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Wildlife implications across snag treatment types in jack pine stands of Upper Michigan

Shelby A. Weiss[a,*], R. Gregory Corace III[b], Eric L. Toman[a], Daniel A. Herms[c,1], P. Charles Goebel[a,2]

[a] School of Environment and Natural Resources, The Ohio State University, 2021 Coffey Road, Columbus, OH 43210, USA
[b] U.S. Fish and Wildlife Service, Seney National Wildlife Refuge, 1674 Refuge Entrance Road, Seney, MI 49883, USA
[c] Department of Entomology, The Ohio State University, 1680 Madison Avenue, Wooster, OH 44691, USA

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ABSTRACT

Standing dead trees, or snags, represent post-disturbance biological legacies in forest ecosystems, and intentional creation of new snags is increasingly common during forest treatments. The abundance, volume, size, and distribution of snags can affect wildlife communities and stand-level biological diversity. Characteristics such as the wood properties of different tree species, environmental conditions, and cause of tree death (e.g., insects, disease, senescence, wind, fire) can influence decomposition and subsequent use of snags by wildlife. The objectives of this study were to characterize decay patterns in jack pine (*Pinus banksiana*) snags that had been killed by prescribed fire, topping, and girdling and determine the effects of these treatments on subsequent snag use by subcortical insects and primary cavity-nesting birds. The prescribed fire, topping, and girdling treatments were implemented in 2003, 2004, and 2007, respectively; bird excavations were quantified in 2014 and insect activity was measured in 2016. One-way analysis of variance tests were used to examine any differences among treatments in snag characteristics, decay characteristics, past insect activity, and past use by birds. An information theoretic approach to model selection was then used to rank potential predictors of bird foraging activity and cavities. The topping treatment had unique decay characteristics relative to the other two treatments; topped snags had the highest levels of past insect colonization, were softer, and had higher proportions of loose bark remaining on the boles. Trees killed by prescribed fire had the greatest number of foraging excavations and cavities. Girdled snags had the lowest evidence of past insect colonization and showed different levels of decay and insect use at different vertical positions on the snag bole. Comparison of candidate models showed that a model containing treatment type alone was the highest ranked when predicting foraging by birds, while snag diameter was the highest ranked when predicting the presence of cavities. A model containing treatment and snag density was also a highly ranked for predicting cavity presence. Our findings suggest that different jack pine snag treatments result in unique decay trajectories that may influence snag use by an array of wildlife taxa. Our characterization of three snag creation treatments can also inform options for generating snags, depending on the desired outcome, when management for biological legacies and wildlife habitat is of interest within mixed-pine forests of the Great Lakes region.

1. Introduction

Dying trees, standing dead trees (snags), and downed woody material have numerous ecological functions and contribute to structural complexity and biodiversity within forests (Harmon et al., 1986, Franklin, 1988). For example, dying trees increase availability of resources such as light, nutrients, and water, and provide structure and food for a wide range of taxa (Franklin et al., 1987). A diversity of fungi, plants, and animals utilize snags and downed wood throughout their life cycles (Boddy, 2001, Jonsell and Weslien, 2003, Jonsson et al., 2005, Lonsdale et al., 2008).

Within conifer forests of the Great Lakes and boreal regions farther north, past management activities have, in some instances, homogenized stand structure and composition in ways that decrease

* Corresponding author.
E-mail address: shlbweiss@gmail.com (S.A. Weiss).
[1] Present address: 107 N. Walnut St., Wooster, OH 44691, USA.
[2] Present address: Department of Forest, Rangeland, and Fire Sciences, University of Idaho, 875 Perimeter Drive, Moscow, ID 83844, USA.

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resilience to catastrophic disturbance (Bergeron et al., 1998, Perry, 1998, Drever et al., 2006). Additionally, widespread fire suppression and land use changes have altered many forests, resulting in reduced complexity and diversity relative to pre-European settlement conditions (Schulte et al., 2007, Tucker et al., 2016). Although forest management aimed at timber production often has been implicated in forest simplification, forest management specifically directed at wildlife habitat may also fail to generate all structural features characteristic of natural disturbance regimes. For example, jack pine (*Pinus banksiana*) stands on public lands in Lower Michigan are managed for the endangered Kirtland's warbler (*Setophaga kirtlandii*). Treatments to establish breeding habitat begin by clear-cutting mature jack pine, followed by artificial regeneration (hand or machine planting) of jack pine seedlings in an opposing wave pattern (MDNR et al., 2015). Seedlings are planted to produce dense patches of regeneration and other areas are left unplanted and open. While these practices have contributed to the recovery of this neotropical migrant songbird, they have also resulted in unnatural patterns of regeneration (Kashian et al., 2017), with significantly lower levels of snags in plantations (3 snags ha^{-1}) relative to fire-regenerated stands (252 snags ha^{-1}; Spaulding and Rothstein, 2009).

Snags are used by a variety of invertebrates, including subcortical insects that complete a portion of their life cycle beneath the bark of woody plants. Many of these insects colonize certain tree species or utilize trees at specific stages of decay (Byers, 1995, Saint-Germain, 2007). Evidence of past colonization of snags by bark beetles (Curculionidae: Scolytinae) and wood-borers (Cerambycidae: Buprestidae) include entrance and emergence holes on the bole and larval galleries (Wood, 1982). According to Boulanger and Sirois (2007), colonization of dead trees by subcortical insects proceeds in two successional "waves." The first wave occurs when insects colonize standing snags soon after tree death. The second wave occurs with epigeic species that utilize snags after they have fallen. Snag size and stem density are known to influence colonization by subcortical insects as well as subsequent excavation by predatory birds (Saint-Germain et al., 2004, Farris and Zack, 2005). Colonization by insects and foraging by birds are also thought to accelerate snag decay (Harmon et al., 1986, Farris et al., 2004).

