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Long-term dynamics and characteristics of snags created for wildlife habitat

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ABSTRACT

Snags provide essential habitat for numerous organisms and are therefore critical to the long-term maintenance of forest biodiversity. Resource managers often use snag creation to mitigate the purposeful removal of snags at the time of harvest, but information regarding how created snags change over long timescales (> 20 y) is absent from the literature. In this study, we evaluated the extent to which characteristics of large (> 30 cm diameter at breast height [DBH]) Douglas-fir (*Pseudotsuga menziesii*) snags created by topping had changed after 25–27 y. We also tested whether different harvest treatments and snag configurations influenced present-day snag characteristics. Of 690 snags created in 1989–1991, 91% remained standing during contemporary surveys and 65% remained unbroken along the bole. Although most snags were standing, we detected increased bark loss and breaking along the bole relative to prior surveys conducted on the same pool of snags. Although snag characteristics were not strongly influenced by snag configuration, we found that snags in one harvest treatment (group selection) experienced less bark loss and had lower evidence of use by cavity-nesting birds (as measured by total cavity cover) relative to snags created with clearcut and two-story harvest treatments. Our results indicate that Douglas-fir snags created by topping can remain standing for long time-periods (≥25 y) in managed forests, and that the influence of harvest treatment on decay patterns and subsequent use by wildlife is an important consideration when intentionally creating snags for wildlife habitat.

1. Introduction

Standing dead trees, or snags, are important ecological structures that can be formed naturally through the actions of fire, wind, insects, and fungi (Morrison and Raphael, 1993; Rose et al., 2001). Snags play a crucial role in forest health by storing terrestrial carbon and contributing to soil development as snags decompose (Harmon et al., 1986; Rose et al., 2001; Angers et al., 2012). In addition, they enhance biodiversity by providing nesting and foraging habitat for many species of insects, amphibians, birds, and mammals during their transition from a living tree to a snag (Thomas, 1979; Harmon et al., 1986; Newton, 1994; Rose et al., 2001; Seibold et al., 2016). For example, decay in living trees and snags creates pockets of rot that provide critical nesting and roosting habitat for species that require cavities (e.g., woodpeckers) and areas under loose bark (e.g., bats, Brown Creeper [*Certhia americana*]; Harmon et al., 1986; Franklin et al., 1987; Chambers et al., 2002; Bunnell, 2013; Geleynse et al., 2016). As snag decay progresses, parts of the snag begin to break and fall to the ground and become downed wood, providing additional shelter and feeding substrates for many species of insects, amphibians, and mammals (Franklin et al., 1987; Duane, 2001; Manning and Edge, 2004; Rose et al., 2001; Waldien et al., 2006; Kluber, 2007; Kilgo and Vukovich, 2014).

Despite their ecological significance, snags are often removed during timber harvest because of their commercial value and to comply with safety regulations (McComb et al., 1993; Kroll et al., 2012). Therefore, decades of intensive forest management practices, such as clearcutting and fire suppression, have resulted in a reduction in the number of snags within managed forest landscapes (Cline et al., 1980; Swanson and Franklin, 1992; Wilhere, 2003). A reduction in snags can reduce native biodiversity by degrading or eliminating habitat (Hane et al., 2012). Therefore, intentional creation of snags, which is typically undertaken at the time of harvest, has been implemented to mitigate loss of wildlife habitat in managed forests (Bull and Partridge, 1986).

The amount of time that created snags remain standing and the rate at which snags decay are critical for determining their useful lifespan as wildlife habitat, and snag lifespan can be influenced by the density of residual live trees and the configuration of snags following harvest. Direct exposure to environmental factors, such as solar radiation, precipitation, and wind can cause rapid changes in moisture content of wood within snags, in turn influencing bark and wood retention. Therefore, greater residual live tree density around snags may decrease breaking rates and increase bark and wood retention by protecting

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snags from environmental factors (Harmon et al., 1986). Whether snags are retained in clusters or scattered throughout a harvest unit may also affect their decay rate; clustered snags may promote greater insect colonization and subsequent mineralization of wood and colonization by fungi, bacteria and other invertebrates (Chamberlin, 1918; Angers et al., 2012). The presence of insects can also attract additional species such as woodpeckers, which further contribute to snag decay through fragmentation of wood during their foraging and excavating activities (Harmon et al., 1986) and can facilitate the establishment of fungi (Jusino et al., 2016). Although wildlife use of snags tends to increase with snag age (Schreiber and DeCalesta, 1992; Chambers et al., 1997; Hallett et al., 2001; Walter and Maguire, 2005; Arnett et al., 2010), information is lacking about how long snags persist, and how harvest type and snag configuration may influence snag characteristics that are important for wildlife. Nevertheless, this information is critical for resource managers who are charged with creating snags as a form of habitat mitigation for snag-associated wildlife species within managed forest landscapes (Kroll et al., 2012).

In this study, our goal was to quantify characteristics of snags that were intentionally created in 1989–1991 as part of a long-term silvicultural experiment at Oregon State University (i.e., College of Forestry Integrated Research Project; Maguire and Chambers, 2005). Snags were created at the time of harvest in one of three harvest treatments (group selection: uneven-aged with 33% tree volume removed in patches, two-story: even-aged with 75% tree volume removed uniformly, clearcut: even-aged with all tree volume removed except for 1.3 live trees/ha) and one of two spatial configurations (clustered, scattered), both of which were applied at the stand level (Chambers et al., 1997). Our objectives were to (1) test whether experimental harvest treatment and snag configuration influenced persistence of created snags, (2) quantify how current-day snag characteristics related to decay were influenced by harvest treatment and snag configuration, and (3) incorporate historic data from the same pool of snags to document changes in characteristics and use by cavity-nesting birds across a ≥25-y period.

