Surveying Breeding Birds in Recently Harvested & Unharvested Boreal Stands

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Executive Summary

The boreal forest is home to 1-3 billion nesting birds each summer and provides important stopover habitat for migrating species. Although the boreal forest biome is estimated to be 80% intact, habitat loss and fragmentation is increasing, particularly in Alberta. With the migratory nature of most boreal breeding birds, the consequences of failing to maintain breeding habitats in the boreal forest could ripple through global ecosystems, human recreation, and industry. Most bird species can respond rapidly to changes in habitat conditions and the vocal nature of many songbirds makes them relatively easy to survey. Understanding how boreal songbirds are using habitats on small scales can help managers maintain biodiversity and associated ecosystem services on a landscape level. Immediate shifts in bird communities after timber harvest is well documented, but beyond the first five years post-harvest, less is known about avian recolonization trends. This data deficiency has the potential to limit models predicting avian distributions in dynamic mixed-use environments, which in turn may limit productive land-use planning.

Herein is described three years of field study (2018, 2020, and 2021) in the boreal forest of north-central Alberta in Vanderwell Contractors (1971) Ltd. cutblocks aged 1-10, 11-20, and 21-30 years post-harvest, as well as unharvested stands 80+ years post-disturbance. Stands were further classified by reforestation designations and AVI stand stratifications (C, CD, and DC). Each point count station (n = 373) was visited once. Point counts recorded all birds detected in an unlimited distance 5-minute silent listening period. Observers also conducted a brief vegetation structural assessment of the immediate area around point count centres and took photos facing each cardinal direction. Surveying was limited in 2018 due to heavy rainfall and cancelled altogether in 2019 due to forest fires. Efforts were concentrated to 2020 and 2021.

In total 4,980 birds from 95 species were detected. Overall bird abundance, species richness, and species diversity was calculated for each forest classification. Abundances were lowest in cutblocks aged 1-10 years post-harvest (6.0 to 8.3 birds per site) and C80+ (7.3 birds per site). Abundances were highest in DC11-20 (11.9 birds per site) and CD11-20 (11.6 birds per site). Species richness was estimated using coverage-based rarefaction to compare samples of equal completeness. Rarefied species richness tended to increase as stand age increased, ranging from 21.5 species in DC1-10 to 34.9 species in C80+. Despite hosting fewer individuals on average, coniferous stands were often richer than mixedwood stands of the same age. Statistically significant increases in species richness were detected immediately between C1-10 and C11-20, and DC1-10 and DC11-20 cutblocks alongside dramatic shifts in vegetation that increased structural complexity to provide a multitude of foraging and nesting opportunities. Young CD cutblocks did not exhibited a significant increase until 21-30 years post-harvest due to the unusual vegetative structure of the CD11-20 class. Diversity was estimated using coverage-based rarefaction of the Shannon Index. Since species richness is a component of diversity analyses, trends in Shannon Index values followed similar patterns to those described for species richness, but smaller differences between unharvested diversity and cutblocks than exhibited in species richness analyses suggests cutblocks have less even distributions of individuals between species than unharvested stands.

To estimate the similarity of species composition among forest classes, the number of birds detected per site for each species was used in a Euclidean distance average-linked hierarchical clustering algorithm validated by maximizing the Dunn Index. There were four general avian community groupings. In order of increasing similarity: (1) cutblocks 1-10 years post-harvest; (2) mixedwood cutblocks 11-20 years post-harvest; (3) unharvested coniferous stands; and (4) unharvested mixedwoods, cutblocks 21-30 years post-harvest, and coniferous and understory protection cutblocks 11-20 years post-harvest. All cutblocks in the fourth cluster are more similar to unharvested stands than they are to 1-10 year post-harvest cutblocks possibly due to similarities in abundances of coniferous-nesting species. Common species within C80+ were rarely detected in other habitats and may have contributed to this sample's uniqueness.

Species were grouped into guilds by previously documented stand age preferences, typical foraging behaviours during the breeding season, nesting locations, and migration distances. As expected, abundances of old-growth specialist species increased with stand age, while abundances of young forest specialist species decreased. Between foraging guilds, foliage gleaners were most abundant and diverse in older cutblocks and unharvested stands, while ground gleaners were most abundant and diverse in young cutblocks. Aerial insectivores were most common in stands younger than 21 years post-harvest. Between nesting guilds, ground nesting species were often the most abundant. Abundances of shrub nesting species were highest in cutblocks 11-30 years post-harvest with high correlation to recorded shrub densities. Shrub nesting abundances were often higher in cutblocks than unharvested stands, but abundances of cavity and canopy nesters tended to be lower in cutblocks. Between migratory guilds, species richness and abundance of long-distance migrants increased with cutblock age. Short-distance migrants were most abundant in cutblocks aged 1-10 years post-harvest and least abundant in cutblocks 21-30 years post-harvest. Resident species were infrequently detected, especially in 1-10 aged cutblocks. Similarity to unharvested stands was estimated by subtracting guild abundances of unharvested cover types from each cutblock class. Overall, dissimilarity of guild abundances between cutblocks and unharvested stands was most noticeable in cutblocks 1-10 years post-harvest. By 21-30 years post-harvest, guild abundances were generally close to convergence with unharvested stands.

Since harvestable aspen stands often have a spruce understory, understory protection harvesting (UP) attempts to leave portions of spruce during harvest to promote regeneration into a coniferous stand, but little is known about UP's impacts on avian biodiversity. Despite potentially confounding environmental variables and a small sample size, the UP sample yielded interesting results. Detected per-site abundances, species richness, and diversity were relatively low. Guild abundances of the UP sample were often closer to coniferous cutblock samples than to other cover types. Furthermore, guild abundances and overall community structure was closer to cutblocks 21-30 years post-harvest than cutblocks in the same age category of 11-20 years post-harvest. These results suggest that UP can readily provide breeding habitat for conifer-dependant species and that understory protection harvesting may return to unharvest benchmarks quicker than other harvest methods.

Breeding bird surveys have been conducted in the FMA to contribute to ecosystem-based forest management planning in 2001, 2005, 2009, and 2012. Some of these transects were revisited in 2018 and 2021 to resampled sites aged 80+ year post-disturbance and the understory protection stand using boxplots to detect changes in total yearly bird abundance and species richness with single-factor ANOVA and Tukey HSD tests for between-year differences. Both abundance and richness differed for undisturbed transects with significant increases between 2009 to 2012 and 2012 to 2021. Oddly, significant increases in abundances were not detected for the UP sample, potentially suggesting that UP achieves a more stable successional path than traditional harvesting methods without dramatic shifts in the first 1-20 years post-harvest.

Point count surveys identified 20 species of conservation concern with 13 species detected using habitats within cutblocks and 16 species detected in edge habitats or stands aged 80+ years post-disturbance. Surveyors recorded a total of 14 incidentally located nests. This included two Common Nighthawk (a threatened species) nests in cutblocks aged 1-10 years post-harvest.

Timber harvest destroys habitat for old-growth specialists in the short-term, but simultaneously creates habitat for other generalist species that is distinct on the landscape for the first 1-10 years post-harvest. However, forestry practices must ensure harvest rotations allow for the recruitment of old-growth and pure coniferous stands, which host unique avian assemblages. Mature forest birds may return faster to unharvested benchmarks when retention of residual patches at time of harvest is high and corridors between key habitats are preserved.

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Section 1: Introduction

1.1. Birds as Ecological Indicators

The boreal forest provides ecosystem services estimated to be worth $880 billion CDN per year (adjusted to 2021; Anielski and Wilson 2009) and is some of the last remaining habitat for several wildlife species, including large predators (Wells et al. 2020). For birds, this biome's importance cannot be overstated. The boreal forest is referred to as *North America's bird nursery* since 1-3 billion birds nest here each summer (Wells and Blancher 2011). These regular breeders represent over 300 bird species - nearly half of all bird species found in North America. Furthermore, 50% or more of 96 species' breeding populations is sustained by the boreal forest (Wells and Blancher 2011). In addition to providing critical breeding habitat, the boreal forest also provides important stopover habitat for migrating boreal and tundra breeding species.

With the migratory nature of most boreal breeding birds, the consequences of failing to maintain intact habitats in the boreal forest could have a global reach (Wells and Blancher 2011). Cascading effects of declines in the boreal are unpredictable since complex interactions between each bird species and their environment during breeding, migration, and wintering life stages are complex and poorly understood (Wenny et al. 2011). Declines in populations for some bird species may even cause declines in the health of the boreal ecosystem itself, which in turn could further reduce biodiversity (Wenny et al. 2011).

Deterioration of bird populations may impact humans as well. In addition to being a resource for recreation through birdwatching and hunting, birds also provide a wealth of ecosystem services although the exact value of these services is currently indeterminable (Wenny et al. 2011). Through their diverse diets that can include rodents, insects, carrion, and/or seeds, birds have been shown to be important for disease regulation and nutrient cycling (DeVault et al. 2003), to increase crop yields (Whelan et al. 2008), and to disperse seeds and strengthen gene flow, colonization, germination, and pollination of native plant species (Sekercioglu 2006). In these ways, birds provide links within and between a diversity of ecosystems. Healthy bird populations also directly benefit forestry as some species can reduce the defoliation resulting from spruce budworm outbreaks, lessening restrictions on growth rates and tree mortality, and thus reducing timber losses (Takekawa and Garton 1984, Whelan et al. 2008). Bay-breasted Warblers in particular respond so strongly to larval budworm densities that this species can be used as an indicator of early stages of outbreaks (Moisan Perrier et al. 2021).

Many other bird species can respond rapidly to changes in food availability and environmental and habitat conditions due to their large clutch sizes and their ability to locate species-specific microhabitats and to raise multiple sets of young per breeding season (Wenny et al. 2011). As a result, monitoring bird populations can provide an estimate of broad conditions within ecosystems. In general, the vocal nature of songbird species during the breeding season makes them relatively easy to survey compared to other wildlife. Understanding how boreal songbirds are using habitats on small scales can help managers maintain biodiversity and associated ecosystem services on a landscape level.

Bay-breasted Warblers are a spruce budworm specialist dependant on old growth forests.

1.2. Arboreal Habitat Loss and Fragmentation

The boreal forest is a dynamic ecosystem containing a mosaic of different forest types and ages created by natural and anthropogenic disturbances and subsequent succession. Although the boreal forest biome is estimated to be 80% intact (defined by continuous forest area ≥ 500 km^2), habitat loss is increasing in its southern reaches with expanding urbanization and resource development (Wells et al. 2020). Furthermore, natural disturbances are intensifying with climate change (Flannigan et al. 2005, Cadieux et al. 2020).

Of relevance for this study is the Boreal Taiga Plains bird conservation region (NABCI 2021, Figure 1), which contains the Boreal Plains ecozone in the south and the Taiga Plains ecozone in the north. While 78% of the Taiga Plains ecozone remains intact, only 36% of the Boreal Plains ecozone is similarly intact (Lee et al. 2006). Of any boreal province, Alberta has the least remaining intact forest at just 16% (Smith and Cheng 2016). However, when smaller patches are included, 57% of the Boreal Plains ecozone is forested (NFI [date unknown]). These smaller forests are often suitable for breeding songbirds but may be too small for area-sensitive species, including Bay-breasted Warblers and Canada Warblers (Odsen et al. 2018).

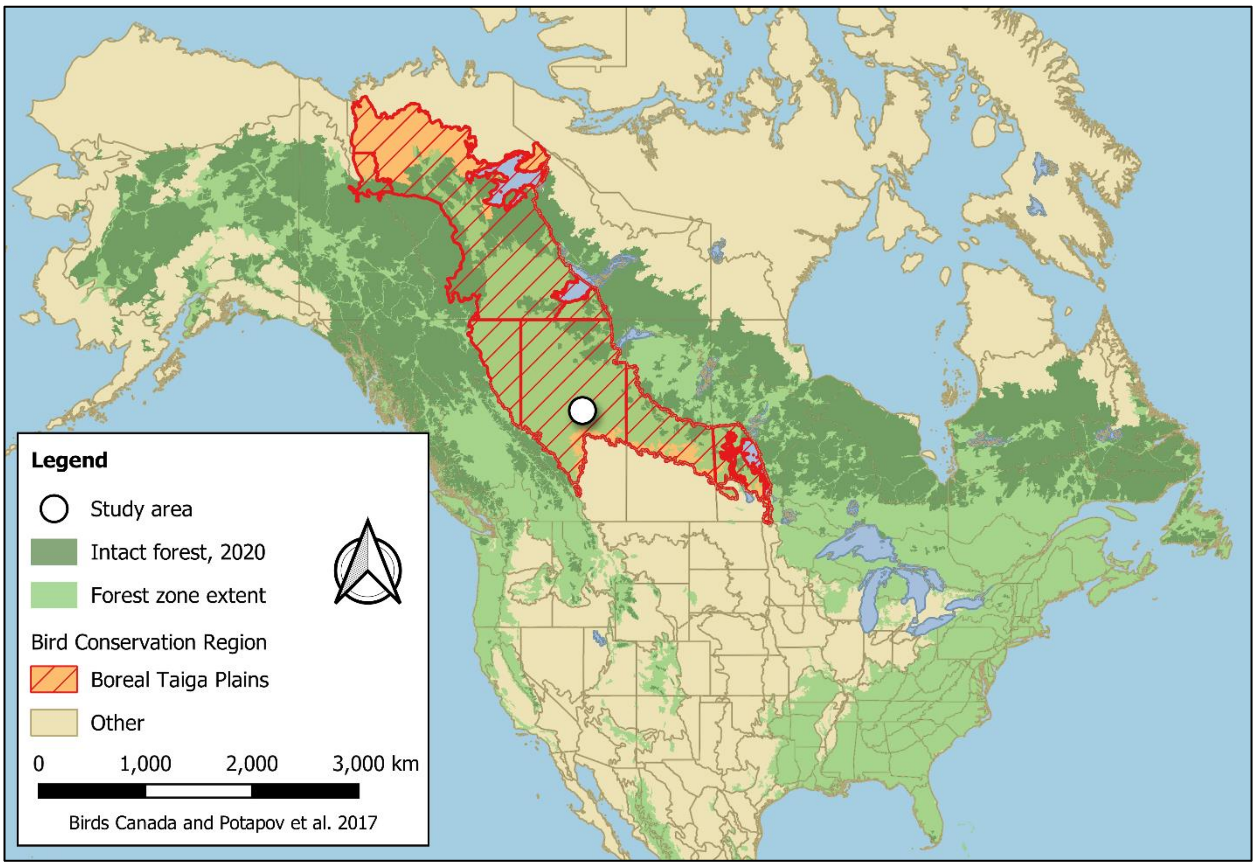

Figure 1. Extent of the Boreal Taiga Plains bird conservation region and of intact forests (≥ 500 km^2).

Alongside habitat loss is habitat fragmentation, the process whereby contiguous habitat is subdivided into smaller, isolated pockets that can be unreachable for recolonization and can result in local extinctions and range-wide population declines (Hanski and Ovaskainen 2000). Habitat fragmentation and associated edge effects can increase avian nest predation (e.g., Thompson et al. 2008) and parasitism (e.g., Bernath-Plaisted et al. 2017) and reduce food and nesting habitat availability (e.g., Betts et al. 2006). Due in part to habitat loss and fragmentation, some bird species which were once abundant in Alberta are experiencing population declines (Schmiegelow and Monkkonen 2002, Balmford et al. 2003).

1.3. Avian Responses to Boreal Habitat Disturbance

Bird communities shift in response to changes in habitat structure after disturbances on local and landscape scales (Hobson and Schieck 1999, Schieck and Song 2006, Galitsky and Lawler 2015). Timber harvest can simultaneously remove habitat for some bird species while creating habitat for others depending on species-specific stand age (Drapeau et al. 2000, Schieck and Song 2006) and cover type preferences (Westworth and Telfer 1993, Betts et al. 2007). Due to differing disturbance intensities, forestry may alter forest composition differently than natural disturbances (Norton and Hannon 1997, Hobson and Schieck 1999, Martin et al. 2021), resulting in different bird communities (Drapeau et al. 2000, Schieck and Song 2006, Leston et al. 2018).

Furthermore, various methods of forest harvest can influence regenerative successional paths, which in turn impacts species recolonization. For example, avian communities return faster to unharvested benchmarks in cutblocks with higher stand retention (Van Wilgenburg and Hobson 2008, Odsen et al. 2018). High retention levels can also sustain some of the mature forest bird community lost with clearcutting while hosting early successional species (Norton and Hannon 1997, Tittler et al. 2001). Maintaining connectivity using intact corridors between habitat fragments may also reduce the impacts of forestry (Schmiegelow et al. 1997).

Post-harvest stands in the boreal forest are estimated to take 30 to 60 years for distinct differences with post-fire forests to diminish (Hobson and Schieck 1999, Schieck and Hobson 2000, Schieck and Song 2006). However, Bayne and Hobson (2001) suggest that many fragmentation effects within even low-retention clearcuts may be short-lived as cutblocks regenerate and return to preharvest conditions.

1.4. Sensitive and At Risk Species

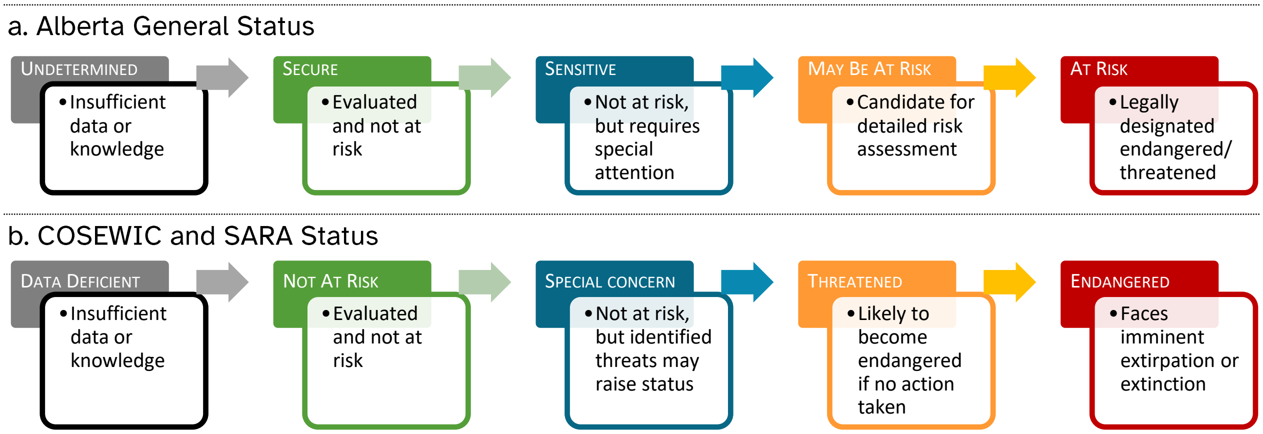

Figure 2. General (a) provincial and (b) federal conservation status categories, definitions, and hierarchy.

The Boreal Taiga Plains bird conservation region (Figure 1) is home to at least 50 bird species that are in decline (Smith et al. 2020). Species that require special protections because they are at risk of extirpation or extinction are listed provincially under schedule 6 of Alberta's Wildlife Regulations (GoA 2021) and Alberta's general species status listing (GoA 2022; Figure 2a) as determined by the Endangered Species Conservation Committee. Federally these species are listed under schedule 1 of the Species At Risk Act (SARA; GoC 2021a) as determined by the Minister of Environment and Climate Change Canada. Recommendations for SARA listings are issued by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), an independent panel of experts from academia, non-governmental organizations, and public and private sectors. COSEWIC statuses may differ from SARA listings, but both use similar designations (Figure 2b). Species of conservation concern which breed in the boreal forest are listed in Table 1.

Table 1. Species of provincial or federal conservation concern that commonly breed in the boreal forest.

