Forest Ecology and Management 363 (2016) 267–276

Contents lists available at ScienceDirect

Forest Ecology and Management

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

Snag dynamics in northern hardwood forests under different management scenarios

Karin S. Fassnacht [a,*], Thomas W. Steele [b]

[a] Wisconsin Department of Natural Resources, 101 South Webster Street, P.O. Box 7921, Madison, WI 53707-7921, USA
[b] Kemp Natural Resources Station, University of Wisconsin – Madison, 9161 Kemp Road, Woodruff, WI 54568, USA

ARTICLE INFO

Article history:
Received 27 August 2015
Received in revised form 21 November 2015
Accepted 3 December 2015
Available online 21 January 2016

Keywords:
Snag management
Created snags
Tree girdling
Snag supplementation
Timber harvest
Stand complexity

ABSTRACT

Snag retention is increasingly being incorporated into forest management guidelines. Questions remain, however, in northern hardwood systems regarding factors affecting retention in actively managed stands, the effectiveness of snag creation, and the net effects of snag creation and timber harvesting on snag numbers and sizes. To address some of these questions, we examined the dynamics of natural and created snags within mature, even-aged northern hardwood forests under seven different management scenarios: three Harvest Only treatments, three Harvest Plus (created) Snags treatments, and one untreated Control. We found tree diameter, tree species, and stand treatment status (i.e., managed or Control) to be related to the retention of natural snags, created snags, or both. Snags were less likely to remain standing if they had smaller diameters, were species with relatively rapid decay rates, or were found in stands that had been logged. We found girdling trees to be an effective method of dead wood creation, although trees took longer to die than we expected. At least 84% of girdled trees had died in most stands within 4.5 years of girdling, and 30–77% of girdled trees were still standing 5.5 years after treatment. Comparison of net effects of snag creation and timber harvesting among treatments showed that managed stands, on average, experienced net snag losses compared to untreated Controls. These losses were statistically significant for all snag sizes, but not for large snags alone (i.e., dbh $\geqslant$25.4 cm). Active management prescriptions that included snag creation demonstrated the potential to mitigate snag losses, with the extent of mitigation varying with the type of management. Surprisingly, mitigation was primarily driven by significantly greater *natural* snag recruitment in Plus Snags treatments, potentially due to competition from girdled trees that had not yet died. Our results may help inform the development of snag management guidelines in even-aged, second-growth northern hardwood systems for forest managers who are interested in enhancing the structural complexity of these forests.

1. Introduction

Standing dead trees, colloquially known as snags, play a vital role in the provision of ecosystem services. For example, they comprise essential habitat for many wildlife species (Davis et al., 1983; Maser et al., 1979; Thomas et al., 1979), and they contribute to fundamental ecological processes such as nutrient cycling, carbon storage, and seedbed creation through their ultimate fragmentation and fall (Harmon et al., 1986). Historically, silvicultural prescriptions sought to maximize timber productivity and minimize the loss of merchantable trees to mortality by assessing tree health during timber marking, and harvesting at-risk trees during periodic stand entries. Over time, such management practices contributed to a reduction in the number of large snags and a decrease in stand complexity (Crow et al., 2002; Goodburn and Lorimer, 1998; McGee et al., 1999).

The importance of snags to forest health has been documented extensively in the literature (e.g., Franklin et al., 2007), and snag retention is increasingly incorporated into forest management guidelines (e.g., Minnesota Forest Resources Council, 2013; Smith et al., 2009; Sustainable Forestry Initiative, 2015) often as a means of maintaining or restoring forest complexity, diversity, and resilience (Franklin et al., 2007; Lindenmayer and Franklin, 2002; Minnesota Forest Resources Council, 2013; Michigan Department of Natural Resources, 2013a,b; Tubbs et al., 1987). Large-diameter snags are especially valuable, conferring more ecological benefits than small-diameter snags (Bull et al., 1997; Harmon et al., 1986; Mannan et al., 1980). Some management guidelines

* Corresponding author.
E-mail addresses: karin.fassnacht@wi.gov (K.S. Fassnacht), thomas.steele@wisc.edu (T.W. Steele).

http://dx.doi.org/10.1016/j.foreco.2015.12.003
0378-1127/

acknowledge this difference by specifically encouraging the retention of large snags (e.g., Michigan Department of Natural Resources, 2013a,b; New York State Department of Environmental Conservation, 2011; Wisconsin Department of Natural Resources, 2010).

A thorough understanding of snag dynamics – that is the patterns of snag retention, recruitment, and net change over time – is necessary to develop effective snag management prescriptions which may suggest the number, size, species, and/or spacing of retained or created snags. Such an understanding includes having knowledge about potential impacts of timber harvesting on pre-existing, naturally occurring snags, as well as understanding the dynamics of snags created via girdling. This information not only makes it possible to assess the feasibility of meeting snag retention goals (Doyon et al., 2005; Garber et al., 2005; Russell et al., 2006; Smith et al., 2009), but also helps identify key silvicultural and operational factors that can be modified to increase snag retention where desirable (Vanderwel et al., 2006).