Experimental harvest treatments in our study differed in the amount of basal area removed, so we hypothesized that greater harvest intensity would result in greater levels of decay, as tree density is thought to influence decay rate (Garber et al., 2005; Harmon et al., 1986; Seibold et al., 2016). Based on findings from previous surveys conducted on the same snags (Chambers et al., 1997; Walter and Maguire, 2005), we also hypothesized that snags created in the clearcut and two-story treatments would receive more cumulative use by birds over time than those in the group selection treatment, as measured by the extent of cavity cover. We defined cavity cover as the cumulative area on the snag bole that comprised of nesting, foraging, and natural cavities because (1) many snags in our study were extensively decayed, making it impossible to distinguish between cavity types, and (2) it is possible that some cavities on created snags began as one cavity type (e.g., nesting) but were expanded to become a different cavity type (e.g., foraging) during the lifetime of the snag. With respect to snag configuration, we hypothesized that snags created in clusters would experience greater use than scattered snags because snag proximity may increase foraging efficiency for birds. Under this assumption, we expected snags to have greater external decay resulting from foraging activity and greater cavity cover within the clustered configuration, relative to snags in the scattered configuration. Given the influence of foraging on snag decay, we also predicted that snags created in clusters would have greater fall rates, break along the bole faster, and have more bark lost than scattered snags (Harmon et al., 1986; Jusino et al., 2016; Lorenz et al., 2015). Alternatively, snags created in clusters may be more protected from wind than snags that are scattered and may therefore be less likely to fall or break due to wind damage. As the first to quantify the decay process of created snags in managed forests across ≥25 y, our study provides a critical step in understanding the implications of a widespread management technique for creating wildlife habitat that is commonly used within working forest landscapes.

2. Methods

2.1. Site description

Our study sites were located within Oregon State University's McDonald-Dunn Research Forest (123°15′W, 44°35′N) near Corvallis, Oregon on the lower east slope of the Coast Range. The original study design comprised 30 stands (5–18 ha each) dominated by Douglas-fir (*Pseudotsuga menziesii*) that had regenerated naturally after harvest. These stands included two understory plant association types: hazel (*Corylus cornuta* var. *californica*)/brome (*Bromus vulgaris*) and vine maple *(Acer circinatum*)/salal (*Gaultheria shallon*; Franklin and Dyrness 1973). Dominant trees on stands were 45–150 y old at the time of harvest treatments were applied and snag creation took place (see below), and stands were similar in plant species composition among treatments prior to harvest (Chambers, 1996). Mean density of live conifers was approximately 540 trees/ha, live hardwood tree density averaged 165 trees/ha, and natural snag (i.e., snags formed naturally without tree topping) density averaged < 1.9 snags/ha (Chambers, 1996). At the time of our research (2015–2016), natural snag densities varied relative to harvest treatment: group selection treatment: 10.6 snags/ha (SE ± 1.9, n = 16 stands), two-story treatment: 6.4snags/ha (SE ± 2.2, n = 7 stands), clearcut treatment: 13.3 snags/ha (SE ± 5.1, n = 3 stands; Barry, 2017).

2.2. Study design

Our study consisted of a randomized, complete block design with three study blocks, with each block harvested in a separate year (i.e., Lewisburg block in 1989, Peavy block in 1990, Dunn block in 1991) and planted the spring following harvest. Each block contained n = 10 stands in which snags were created at the time of harvest. Individual stands within each block were assigned randomly to one of three harvest treatments and one of two snag configurations. The harvest treatments and snag configurations were intended to mimic variations in natural disturbance patterns and test the effects of operational alternatives to traditional clearcutting on a range of ecological responses (Chambers et al., 1999). Experimental harvest treatments included (1) group selection, which represented localized, low intensity disturbance and resulted in 33% of the tree volume removed in 0.2 ha patches; (2) two-story, which represented evenly distributed moderate disturbance and resulted in 75% of the tree volume removed uniformly; and clearcut, which represented high intensity, stand-replacing disturbance and resulted in all tree volume removed except for 1.3 live trees/ha. All stands were replanted with Douglas-fir seedlings at a density of 625–865 trees/ha, depending on harvest treatment, and received herbicide applications 2–5 y after harvest to control competing vegetation (Chambers et al., 1997).

At the time stands were harvested, snags were created in either a clustered configuration with 3–5 discrete groups within each stand, or scattered uniformly throughout each stand. In both configurations, mean density of created snags was equal at the stand scale (3.8 snags/ha). When available, natural snags were included in clusters of created snags (Chambers et al., 1997). Snags were created throughout each stand except for the group selection treatment, where the small size of the harvested patches constrained snag creation to unharvested areas (Maguire and Chambers, 2005). All snags were created by topping live Douglas-fir trees with a chainsaw at a mean height of 17 m (minimum: 15 m) and a mean diameter at breast height (DBH) of 75 cm (range: 33–198 cm). Each snag was marked with a uniquely marked aluminum tag, allowing us to document changes in individual snags across time. Due to modification of treatments in some stands over time, only 26 of the 30 original stands were available for our study (group selection: n = 16, two-story: n = 5, clearcut: n = 5).

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