SPECIES	STATUS (YEAR LAST ASSESSED/LISTED)		
Common name	**Alberta Status (2020)** [1]	**COSEWIC Assessment** [2]	**SARA Schedule 1** [3]
Trumpeter Swan	Sensitive	Not at Risk (1996)	
White-winged Scoter	Sensitive		
Sharp-tailed Grouse	Sensitive		
Pied-billed Grebe	Sensitive		
Horned Grebe	Sensitive	Special Concern (2009)	Special Concern (2017)
Eared Grebe	Sensitive		
Western Grebe	At Risk	Special Concern (2014)	Special Concern (2017)
Common Nighthawk	Sensitive	Special Concern (2018)	Threatened (2010)
Sora	Sensitive		
Yellow Rail	Undetermined	Special Concern (2009)	Special Concern (2003)
Sandhill Crane	Sensitive		
Whooping Crane	At Risk	Endangered (2010)	Endangered (2003)
Piping Plover	At Risk	Non-active (2001)	
Lesser Yellowlegs	Secure	Threatened (2020)	
Black Tern	Sensitive	Not at Risk (1996)	
Forster's Tern	Sensitive	Data Deficient (1996)	
American White Pelican	Sensitive	Not at Risk (1987)	
American Bittern	Sensitive		
Great Blue Heron	Sensitive		
Golden Eagle	Sensitive	Not at Risk (1996)	
Northern Goshawk	Sensitive		
Bald Eagle	Sensitive	Not at Risk (1984)	
Broad-winged Hawk	Sensitive		
Barred Owl	Sensitive		
Great Gray Owl	Sensitive		
Short-eared Owl	May Be at Risk	Threatened (2021)	Special Concern (2012)
Black-backed Woodpecker	Sensitive		
Pileated Woodpecker	Sensitive		
American Kestrel	Sensitive		
Eastern Kingbird	Sensitive		
Olive-sided Flycatcher	May Be at Risk	Special Concern (2018)	Threatened (2010)
Western Wood-pewee	May Be at Risk		
Eastern Phoebe	Sensitive		
Bank Swallow	Sensitive	Threatened (2013)	Threatened (2017)
Barn Swallow	May Be at Risk	Special Concern (2021)	Threatened (2017)
Brown Creeper	Sensitive		
Evening Grosbeak	Secure	Special Concern (2016)	Special Concern (2019)
Rusty Blackbird	Sensitive	Special Concern (2017)	Special Concern (2009)
Common Yellowthroat	Sensitive		
Cape May Warbler	Sensitive		
Bay-breasted Warbler	Sensitive		
Blackburnian Warbler	Sensitive		
Black-throated Green Warbler	Sensitive		
Canada Warbler	May Be at Risk	Special Concern (2020)	Threatened (2010)
Western Tanager	Sensitive		

1. Government of Alberta: Wild Species Status Search 2020 Status Listing (GoA 2022)
2. Committee on the Status of Endangered Wildlife in Canada: Canadian Wildlife Species at Risk (GoC 2022)
3. Government of Canada: Species at Risk Act, Schedule 1 (GoC 2021a)

1.5. Research Gaps

Avian Post-harvest Recolonization

Immediate shifts in bird communities after timber harvest are well documented (e.g., Westworth and Telfer 1993, Norton and Hannon 1997, Schmiegelow et al. 1997, Tittler et al. 2001), but beyond the first 5 years post-harvest, less is known since studies often use broad age classifications that may obscure early recolonization patterns (e.g., Drapeau et al. 2000, Machtans and Latour 2003, Schieck and Song 2006, Van Wilgenburg and Hobson 2008). While some studies use more precise age categories, they fail to consider the impacts of post-harvest management strategies which influence regenerative vegetative structure toward the goal of obtaining tree compositions similar to pre-harvest benchmarks (e.g., Hobson and Schieck 1999, Schieck and Hobson 2000, Odsen et al. 2018). Thorough understandings of avian recolonization rates in the first 30 years post-harvest wherein vegetative structure changes drastically, as well as the impacts of various post-harvest management strategies, are required for better landscape management.

Understory Protection Harvesting

Since harvestable aspen stands often have a spruce understory, understory protection harvesting (UP) attempts to leave approximately 50% spruce to promote regeneration into a coniferous stand with just 20% retention of residual forest (Grover et al. 2014). This can accelerate the released spruce's growth rates by 40-90% compared to unharvested stands. UP conifer yields can converge with unharvested mixedwoods within 60 years (Man and Greenway 2004, Grover et al. 2014). Additionally, since conifers are well established, the resulting stand is unlikely to require expensive vegetation control post-harvest (Lieffers and Grover 2004). This method leaves linear rows alternating between unharvested mixedwood shelterbelt, young white spruce, and vegetation-free corridors (Grover et al. 2014). Despite being a unique harvesting method with the potential to host distinct avian species assemblages, little research has been conducted on UP's impacts to avian biodiversity (Bradbury et al. 2004, Charchuk and Bayne 2018).

1.6. Study Objectives

Breeding bird surveys are a common way to determine the diversity and abundance of birds during critical breeding cycles (Ralph et al. 1993). These surveys can inform various stakeholders of bird communities found in different stand ages and forest types throughout managed areas and thus help guide decisions to maintain bird diversity. The goal of the breeding bird surveys described herein was to document songbird abundances in stands relatively recently harvested by Vanderwell Contractors (1971) Ltd. Breeding bird surveys were conducted in post-harvest and unharvested coniferous, coniferous-leading mixedwood, and deciduous-leading mixedwood stands over three breeding seasons to meet the following objectives:

1. document avian species and their breeding activity detected in each surveyed stand,
2. evaluate the short-term (< 30 years post-harvest) impacts of timber harvesting on songbird species richness, diversity, distribution, and habitat use,
3. identify species at risk and sensitive species and describe potential threats of forestry activities,
4. and compare results to similar studies conducted in Alberta and western Canada.

Periodic breeding bird surveys have been conducted within the study area (2001, 2005, 2009, and 2012) as part of the biodiversity monitoring activities of the Detailed Forest Management Plan for the Marten Hills Joint Forest Management Area. These surveys documented and compared bird diversity and species richness within broad stand ages and forest cover categories and included an understory protection sample. This understory protection transect and other predominantly undisturbed old-growth transects were resampled for this study to compare temporal shifts over a long timeframe and to sample an unharvested control.

Section 2: Study Area

The study area is in the Boreal Taiga Plains bird conservation region and in the Northern Alberta Uplands region which contains both Central Mixedwood and Lower Foothills natural subregions (Figure 1). Sampling prioritized stands managed by Vanderwell within the Marten Hills Joint Forest Management Area (S17) located north of the Lesser Slave River, and within the Vanderwell Contractors Forest Management Area (S24) west of the Athabasca River (Figure 3). To expand the sample size for deciduous-leading mixedwoods aged 21-30 years post-harvest, 21 sites were located within S20 south of the Lesser Slave River which is presently granted to West Fraser Mills Ltd. S17, S20, and S24 will hereafter be collectively referred to as the FMA.

The forested landscape is generally characterized by rolling hills with mixedwood stands of Trembling Aspen (*Populus tremuloides*), Balsam Poplar (*P. balsamifera*), White Spruce (*Picea glauca*), and Black Spruce (*P. mariana*) with limited stands of Paper Birch (*Betula papyrifera*), Tamarack (*Larix laricina*), Lodgepole Pine (*Pinus contorta*), and Jack Pine (*P. banksiana*). The FMA contains a complex mosaic of old-growth forest, natural and human-caused disturbances, and associated successional stages. Logged stands are frequently near or even contain burnt forest, infrastructure for oil and gas, or transportation corridors. Since logged stands are often clustered on the landscape, sampling distributions were similarly clustered (Figure 4).

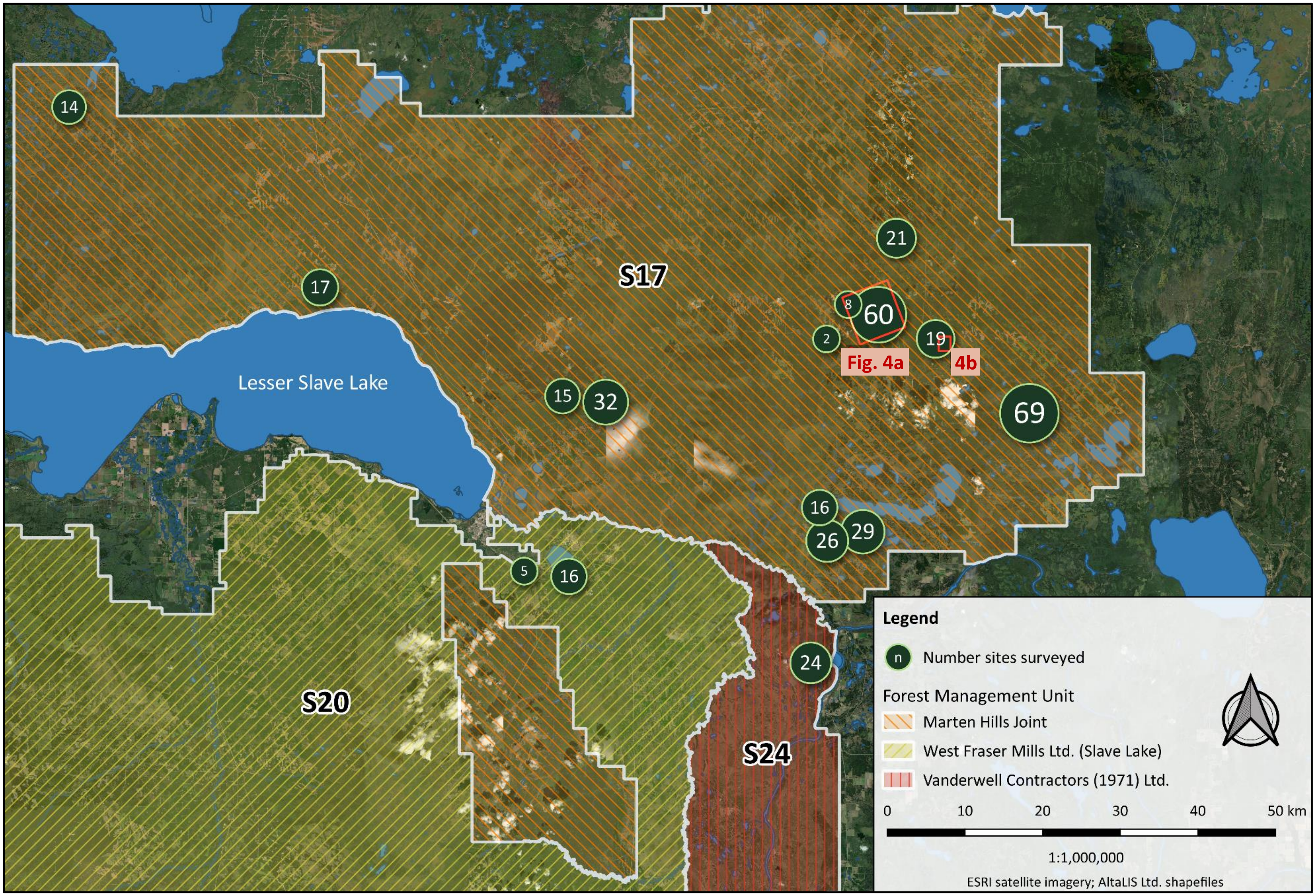

Figure 3. Approximate location of sample clusters within the FMA of the 2018-2021 breeding bird surveys. Sampling was non-random and used selection criteria described in Section 3. For coordinates of all survey locations see Appendix B.

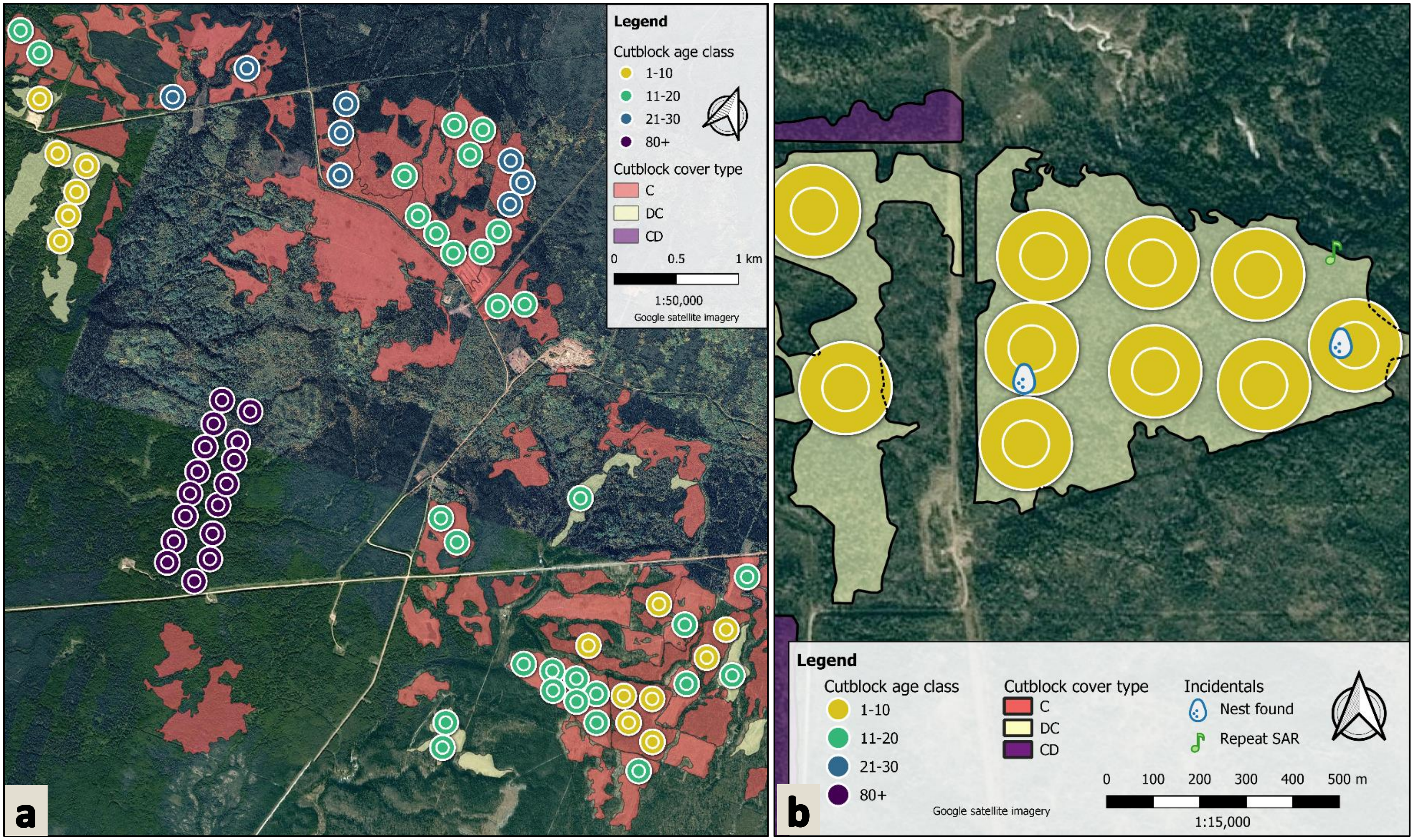

Figure 4. (a) Example spatial arrangement of point count sites within cutblocks and along an undisturbed previously sampled transect. Concentric rings of 50 m and 100 m radii were replicated on point count datasheets. Whenever possible, point counts were located 100 m from forest edge (minimum 60 m) with a separation between centres of ≥ 200 m (minimum 150 m). (b) Example of incidental nest records within a cutblock and location of a repeatedly detected Olive-sided Flycatcher.

Section 3: Methods

3.1. Forest Classifications

Age

Cutblocks were divided into three classes by the time elapsed since harvest: 1 to 10 years, 11 to 20 years, and 21 to 30 years (Figure 5). Stand age was updated yearly prior to surveys to reflect changes in classification between years. Unharvested forests were similarly classified using the Alberta Vegetation Inventory (AVI) to determine historical breeding bird survey routes without significant disturbances in 80 years or more for resampling.

Figure 5. Example habitat features of sites located in each age class: (a) 1-10, (b) 11-20, (c) 21-30, and (d) 80+. Exact vegetative height and composition was highly variable between sites.

Stand Type

Since various stand types contain different avian species assemblages (Hobson and Bayne 2000, Girard et al. 2004), reforestation designations and AVI stand stratifications were grouped into broad cover types: coniferous, coniferous-leading mixedwood, and deciduous-leading mixedwood (Table 2). Pure deciduous stands were not surveyed. An understory protection block (harvested in 2004-05) was also sampled using a historical breeding bird survey transect.

Table 2. Alberta forest stratification classes and simplified definitions (adapted from ASRD 2006).

Broad Cover Group	Code	Definition
Coniferous	**C**	Sum of coniferous cover ≥ 80 %
Coniferous-leading mixedwood	**CD**	Sum of coniferous cover < 80 % and ≥ 50 %
Deciduous-leading mixedwood	**DC**	Sum of deciduous cover < 80 % and ≥ 50 %
Deciduous	**D**	Sum of deciduous cover ≥ 80 % (not actively sampled)
Understory protection harvest	**UP**	Rows of deciduous between rows of young conifers

3.2. Site Selection Criteria

Sampling was limited by the number of cutblocks fitting each classification type and was based on non-random selection criteria. After forest fires in 2019 destroyed several sites, remaining cutblocks had to be intensively surveyed to obtain desired sample sizes, especially for cutblocks 21-30 years post-harvest. The following criteria were used when selecting survey sites:

1. **Number of point counts:** A minimum of 30 point counts are required to detect meaningful differences between bird communities occupying different habitats (Ralph et al. 1995), thus a minimum of 30 survey sites within each age category and cover type were plotted.
    a. **Unharvested stands:** Periodic breeding bird surveys within the FMA used transects established in 2001 and revisited in 2005, 2009, and 2012. To sample forest stands aged 80+ some of these transects were resurveyed in 2021. However, due to disturbances across the landscape since 2001, a sample size of 30 point counts could not be obtained for each unharvested cover type. To bolster sample size of unharvested blocks, 11 new stations were created near these transects.
    b. **Understory protection:** This unique harvesting strategy represents too small an area within the FMA to meet the minimum of 30 surveys. Instead, the original transect route (established 2005), was visited in 2018 to provide a continuation of a long-term data set, but a low sample size.
2. **Distance to cutblock edge:** To minimize edge effects, point counts should be ≥ 100 m from the forest edge (Figure 4). Although many similar studies successfully use this distance (e.g., Ralph et al. 1995, Hobson and Bayne 2000, and Leston et al. 2018), other studies have found 100 m impractical for obtaining the required sample size. Several studies reduce this distance to 75 m (e.g., Betts et al. 2006, Betts et al. 2007, and McNeil et al. 2014) or as low as 50 m (e.g., Hobson and Schieck 1999, Schieck et al. 2000, and Harrison et al. 2005). For this study, the distance from the forest edge to point count centre was a minimum of 60 m to increase the number of sites within cutblocks and to consider smaller cutblocks. When possible, a 100 m distance was maintained.
3. **Distance between point counts:** A single cutblock was not large enough to contain all 10-15 sites that could be visited in a day, but large distances between cutblocks can reduce the number of surveys that can be completed within the morning's survey window. Ralph et al. (1993) recommends a minimum distance of 250 m between sampling sites to increase statistical independence, but other studies have used 200 m (e.g., Norton and Hannon 1997, Schieck and Hobson 2000, MacFaden and Capen 2002, Girard et al. 2004, and Leston et al. 2018). Some studies have separations as low as 150 m (e.g., Saab 1999, and Harrison et al. 2005) or even 100 m (e.g., Hunt et al. 2017). A primary separation distance between point count locations of 200 m was used for this study with few exceptions that reduced this distance to ≥ 150 m to increase sample size and efficiency (Figure 4).
4. **Additional spacing requirements:** To maximize the number of sites visited in a single morning, no site was isolated ≥ 800 m from another point count location, unless it was ≤ 300 m from a road.

3.3. Point Count Surveys

Point counts could be conducted from June 1 to 30. This period is the peak breeding season of most songbird species expected in the FMA and when detection rates are most stable (Ralph et al. 1993). Surveys began at sunrise and ran no later than 10 AM, encompassing the period when bird activity is highest to bolster detection rates (Ralph et al. 1993). Surveys were conducted in fair weather conditions: temperatures above 0 °C, no more than a light drizzle, and wind no greater than 3 on the Beaufort scale (> 20 km/hr, GoA 2013). Each point count station was visited only once to increase the statistically independent sample size (Ralph et al. 1995).

