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Avian community response to understory protection harvesting in the boreal forest of Alberta, Canada

Connor Charchuk*, Erin M. Bayne

Department of Biological Sciences, University of Alberta, Edmonton, AB, Canada

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A B S T R A C T

Traditional harvesting in western boreal forests seeks to approximate natural disturbances, such as wildfire. In mixedwood forests, understory conifers such as white spruce are typically destroyed during natural disturbance harvest (NDH). Understory protection (UP) is a harvesting approach that seeks to protect understory conifers during hardwood harvesting in mixedwood forests. While understory protection harvesting has been implemented for over a decade in Alberta, Canada, there has been no assessment of its use by birds. We surveyed birds in UP and NDH harvest blocks, and the nearby unharvested forest, and evaluated differences in species richness and community composition between the three treatment types. We found NDH had significantly higher species richness than unharvested forests, but did not differ from UP. The three treatments all had significantly different avian community compositions, and NDH showed no convergence with the unharvested forest over 15-years post-harvest. However, UP represented an intermediary between NDH and unharvested forests. When comparing the oldest age class of UP with unharvested forest, we found no significant difference in the bird communities 12 years post-harvest. These results suggest that following understory protection harvest, the retained forest regenerates quickly, rapidly providing habitat to more mature forest species than NDH.

1. Introduction

Approximately 30% of Canada's boreal forest is managed for timber harvest (Venier et al., 2014), of which over 60% has been harvested at least once (Burton et al., 2003). Timber harvesting in the boreal historically relied on clearcutting (Ralston et al., 2015). Clearcutting is beneficial for its economic effectiveness and efficiency (Smith and DeBald, 1978), but critics have expressed concerns about its effects on biodiversity (Lindenmayer et al., 2012). These concerns have led the forestry industry to adopt a natural disturbance model of harvesting (hereafter NDH), whereby harvesting approximates some elements of natural disturbances such as fire. NDH has been implemented based on the assumption that communities disturbed by natural processes will be more resilient than those disturbed by anthropogenic processes (Hunter, 1993). NDH results in greater retention of snags and mature trees within harvested areas and may achieve habitat convergence relative to natural disturbances more quickly than clearcutting (Huggard et al., 2015). Retention of snags in NDH may serve as a "lifeboat" to promote habitat use for many species (Franklin, 1997), but NDH does not mimic fire disturbance exactly at any stage of succession. Communities of mammals (Zwolak, 2009), birds (Hobson and Schieck, 1999; Schieck and Song, 2006), beetles (Gandhi et al., 2004), plants (Peltzer et al., 2000), forest structure (McRae et al., 2001) and composition of soil nutrients (Kishchuk et al., 2014) have all been shown to differ between NDH areas and burns following the disturbance event. Some researchers argue NDH cannot adequately replicate fire disturbance due to the underlying differences in the disturbance process itself (Palik et al., 2002; Drever et al., 2006) or due to lack of knowledge about natural fire rotations (Armstrong, 1999).

At present, there are no long-term studies of the ability of NDH to approximate natural disturbances when the forest has matured. At the far end of the successional gradient, concerns exist about the amount of old forest that will persist in areas managed for forestry and the species that rely on such conditions. Thus, one of the secondary objectives of NDH is to shorten the interval for the forest to return to pre-harvest conditions to ensure habitat for such species. The objective is that by approximating natural processes, development of conditions typical of older forests will be faster than what is created following clearcutting (Bauhus et al., 2009). Whether or not NDH is an effective way to develop old-growth conditions quickly remains an area of active investigation. Some research suggests NDH begins to converge with post-fire disturbances just 15-years post-disturbance (Huggard et al., 2015). However, one question about NDH that remains poorly explored is how NDH influences the supply of softwoods that will exist on the landscape

* Corresponding author at: Department of Biological Sciences, University of Alberta, L1-199 CCIS, Edmonton, Alberta T6G 2E9, Canada.
E-mail address: ccharchu@ualberta.ca (C. Charchuk).

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in the future.

Clearcutting and NDH typically result in the destruction of understory white spruce during mixedwood harvesting. By losing unmerchantable conifer stock, there is an overall reduction in long-term softwood yield for timber companies. The regeneration of white spruce stock in mixedwood forests following harvesting has been deemed one of biggest challenges facing forest managers in western Canada (Lieffers and Beck, 1994). Understory protection harvesting (hereafter UP) is a recently developed practice of harvesting that seeks to protect unmerchantable white spruce during mixedwood harvesting to facilitate future softwood timber yield. First proposed by Brace and Bella (1988), the two-pass UP harvest strategy seeks to minimize damage to the white spruce understory during the overstory hardwood harvest to allow earlier future harvesting of softwoods (Navratil et al., 1994). Following the first-pass harvest, a mosaic of strips are left behind: a 3-meter wide unharvested strip is used to reduce windthrow of the protected understory, a 6-meter wide protection strip containing understory white spruce freed from competition with overstory aspen, and a 6-meter wide skid row cleared of vegetation (see: Grover et al., 2014: Fig. 2). Following the first-pass harvest, the understory spruce is released from competition, and growth can be accelerated by up to 40% (Yang, 1991). This can lead to a similar conifer yield as unharvested mixedwoods within about 60 years (Grover et al., 2014).