Although snag dynamics have been studied within forested systems of the western United States for some time (Cline et al., 1980; Everett et al., 1999; Raphael and Morrison, 1987; Russell et al., 2006), they have received attention only recently in the east (e.g., Corace et al., 2010; Garber et al., 2005; Moorman et al., 1999; Tyrrell and Crow, 1994; Wilson and McComb, 2005); and studies examining snag dynamics in northern hardwood systems are especially lacking (Vanderwel et al., 2006). Questions remain regarding factors contributing to the retention of both natural and created snags in actively-managed northern hardwood systems, the effectiveness of creating snags through girdling and other means, and the net effects of snag creation and timber harvesting on total snag numbers and sizes. On questions regarding created snags in particular, species-specific differences in wound response and decay rates, and how those interact with local climate, make comparisons across forests and regions difficult.

To help address some of these outstanding questions, in this paper we seek to describe the dynamics and characteristics of natural and created snags within mature, even-aged northern hardwood forests under seven different forest management scenarios. Specifically, we ask: (1) What effect, if any, does timber harvesting have on natural snag retention and recruitment? Does effect vary by silvicultural prescription? (2) What individual characteristics affect the probability a natural snag will fall? (3) How long does a girdled tree take to die? How long will that created snag remain standing? (4) What factors affect the probability a girdled tree will die and remain standing? (5) What is the combined (net) effect on snag density of timber harvest and snag-creation practices? Answers to these questions will help inform the development of effective snag management guidelines for northern hardwood forests.

2. Materials and methods

2.1. Study area

Our study was one component of a long-term, multidisciplinary, operational-scale experiment assessing the effectiveness of silvicultural methods to accelerate the development of structural and compositional complexity in second-growth northern hardwood forests (Fassnacht et al., 2013). The experiment is being conducted on three public forests in northern Wisconsin (Fig. 1), a region with warm, humid summers and cold, snowy winters (University of Wisconsin Extension, 2011). Soils range from silt loam over sandy loam at the Flambeau site (Fig. 1) (Voigtlander, 2006a,b), to sandy loam over stratified outwash sand and gravel at the Highlands site (Natzke and Hvizdak, 1988), to sandy loam soils that are typically stony at the Argonne site (Boelter et al., 1995). Study stands were generally dominated by maple (*Acer saccharum*, *A. rubrum*) and basswood (*Tilia americana*) and were 70–90 yr old at the beginning of the study (Appendix A Table A.1). Detailed site descriptions can be found in Fassnacht et al. (2013).

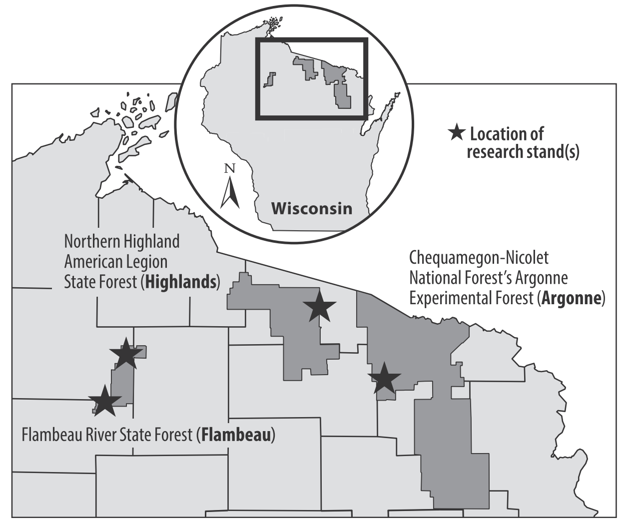

Fig. 1. Locations of northern Wisconsin study sites for the Managed Old-growth Silvicultural Study (MOSS). Figure from Fassnacht et al. (2013).

2.2. Study design and treatment description

Six active silvicultural treatments and one passive, unmanaged Control are replicated at each of the three study sites. Active treatments combine three canopy treatments with two snag treatments in an augmented split-plot design (Piepho et al., 2006). Canopy treatments are whole plots (~50 ha), while snag treatments are split plots (~25 ha; Appendix A Fig. A.1). Unmanaged Control stands contain neither canopy nor snag treatments and are ~50 ha in size.

The three active canopy treatments include Small Gaps, Large Gaps, and Irregular Multi-cohort prescriptions. In the Small Gaps treatment, approximately ten 10.7-m diameter gaps ha^{-1} were created and the inter-gap area (i.e., matrix) was thinned. In the Large Gaps treatment, approximately two gaps per hectare were created, alternating in size between 18.3 m and 24.4 m in diameter. The matrix in these stands was thinned as well. The Irregular Multi-cohort treatment was designed to mimic a moderate-intensity wind disturbance (i.e., 30–60% basal area removal). This was achieved by creating a moderately-disturbed matrix with embedded patches of low- and high-intensity disturbance.

The two snag treatments consist of a Harvest Plus Snags treatment (hereafter referred to as Plus Snags) and a Harvest Only treatment. In the Plus Snags treatment, new snags were created purposely via girdling, whereas in the Harvest Only treatment, no trees were girdled. The objective of the Plus Snags treatment was to increase the structural complexity of the second-growth stands beyond that achieved through the canopy treatments alone. Snag-creation levels were established for each location to reflect a balance between enhancing structural complexity and minimizing the impact to stumpage revenues. Approximately five snags per hectare were added, although there was some variation among sites (Appendix A Table A.2) (Fassnacht et al., 2013). Created snags were established by double girdling poor-quality live trees $\geqslant$25.4 cm dbh with a chainsaw (Fassnacht et al., 2013). Girdling occurred subsequent to timber harvest in mid-to-late winter (Argonne), early spring (Flambeau), or late summer (Highlands).