Surveyors were proficient at identifying all Alberta boreal bird species by sight, sound, and behaviour. Observers located the centre of the point count using coordinates from handheld GPS units. All birds observed were recorded within a 5-minute silent listening period (Ralph et al. 1995, Matsuoka et al. 2014). North was confirmed with a compass to note the approximate direction of bird detections. The distance of each bird was documented to within a 50 m or 100 m radius or beyond 100 m from the point count centre (Figure 4; Matsuoka et al. 2014). Observers also recorded the type of observation to infer breeding activity, although these methods are insufficient to determine nesting sites or breeding status in most cases (Table 3). Surveyors made careful notes so birds using the edge could be excluded from analysis by sketching the cutblock edge on the point count datasheet prior to performing the count. Although the outermost segments of adjacent sample sites may overlap, double counting was minimized by noting repeat individuals in the field.

Table 3. Codes used by observers to describe the breeding activity for each species detected, ordered from weak evidence of breeding activity to direct evidence.

Code	Description
O	Observed (seen) or flying over (with direction), no evidence of breeding.
C	Heard calling.
S	Heard singing (or other sounds associated with breeding activity, for example drumming).
D	Courtship displays (both male and female involved) or territorial disputes.
NB	Nest building (carrying nesting material).
NA	Evidence of nesting activity (carrying food, faecal sac).
DD	Distraction display (attempts to draw attention away from nest).
F	Observed fledged young.
N	Location of active nest found.

3.4. Vegetation Structural Assessments

Observers conducted a vegetation structural assessment of the immediate area around the point count centre. Modified AVI codes were recorded to estimate canopy tree composition, canopy cover (%), and average canopy height (m). Other descriptions included understory cover (%), understory height (m), ground cover (%), ground cover height (m), and the amount of woody debris. Additionally, dominant shrub and herbaceous species were identified. In practice, if three distinct vegetative layers could be identified, the topmost was considered the canopy, even if this layer was relatively short. If only two distinct layers were identified, no canopy was recorded, and the topmost layer was documented as the understory. A brief description of general site features was written, and photos were taken facing each cardinal direction. Other variables, such as measures of tree density and diameter (e.g., Hegan and Meehan 2002) and shrub density and stem count (e.g., Saab 1999) were not collected. Obtaining these measures is a time-consuming process and would severely reduce the number of point counts that could be completed in a single morning. Additionally, variables of leaf litter depth, cutblock size, retention, surrounding habitat type and age, and other landscape disturbances were not compiled or included in analyses. These variables can influence avian distributions and their exclusions may confound results herein. Habitat description protocols were modified slightly between 2018 and 2020 to improve consistency between surveyors and to include protocols for site photos (no site photos were taken in 2018).

Section 4: Analysis

4.1. Generalizations and Exclusions

Subspecies identified in the field were generalized to species. To better estimate avian habitat use, reduce confounding edge effects, and increase independence between surveys, the following detections were excluded from all analyses: flyovers, repeat observations, birds observed over 100 m away or in edge habitat, and sites where habitat edge was less than 60 m from point count centre. The resulting dataset was used for general guild associations. To better estimate habitat associations for breeding birds specifically, additional data cleaning for estimations of species richness, diversity, and community similarity omitted waterfowl, shorebirds, grouse, raptors, Pine Siskins, and White-winged Crossbills due to their large home ranges, irruptive populations, and gregarious behaviour (Odsen et al. 2018).

4.2. Species Richness and Diversity

Overall bird abundance (the number of birds detected, **i**) and observed species richness (the number of species detected, **S**) was calculated for each forest classification. Sampling was not even across classes, so these values were divided by the number of sites surveyed (**n**) for comparisons between observed values. Since detection is imperfect, sampling was unequal, and observed species richness of diverse communities often depends on sample size, species richness was also estimated using coverage-based rarefaction to more accurately compare samples of equal completeness (Chao and Jost 2012, Odsen et al. 2018). Rarefaction controls for the dependence between detection and sample size by down-sampling large samples until they are similar to smaller samples. Coverage-based rarefaction discards less data to yield less biased assessments than traditional size-based rarefaction even with small sample sizes (Chao and Jost 2012). The iNEXT package (Hsieh et al. 2016) was used to estimate coverage-based rarefied species richness with 95% bootstrap confidence intervals using 500 permutations for each estimate. Large samples with more complete coverage could be interpolated in analyses, while smaller samples had to be extrapolated based on iNEXT's sample coverage estimates. The lowest sample coverage estimate (**SC**) was used to standardize results between classifications with comparisons restricted to this minimum coverage level. Non-overlapping confidence intervals indicate significant differences between samples at $p \leq 0.05$ (Chao and Jost 2012).

The Shannon Index (**H'**) provides insight into community diversity as follows: $H' = -\Sigma\, pi \ln(pi)$, where relative abundance (***pi***) is the number of individuals detected of one species divided by total number of individuals detected ($pi = i / I$, Shannon and Weaver 1949). The Shannon Index provides a measure of diversity that accounts not just for species richness, but also for the evenness with which individuals are distributed among all species. As a result, H' is sensitive to unique and rare species as well as common species. Between forest classes, high H' diversity values suggest a habitat with high diversity, i.e. a habitat that has high species richness with an even distribution of individuals between species. Low H' values indicate a habitat has few species and/or an uneven distribution of individuals such that a handful of species account for most detections. Since H' can be biased by sample size in the same way as species richness, rarefaction of Shannon Index values was performed in iNEXT with 95% bootstrap confidence intervals using 500 permutations for each estimate to control for sampling coverage.

4.3. Songbird Community Similarity

To estimate similarity of species composition (both richness and abundance) among forest classes, the number of birds detected was divided by the number of sites surveyed for each species. In the statistical program, R (R Core Team 2021), the pairwise Euclidean distance of species observations and forest classification was stored in a distance matrix. A hierarchical machine learning algorithm (Murtagh 1985) was then used to cluster points with three measures of distance: the minimum distance between clusters, the maximum distance, and the average distance. Each of these three distance measurements result in different class groupings, so the most valid output was selected through maximization of the Dunn Index (Handl et al. 2005). Results were visualized with a cluster dendrogram. A small distance before a group is merged with another indicates high similarity between those groups. When a large distance occurs before groups merge, these groups are dissimilar.

Since the produced dendrogram shows which communities are similar, but is unable to indicate where these similarities arise, the most common species detections were summarized. The percent relative abundance (see Section 4.2) of each species was compiled, then ranked from most abundant to least. The five most frequently detected species and their percent relative abundances were tabulated for each forest classification.

4.4. Guild Associations

Species were grouped into guilds by: documented stand-age preferences, typical foraging behaviour during the breeding season, nesting location, and migration distance (Table 4, Table A2). Guild associations included species with large home ranges, irruptive populations, and gregarious behaviour. To account for smaller sample sizes within some habitats, the sum of birds detected was divided by the number of sites surveyed.

Table 4. Codes and definitions of general forest age, foraging, nesting, and migratory guilds (adapted from Stelfox 1995, Norton and Hannon 1997, Schieck and Song 2006, Leston et al. 2018, and Cornell Lab 2022).

1. Stand age preference	Code	Strong preferences documented for…
Young	**Y**	… shrublands and recently disturbed forests.
Old	**O**	… forests more than 60 years post-disturbance.
Generalist	**G**	… multiple forest age-classes.
Aquatic	**A**	… open water rather than a specific forest age.
2. Foraging strategy	**Code**	**Diet consists primarily of…**
Aerial insectivore	**AI**	… invertebrates captured while flying.
Foliage gleaning	**FG**	… invertebrates from the surfaces of leaves and stems.
Bark gleaning	**BG**	… invertebrates from bark and within wood.
Ground gleaning	**GG**	… invertebrates from soil and leaf litter.
Insectivorous other	**IX**	… invertebrates from more than one of the previous methods.
Granivorous/frugivorous	**SF**	… seeds and berries.
Other	**O**	… invertebrates and seeds or berries, other animals, carrion.
3. Nesting strategy	**Code**	**Typically nests…**
Ground	**G**	… directly on the ground or floating on water.
Shrub	**S**	… below 4 m heights in shrubs and trees.
Canopy	**Cp**	… above 4 m heights in the forest canopy.
Cavity	**Ct**	… in cavities, typically of snags.
Parasitism	**P**	… by laying eggs in the nests of other birds.
4. Migration strategy	**Code**	**Description**
Resident	**R**	Does not migrate.
Short-distance	**SD**	Travels short distances south as far as northern Mexico for the winter.
Long-distance	**LD**	Travels long distances to Central and South America for the winter.
Irruptive	**I**	Distance traveled is variable and generally determined by food availability.

Similarity to the climax community (80+ years post-disturbance) was estimated by subtracting guild abundances per site of unharvested cover types from abundances at each harvested age class (Norton and Hannon 1997). For example, abundance of aerial insectivores in DC80+ was subtracted from the abundance of aerial insectivores in DC1-10, while C80+ abundances were subtracted from C1-10. Negative differences indicate that the harvested habitat has lower abundances than its unharvested counterpart and a positive difference indicates a higher abundance within the harvested sample (results in Section 5.4). Since understory protection (UP) is a relatively new harvesting technique, the difference between UP was considered against all other categories with negative values indicating higher abundances in the UP sample (results in Section 5.5). Standard error was calculated for each guild abundance. Detections for several guilds in all strategies were often too small for further statistical evaluations of significance.

4.5. Temporal Changes in Resampled Transects

Within the FMA, the first breeding bird surveys contributing to ecosystem-based forest management planning was undertaken by Weyerhaeuser Co. Ltd. in 2001 using several transects that contained various general forest types and stand ages (Brown 2001). By 2005, the FMA had changed hands and a second round of surveys was completed by Tolko Industries Ltd. in cooperation with Vanderwell Contractors (1971) Ltd. with an expanded sampling regime that included burnt, recent cutblock, and understory protection (UP) harvesting samples (Savignac 2006). After management of S17 was transferred again to Vanderwell, Tolko, and Alberta Plywood Ltd. with a joint Forest Management Agreement, these transects were revisited in 2009 (Krikun 2010) and 2012 (Krikun 2013). Sampling has since lapsed, but 5 transects crossing predominantly undisturbed old forests and the UP block (harvested 2004/05) were revisited once for this study.

Since data for the 2001 surveys is unavailable, data from 2005, 2009, and 2012 was compiled for resampled sites (Appendix B). Undisturbed transects (surveyed 2021) were grouped together to bolster statistical power, but the UP sample was considered separately because it was resurveyed in 2018. To detect changes in community characteristics, boxplots for total yearly bird abundance and species richness were generated. Since sample size was equal across years, rarefaction was not necessary. A single-factor ANOVA tested if differences between years were significant with a Tukey HSD test to indicate how years differed by comparing means with a 95% family-wise confidence level (Tukey 1949) with significance at $p < 0.05$.

4.6. Vegetative Structure

Since field records of habitat covariates were of insufficient detail for most models (Hagan and Meehan 2002, Leston et al. 2018), these variables were not included in analyses. Instead, general descriptions are provided to contextualize other findings. Field estimations of canopy, understory, and ground cover density and height were averaged within each forest classification. Since canopy density was recorded as a modified AVI code, the midpoint of each recorded category was averaged, increasing the associated uncertainty. Dominant vegetative cover was estimated by tallying the number of sites with each species recorded. Vegetation assessment datasheets permitted entry of up to nine understory species and twelve ground cover species to describe only dominant cover and to improve survey speed. Most sites did not require these fields be filled, so understory generalizations were restricted to the first five entries (includes 97.5% of field records, Appendix C, Table C1) and ground cover was restricted to the first eight (includes 94.5% of field records, Table C2). These records were further generalized by combining unidentified and identified species of each family and limiting descriptions to only species or families detected at ten sites or more. Generalized totals were divided by the number of sites surveyed for each forest classification. Understory and ground cover values were not weighted by the hierarchy of dominance recorded in the field as they cannot be translated to quantitative densities. To maintain consistency, canopy species were not weighted either although density values are available.

Section 5: Results

5.1. Survey Effort and Conditions

Avian species and their breeding activity was documented at 373 stations (Table 5a, Appendix B), including 298 new locations and 75 revisited locations from five periodic breeding bird survey transects. All point counts were performed between June 8 and June 26 yearly and 4:45 to 10:00 AM daily (Table 5b). Analyses included 368 stations after five sites were excluded due to unexpected habitat disturbances reducing the buffer between point count centre and edge habitat to below 60 m. No surveys were excluded due to poor environmental conditions as temperatures ranged from 2 to 22 °C ($\bar{x}$ = 12 °C), wind ranged from 1 to 3 on the Beaufort scale ($\bar{x}$ = 0.5), and only eight surveys experienced light precipitation. All sites received a vegetation structural assessment and 307 sites were photographed in 2020 and 2021.

Table 5. The number of sites (a) included in analyses over the number of sites surveyed for each cover and age class and (b) sampled in each year within the survey period.

a.	**COVER TYPE**				
AGE	**C**	**CD**	**DC**	**UP**	**Total**
1-10	36	34	31 / 33	0	**101** / 103
11-20	33	28	32	10	**103**
21-30	32	33	33	0	**98**
80+	24 / 27	20	22	0	**66** / 69
Total	**125** / 128	**115**	**118** / 120	**10**	**368** / 373

b. YEAR	**Survey period**	**Sites surveyed**
2018	June 14 - 17	53
2019	-	0
2020	June 11 - 26	125
2021	June 8 - 26	195
Total	**June 8 -26**	**373**

A total of 4,980 detections from 95 avian species were recorded (Appendix A, Table A1), from which there were 3,393 detections of 83 bird species used in guild association analyses (Table A2) and 3,201 detections of 64 songbird and woodpecker species used in diversity and distributions analyses after omitting detections likely to confound results (see Section 4.1). There were no unexpected species encountered.

Interruptions in Data Collection

Effort was limited in 2018 when heavy rainfall washed out bridges required to access most sites (Table 5b). Surveying was cancelled altogether in 2019 after the McMillan Complex forest fire started late May and was not declared under control until July 1, eventually burning 273,045 hectares. Despite the COVID-19 pandemic introducing unique hygiene protocols and challenges to surveyors, it did not impact sampling regimes such that 2020 and 2021 sampled more sites than initially planned to compensate for reduced efforts in 2018.

Sample Size Constraints

Sample sizes ranged from 10 to 36 point count stations within forest classifications. UP, CD80+, C80+, DC80+, and CD11-20 contained fewer than 30 point count stations each (Table 5a). For UP and 80+ samples, this was due to the limited availability of these habitats within the periodically resampled FMA breeding bird surveys. Meanwhile, the CD11-20 class was largely removed from the landscape by the McMillan Complex forest fire. Conversely, forestry activities increased C1-10 beyond 30 samples because some planned C80+ sites were logged in the time between planning and sampling.

5.2. Species Richness and Diversity

Estimated sampling coverage among all surveys was over 93% and ranged from 91% for C80+ (n=24) to 96% for DC1-10 (n=31), indicating that coverage was generally good (Table 6). Bird abundances were lowest in cutblocks 1-10 years post-harvest and C80+ (6.9-7.3 birds detected per site) and highest in DC11-20 and CD11-20 (11.6-11.9 birds per site). Within age classes, CD stands supported higher abundances than other cover types, while C stand abundances were frequently lower than similar aged stands.

Table 6. Sample size and coverage, and species abundance, richness, and diversity for each age and cover type.

Statistical analysis (see Section 4.2)		AGE AND COVER CLASS 1-10 C	1-10 CD	1-10 DC	11-20 C	11-20 CD	11-20 DC	11-20 UP	21-30 C	21-30 CD	21-30 DC	80+ C	80+ CD	80+ DC	All sites
n	Number of point count stations included in analysis	36	34	31	33	28	32	10	32	33	33	24	20	22	368
	Estimated coverage (SC %)	≥ 94	≥ 94	≥ 96	≥ 94	≥ 94	≥ 94	93	≥ 93	≥ 93	≥ 93	≥ 91	≥ 92	≥ 92	≥ 93
i	Abundance, detected	250	283	225	278	324	381	78	304	343	324	176	224	203	3393
	Abundance, after exclusions	238	262	197	274	311	357	73	286	317	318	158	210	200	3201
	Mean number of birds per site	6.9	8.3	7.3	8.4	11.6	11.9	7.8	9.5	10.4	9.8	7.3	11.2	9.2	9.2
S	Species richness, detected	32	35	30	39	36	38	21	40	45	38	38	44	36	83
	Richness, after exclusions	27	30	23	36	31	33	19	36	38	35	36	39	34	64
	Rarefied richness (at 91% SC)	23.0	24.8	21.5	29.8	24.6	29.8	19.0	30.1	29.6	27.7	34.9	34.3	30.2	34.1
	Mean richness per site	4.8	5.8	4.6	6.4	7.5	7.2	5.9	6.6	7.2	7.2	5.6	7.8	6.7	6.4
H'	Observed diversity	2.53	2.77	2.59	2.97	2.68	2.66	2.61	2.93	2.96	2.84	3.06	3.11	2.86	3.22
	Rarefied diversity (at 91% SC)	2.43	2.64	2.46	2.86	2.56	2.86	2.57	2.82	2.84	2.72	3.04	3.05	2.81	3.03

For direct comparisons between classes unbiased by sampling coverage, rarefied species richness and diversity for sites with large samples was interpolated to what would have been detected had sampling been equal at 91% coverage, thus rarefied species richness was often less than that detected during sampling (Table 6, Figure 6). Due to UP's small sample size, rarefied species richness was calculated from extrapolations of the UP rarefaction curve. True species richness and diversity (at 100% coverage) is higher than rarefied values.

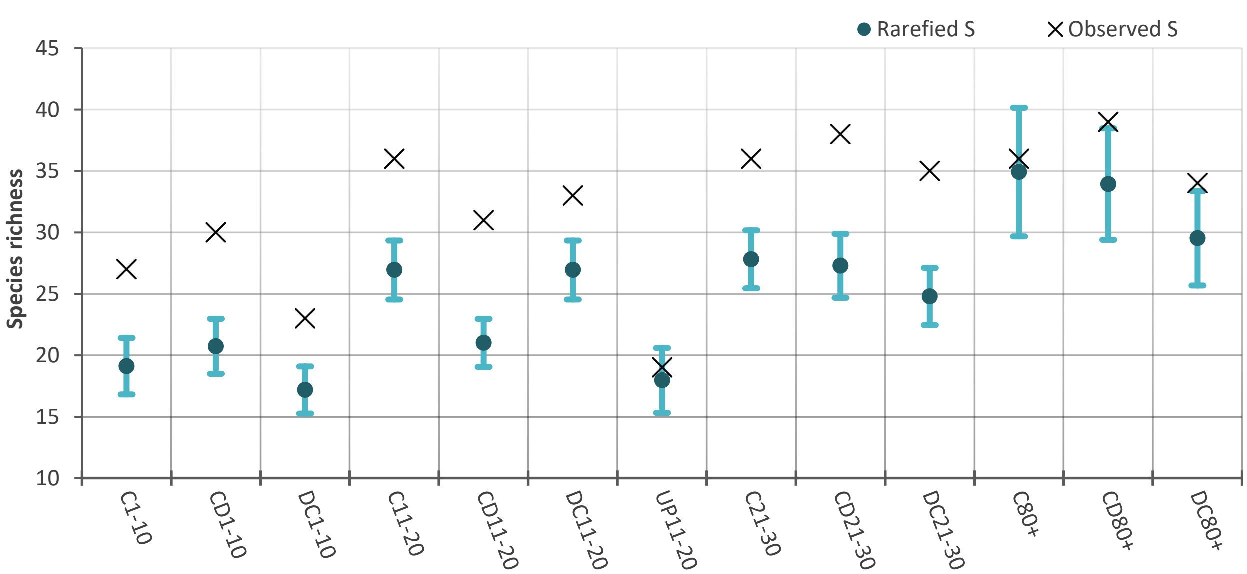

Figure 6. Species richness detected (observed) and estimated to 91% sampling coverage with 95% bootstrap confidence intervals (rarefied) for each combined age and cover class.

Species richness tended to increase as stand age increased (Figure 6). Despite hosting fewer individuals, coverage-standardized coniferous stands often had slightly more species than mixedwood stands of the same age (Table 6). When comparing cover type within each age class, species richness of the UP11-20 sample was significantly lower than C11-20 and DC11-20 samples, but not CD11-20 - itself with significantly less richness than these samples. However, since only 10 sites were visited on a single day, the UP sample may be strongly influenced by environmental conditions not controlled for by coverage-based rarefaction. No additional significant differences between cover types within other age classes were detected.