The UP harvest method results in retention of approximately 50% of the understory spruce and 20% of the residual forest on average (Grover et al., 2014). The retention of a higher proportion of residual forest during harvesting (i.e. retention forestry) is often done with the objective of maintaining some of pre-harvest forest structure and conditions (Gustafsson et al., 2012). Retention forestry may provide more effective conservation of species associated with mature forest than NDH management (Lindenmayer et al., 2012). A meta-analysis by Fedrowitz et al. (2014) suggests retention forestry can maintain populations of both open-habitat species and forest species, and overall supports more diverse communities than NDH. However, the type and amount of retention required to provide habitat is highly variable and species dependent (Fedrowitz et al., 2014). Therefore, assessment of UP as a form of retention forestry is required.

Despite the growing implementation of UP, there has been a lack of research into the ecological responses to UP harvesting (Lieffers and Grover, 2004). The goal of this study was to compare bird diversity and communities in UP, NDH and unharvested forests. We hypothesized that bird communities in UP would differ from those in NDH due to the greater level of tree retention in UP providing habitat for mature forest birds. We further predicted that the bird community in UP would be more similar to the unharvested forest than would the NDH. Finally, we hypothesize there will be differential community trajectories in UP blocks relative to NDH areas because white spruce growth is expedited (Grover et al., 2014) and aspen suckering is suppressed due to soil disruption by the feller buncher (Lennie et al., 2009). We achieve this comparison by conducting bird surveys in unharvested forests paired with a chrono-sequence of UP and NDH blocks to quantify the avian community response to harvesting over time.

2. Methods

2.1. Sites

This study was conducted on lands managed by Alberta-Pacific Forest Industries Inc. (hereafter Al-Pac; Boyle, Alberta, Canada) in the boreal forest of northeastern Alberta, Canada. NDH conducted by Al-Pac involves variable retention of an average of 5% merchantable trees and snags within each individual harvest area (for an overview of Al-Pac's harvesting at the stand and landscape level see Dzus et al. (2009)). UP has been implemented by Al-Pac since 2005 in deciduous stands with an understory of white spruce > 600 stems per hectare. For a detailed description of the UP harvesting procedure conducted by Al-Pac, see Greenway et al. (2006) and Grover et al. (2014). UP and NDH blocks were surveyed throughout the extent of Al-Pac's forest management area, west to 113°37′3.6″W north to 56°13′45.0″N east to 108°10′23.6″W and south to 54°50′19.1″N. For some analyses, harvest blocks were binned into two age classes: young NDH at 1–9 years and old NDH at 10+ years; young UP at 1–8 years and old UP at 9–12 years, to create age categories with relatively equal sample sizes.

Unlimited distance point counts were conducted using autonomous recording units (ARU) to remotely survey vocalizing species. We used SM2+ and SM3 song meters developed by Wildlife Acoustics (Maynard, Massachusetts, USA). ARU deployments were conducted during the breeding bird season when songbirds are most vocally active (May 25 – July 4) in 2015 and 2016. A single ARU was used to survey each harvest block or unharvested control, and is hereafter referred to as a site. ARUs were deployed to each site for four consecutive days before being rotated to a new site. UP sites were selected in ArcMap 10.2 (ESRI, 2016) using a layer from Al-Pac that delineates the UP harvested area. Harvested areas were mapped out on-the-ground during harvesting using tracks from GPS-enabled feller bunchers; ARU locations were centered within the harvested area. NDH and unharvested sites were selected using a combination of layers developed by Al-Pac and the Alberta Vegetation Inventory (AVI, http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/formain15910/$file/AVI-ABVegetation3-InventoryStan-Mar05.pdf). UP blocks were selected based on ease of access and age such that we surveyed a full chrono-sequence of UP blocks. NDH sites were thereafter selected based on closest proximity to UP sites, and unharvested sites were chosen based on the oldest forest patch available within 1 km of the UP block. We used a randomized block design, so each block (hereafter *location*) contained one UP site, one NDH site, and one unharvested forest site all of which were surveyed concurrently. Sites were restricted to < 300-meters apart to reduce double counting birds, and > 1 km away to minimize extraneous variation within the location. Within a location, NDH and UP were not typically of the same age (i.e. they were harvested in different years).

2.2. Listening

Sound files recorded by the ARUs (32-bit WAV) were manually processed in the lab to transcribe all individuals that could be identified via acoustic identification. Listening for this project was conducted by five experienced listeners (> 1-year experience with western boreal songbirds). Three-minute long recordings between 04:00 am–07:00 am were listened to using Adobe Audition or Audacity software, and circumaural headphones. All birds vocalizing in each recording were identified and the time of first detection within each 1-min bin was transcribed. Multiple individuals of the same species were identified using the relative strength of the vocalization on stereo microphones (i.e. left and right channels) and/or the presence of overlapping signals. Four recordings for each site were processed across three or four days depending on weather (i.e. 4 visits per site). Recordings were chosen on different days whenever possible, which were usually consecutive days in the season. Recordings with moderate to strong wind or rain contamination were not processed.

2.3. Analysis

We used a randomized block design wherever possible to control for sources of variation due to geographical location, survey time within the season, forest composition in the region, and weather during the survey. We were unable to test the detection radius for each ARU and species combination; therefore, we were likely dealing with different sampling areas for UP, NDH, and unharvested forest due to differential sound attenuation as a function of vegetation structure. To reduce this effect, species richness estimates were rarefied to account for varying abundance structures resulting from differential sampling radii (Gotelli