A wide range of vertebrates also use snags for shelter, including bats (Chioptera), rodents, bears, and herpetofauna (Holloway and Malcolm, 2007; Bull, 2002; Foster and Kurta, 1999; Johnson and Pelton, 1981). Woodpeckers (Picidae) and even songbirds (e.g., black-capped chickadee, *Poecile atricapillus*) excavate cavities and forage for insects on decaying trees. Primary cavity-nesting bird species often construct cavities that are subsequently exploited by secondary cavity-nesting species (e.g., wood duck, *Aix sponsa*; American kestrel, *Falco sparverius*). However, snags may become less suitable for foraging by birds as snags deteriorate, as colonization by subcortical insects peaks within one to three years following tree death in pine ecosystems (Farris et al., 2002, Farris and Zack, 2005). As decay progresses, more decayed snags are thought to become more suitable for cavity excavation (Farris and Zack, 2005). Previous research suggests that proximate cause of tree death affects the probability of cavity excavation, as does wood softness, snag size, and stem density (Petit et al., 1985, Parks et al., 1999, Lehmkuhl et al., 2003, Bagne et al., 2008).

The concept of ecosystem management calls for greater retention of snags and other biological legacies in managed forests (Franklin et al., 1987, Harmon, 2001, Dudley and Vallauri, 2005). Such management maintains structural complexity and biodiversity (Franklin et al., 2002, Lindenmayer and Noss, 2006). Recognizing the importance of retaining or augmenting the abundance or volume of snags in forests, previous studies have investigated methods for creating snags such as girdling and topping of trees, herbicide application, and/or inoculating trees with fungi (Bull and Partridge, 1986, Chambers et al., 1997, Hallett et al., 2001, Brandeis et al., 2002, Shea et al., 2002, Filip et al., 2004, Arnett et al., 2010). Wildlife responses to snag creation and decay processes have been studied more in the western United States than in the sub-boreal, mixed-pine forests of the Great Lakes region. One study conducted in Upper Michigan investigated snag creation methods and found that jack pine snags generated by girdling developed into advanced decay classes faster than snags created by topping or prescribed fire (Corace et al., 2013). However, wildlife response to the methods of snag creation was not evaluated. Moreover, recent proposals to list the northern long-eared bat (*Myotis septentrionalis*) and other bat species that utilize snags under the *Endangered Species Act* have heightened the need for more research that investigates snag management within an ecological context.

We focus here on two types of snag use by forest birds that we collectively term an excavation: (1) use of a snag for a cavity (be it for cover or nesting) and (2) use of a snag for potential food resources. The objectives of this study were to quantify differences in the treatments implemented and evaluated by Corace et al. (2013) in terms of decay variables and use by subcortical insects and primary cavity-nesting bird species, as well as to explore which variables best predict variation in observed bird excavations. Understanding the interactions between snag decay, insects, birds, and the environment can contribute to a better understanding of the outcomes of forest treatments that aim to retain or enhance biological legacies and provide complexity in mixed-pine forests.

2. Material and methods

2.1. Study site

Our study was conducted at Seney National Wildlife Refuge (SNWR) in eastern Upper Michigan (N46.288, W85.945). Proximity to the Great Lakes influences the local climate. Most winds are typically from the southwest to the northwest. The area experiences 81 cm of annual precipitation on average, and the average daily humidity ranges from 50 to 60% (USFWS, 2009). Temperatures typically range from −14 to 26 degrees Celsius (MRCC, 2017). The landscape is part of the Seney Sand Lake Plain ecoregion (Albert, 1995). The majority of upland soils are xeric sands that historically supported red pine (*P. resinosa*) forests, with a lesser component of eastern white pine (*P. strobus*). During the late 19th and early 20th centuries, those stands accessible to logging across the wetland matrix were cut and burned outside the natural range of variation (Losey, 2003); stands inaccessible to logging were left alone and now provide benchmarks for studying fire regimes (Drobyshev et al., 2008a, Drobyshev et al., 2008b), forest structure and regeneration dynamics (Corace et al., 2013, Nyamai, 2013, Nyamai et al., 2014), and wildlife communities (Corace et al., 2014). Altered stands are currently dominated by jack pine and have different structure, wildlife communities, and associated fire behavior compared to benchmark stands (red pine). As such, the restoration of ecosystems dominated by red pine and eastern white pine and the restoration of a fire regime with a fire return interval of low to mixed-severity fires approximately every 25–35 years are priorities for management (Drobyshev, 2014).

2.2. Creation and selection of snags

All forest stands in which we worked were part of a previous snag study (Corace et al., 2013), itself part of a larger effort to restore red pine, reduce heavy fuels (e.g., jack pine), and prepare sites for prescribed fire. All stands included in this study were growing on the white pine/blueberry (*Vaccinium*)/trailing arbutus (*Epigaea repens*) habitat type of the soil classification of Burger and Kotar (2003). Red pine and eastern white pine are late successional dominants and jack pine is the common dominant at earlier successional stages on this soil type.

In brief, snags were created mechanically in two harvested stands and in an additional stand via a prescribed fire. Harvesting occurred in mixed-pine stands with even-aged jack pine being the most common