When comparing age classes within each cover type, there were more significant differences detected, potentially indicating that stand age influences species richness more than cover type. Significant increases for coniferous cutblocks were detected immediately between C1-10 and C11-20 cutblocks. Although C11-20 was similar to C21-30, there was another increase in species richness to C80+, but confidence intervals marginally overlap. However, non-overlapping confidence intervals may be a result of high degrees of uncertainty and does not necessarily imply non-significance (Chao and Jost 2012). DC1-10 similarly exhibited significantly lower rarefied species richness than DC11-20, but further significant differences were not detected between other age classes. Meanwhile CD species richness did not significantly increase until 21-30 years post-harvest.

Observed species diversity across the FMA was greater than any single sampled forest classification (H’=3.22, Table 6), but after standardizing to 91% sampling coverage, the FMA’s rarefied diversity was lower than C80+ and CD80+ due to the steep slope of the landscape rarefaction curve at 91% coverage where these other blocks had plateaued. This indicates that more sampling may be necessary for landscape-wide studies beyond the focused surveys presented here. Since species richness (Figure 6) is considered in species diversity analyses, trends in Shannon Index values (Figure 7) followed similar patterns to richness with deviations resulting from differences in community evenness. These deviations included: highoverlap between observed and rarefied diversity; failure to detect statistically significant differences between UP11-20 and other 11-20 cutblocks due to high uncertainty; and smaller differences between unharvested diversity and cutblocks than exhibited through species richness indicating that cutblocks may be more uneven than unharvested stands.

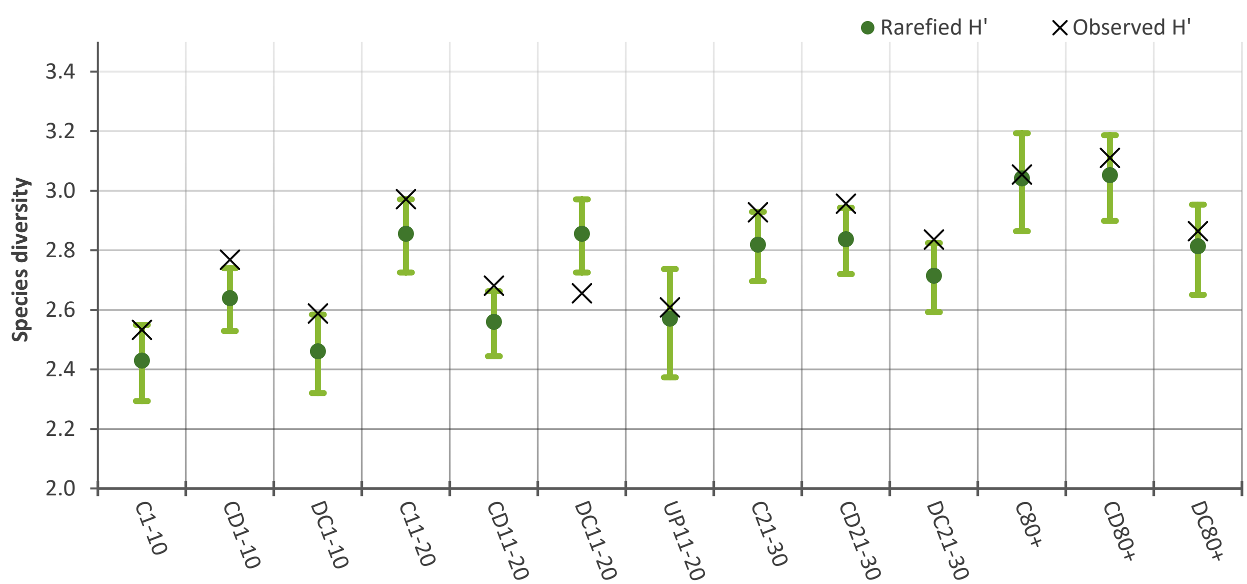

Figure 7. Shannon Index detected (observed) and estimated to 91% sampling coverage with 95% bootstrap confidence intervals (rarefied) for each forest classification.

5.3. Songbird Community Similarity

After algorithmically clustering avian communities, the Dunn Index for average-linked clusters was 0.8465278, indicating that average-distance clusters provided a more valid model than maximum-distance or minimum-distance clustering (Dunn=0.7158985 and 0.7429748, respectively). The results of averaged-distance hierarchical clustering are presented in Figure 8. There were four general community groups categorized as cutblocks 1-10 years post-harvest (orange), mixedwoods 11-20 years post-harvest (red), unharvested coniferous stands (blue), and unharvested mixedwoods, older cutblocks, and coniferous and understory protection cutblocks 11-20 years post-harvest (purple). Young cutblocks had high degrees of dissimilarity from any other sample. Within this cluster, C1-10 and CD1-10 exhibited the most similar community assemblages of any habitats surveyed. Although bird communities between CD11-20 and DC11-20 were quite dissimilar, they shared more in common than any other habitats. Among the remaining forest classifications, stands aged 21-30 years post-harvest were the most similar before linking to DC80+ and UP11-20. Unexpectedly, C11-20 and CD80+ were linked and showed high degrees of dissimilarity with other classes. C80+ had distinct bird communities, but was more similar to other unharvested stands and older cutblocks than to young cutblocks.

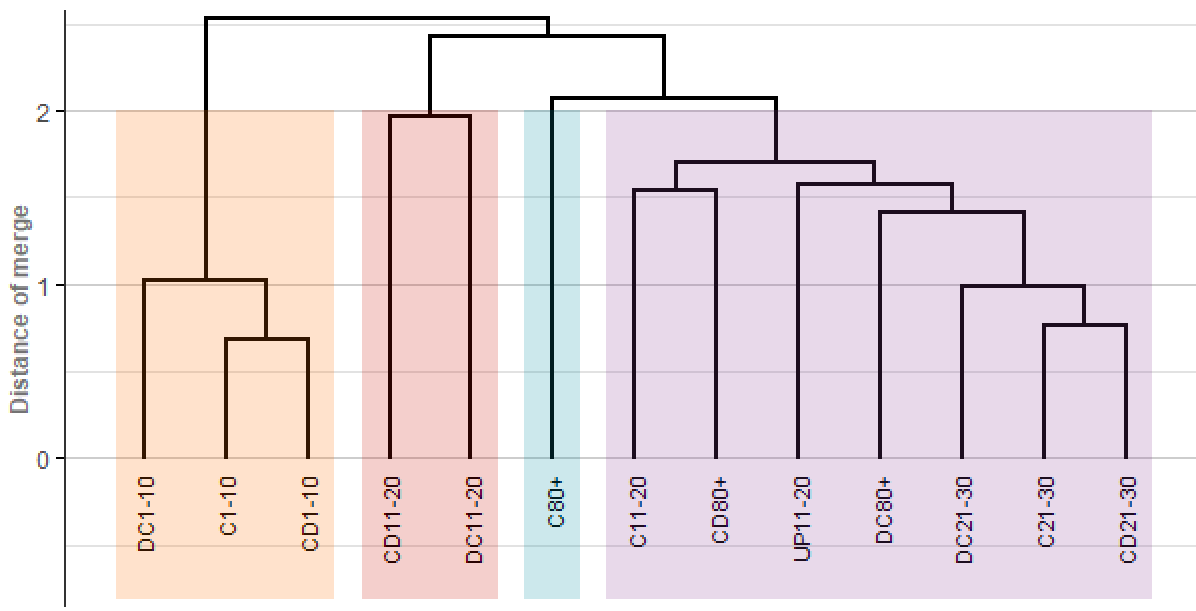

Figure 8. Cluster dendrogram for avian community structural similarity among forest classifications using average-linked Euclidean distance hierarchical clustering. Shorter distances before clusters merge indicates more similar communities.

The similarity between forest classifications can be partially attributed to abundances of the most common species (Table 7). White-throated Sparrows were common in all forest classifications, while Tennessee Warblers were common after the first 1-10 years post-harvest. There was relatively little overlap between common species in C1-10 and CD1-10 despite being tightly clustered, suggesting that rare species may drive this similarity. More coniferous-nesting species were detected in C11-20 and UP11-20 than in CD11-20 or DC11-20. These species were also most present in older cutblocks and unharvested forests. This may explain why C11-20 and UP11-20 are more similar to older stands than to stands of a similar age. Two of the most common species within C80+, Ruby-crowned Kinglets and Dark-eyed Juncos, were rarely detected in other habitats and may have contributed to this sample's high rate of dissimilarity. Other differences among the most detected species are discussed briefly in Section 5.4 where they pertain to shifts in guild abundances.

Table 7. Five most frequently detected species in each forest class with percent relative abundance in brackets.

Top	C1-10 Σ top 5 = **66.8%**	CD1-10 57.6%	DC1-10 61.9%
1	Lincoln's Sparrow (20.2%)	Alder Flycatcher (14.1%)	Lincoln's Sparrow (21.8%)
2	Alder Flycatcher (16.0%)	White-throated Sparrow (14.1%)	Alder Flycatcher (13.2%)
3	White-throated Sparrow (13.9%)	Lincoln's Sparrow (12.6%)	Clay-coloured Sparrow (11.2%)
4	Clay-coloured Sparrow (10.1%)	Common Yellowthroat (8.8%)	White-throated Sparrow (8.6%)
5	Tennessee Warbler (6.7%)	Red-eyed Vireo (8.0%)	Cedar Waxwing (7.1%)
Top	**C11-20 53.6%**	**CD11-20 62.4%**	**DC11-20 65.0%**
1	Tennessee Warbler (14.2%)	Red-eyed Vireo (15.1%)	Tennessee Warbler (26.6%)
2	Swainson's Thrush (12.4%)	Alder Flycatcher (13.5%)	Alder Flycatcher (13.2%)
3	Alder Flycatcher (11.3%)	Tennessee Warbler (12.9%)	White-throated Sparrow (10.6%)
4	White-throated Sparrow (10.6%)	White-throated Sparrow (11.6%)	Red-eyed Vireo (9.5%)
5	Red-eyed Vireo (5.1%)	Swainson's Thrush (9.3%)	Swainson's Thrush (5.0%)
Top	**C21-30 55.9%**	**CD21-30 53.3%**	**DC21-30 59.4%**
1	Tennessee Warbler (17.1%)	Red-eyed Vireo (15.1%)	Red-eyed Vireo (18.2%)
2	Red-eyed Vireo (14.7%)	Tennessee Warbler (13.6%)	Tennessee Warbler (11.9%)
3	Swainson's Thrush (10.8%)	Swainson's Thrush (10.1%)	White-throated Sparrow (11.3%)
4	White-throated Sparrow (8.0%)	White-throated Sparrow (8.5%)	Swainson's Thrush (10.1%)
5	Chipping Sparrow (5.2%)	Yellow-rumped Warbler (6.0%)	Ovenbird (7.9%)
Top	**C80+ 50.0%**	**CD80+ 48.6%**	**DC80+ 57.5%**
1	Chipping Sparrow (12.0%)	Tennessee Warbler (15.7%)	Tennessee Warbler (15.5%)
2	Ruby-crowned Kinglet (10.1%)	Swainson's Thrush (11.0%)	Swainson's Thrush (15.0%)
3	Dark-eyed Junco (10.1%)	Chipping Sparrow (7.6%)	Ovenbird (12.0%)
4	Swainson's Thrush (8.9%)	White-throated Sparrow (7.6%)	Red-eyed Vireo (9.0%)
5	Tennessee Warbler (8.9%)	Yellow-rumped Warbler (6.7%)	White-throated Sparrow (6.0%)

5.4. Guild Associations

The following describes associations of forest-age preferences, foraging, nesting, and migratory guilds within each cutblock classification. See Section 5.5 for guild associations of the understory protection sample.

Stand Age Preferences

Habitat age preference grouping categorized 1,479 birds of 12 species as habitat generalists, 1,113 birds of 36 species as young forest specialists, 788 birds of 29 species as old-growth specialists, and 13 birds of 6 species as aquatic (excluded from figures due to low abundances). Richness of species that prefer young forests was generally high with 15-18 species detected per forest class except in C21-30 (14 species) and DC80+ (13 species). Generalists and old-growth specialists tended to be richer in older cutblocks and unharvested stands (7-12 and 12-18 species, respectively) than young forests (5-7 and 7-9 species, respectively).

Abundances of young forest specialists were highest in young cutblocks and declined as cutblock age increased (Figure 9). Within age categories, coniferous cover types had fewer young-forest associated species than mixedwoods. Of young forest specialists, Alder Flycatchers, Clay-coloured Sparrows, Lincoln's Sparrows, and Common Yellowthroats were most common in stands younger than 21 years post-harvest, while Magnolia Warblers and Black-and-white Warblers were more common in older stands. Detections of old-growth specialists increased with stand age. Coniferous cutblocks often had the highest old-growth specialist abundances within age classes. Of old-growth specialist species, Canada Jays were more commonly detected in stands younger than 20 years post-harvest and older forests saw more Yellow-rumped Warblers and Red-breasted Nuthatches. Winter Wrens and Swainson's Thrushes were relatively common throughout age-classes. Generalist species were more common in older cutblocks with abundances especially high in DC11-20.

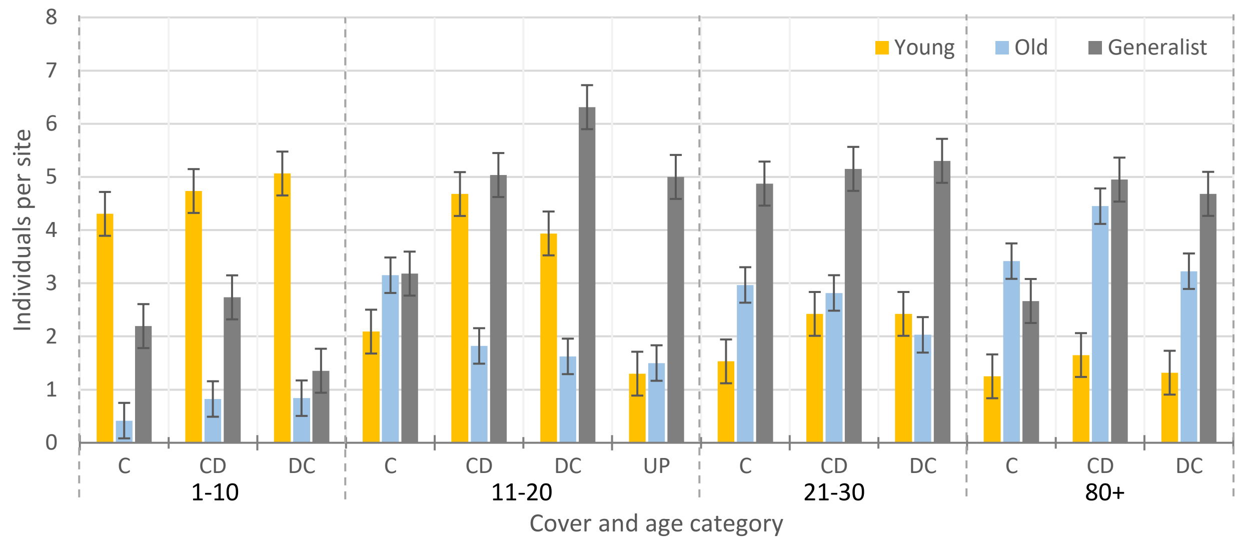

Figure 9. Mean bird abundance and standard error per site by stand age and cover type for birds categorized within each generally accepted forest-age preference.

When abundances among forest preferences were compared to unharvested stands of the same cover type (Figure 10), similarity to 80+ classes was highest in stands 21-30 years post-harvest and C11-20. Other samples saw higher abundances of young forest specialists and lower abundances of old-growth specialists. Generalist species were variable and tended to be slightly more common in cutblocks than unharvested stands.

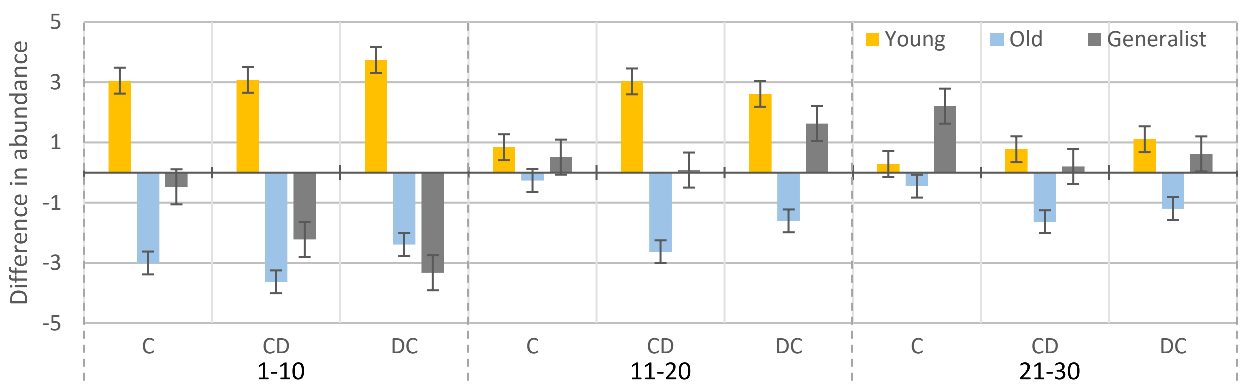

Figure 10. Differences in mean bird abundance per site (standard error) between cutblock categories and the associated unharvested sample for each guild of stand-age preferences.

Foraging

Between all sampled habitats, 1,184 birds of 18 species were categorized as foliage gleaning, 820 birds of 24 species as ground gleaning, 605 birds of 13 species as fruit or seed eating, 296 birds of 3 species as general insectivores, 288 birds of 7 species as aerial insectivores, 116 birds of 11 species as bark gleaners, and 84 birds of 19 species fit none of these categories (mostly waterfowl and raptors). For foliage gleaners, the highest species richness was in CD80+ and CD21-30 with 12 and 11 species, respectively, while the lowest richness was in DC1-10 with 5 species. The inverse pattern was observed for ground gleaning birds with DC1-10 exhibiting the highest richness at 15 species and DC80+ the lowest at 7 species. Differences in species richness was less pronounced for other foraging guilds.

Ground gleaning birds were most common in 1-10 aged stands of all cover types (Figure 11) with species composition dominated by various sparrow species in young stands and Ovenbirds in older stands. In stands 11+ years post-harvest, foliage gleaning birds tended to be the most common driven by Tennessee Warbler and Red-eyed Vireo detections. Aerial insectivores were most common in stands younger than 21 years post-harvest due mostly to Alder Flycatcher abundances. Bark gleaners were uncommon overall except in DC80+. Granivorous/frugivorous abundances were erratic with unreliable associations. Birds categorized as other saw an increase in abundances in stands 11+ years post-harvest driven by Swainson's Thrush detections.

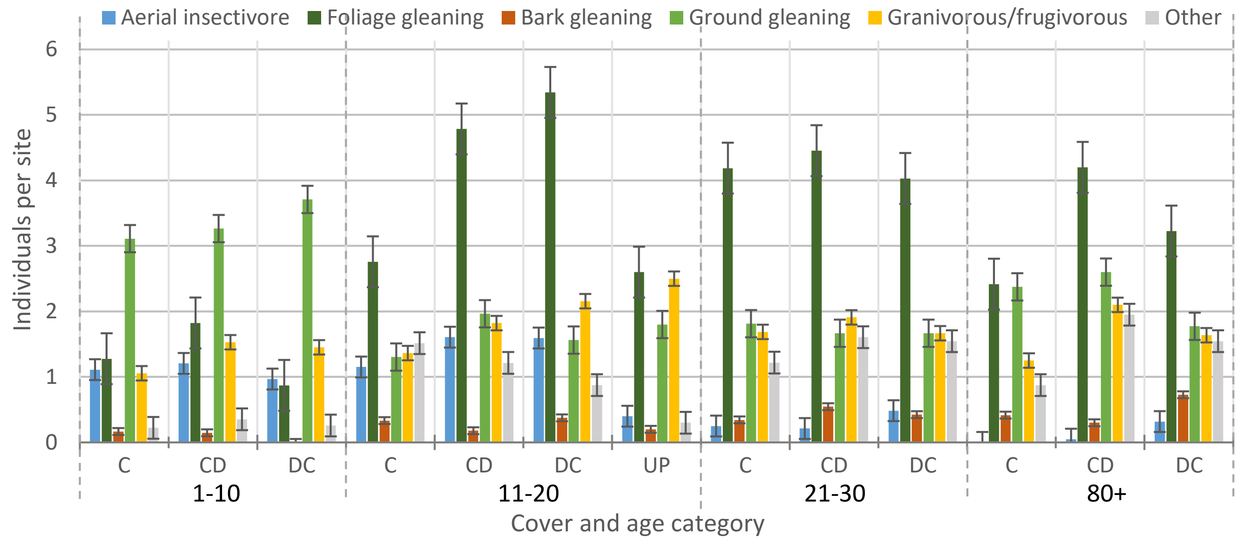

Figure 11. Mean bird abundance and standard error per site by stand age and cover type for each foraging guild. "Insectivorous other" and "other" categorizations combined.

