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Do aggregated harvests with structural retention conserve the cavity web of old upland forest in the boreal plains?

Hilary A. Cooke*, Susan J. Hannon

Department of Biological Sciences, University of Alberta, Edmonton, AB, Canada T6G 2E9

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ABSTRACT

Boreal species that are dependent on old forests, such as many cavity-using birds and mammals, are at high risk from conventional harvest practices. These species may benefit from ecologically sustainable forest management practices that increase heterogeneity within stands and across landscapes. Structural retention within cutblocks and spatial aggregation of cutblocks into large (1000s ha) harvest units are two such management practices being implemented by forestry companies in the boreal plains of Alberta and Saskatchewan. However, little is known about the implications of these practices for old forest species. The goal of our study was to determine if the cavity-using assemblage associated with old upland forest in this region is retained within aggregated harvests with structural retention. We used a cavity web approach to describe and contrast interactions among cavity excavators (woodpeckers, chickadees, and nuthatches) and the secondary (i.e. non-excavating) species reusing their cavities. We described the cavity web for two intact landscapes of old upland forest and for two aggregated harvest landscapes. We identified four key excavators of intact forest: yellow-bellied sapsucker (*Sphyrapicus varius*), hairy woodpecker (*Picoides villosus*), northern flicker (*Colaptes auratus*), and pileated woodpecker (*Dryocopus pileatus*). These woodpeckers should be considered key excavators primarily of mature and old aspen forest, which dominated the study landscapes. Each woodpecker filled a unique role in the cavity web and all are important for conservation of two mammal and three bird species that used their cavities. In the short term (i.e. within four years post-harvest), the key cavity excavators and many secondary cavity-using species associated with intact forest were retained in the harvested landscapes. One secondary species (American kestrel (*Falco sparverius*)) was unique in the harvest cavity web. Compared to the intact cavity web, the harvest web had lower abundance of sapsuckers, greater abundance of flickers, and high reuse of flicker cavities by kestrels. These differences were associated with the shift from intact forest to a landscape characterized by patches of old forest surrounded by early-successional habitat. Abundances of hairy and pileated woodpeckers were too low to detect differences between intact and harvested landscapes. The key excavators primarily used trembling aspen (*Populus tremuloides*) for cavity trees and thus aspen should be targeted for retention in harvested landscapes. A more detailed examination of the habitat requirements of the key excavators is needed to develop best practices for tree and patch retention and ensure conservation of the cavity-using assemblage in aggregated harvests.

1. Introduction

Old boreal and temperate forests support diverse and/or unique assemblages of plants, animals, and fungi and thus are critical for conservation of biodiversity (Franklin et al., 1981; Hansen et al., 1991; Hanski, 2000; Hart and Chen, 2006; Lindenmayer et al., 2000; Lindenmayer and Franklin, 2002; Niemi et al., 1998; Norton, 1996; Spence et al., 1996). In the boreal forests of western Canada the abundances of approximately one third of bird species and several mammals are highest in old stands (Fisher and Wilkinson, 2005; Kirk et al., 1996; Schieck and Song, 2006). Among these are cavity users that specialize on the large dead and decaying trees indicative of older forest. Conventional harvest practices in boreal and temperate regions threaten the availability of late-successional forests (Hansen et al., 1991; Lindenmayer et al., 2000; Lindenmayer and Franklin, 2002; Linder and Ostlund, 1998; Seymour and Hunter, 1999). In particular, spatially dispersed clearcutting and short harvest rotation periods result in even-aged stand structure and loss and fragmentation of remaining old forest (Lindenmayer et al., 2000; Linder and Ostlund, 1998; Schneider et al., 2003; Sougavinski and Doyon, 2005). These changes are associated with declines in the abundances of old forest species (Berg et al., 1994; Hansen et al., 1991; Lindenmayer and Franklin, 2002; Schieck and Song, 2006).

* Corresponding author. Present address: Wildlife Conservation Society Canada, 22B Sunset Drive North, Whitehorse, YT, Canada Y1A 4M8. Tel.: +1 867 668 6957.
E-mail address: hcooke@wcs.org (H.A. Cooke).

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Concern over the impact of conventional harvest practices on boreal and temperate forest biodiversity has led to the development of ecologically sustainable practices, primarily increasing heterogeneity within stands and across landscapes (Bergeron et al., 2002; Franklin et al., 1997; Haila, 1994; Hansen et al., 1991; Lindenmayer and Franklin, 2002; Vaillancourt et al., 2009). Greater structural heterogeneity within stands is achieved by retaining live trees and patches of trees. Structural retention strategies may be modelled on the types and patterns of unburned structure that remain after fire or designed to achieve specific management objectives (Bunnell et al., 1999; Franklin et al., 1997; Serrouya and D'Eon, 2004; Sougavinski and Doyon, 2005). For many birds and mammals associated with old boreal forest, residual trees and patches offer habitat 'lifeboats' in small, recently harvested cutblocks (Fisher and Wilkinson, 2005; Mahon et al., 2008; Schieck and Song, 2006; Serrouya and D'Eon, 2004; Vanderwel et al., 2009). At the landscape scale, forestry companies maintain heterogeneity by harvesting along existing stand boundaries and increasing the range of cutblock sizes to better approximate natural patterns (Bergeron et al., 2002; Dzus et al., 2009; Hunter, 1993; Lee et al., 2002; Sougavinski and Doyon, 2005). Landscape patterns associated with large fire disturbances in Canada's western boreal forest are approximated by spatially aggregating cutblocks into large (1000s ha) harvest units (Dzus et al., 2009; Lee et al., 2002). Compared with small cutblocks, these large planning units can accommodate a greater range of residual patch sizes (from single trees to 100s ha) (Lee et al., 2002), which may improve the value of retained structure for old forest species. Several forestry companies in the boreal plains of Canada are incorporating structural retention with spatial aggregation of cutblocks. In this region, aggregated harvests better approximate post-fire landscapes for bird communities (Van Wilgenburg and Hobson, 2008). However, there is little information on the implications for old forest species, which are most at risk from intensive forest harvesting.

