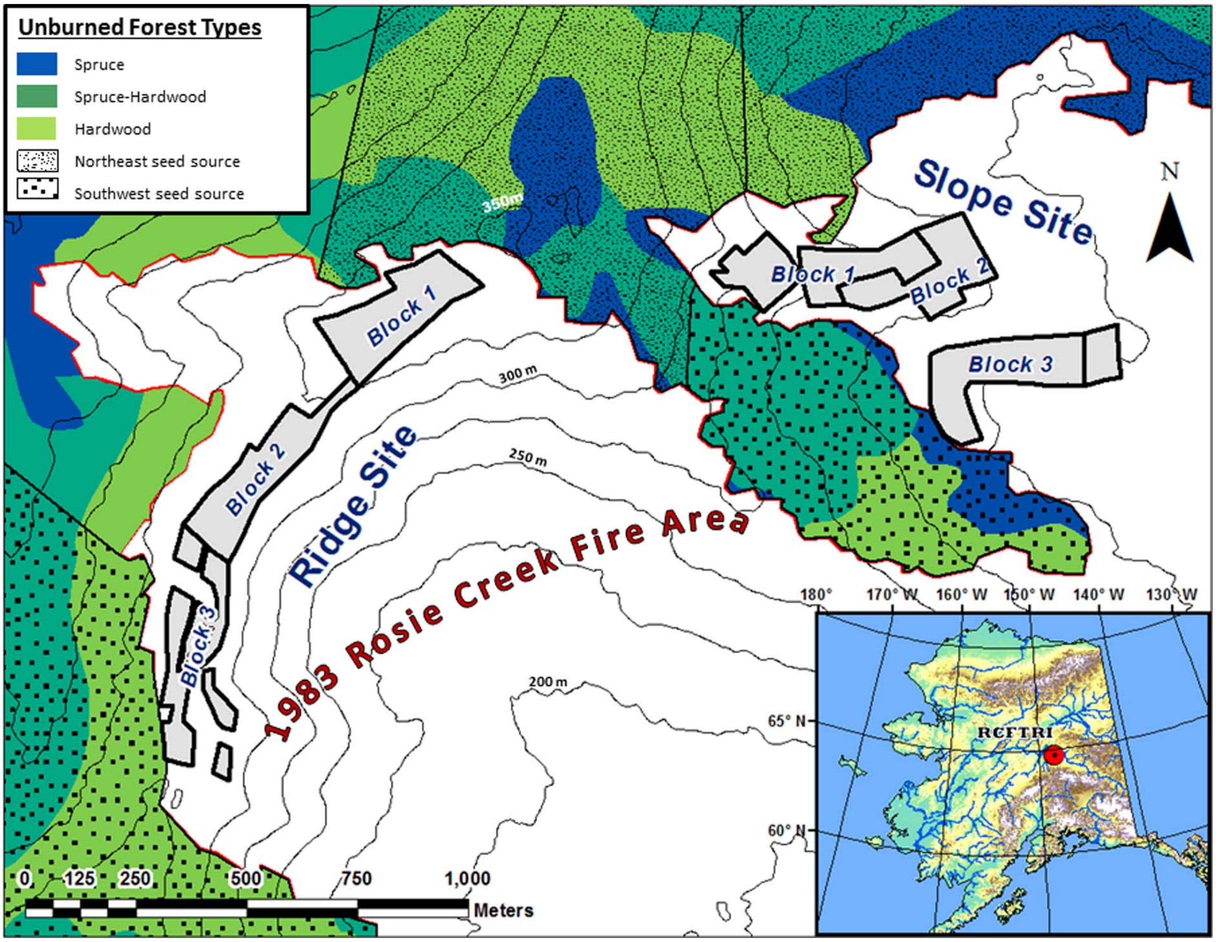

Fig. 1. Overview map of RCFTRI with unburned forest types and GIS-classified wind-dispersed seed sources. Pre-fire forest types classified by AHAP (1988). Seed source regions and burned area classified by authors using ArcMap 10.1 (ESRI, Redlands, CA). Prevailing wind during fall seed abscission comes with equal likelihood from the northeast and southwest (Youngblood and Max, 1992).

must be achieved during the boreal forest's brief stem initiation stage before canopy closure and organic layer accumulation significantly reduce the probability of further tree establishment (Johnstone et al., 2004; Johnstone and Chapin, 2006).

Boreal forest management activities not only aim to reestablish tree seedlings after a stand-replacing disturbance, but also to channel site productivity into preferred species and reduce rotation length (Hawkins et al., 2006; Cortini et al., 2010). Similar to post-fire effects, site preparation such as mechanical scarification reduces overtopping vegetation and exposes mineral soil, which increases rooting zone temperatures and reduces competition faced by small tree seedlings (Zasada and Grigal, 1978; Bella, 1986). Another common boreal silvicultural practice is the introduction of seed or planted seedlings to re-establish desired tree species (Youngblood and Zasada, 1991), which may otherwise decline in abundance or growth. The addition of seed or seedlings to a site post-harvest can be similar to the effect that residual seed trees produce in a patchy post-fire mosaic. Silvicultural practices which reliably produce the desired lasting effects on forest composition are especially critical in boreal forest ecosystems, where low productivity and thin economic margins place great importance on efficient, low-intensity management (Wurtz et al., 2006).

Boreal silvicultural research historically addressed the regeneration challenges of non-serotinous conifers following harvest (see Gärtner et al., 2011; Juday et al., 2013), focusing especially on the stem initiation stage of forest development for a single tree species: white spruce (*Picea glauca* Moench [Voss]) (see for example Zasada and Grigal, 1978; Wurtz et al., 2006). However, the stem exclusion stage that follows, during which trees grow into saplings and the canopy closes, involves intense competition between individuals and species for light, moisture, and nutrients (Zasada and Packee, 1995), has not been well evaluated. Ingrowth of non-crop species may compromise the effectiveness of silvicultural practices meant to foster a single species, for example the reversion of cutover spruce sites in Alberta to high-density hardwoods (Henderson, 1988).

Within minimally tended boreal mixed forests, crop tree characteristics measured early in a stand's development may not account for future stand conditions for three reasons. First, early regeneration treatments may attenuate over time as the competitive environment changes (see for example Bedford et al., 2000, Boateng et al., 2006). Second, unintended results of treatments may become apparent later in stand development (see for example Wurtz and Zasada, 2001). Third, boreal mixedwood stands may experience extended recruitment periods of shade-tolerant conifers, including continued recruitment on decomposing logs further into the life of the new stand. For example, quaking aspen (*Populus tremuloides* Michx.) canopies can let in sufficient light to permit continued white spruce establishment, typically reaching maximum stem density more than 20 years post-fire (Youngblood, 1995; Lieffers et al., 1996). Confirming truly effective regeneration practices in the boreal mixed forest requires an examination of the durability of initial results in later stages of stand development for all tree species present.

The goal of this study was to reevaluate whether early assisted regeneration practices typically used in western North American boreal forests meet two objectives: increase forest composition of target tree species and decrease non-target species in the stem exclusion stage. We analyzed an assisted regeneration trial established following a stand-