When harvested cover types were compared to unharvested stands of the same cover type (Figure 12), dissimilarity between foraging guild abundances was most noticeable in cutblocks 1-10 years post-harvest. In these young stands, aerial insectivores and ground gleaners were more abundant, while foliage gleaning and granivorous birds were far less abundant than unharvested stands. By 21-30 years post-harvest, foraging guild abundances were generally close to convergence with unharvested stands.

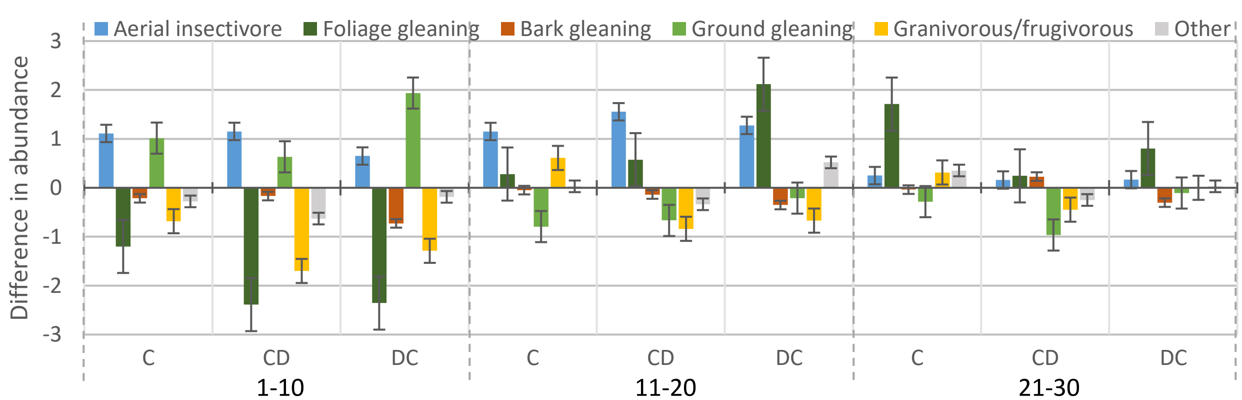

Figure 12. Differences in mean bird abundance per site (standard error) between cutblock categories and the associated unharvested sample for each foraging guild. "Insectivorous other" and "other" generalized to *other*.

Nesting

Two nesting guilds dominated detections: 1,768 birds of 36 species were classified as ground nesting and 1,120 birds of 12 species as shrub nesting. Just 381 birds of 28 species were canopy nesting and 123 birds of 18 species were cavity nesting. Only one Brown-headed Cowbird detected in a DC21-30 survey was classified as using a nest parasitism strategy (excluded from figures). Species richness of ground nesters was highest in C1-10 and CD21-30 with 17 species each and lowest in DC80+ with 12 species. Shrub nesting species richness was variable ranging from 6 to 11 species per class with mixedwood stands generally the richest. Canopy nesting was similarly variable with CD often detecting the highest richness of each age category. Cavity nesting richness was highest in C80+ with 7 species and lowest in DC1-10 with no detections.

Ground nesting species were the most abundant, except in CD11-20 cutblocks where abundances were equal to shrub nesters (Figure 13). In 1-10 aged cutblocks, Clay-coloured and Lincoln's Sparrows were the most common ground nesters, but after 11 years post-harvest Swainson's Thrush and Tennessee Warblers became the most abundant. Abundances of shrub nesting species were highest in cutblocks 11-30 years post-harvest. In young cutblocks, Alder Flycatchers were the most abundant shrub nesters, but were replaced by Red-eyed Vireos and Yellow-rumped Warblers in older cutblocks. Canopy nesters were most abundant in 80+ stands, but other associations were inconsistent. Most detections of canopy nesters in 1-10 aged stands were noted as foraging or singing from retained trees. Cavity nesters were largely absent from 1-10 aged cutblocks and most abundant in unharvested stands largely driven by Red-breasted Nuthatch detections.

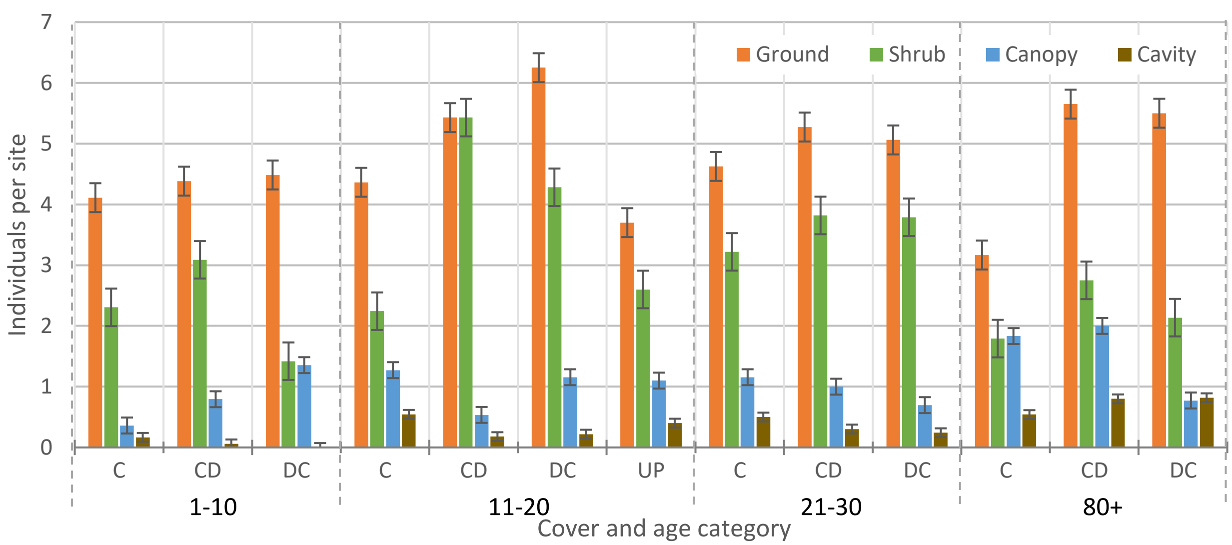

Figure 13. Mean bird abundance (standard error) per site by stand age and cover type for each nesting guild.

Ground nesters were consistently more common in coniferous cutblocks than C80+ (Figure 14). Although mixedwood cutblocks had lower ground nesting abundances than unharvested samples, these stands were close to convergence by 21-30 years post-harvest. Shrub nesters were often more common in cutblocks than unharvested stands, but abundances of cavity and canopy nesters was generally lower in cutblocks.

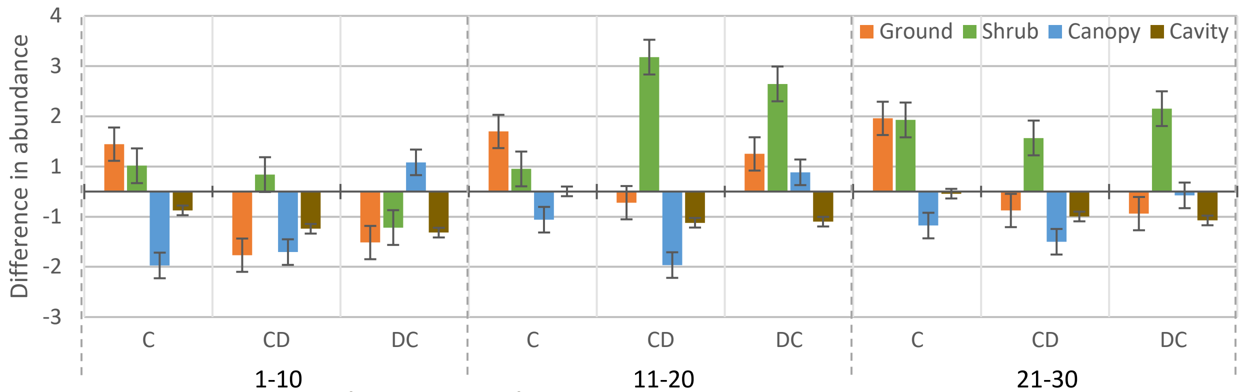

Figure 14. Differences in mean (standard error) bird abundance per combined age and cover category between each post-harvest cover type and the associated unharvested sample for each nesting guild.

Migration

Migratory strategies were similarly dominated by just two guilds: 1,969 birds of 40 species were classified as long-distance migrants and 1,146 birds of 26 species were short-distance migrants, but just 189 birds of 15 species were residents and 89 birds of 4 species were irruptive. In general, species richness of long-distance migrants increased with cutblock age and CD stands were the richest (23 and 21 species detected in CD80+ and CD21-30, respectively) and C blocks had the lowest richness (14 species in all C stands except C21-30). Richness of short-distance migrants was generally 13 to 15 species for all stands except the high of 16 species in C11-20 and low of 9 species in DC80+. Species richness of resident species was lowest in cutblocks aged 1-10 years post-harvest, but higher with little variation in other stand categories. Differences in species richness was less pronounced for irruptive species.

Long-distance migrants were relatively scarce in 1-10 aged cutblocks, but otherwise the most common migratory guild except for in C80+ stands (Figure 15). Several of the species driving this pattern (Tennessee Warbler, Red-eyed Vireo, Swainson’s Thrush, and Magnolia Warbler) were most abundant in cutblocks 11-30 years post-harvest. Short-distance migrants were most abundant in cutblocks aged 1-10 years post-harvest and in CD mixedwoods except for CD21-30 stands. This pattern was driven by declines in Clay-coloured Sparrow and Lincoln’s Sparrow abundances and increases in Yellow-rumped Warbler with increasing cutblock age. Overall, cutblocks 21-30 years post-harvest had the lowest abundances of short-distance migrants. Resident species were infrequently detected, especially in 1-10 aged cutblocks. Resident abundances were highest in 80+ stands due mostly to Red-breasted Nuthatch detections. Irruptive birds were similarly uncommon with loose associations to any habitat type.

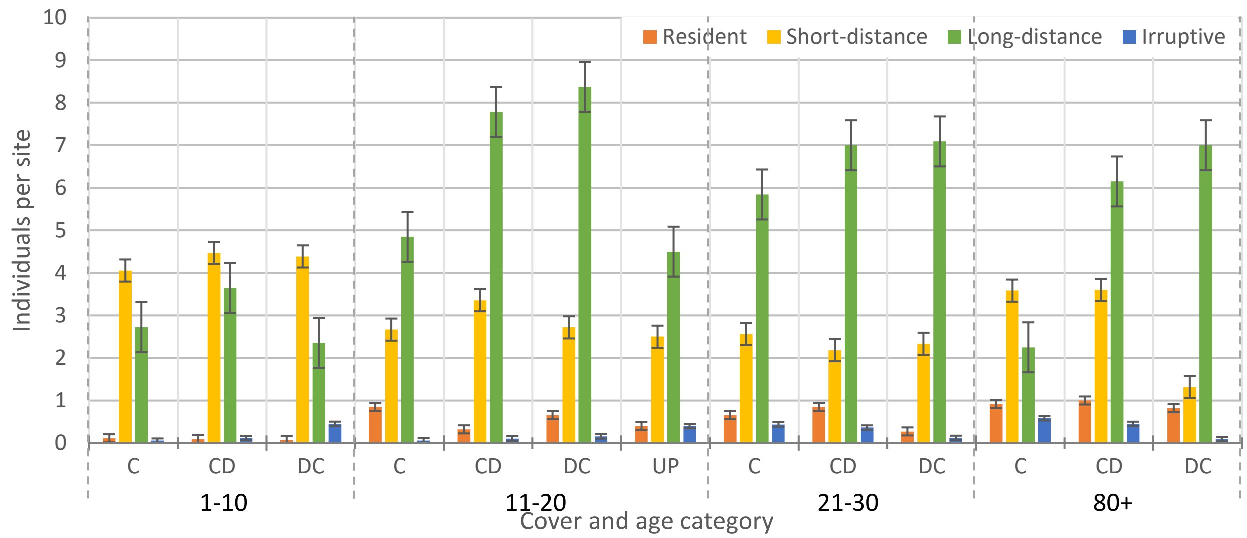

Figure 15. Mean bird abundance (standard error) per site by stand age and cover type for each migratory guild.

When compared to unharvested stands of the same cover category, there was close convergence in migratory guild abundances by 11-20 years post-harvest (Figure 16). In DC1-10 and CD1-10 cutblocks, short-distance migrants were more abundant and long-distance migrants were less abundant. Conversely, long-distance migrants were more abundant in cutblocks aged 11+ than in unharvested blocks.

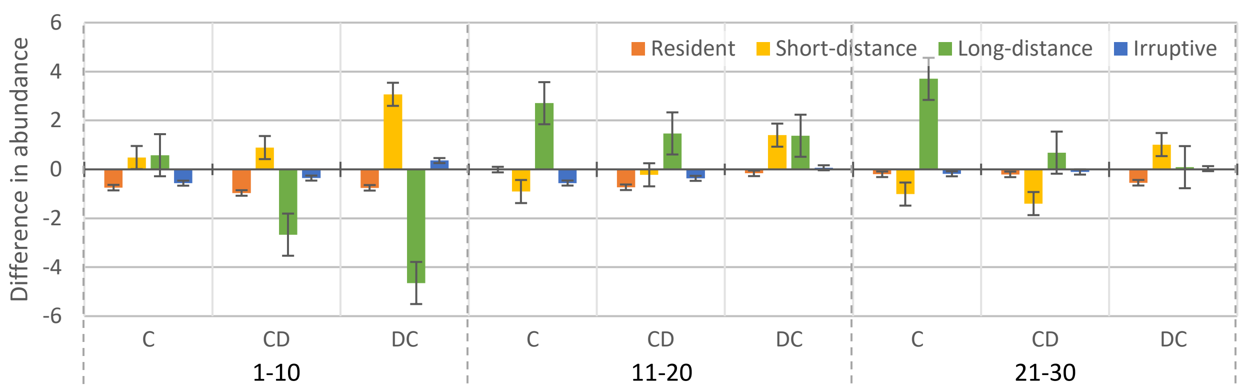

Figure 16. Differences in mean bird abundance per site (standard error) between post-harvest cover types and the associated unharvested samples for each migratory guild.

5.5. Understory Protection Harvesting

Data Limitations

Statistical uncertainty within the UP sample was often more than twice that of other cutblocks due to its small sample size (n=10; Figure 17). However, when standardized to 91% sampling coverage, the rarefaction curve for the UP sample appeared to have a smaller slope than other samples potentially indicating that additional sampling may not have resulted in significantly higher species richness or diversity values. However, it is probable that the UP sample was substantially influenced by seasonal variation in detectability, weather conditions, and impacts of intense rainstorms on breeding activities in 2018 - the year this cover type was surveyed on a single visit. Indeed, the Lesser Slave Lake Bird Observatory noted unusually high evidence of ongoing mid-season territory establishment and renesting attempts shortly after the UP stand was surveyed (Krikun 2018a, Kirkun 2018b, Perkins 2018). Furthermore, detected abundances of species with cyclic population fluctuations (for example, Tennessee Warblers) may have been impacted by sampling in a single year. As a result of these likely confounding variables, caution is advised when evaluating the following.

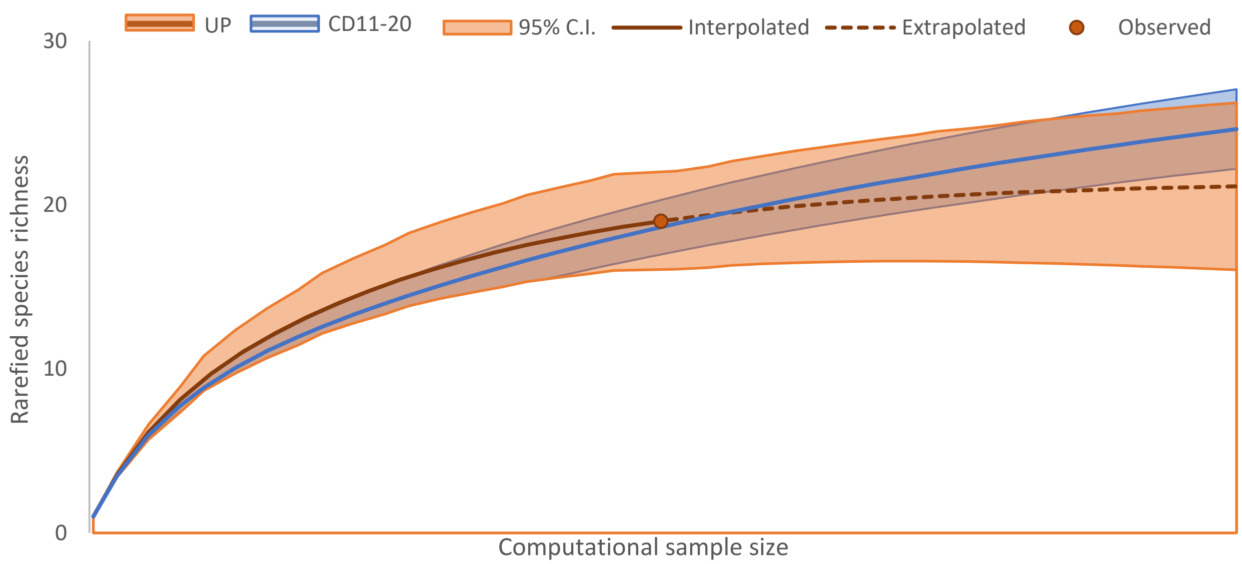

Figure 17. Rarefaction curves for UP11-20 and CD11-20 samples. Sample coverage was high enough for CD11-20 that extrapolation was not required, and uncertainty is low. UP required extensive extrapolation which involved high degrees of uncertainty.

Temporal Changes in Abundance and Species Richness

Between the years that the undisturbed transects were sampled, abundances (Figure 18a) and species richness (Figure 19a) differed ($F = 20.65$, $p < 0.001$ and $F = 22.64$, $p < 0.001$, respectively). For these undisturbed transects, there were no discernable differences in avian abundance or richness between surveys in 2005 and 2009, but both abundance and richness were significantly higher for surveys in 2012, with another statistically significant increase in both measures between 2012 to 2021. Although this could be due to covariates not included in the model, such as weather or surveyor experience and skill, monitoring from 2009 to 2021 was undertaken by the same surveyors or individuals they directly trained. For the understory protection transect, between-year abundances (Figure 18b) and species richness (Figure 19b) were similar, with a modest, but non-significant increase as year increased ($F = 0.569$, $p = 0.6$ and $F = 2.575$, $p = 0.06$, respectively).