The goal of this study was to evaluate whether cavity-using birds and mammals associated with old forest are conserved in large spatially aggregated harvests with structural retention in the boreal plains of western Canada. The cavity-using assemblage was selected for study because the species in it are sensitive to intensive harvest practices (Angelstam and Mikusiński, 1994; Imbeau et al., 2001) and have a strong association with old upland forest in this region (Schieck and Song, 2006). Cavity-using species are differentiated by their ability to produce cavities. Primary excavators (woodpeckers) excavate their own cavity. Weak excavators (chickadees, nuthatches, and some woodpeckers) may excavate their own cavity but will also use a woodpecker cavity or one created naturally in broken limbs or tree trunks. Secondary cavity users (other birds and mammals) depend on woodpecker or naturally created cavities. The interspecific interactions associated with the production and reuse of cavities can be visually depicted using a cavity web (Martin and Eadie, 1999).

Understanding the interactions that structure the cavity web will facilitate management for this unique assemblage (Martin and Eadie, 1999). In particular, one or a few woodpeckers in the cavity web may produce the majority of cavities used by secondary cavity users (Bednarz et al., 2004; Blanc and Walters, 2008a; Daily et al., 1993; Dobkin et al., 1995; Martin et al., 2004; Martin and Eadie, 1999; Virkkala, 2006). A cavity excavator that has a strong influence on web structure may be a keystone species (*sensu* Power et al., 1996; i.e. its cavities have an influence on web structure that is disproportionate to their abundance) or may be the dominant cavity producer in the web (e.g. Aitken and Martin, 2004). Conservation of secondary users in landscapes managed for forestry depends on conserving all key cavity excavators in the web (Angelstam and Mikusiński, 1994; Martin and Eadie, 1999). We consider a woodpecker to be a key cavity excavator in the web if it produces cavities reused by multiple secondary species, reused exclusively by one or more species, selected for reuse over cavities produced by other excavators, and/or reused at high rates (Aitken et al., 2002; Aitken and Martin, 2004; Blanc and Walters, 2008a; Bonar, 2000; Dobkin et al., 1995; Martin et al., 2004; Sedgwick, 1997).

Our first objective was to use a cavity web approach to describe and contrast interactions among cavity producers and species reusing cavities in two intact landscapes of old upland forest and in two landscapes modified by spatially aggregated harvesting with structural retention. Our second objective was to identify the key cavity excavators for secondary cavity-using species in intact and harvested landscapes. Our final objective was to evaluate whether the abundances of key excavators and rates of reuse of their cavities differed between intact forest and the aggregated harvests.

2. Methods

2.1. Study area

This study was conducted in northeastern Alberta (AB) and northwestern Saskatchewan (SK) in the boreal plains ecozone (Ecological Stratification Working Group, 1995). Upland forest is comprised of pure and mixed stands of trembling aspen (*Populus tremuloides*), balsam poplar (*Populus balsamifera*), and white spruce (*Picea glauca*) (Ecological Stratification Working Group, 1995; Peterson and Peterson, 1992). Upland stands are considered mixedwood when composed of <80% deciduous and <80% coniferous tree species (Al-Pac, 2004). Mesic sites are dominated by black spruce (*Picea mariana*) and tamarack (*Larix larcina*); dry and sandy sites are occupied by jack pine (*Pinus banksiana*). Deciduous-dominated (i.e. aspen, balsam poplar) and mixedwood stands are considered mature when 61–100 years old and old when >100 years (Al-Pac, 2004). White spruce stands are mature between 61 and 120 years and old when >120 years. Merchantable forest in this region is primarily the mature and old seral stages of upland stands (aspen, mixedwood, white spruce).

Within each province we paired an intact landscape of mature and old upland stands with a landscape located in a large, spatially aggregated harvest (Fig. 1). The intact landscape in Alberta (hereafter AB-intact) included part of Lakeland Provincial Park and Recreation Area and the Alberta-Pacific Forest Industries Inc. (Al-Pac) Forest Management Area (FMA) east of the town of Lac La Biche (54°44′N, 111°58′W). Research activities in AB-intact were conducted within ~1600 ha of contiguous stands of primarily mature and old aspen (52%), old mixedwood (7%), old white spruce (13%), and mature black spruce (9%). The harvested landscape in AB (hereafter AB-harvest) is ~1600 ha of aggregated cutblocks harvested in autumn 2004. AB-harvest is within a 9500-ha planning unit located north of Lakeland Provincial Park on the Al-Pac FMA. The AB-harvest boundary is 2.9 km northeast of the boundary of AB-intact. Pre-harvest stand type was predominantly mature and old aspen (48%), old mixedwood (28%), and old white spruce (13%).

In Saskatchewan, the intact landscape (hereafter SK-intact) is located in Meadow Lake Provincial Park north of the town of Goodsoil (54°23′N, 109°14′W) (Fig. 1). Due to logistical constraints on accessing interior areas of the park, and limitations in the availability of large contiguous forested areas without lakes, we were unable to establish a contiguous intact landscape. Instead, research activities were conducted in five distinct areas of the park (totalling ~3100 ha). These areas are completely embedded in the contiguous forest landscape of the park and thus are part of a larger landscape of intact mature and old upland forest. Stands were predominantly mature aspen (78%) and old mixedwood (8%). The harvested landscape in SK (hereafter SK-harvest) is ~3500 ha of aggregated cutblocks harvested in 2001 and 2002. SK-harvest is located within