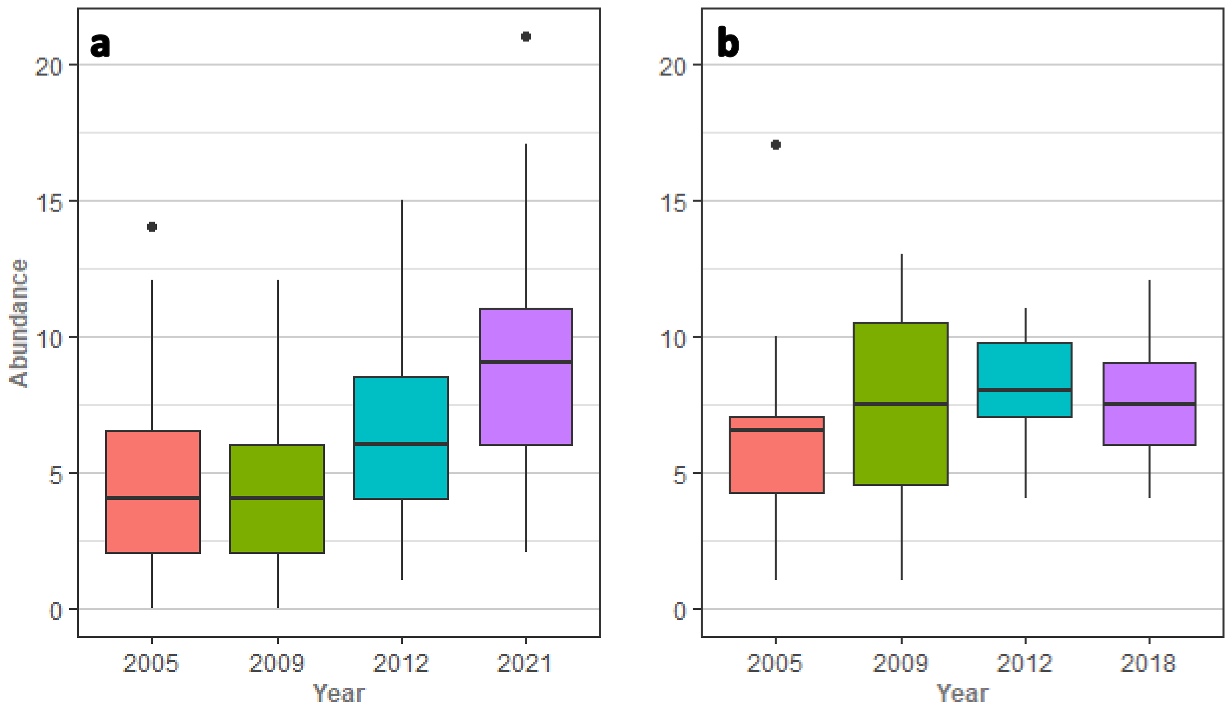

Figure 18. Boxplots of the average number of individuals detected in (a) undisturbed transects (4 transects, n = 51 sites/year) and (b) the understory protection harvesting transect (n = 14 sites/year) in each year of periodic resampling.

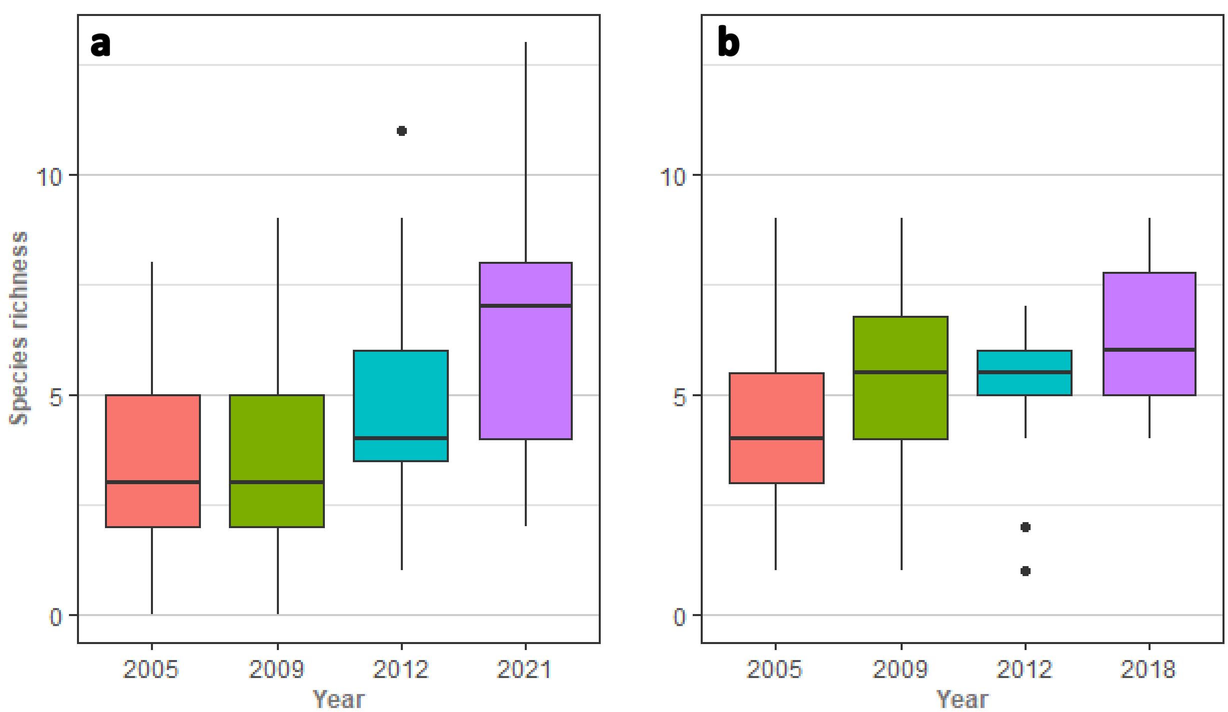

Figure 19. Boxplots of the average number of species detected of (a) undisturbed transects (4 transects, n = 51 sites/year) and (b) the understory protection harvesting transect (n = 14 sites/year) for each year of resurveying.

Understory Protection Harvesting Guild Associations

Since sample size was small for the UP cover class (n=10), guild associations are generally weak and may be biased by seasonal and environmental conditions at time of sampling. Since understory protection harvesting promotes regeneration toward a coniferous-leading mixedwood and is a relatively new harvesting technique without a direct 80+ aged equivalent, the UP sample is frequently detailed against CD samples below.

For the UP11-20 sample, abundances of species which prefer young forests were closest to unharvested stands (Figure 20a) with low abundances of Clay-coloured Sparrow, Common Yellowthroat, Lincoln's Sparrow, and Alder Flycatcher in each of these age classes compared to younger stands and low abundances of Magnolia Warbler and Black-and-white Warbler compared to 21-30 year post-harvest cutblocks (Table 7, Table 8). For species which prefer old forests, abundances within the UP11-20 sample were higher than cutblocks 1-10 years post-harvest with more woodpeckers, but generally lower than other cutblocks and unharvested stands with similarity highest to 11-20 aged mixedwood cutblocks. Abundances of generalists were most similar to cutblocks 21-30 years post-harvest. Overall, UP11-20 abundances among all forest age preferences was closest to 21-30 aged stands.

Table 8. Ten most frequently detected species in the 2018 understory protection harvesting sample with percent relative abundance in brackets.

Top	UP11-20	Σ top **5** = **60.3%**
1	White-throated Sparrow (17.8%)	
2	Red-eyed Vireo (12.3%)	
3	Ovenbird (12.3%)	
4	Tennessee Warbler (12.3%)	
5	Alder Flycatcher (5.5%)	

Top	UP11-20	Σ top **10** = **82.2%**
6	Chipping Sparrow (5.5%)	
7	Rose-breasted Grosbeak (5.5%)	
8	American Robin (4.1%)	
9	Magnolia Warbler (4.1%)	
10	Philadelphia Vireo (2.7%)	

Overall, UP foraging guild abundances were often closer to C samples than to other cover types (Figure 20b). Abundances of foliage gleaners were most alike C11-20 and C80+, but Red-eyed Vireos contributed much more to foliage gleaner abundances in UP than these other sites (Table 7, Table 8). Aerial insectivore abundances were more similar to 21-30 aged cutblocks and unharvested stands than to 11-20 cutblocks because of much lower abundances of Alder Flycatchers. Ground gleaner counts and composition were close to other mid-aged cutblocks. Other foraging birds were less common in the UP11-20 sample than any sample older than 11 years post-harvest due largely to low abundances of Swainson's Thrushes, while high abundances of granivorous birds were similar to DC11-20 and CD80+.

Abundances of nesting guilds were also closest to C11-20 and C21-30 (Figure 20c). Ground nesting birds were less common in the UP sample than all other samples except C80+ driven by Tennessee Warbler abundances. There were also fewer shrub nesting birds than in 11-20 and 21-30 mixedwoods in part since shrub nesting species richness was low in C and UP samples compared to these mixedwoods. Abundances of cavity and canopy nesters were similar to 21-30 aged cutblocks. Compared to the CD80+ sample, abundances were similar for all nesting guilds except ground and canopy nesters, which saw lower UP11-20 abundances.

Lastly, UP11-20 migratory guild abundances were again closest to C11-20 and C21-30 (Figure 20d). Short-distance migrants were less common in the UP11-20 sample than 1-10 aged cutblocks, but often marginally more abundant than other cutblocks and unharvest stands due primarily to sparrow detections. Conversely, long-distance migrants were generally more abundant than in 1-10 aged cutblocks, but less abundant than other cutblocks and unharvested stands. The exception again was the C80+ sample, which itself saw low abundances of long-distance migrants. Resident species detections were similar to other samples. Between the undisturbed samples, the UP11-20 block had the highest similarity with CD80+.

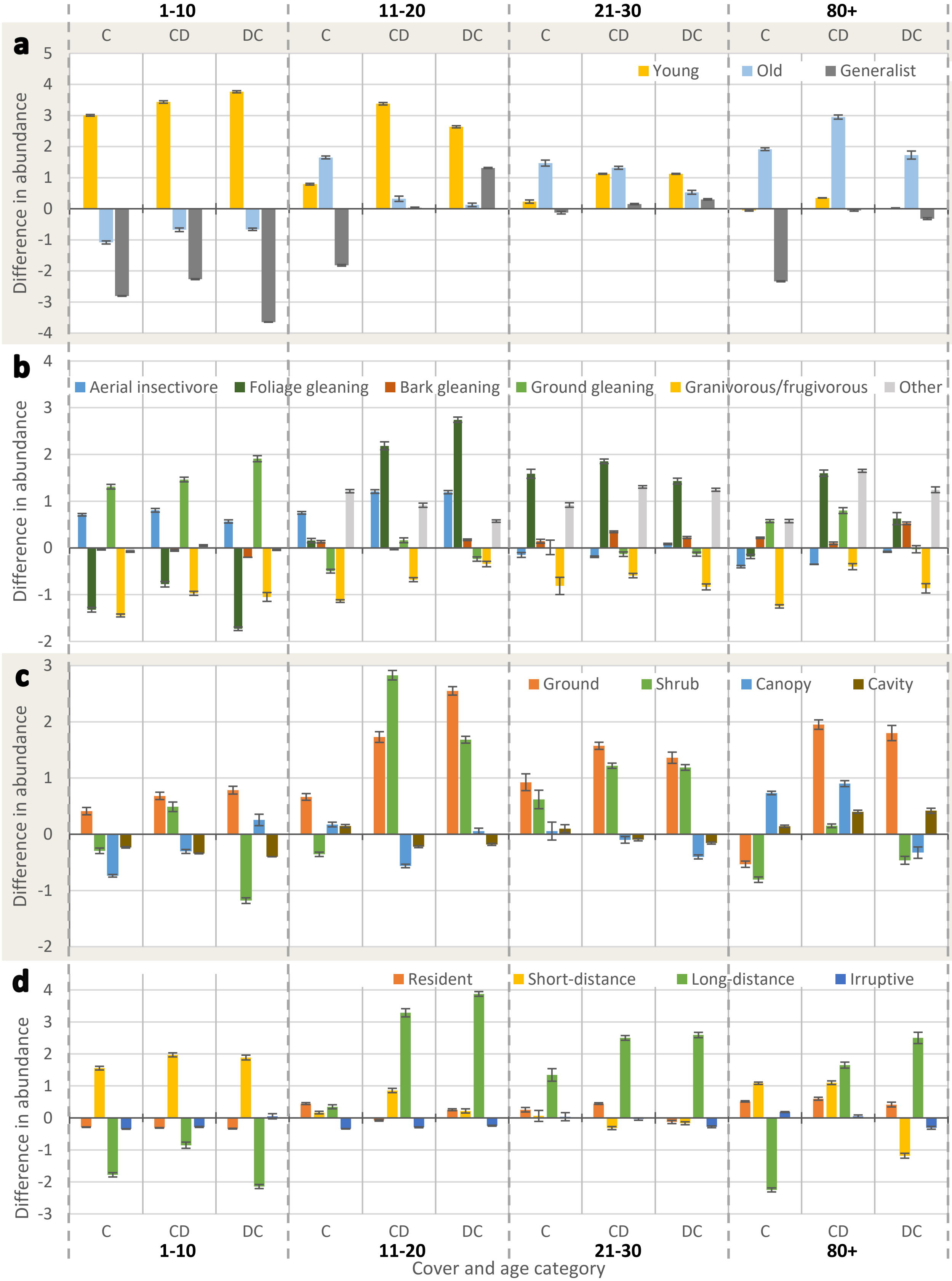

Figure 20. Differences in mean per site abundance (standard error) between understory protection samples and other age and cover categories for (a) stand age preferences, (b) foraging, (c) nesting, and (d) migratory guilds.

5.6. General Vegetative Structure

Below summarizes general results of vegetation structural assessments limited to cumulative families or species detected at ten or more sites. For detailed records, see Appendix C. In young cutblocks, canopy descriptions often reflected characteristics of retained vegetation and young trees were recorded as part of the understory or ground cover depending on their heights relative to other vegetation (Table 9). By 21-30 years post-harvest, canopy descriptions often included both retention and trees planted or germinated shortly after harvest as they distinctly reached above the understory.

The proportion of sites with coniferous species detected near the count centre increased from DC to C cover types, but detections of at least a small number of deciduous trees was consistent across forest classifications (Table 9). Stands designated as coniferous also tended to have the highest diversity of coniferous trees detected. Within 1-10 aged samples, there was more retained vegetation detected in C and CD blocks than DC, which had the lowest average canopy densities and height of any sample. The canopy became taller and denser by 11-20, except for CD11-20 (Table 9). CD11-20 was an outlier with a stunted canopy compared to other 11-20 aged cutblocks (Figure 21). Most CD11-20 sites were described as hummocky and wet or marshy. It is possible that techniques used during timber harvest or scarification in combination with landscape features altered soil structure and drainage, which together may be impacting CD11-20's successional processes. Similar hummocky and wet terrain was frequently described in C21-30 and, to a lesser extent, CD21-30 and DC21-30, but do not appear to be impacting the vegetation in these classes as strongly. Canopy density of the UP11-20 sample was more similar to 21-30 and 80+ aged stands.

Table 9. Percentage of sites surveyed with detections of each canopy species and average canopy density and height by forest classification.

	AGE AND COVER CLASS (% n)													
CANOPY SPECIES	**1-10**			**11-20**				**21-30**			**80+**			**All**
(see Appendix C)	**C**	**CD**	**DC**	**C**	**CD**	**DC**	**UP**	**C**	**CD**	**DC**	**C**	**CD**	**DC**	**sites**
White Spruce	16.7	26.5	6.5	21.2	57.1	50.0	90.0	75.0	93.9	84.8	8.3	45.0	81.8	48.1
Black Spruce	5.6	11.8	3.2	24.2	0	18.8	30.0	12.5	0	0	87.5	60.0	9.1	17.1
Jack Pine	0	5.9	0	9.1	0	0	0	0	3.0	0	4.2	0	4.5	2.2
Lodgepole Pine	2.8	0	0	42.4	0	0	0	12.5	12.1	0	29.2	10.0	0	8.7
Unidentified Pine sp.	0	0	0	3.0	0	3.1	0	3.1	0	0	0	5.0	0	1.1
Balsam Fir	5.6	2.9	0	0	0	0	30.0	0	3.0	0	0	10.0	4.5	2.7
Tamarack	0	0	0	0	0	3.1	0	3.1	3.0	0	0	0	0	0.8
Balsam Poplar	8.3	20.6	6.5	12.1	39.3	12.5	20.0	21.9	6.1	33.3	12.5	25.0	40.9	19.0
Trembling Aspen	25.0	32.4	9.7	24.2	46.4	71.9	90.0	56.3	78.8	60.6	12.5	75.0	77.3	47.6
Paper Birch	11.1	2.9	6.5	87.9	50.0	37.5	10.0	78.1	27.3	60.6	4.2	10.0	45.5	35.3
Canopy density (%)	11.7	8.4	5.0	37.8	34.7	40.5	46.3	46.7	47.8	41.5	42.5	43.0	51.8	35.2
Canopy height (m)	6.6	7.6	2.3	11.9	3.5	14.0	12.4	12.9	15.6	11.3	20.0	25.1	23.4	12.8

Understories were sparse 1-10 years post-harvest (Table 10). By 11-20 years post-harvest, understory density peaked (Figure 21b) before decreasing as the canopy became thicker and competition for sunlight increased. Understory height increased with stand age. In general, saplings of overstory species, willow species, and Green Alder were common. Not only were understories of mid-aged cutblocks the densest, but they were also the most complex with other low-lying shrub families, such as wild rose, honeysuckle, and currant species all most common 11-30 years post-harvest. Although the hummocky terrain appears to have affected the understory height of CD11-20, its density was similar to C11-20. The UP sample may be the outlier of the understory dataset since the UP11-20 average height is most alike DC1-10, the UP11-20 average understory density is closest to C21-30, but dominant vegetative compositions appear to be uniquely diverse.

Figure 21. Example vegetative structure for (a) CD11-20 cutblocks, which were often described as hummocky with stunted vegetation, and (b) of general CD11-20 cutblocks with thicker understories and taller trees.

Table 10. Percentage of sites surveyed with detections of each of the five most dominant understory species (detected at ≥ 10 sites) and average understory density and height by forest classification.

UNDERSTORY SPECIES (see Appendix C)	AGE AND COVER CLASS (% n) 1-10 C	1-10 CD	1-10 DC	11-20 C	11-20 CD	11-20 DC	11-20 UP	21-30 C	21-30 CD	21-30 DC	80+ C	80+ CD	80+ DC	All sites
Trees														
Spruce spp. sapling	75.0	70.6	48.4	57.6	60.7	81.3	10.0	93.8	78.8	78.8	100.0	80.0	50.0	68.1
Pine spp. sapling	16.7	11.8	3.2	45.5	0	9.4	0	12.5	0	0	0	5.0	0	8.0
Balsam Fir sapling	8.3	14.7	0	0	0	0	0	0	6.1	3.0	12.5	20.0	9.1	5.7
Balsam Poplar sapling	19.4	38.2	38.7	6.1	10.7	15.6	0	9.4	6.1	6.1	4.2	0	13.6	12.9
Trembling Aspen sapling	63.9	70.6	90.3	21.2	28.6	59.4	60.0	31.3	57.6	36.4	4.2	35.0	50.0	46.8
Paper Birch sapling	47.2	20.6	41.9	90.9	64.3	65.6	30.0	84.4	57.6	57.6	20.8	55.0	54.5	53.1
Shrubs														
Green Alder	13.9	11.8	16.1	51.5	17.9	21.9	10.0	15.6	6.1	27.3	29.2	45.0	59.1	25.0
Willow spp.	38.9	35.3	74.2	36.4	82.1	59.4	20.0	75.0	72.7	90.9	29.2	30.0	36.4	52.3
Red-osier Dogwood	0	0	6.5	6.1	3.6	6.3	0	0	0	24.2	0	0	0	3.6
Saskatoon	2.8	0	0	3.0	0	18.8	20.0	0	0	3.0	0	0	0	3.7
Wild Rose spp.	8.3	0	3.2	6.1	3.6	3.1	60.0	9.4	6.1	6.1	0	0	0	8.1
Wild Red Raspberry	5.6	0	12.9	3.0	0	3.1	10.0	6.3	0	3.0	0	5.0	4.5	4.1
Currant spp.	0	0	6.5	6.1	25.0	12.5	30.0	15.6	6.1	3.0	0	0	9.1	8.8
Cranberry spp.	0	0	0	0	0	0	30.0	6.3	3.0	15.2	0	0	0	4.2
Bracted Honeysuckle	2.8	0	0	6.1	14.3	12.5	30.0	9.4	0	12.1	0	0	9.1	7.4
Understory density (%)	**23.7**	**38.8**	**24.7**	**43.3**	**43.2**	**55.9**	**30.5**	**30.5**	**28.7**	**35.2**	**33.3**	**34.8**	**37.5**	**23.7**
Understory height (m)	**2.3**	**3.4**	**1.9**	**3.5**	**2.3**	**4.4**	**1.5**	**3.9**	**5.1**	**3.7**	**4.6**	**5.8**	**4.5**	**2.3**

Ground cover density was fairly consistent but tended to be higher in DC cover types (Table 11). Ground cover height was similarly consistent. Potential food sources for granivorous or frugivorous avian species, such as wild rose, raspberry, cranberry, and bunchberry, were common throughout forest classifications. Seedlings of spruce and Trembling Aspen (often shorter than knee height) were most frequently detected in 1-10 and 80+ aged stands. Tufts of grass may be used by certain ground nesting bird species to build their nests and grass was a particularly dominant feature of most forest classes except UP11-20 and 80+ samples. Mosses that can also be used by ground nesters were most common in C stands and moss dominance increased with stand age. Compared to other samples, C80+ exhibited low diversity within ground cover records. Noxious weeds (GoA 2016) were infrequently detected with Tall Buttercup, Perennial Sow-thistle, and Canada Thistle recorded at fewer than 10 sites all aged 1-10 years post-harvest (Table C2).

Table 11. Percentage of sites surveyed with detections of each of the eight most dominant ground cover species (detected at ≥ 10 sites) and average ground cover density and height by forest classification.

	AGE AND COVER CLASS (% n)													
GROUND COVER SPECIES	**1-10**			**11-20**				**21-30**			**80+**			**All**
(see Appendix C)	**C**	**CD**	**DC**	**C**	**CD**	**DC**	**UP**	**C**	**CD**	**DC**	**C**	**CD**	**DC**	**sites**
Trees														
Spruce spp. seedling	13.9	11.8	29.0	9.1	0	9.4	0	3.1	3.0	3.0	29.2	20.0	9.1	10.8
Trembling Aspen seedling	8.3	29.4	6.5	0	0	0	0	0	0	0	0	0	9.1	4.1
Shrubs														
Willow spp.	2.8	8.8	9.7	3.0	0	6.3	0	0	0	0	4.2	5.0	0	3.1
Wild Rose spp.	25.0	61.8	51.6	12.1	35.7	50.0	10.0	53.1	48.5	54.5	16.7	30.0	54.5	38.7
Raspberry spp.	88.9	76.5	74.2	33.3	64.3	62.5	20.0	37.5	45.5	42.4	16.7	50.0	54.5	51.3
Currant spp.	27.8	23.5	19.4	6.1	32.1	78.1	0	40.6	30.3	21.2	12.5	50.0	40.9	29.4
Cranberry spp.	0	23.5	3.2	6.1	32.1	3.1	20.0	40.6	57.6	57.6	16.7	20.0	59.1	26.1
Honeysuckle spp.	11.1	14.7	12.9	15.2	10.7	56.3	20.0	21.9	18.2	30.3	4.2	40.0	59.1	24.2
Blueberry spp.	25.0	0	3.2	54.5	0	12.5	10.0	21.9	12.1	3.0	100.0	20.0	13.6	21.2
Labrador Tea	16.7	0	3.2	48.5	3.6	3.1	0	15.6	3.0	6.1	79.2	25.0	9.1	16.4
Herbaceous														
Maianthemum spp.	2.8	0	0	0	10.7	6.3	10.0	3.1	6.1	9.1	0	5.0	0	4.1
Bishop's Cap	0	8.8	0	0	0	3.1	10.0	9.4	27.3	15.2	0	15.0	4.5	7.2
Strawberry spp.	19.4	17.6	38.7	9.1	21.4	31.3	50.0	28.1	39.4	27.3	0	5.0	4.5	22.5
Vetch/Peavine spp.	8.3	11.8	16.1	6.1	10.7	25.0	20.0	25.0	15.2	18.2	0	0	0	12.0
Clover spp.	0	5.9	0	3.0	7.1	6.3	0	0	3.0	21.2	0	0	0	3.6
Violet spp.	2.8	8.8	0	0	7.1	12.5	0	0	0	3.0	0	5.0	13.6	4.1
Fireweed	52.8	29.4	83.9	36.4	7.1	37.5	10.0	53.1	36.4	24.2	0	15.0	9.1	30.4
Starflower	2.8	0	6.5	6.1	0	0	0	3.1	0	9.1	4.2	0	4.5	2.8
Common Dandelion	11.1	5.9	0	6.1	7.1	3.1	0	3.1	6.1	18.2	0	0	0	4.7
Palmate-Leaved Coltsfoot	8.3	14.7	0	9.1	3.6	9.4	20.0	34.4	24.2	36.4	0	0	4.5	12.7
Wild Sarsaparilla	5.6	23.5	9.7	6.1	14.3	18.8	50.0	21.9	30.3	24.2	12.5	40.0	40.9	22.9
Bunchberry	33.3	20.6	22.6	45.5	10.7	28.1	90.0	59.4	57.6	36.4	25.0	35.0	40.9	38.8
Bluebell spp.	16.7	26.5	67.7	12.1	21.4	18.8	0	40.6	48.5	18.2	0	10.0	27.3	23.7
Bedstraw spp.	16.7	11.8	29.0	9.1	21.4	6.3	30.0	0	6.1	18.2	0	5.0	0	11.8
Grass spp.	97.2	97.1	96.8	72.7	96.4	96.9	50.0	87.5	78.8	87.9	29.2	70.0	63.6	78.8
Fern spp.	11.1	2.9	6.5	9.1	0	3.1	0	3.1	0	9.1	8.3	15.0	40.9	8.4
Horsetail spp.	72.2	52.9	83.9	54.5	57.1	56.3	30.0	71.9	54.5	57.6	20.8	65.0	63.6	57.0
Moss spp.	8.3	5.9	3.2	51.5	0	9.4	0	21.9	18.2	18.2	83.3	40.0	18.2	21.4
Ground cover density (%)	**79.4**	**75.7**	**88.9**	**80.8**	**88.4**	**78.9**	**60.0**	**78.0**	**68.3**	**82.4**	**74.4**	**74.3**	**77.3**	**79.4**
Ground cover height (cm)	**5.9**	**7.8**	**7.0**	**5.3**	**5.6**	**5.4**	**4.9**	**5.4**	**5.4**	**6.0**	**7.3**	**7.3**	**8.0**	**5.9**

5.7. Species at Risk and Sensitive Species

Point count surveys identified 20 species of conservation concern in the FMA (Table 12), of which 13 species were detected within cutblocks and 16 species were detected in edge habitats or unharvested stands. There were no detections of species listed as *endangered* under schedule 6 of Alberta's Wildlife Regulations (GoA 2022) or schedule 1 of the Species At Risk Act (GoC 2021a). In most cases, these sensitive and at risk species were detected too infrequently for rigorous statistical analyses of habitat associations.

Table 12. For species of conservation concern (highest status from Table 1), individuals detected within cutblock habitats over total numbers of individuals detected during point count surveys, strongest evidence of breeding activity observed (see Table 3), and forest class at count centre for birds using a cutblock, its edge, or a retained stand.

Species	Conservation status	Cutblock / total # ind.	Detection status	Cover type < 100 m of infinite distance detections (% of total individuals)
Common Nighthawk	Threatened	2 / 2	Nest found	C1-10 (50%), DC1-10 (50%)
Sora	Sensitive	2 / 4	Singing	CD11-20 (50%), C1-10 (25%), DC11-20 (25%)
Sandhill Crane	Sensitive	0 / 2	Calling	UP11-20 (100%)
Lesser Yellowlegs	Threatened	2 / 7	Singing	C1-10 (29%), DC1-10 (29%), CD80+ (29%), CD21-30 (14%)
Northern Goshawk	Sensitive	0 / 1	Flyover	CD80+ (100%)
Bald Eagle	Sensitive	0 / 1	Calling	CD21-30 (100%)
Great Gray Owl	Sensitive	1 / 1	Calling	CD21-30 (100%)
Black-backed Woodpecker	Sensitive	0 / 2	Drumming	C80+ (100%)
Pileated Woodpecker	Sensitive	7 / 14	Drumming	CD11-20 (21%), DC21-30 (21%), DC11-20 (21%), CD1-10 (7%), DC1-10 (7%), C21-30 (7%), CD21-30 (7%), UP11-20 (7%)
American Kestrel	Sensitive	1 / 1	Observed	C1-10 (100%)
Olive-sided Flycatcher	Threatened	2 / 5	Singing	DC1-10 (40%), C1-10 (20%), CD1-10 (20%), DC80+ (20%)
Western Wood-pewee	May Be at Risk	4 / 6	Singing	C1-10 (33%), DC11-20 (33%), C11-20 (17%), CD11-20 (17%)
Barn Swallow	Threatened	1 / 1	Flyover	C1-10 (100%)
Brown Creeper	Sensitive	0 / 2	Singing	C80+ (50%), DC80+ (50%)
Evening Grosbeak	Special Concern	1 / 4	Flyover	DC1-10 (75%), DC21-30 (25%)
Common Yellowthroat	Sensitive	92 / 110	Singing	CD11-20 (28%), CD1-10 (22%), C1-10 (15%), DC11-20 (12%), DC1-10 (10%), CD21-30 (4%), DC21-30 (4%), C80+ (2%), CD80+ (2%), DC80+ (2%), C21-30 (1%)
Bay-breasted Warbler	Sensitive	0 / 5	Singing	CD80+ (60%), C80+ (20%), DC80+ (20%)
Black-throated Green Warbler	Sensitive	0 / 18	Singing	CD80+ (39%), DC80+ (33%), C1-10 (11%), DC21-30 (11%), DC1-10 (6%)
Canada Warbler	Threatened	3 / 11	Singing	CD80+ (27%), DC1-10 (18%), DC80+ (18%), C1-10 (9%), CD21-30 (9%), DC21-30 (9%), UP11-20 (9%)
Western Tanager	Sensitive	3 / 11	Singing	CD21-30 (27%), C1-10 (18%), CD1-10 (9%), C11-20 (9%), DC21-30 (9%), C80+ (9%), CD80+ (9%), DC80+ (9%)

Common Nighthawk (*Chordeiles minor*)

Causes of Common Nighthawk population declines require further investigation but may be linked to extensive pesticide use harming their insect prey base and to habitat loss (COSEWIC 2007, English et al. 2018). Common Nighthawk breeding habitat includes open areas with bare ground such that forest fire suppression, reforestation of abandoned fields and harvested forests, and intensive agricultural practices may reduce habitat availability (COSEWIC 2007). Since nighthawks are crepuscular and nocturnal, they were not anticipated during these early morning surveys. However, two nests containing 1-2 eggs were found by flushing adults 40-110 m from point count centres within two cutblocks 1-4 years post-harvest.

Lesser Yellowlegs (*Tringa flavipes*)

After substantial recent population declines, COSEWIC has recommended Lesser Yellowlegs be listed as *threatened*. Although hunting on Caribbean and South American migration and wintering grounds may be primarily responsible for declines, with 80% of breeding occurring in Canada's boreal forest, any continued decline in quality and quantity of breeding habitat through wetland draining may compound problems (COSEWIC 2020). It is currently unclear if forestry activities have direct negative impacts on their populations. In Alberta, Lesser Yellowlegs have a slight preference for forests with bountiful wetlands near recent burns, but travel far from nests while foraging and have large home ranges containing a diversity of habitats. As a result, this species was detected among many habitats with weak associations to any cutblock class between the seven birds detected.

Olive-sided Flycatcher (*Contopus cooperi*)

Olive-sided Flycatcher population declines have unclear origins but may be linked to reduced availability of insect prey, fire suppression, and habitat destruction (GoC 2016). This species is associated with high-contrast forest edges created by wildfires or timber harvest with high retention of tall snags and residual live trees. The impacts of habitat modification on the breeding grounds to population dynamics is uncertain (GoC 2016). Robertson and Hutto (2007) suggest that diminished reproductive success in post-harvest compared to post-fire regenerating stands may limit the benefits suggested by others of forestry activities. Although these surveys cannot provide strong evidence for reproductive success, Olive-sided Flycatchers were associated with edge habitats with four individuals singing from cutblock edges and another singing from a recently reclaimed wellsite. Olive-sided Flycatchers have incredible voice projection in young cutblocks and two individuals could be detected at point counts up to 700 m away from singing locations (Figure 4b).

Western Wood-pewee (*Contopus sordidulus*)

Of all regions in the Western Wood-pewee's range, Alberta has recently experienced the steepest population decline (ACA 2017). As a result, their status in Alberta is *may be at risk*. This flycatcher tends to be associated with open woodlands, forest edges, riparian habitats, and young coniferous-dominated mixedwood stands (ABMI and BAM 2020). Little has been published on responses to habitat disturbances, but abundances may be lower after harvesting than after natural disturbances (ABMI and BAM 2020). Six Western Wood-pewees were detected with two using edge habitat of cutblocks 1-10 years post-harvest and the rest in 11-20 years post-harvest cutblocks of all cover types surveyed.

Barn Swallow (*Hirundo rustica*)

Barn Swallows are seeing steep declines in Alberta and Canada, likely because of agricultural practices that remove nesting and foraging habitats, decreased availability of insect prey, exposure to pesticides, competition with invasive species, and summer cold snaps during breeding (COSEWIC 2021). Forestry activities are unlikely to put direct negative pressure on Barn Swallow populations since this species is associated with buildings for nesting and grassy clearings for foraging. One Barn Swallow was detected foraging over a cutblock 7 years post-harvest. It is likely this bird had a nest on nearby oilfield infrastructure.

Canada Warbler (*Cardellina canadensis*)

Direct sources of Canada Warbler population declines remain unknown, but habitat loss and degradation on their wintering range in the northern Andes (where approximately 90% of forests have now been cleared) are suspected to be the main driver. In western Canada, this species may be vulnerable to forestry, road development, and other losses of old-growth forest and riparian breeding habitats (AESRD and ACA 2014, Hunt et al. 2017). During these surveys, Canada Warblers were detected mainly in undisturbed forests. Of those observed using habitats created by a cutblock, two were detected in unharvested old-growth forest on the edge of cutblocks 1-10 years post-harvest and three were detected within cutblocks 21-30 years post-harvest, including one detection within the UP11-20 sample. These detections appear to be at odds with Canada Warblers' strong associations with old mixedwood forests with dense shrub layers (Krikun et al. 2018). However, these cutblocks in the 21-30 age class were all particularly small, covering areas less than 15 ha, which may compensate for the young stand age.

Federal Species of Special Concern and Provincially Sensitive Species

Of the special concern and sensitive species detected, Northern Goshawk, Great Gray Owl, Black-backed Woodpecker, Pileated Woodpecker, Brown Creeper, Evening Grosbeak, Bay-breasted Warbler, Black-throated Green Warbler, and Western Tanager all depend on mature and old-growth forests for nesting or other portions of their life cycles (GoA 2022). Timber harvest has been identified as a threat to these species which are vulnerable to habitat fragmentation and to forest management practices which lead to a contraction of old-growth forests (GoA 2022). Maintenance of their breeding habitat must be incorporated into management plans. Northern Goshawks, Black-backed Woodpeckers, Brown Creepers, and Bay-breasted Warblers were only detected in interior unharvested forests. Black-throated Green Warblers were more abundant in interior old-growth forests, but four individuals were detected using edge habitat of various cutblocks. Western Tanagers were similarly less selective and were found using multiple habitat types from the edge of 1-10 aged cutblocks to interior old-growth forest with three using CD21-30 cutblocks. Pileated Woodpeckers were detected across a variety of edge habitats such that preferred habitat is ambiguous, yet this species was not detected in interior old-growth forests. However, since they have far vocal projections, there were eleven confirmed repeat detections of individual Pileated Woodpeckers. As a nocturnal species, any detection of Great Gray Owl was unexpected, but one was heard having an altercation with a Red Squirrel within a CD21-30 cutblock. Finally, Evening Grosbeaks were only detected flying over cutblocks or their edges.

Declines of other sensitive species detected during these surveys have not been directly associated with timber harvest because these species do not rely on mature forests. Bald Eagles nest in low densities in Alberta and anthropogenic disturbance may cause nest destruction or abandonment (GoA 2022). Sandhill Crane, Sora, and Common Yellowthroat may be threatened by loss of wetland habitat (GoA 2022). American Kestrel populations in Alberta are experiencing decline, but the causes are unknown. A single Bald Eagle was detected. Since Bald Eagles have home ranges from 6 to 47 km^2 (Garrett et al. 1993), little can be said about this encounter, but there was pond and lake habitat within 2-10 km. Similarly, a pair of Sandhill Cranes was detected, but due to large home ranges and vocal projections, nothing can be inferred of their habitat use. One American Kestrel was detected in a C1-10 cutblock on a snag. This is unsurprising as they are obligate cavity nesters with a preference for open woodlands. Similar to Pileated Woodpecker, Sora have a far-reaching voice and of seven detections, three were repeats. Two Soras were within CD11-20 and DC11-20 cutblocks described as wet and hummocky and the other two were using edge habitat. Finally, Common Yellowthroats were frequently detected anywhere there was a modest wetland, but especially in stands aged 1-10 years post-harvest. Even in old-growth forests they seemed to show a preference for clearings, but it was not assessed if these clearing were created by wetlands.

5.8. Incidental Encounters

Nests

Locating nests was not the goal of these surveys, but there is no stronger evidence of breeding attempts within a habitat. Surveyors recorded nest locations as they were found (e.g., Figure 4b). Between conducting surveys and traveling between points, a total of 14 nests were discovered (Table 13). Nests were not intentionally approached to minimize the risk of damaging the nest or of nest abandonment or predation (GoC 2021b). However, many nests were found when the adult flushed while surveyors were less than a metre away and the nest had to be located to determine an alternative route that avoided accidentally damaging it. Since nest status was only documented once and often estimated, nesting success is unknown. All nests were detected in young forests with only one Chipping Sparrow nest detected outside of a cutblock. This trend could be related to the high abundances of ground nesting species detected within these young forests (Figure 13).

Table 13. Nests located incidentally in associated cutblock age and cover classes.

Species	Date	Cover	Age	Description
Common Nighthawk	18/06/2020	C	1-10	Active ground nest with 1 egg.
Common Nighthawk	26/06/2020	DC	1-10	Active nest with 2 eggs on old temporary road.
Wilson's Snipe	17/06/2018	DC	1-10	Probable active nest by adult behaviour. Not approached.
Wilson's Snipe	25/06/2020	C	1-10	Active nest with 4 eggs in grass cup in hummocky habitat (pictured below).
Wilson's Snipe	24/06/2021	C	1-10	Active ground nest by adult behaviour. Not approached.
Solitary Sandpiper	26/06/2020	DC	1-10	Probable active nest in a wet depression. Not approached.
Hairy Woodpecker	15/06/2018	UP	11-20	Active nest with ≥ 2 nestlings in a snag on clearing's edge.
Red-breasted Nuthatch	19/06/2020	CD	1-10	Active nest in retained coniferous snag. Adult delivering food. Not approached.
Chipping Sparrow	23/06/2020	Burnt	40	Active nest with 5 nestlings in Bracted Honeysuckle < 1 m high.
Chipping Sparrow	11/06/2021	DC	11-20	Old/abandoned nest in young White Spruce < 1 m high.
Lincoln's Sparrow	24/06/2020	C	1-10	Active nest near ground along edge of marsh. Adult delivering food. Not approached.
Lincoln's Sparrow	24/06/2021	DC	1-10	Probable active nest by adult behaviour. Not approached.
Swamp Sparrow	19/06/2021	DC	11-20	Probable active nest by adult behaviour. Not approached.
Tennessee Warbler	22/06/2020	DC	21-30	Active nest with 3 nestlings in grass cup set into moss.

Wilson's Snipes are often associated with undisturbed wetlands and agricultural lands, but there are strong connections to recent boreal cutblocks as well.

Non-avian Wildlife

Due to the short duration and reliance on auditory signals of point count surveys, they are poorly suited for detecting non-avian wildlife (GoA 2013). Nonetheless, while conducting point count surveys, auditory and visual observations of other wildlife were recorded. Most observers lacked the skill required for reliable identification of tracks or scat, so these observations were not included. Furthermore, only species of conservation concern were recorded during travel between sites. In addition to three Western Toads detected during travel, there were 59 detections of non-avian wildlife (Table 14). Notably, the most detected non-avian wildlife species, Red Squirrel, was not detected in forested landscapes younger than 21 years post-harvest.

Table 14. Detections of non-avian wildlife at point count locations.

Species	Scientific name	Status (AB) [1]	Detections	< 100 m cover type
Western (Boreal) Toad	*Anaxyrus boreas*	Sensitive	4	DC1-10 (25%), C11-20 (25%), DC11-20 (25%), DC21-30 (25%)
Boreal Chorus Frog	*Pseudacris maculata*	Secure	2	C21-30 (100%)
Wood Frog	*Lithobates sylvatica*	Secure	2	CD21-30 (100%)
Red Squirrel	*Tamiasciurus hudsonicus*	Secure	44	C21-30 (34%), CD21-30 (25%), CD80+ (18%), DC80+ (18%), C80+ (5%)
Gray Wolf	*Canis lupus*	Secure	2	DC1-10 (100%)
Black Bear	*Ursus americanus*	Secure	2	C1-10 (50%), DC1-10 (50%)
White-tailed Deer	*Odocoileus virginianus*	Secure	2	C1-10 (50%), CD1-10 (50%)
Moose	*Alces alces*	Secure	1	DC21-30 (100%)

1. Government of Alberta: Wild Species Status Search 2020 Status Listing (GoA 2022)

Section 6: Discussion

6.1. Avian Assemblages in Cutblocks

Community Complexity

Over three field seasons we documented avian breeding activity at 373 single visit locations within thirteen predetermined forest classifications. Post-harvest recolonization trends in abundance and species richness were generally consistent with previous studies and deviations were likely due to variable retention rates among sample locations both here and in the literature. Statistically significant increases in complexity of avian communities observed through measures of abundance, rarefied species richness, diversity, and community structure of various guilds between cutblocks 1-10 and 11-20 years post-harvest occurred alongside extensive increases in vegetative complexity. These dramatic shifts in community structure were expected since the increased structural complexity of canopy and understory elements in older forests provides a multitude of foraging and nesting opportunities (Stelfox 1995) which can support more specialist species (Schmiegelow and Monkkonen 2002) and has been noted in similar studies (e.g., Westworth and Telfer 1993, Van Wilgenburg and Hobson 2008, Leston et al. 2018, Odsen et al. 2018). Another more subtle, but distinct shift in avian assemblages occurred between 11-20 and 21-30 years post-harvest as the canopy became more developed. Within each age class, differences between measures of abundance, species richness, and diversity may be attributed to differing retention rates between cover types at time of harvest (Schieck and Song 2006, Odsen et al. 2018).

Distinctions between forest classifications were less pronounced between measures of diversity (Shannon Indices) than measures of species richness as cutblocks were closer to convergence with unharvested stands in diversity than richness calculations. This implies that species are distributed more evenly within young cutblocks, while unharvested stands were uneven and influenced by detections of rare species - often old-growth forest specialists. Timber harvest, like forest fires, destroys habitat for old-growth specialists in the short-term, but simultaneously creates habitat for other more generalist species (Drapeau et al. 2000, Schieck and Song 2006, Betts et al. 2007), some of which are only found in these recently disturbed habitats. Stands aged 1-10 years post-harvest were distinct on the landscape, thus uniquely contributing to landscape-scale diversity. However, the contributions of continually created young habitats need to be balanced against the protection of old-growth forests and their associated specialist bird species found in no other habitat type (e.g., Brown Creeper, Golden-crowned Kinglet, Bay-breasted Warbler, and Black-throated Green Warbler). This is particularly true for old-growth coniferous stands, which were found to be nearly as unique a habitat type as young cutblocks.

Guild Associations

Similar to a recent longitudinal study (Leston et al. 2018), a short-term study establishing shifts in guild abundances (Norton and Hannon 1997), and studies with similar stand age classes (Westworth and Telfer 1993, Hobson and Schieck 1999, Schieck and Hobson 2000), ground nesting and foraging species were the most common guilds in stands aged 1-10 years post-harvest. These guilds were often represented by Solitary Sandpiper, Killdeer, Common Snipe, Clay-coloured Sparrow, Lincoln's Sparrow, and LeConte's Sparrow.

Shrub nesting guild abundances were correlated with understory density trends with both peaking 11-20 years post-harvest before declining as trees and tall shrubs limited light to low-lying shrubs and herbaceous vegetation (Leston et al. 2018). The exception comes through the hummocky terrain left after tree removal in cutblocks 11+ years post-harvest which created water-filled hollows with particularly wet soils in CD11-20 causing outlying vegetative characteristics. A similar soil structure was documented in Leston et al. (2018) and may have implications for avian recolonization trends described in both studies. Although Red-eyed Vireo, Black-and-white Warbler, American Redstart, and Rose-breasted Grosbeak were present in cutblocks 1-10 years post-harvest, their abundances did not peak until 21-30 years post-harvest, despite Westworth and Telfer (1993) finding peak abundances in stands aged 14 years post-disturbance. Furthermore, Alder Flycatchers (highest abundances 1-10 years post-harvest vs 14 years post-disturbance) and Ovenbirds (highest abundances 11-20 years post-harvest vs 30 years post-disturbance) were more common in younger stands than detected by Westworth and Telfer (1993). These species may have a more generalist nature than is often described.

Cavity nesters were unlikely to reoccupy harvested stands by 30 years post-harvest. However, unlike Leston et al. (2018), our surveys found that recolonization of species associated with older forests, resident species, and bark-gleaning species began quickly with abundances of each of these guilds becoming similar to unharvested stands by 21-30 years post-harvest. These old-growth and mature forest bird species were mostly absent from cutblocks 1-10 years post-harvest, but detections in other cutblocks slowly increased as cutblock age increased. Among these guilds generally associated with unharvested forests, Yellow-bellied Sapsucker, Western Wood-pewee, Least Flycatcher, Philadelphia Vireo, Winter Wren, Ruby-crowned Kinglet, and Yellow-rumped Warbler were detected in cutblocks less than 20 years post-harvest. After 20 years, Blue-headed Vireo, Boreal Chickadee, White-breasted Nuthatch, and Canada Warbler also returned to cutblocks in low abundances. These differences in results may be due to other studies investigating clearcuts with little to no retention, while stands surveyed herein had variable, but seemingly high retention rates. This retention, particularly in stands with a pure coniferous reforestation designation increases resource availability for these groups, including mature live trees for canopy and conifer nesters, larger snags with hollows for cavity nesters, and thick bark for bark gleaners (Leston et al. 2018). Indeed, the influence of retention on avian abundance and richness can be profound and detected immediately post-harvest with abundances of canopy, shrub, and cavity nesters decreasing less dramatically in cutblocks with high retention rates than clearcuts (Norton and Hanon 1997) and increasing convergence with unharvested samples as retention increases (Odsen et al. 2018).

Temporal Shifts

For transects within unharvested forests sampled in 2005, 2009, and 2012 FMA biodiversity monitoring surveys, and resampled for this project in 2021, significant increases in abundance and species richness were detected as survey year increased. It is currently unclear if these increases in breeding bird abundances and richness can be detected in similar local datasets, but this trend generally runs against provincial and national population trends showing decreases (Schmiegelow and Monkkonen 2002, Balmford et al. 2003). Indeed, surveys of the UP sample failed to detect similar increases despite differences being expected as the harvested area regenerates. Although populations may be recovering locally, other currently unknown influences cannot be ruled out. These results are not necessarily reflective of population trends across each species' entire range. It is also possible that landscape-scale disturbances have removed old-growth forests such that birds may be forced to concentrate in higher densities within remaining habitats (Tischendorf et al. 2005). Landscape-level density responses to timber harvest are species-specific, complex, and require further investigation (Schmiegelow and Monkkonen 2002, Betts et al. 2006, Guadagnin et al. 2009).

6.2. Understory Protection Harvesting

When compared to unharvested stands and cutblocks older than 11 years post-harvest, the understory protection sample (UP) exhibited significantly lower rarefied species richness. Only the analogous CD11-20 and recent harvests saw richness calculations similar to the UP sample. These samples also shared similar rarefied diversity values (Shannon Indices), perhaps because of the low abundance of birds detected – the lowest per-site abundance of any sample. Oddly, significant increases in abundances were not detected between 2005, 2009, 2012, and 2018 surveys. This may suggest that understory protection harvesting achieves a more stable successional path than other cutblocks without dramatic shifts in the first 1-20 years post-harvest.

Despite these low richness and diversity calculations, species composition was more similar to cutblocks 21-30 years post-harvest and unharvested mixedwoods than to similar aged cutblocks. For guild abundances, the UP sample was closest to 21-30 aged cutblocks for stand preferences and closest to C11-20 for foraging, nesting, and migratory guild abundances. Therefore, the UP plot may be on a successional trajectory closer to a pure coniferous cutblock and may speed avian recolonization compared to traditional harvesting methods due to the high retention of residual forest and the release of the understory spruce.

These results were somewhat inconsistent with research by Charchuk and Bayne (2018), which found close convergence of avian composition between UP blocks and unharvested benchmarks after only 12 years post-harvest. Despite being approximately 17 years post-harvest at time of sampling, our UP sample still required more time to converge with unharvested stands although species compositions were relatively similar.

On a species level, Charchuk and Bayne (2018) highlighted five species as indicators for UP after indicator value analysis: Chipping Sparrow, White-throated Sparrow, Magnolia Warbler, Connecticut Warbler, and Tennessee Warbler. Our results show that reforestation designation of cutblocks influences abundances of some of these species beyond what is described by Charchuk and Bayne (2018) such that their abundances are not as strongly associated with our UP sample. This is because even young C-cutblocks can have relatively high abundances of Chipping Sparrow, White-throated Sparrow, and Tennessee Warbler. However, high abundances of Connecticut Warbler and Magnolia Warbler are indicators of UP in our sample as well. Although our results are limited by sample size, they support the conclusion put forward by Charchuk and Bayne (2018) that UP can readily provide breeding habitat for conifer-dependant species and that understory protection harvesting may return to unharvest benchmarks more quickly than other harvest methods.

6.3. Data Limitations

Since a species' presence is not always a direct indication of productive breeding activity, these results should not be considered an indication of breeding success in surveyed stands. Indeed, several studies have found reproductive fitness within cutblocks to be less than unharvested or fire regenerating stands (e.g., Robertson and Hutto 2007), but more research is required.

We were unable to sample a control for between-year changes in population structure and distributions in order to assess differences that may be attributed to variables operating at wider and sometimes international spatial scales. Future research involving this dataset should attempt to use additional surveys nearby performed by other researchers or use Lesser Slave Lake Bird Observatory capture and observation records between 2018 and 2021 for an approximation of regional population trends that may be due to external influences.

The boreal forest is dynamic with many natural and anthropogenic disturbances. While only stand age and reforestation designation or cover type were included in models herein, additional landscape disturbances from sources including the energy sector, transportation, or recreation have been found to impact avian distributions (Leston et al. 2020). Analysis with additional data (compiled by the Boreal Avian Monitoring Project, for example) could better address the compounding effects of these features.

Section 7: Conclusions

Given the critical role of the boreal forest in maintaining and promoting recovery of international avian populations, understanding associations between avian species and all possible habitats is similarly critical when birds are threatened by climate change (Cadieux et al. 2020), habitat loss and fragmentation (Schmiegelow and Monkkonen 2002, Balmford et al. 2003), and declines in arthropod populations at base trophic levels (English et al. 2018). To maintain avian diversity in the boreal forest, a range of habitats must be available landscape-wide with care taken to proactively manage and maintain forest age and cover distributions (Van Wilgenburg and Hobson 2008). Forestry practices must ensure harvest rotations allow for the recruitment of old-growth and pure coniferous stands, which host unique avian assemblages that include species not found in other habitat types (as above, Hobson and Bayne 2000, Hannon et al. 2004).

7.1. Recommendations

Resource management within the FMA involves multiple stakeholders but can maximize avian diversity through cooperation and adoption of development methods that minimize immediate negative impacts of disturbances and promote faster establishment of pre-disturbance avian assemblages. For timber harvest, although it may take up to 70 years for old-growth specialist bird species to return (Schieck and Song 2006), mature forest birds may return quicker to unharvested benchmarks with the following considerations:

1. Presence of mature forest birds in young stands may be linked to retention levels at time of harvest, supporting other studies which suggest residual patches help to mitigate the effects of harvest by retaining habitat for mature or old-growth associated bird species (Van Wilgenburg and Hobson 2008). Odsen et al. (2018) recommends cutblock retention levels over 20%, while Norton and Hannon (1997) recommend retention levels up to 40%. Benefits of high retention are further increased by leaving more complex vegetative structure within residual patches (Hobson and Schieck 1999, Schieck and Hobson 2000).
2. Vegetative structure surrounding cutblocks must also be considered during planning to ensure corridors between habitat patches are maintained for arboreal species, including birds (Robichaud et al. 2002). This in turn maintains functional connectivity between metapopulations as even vagile resident bird species exhibit an unwillingness to cross large gaps in continuous forest structure first noticeable at gaps as small as 50 m, with 80% of Black-capped Chickadees unwilling to cross gaps of 200 m (St. Clair et al. 1998).
3. Point count data should be submitted to the Boreal Avian Monitoring Project (BAM). Although sample sizes attained herein provided enough sampling coverage to fulfill our objectives, 30 surveys is likely too small to detect meaningful distributions for rare species (Ralph et al. 1995). By bolstering BAM's larger database, the utility of these surveys to detect significant distributions and abundances both now and in the future is greatly improved as are models generated using the BAM database.
4. Since distinct differences in avian assemblages were detected immediately post-harvest, reforestation designations and associated harvesting practices appear to play a role in species recolonizations and should be considered alongside forest age to create more comprehensive models of the impacts of anthropogenic disturbances on breeding birds.
5. Due to the high frequency with which surveyors found nests incidentally within cutblocks, if staff need to enter cutblocks for any reason during the breeding season, we advise that they be trained in signs that a nest may be nearby and how to avoid it. To remove any risk of contravention of the Migratory Birds Convention Act or the Alberta Wildlife Act, disruptive operations should take place outside the critical breeding window to protect bird nests and their young from incidental take.

7.2. Future Research Needs

These results provide clarity and more depth to the ways in which avian species composition changes by reforestation designation in a relatively short time period post-harvest. However, they also raise more questions, including:

1. What role does the edge between each cutblock and undisturbed interior forest play when considering avian diversity? Most studies, including this one, place sample locations a certain distance away from habitat edge to minimize the effects of this potentially confounding variable on avian detections. However, not all habitat edges are equal and can range from young burnt forest to wetlands to old-growth coniferous forests and beyond. The interplay between cutblock characteristics (including cutblock size and retention levels) and characteristics of the cutblock's immediate edge are as of yet poorly understood. Although birds detected in cutblock edges were excluded from these analyses since reliable detection rates diminish greatly 100 m from observers, there appeared to be species-specific responses to the interplay of cutblock edge and interior cutblock characteristics. For example, Olive-sided Flycatchers were only found in the shrubby edge of recently disturbed habitats.
2. How do cutblock management decisions past, present, and future impact avian recolonization? Over the last 30 years, various aspects related to cutblock planning, harvesting, replanting, and management toward reforestation designations have changed. Changing best practices in light of new evidence should be encouraged, but may confound results of this study. Additional research should be performed to assess the impacts of practices surrounding herbicides, scarification, and replanting methods, for example. Since management guidelines have changed, a cutblock harvested today may follow different regenerative paths than one harvested 30 years ago, which could then impact avian recolonization and predictive modeling.
3. Are understory protection harvesting results accurate? The understory protection harvesting sample generated some interesting and unexpected results. However, there was frequently low confidence in these results because the sample size was exceedingly small (n=10) and only visited once in a potentially unusual breeding season following intense rainstorms. Additional research with more rigorous sampling regimes should be undertaken to test the replicability of these findings.

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Appendix A.

Scientific names, guilds, and abundance by cover class of detected bird species

Table A1. Total unlimited distance detections (both sample and edge habitats) across all surveys 2018-21.

SPECIES		AGE CLASS				COVER CLASS				
Common name	**Scientific name**	1-10	11-20	21-30	80+	C	CD	DC	UP	**Total**
Canada Goose	*Branta canadensis*	80	13	0	4	80	3	12	2	**97**
Mallard	*Anas platyrhynchos*	1	2	1	0	1	0	3	0	**4**
Bufflehead	*Bucephala albeola*	0	0	0	1	0	1	0	0	**1**
Common Goldeneye	*Bucephala clangula*	1	0	0	2	1	2	0	0	**3**
Ruffed Grouse	*Bonasa umbellus*	0	13	9	6	5	12	10	1	**28**
Red-necked Grebe	*Podiceps grisegena*	0	1	0	0	0	1	0	0	**1**
Common Nighthawk	*Chordeiles minor*	4	0	0	0	2	0	2	0	**4**
Sora	*Porzana carolina*	1	5	1	0	1	4	2	0	**7**
Sandhill Crane	*Antigone canadensis*	0	2	0	0	0	0	0	2	**2**
Killdeer	*Charadrius vociferus*	4	0	0	0	0	2	2	0	**4**
Wilson's Snipe	*Gallinago delicata*	65	41	11	7	33	50	41	0	**124**
Spotted Sandpiper	*Actitis macularius*	0	0	1	0	0	1	0	0	**1**
Solitary Sandpiper	*Tringa solitaria*	7	3	1	0	2	2	7	0	**11**
Lesser Yellowlegs	*Tringa flavipes*	5	0	1	2	3	3	2	0	**8**
Greater Yellowlegs	*Tringa melanoleuca*	11	3	0	8	12	7	2	1	**22**
Franklin's Gull	*Leucophaeus pipixcan*	10	0	7	0	0	2	15	0	**17**
Common Loon	*Gavia immer*	9	0	14	0	8	14	1	0	**23**
Sharp-shinned Hawk	*Accipiter striatus*	2	0	2	0	0	2	2	0	**4**
Northern Goshawk	*Accipiter gentilis*	0	0	0	1	0	1	0	0	**1**
Bald Eagle	*Haliaeetus leucocephalus*	0	0	1	0	0	1	0	0	**1**
Red-tailed Hawk	*Buteo jamaicensis*	0	1	0	0	0	1	0	0	**1**
Great Gray Owl	*Strix nebulosa*	0	0	1	0	0	1	0	0	**1**
Yellow-bellied Sapsucker	*Sphyrapicus varius*	7	13	1	1	13	3	5	1	**22**
American Three-toed Wood.	*Picoides dorsalis*	0	1	0	0	1	0	0	0	**1**
Black-backed Woodpecker	*Picoides arcticus*	0	0	0	2	2	0	0	0	**2**
Downy Woodpecker	*Dryobates pubescens*	0	0	2	5	0	3	4	0	**7**
Hairy Woodpecker	*Dryobates villosus*	4	4	0	6	8	3	2	1	**14**
Northern Flicker	*Colaptes auratus*	8	6	0	4	7	5	6	0	**18**
Pileated Woodpecker	*Dryocopus pileatus*	6	6	10	3	7	9	9	0	**25**
American Kestrel	*Falco sparverius*	3	0	0	0	3	0	0	0	**3**
Merlin	*Falco columbarius*	1	0	0	0	0	0	1	0	**1**
Olive-sided Flycatcher	*Contopus cooperi*	12	0	0	1	1	4	8	0	**13**
Western Wood-Pewee	*Contopus sordidulus*	2	4	0	0	3	1	2	0	**6**
Alder Flycatcher	*Empidonax alnorum*	135	131	28	6	91	95	109	5	**300**
Least Flycatcher	*Empidonax minimus*	9	10	4	4	9	6	12	0	**27**
Blue-headed Vireo	*Vireo solitarius*	2	0	3	2	3	2	2	0	**7**
Philadelphia Vireo	*Vireo philadelphicus*	3	7	4	5	2	7	8	2	**19**
Warbling Vireo	*Vireo gilvus*	11	15	7	4	19	8	10	0	**37**
Red-eyed Vireo	*Vireo olivaceus*	72	117	156	29	87	146	132	9	**374**
Canada Jay	*Perisoreus canadensis*	23	30	12	16	41	21	18	1	**81**
Blue Jay	*Cyanocitta cristata*	10	10	11	1	15	6	9	2	**32**
American Crow	*Corvus brachyrhynchos*	6	6	8	3	4	10	9	0	**23**
Common Raven	*Corvus corax*	10	3	0	5	12	5	1	0	**18**
Black-capped Chickadee	*Poecile atricapillus*	1	3	8	3	5	3	7	0	**15**
Boreal Chickadee	*Poecile hudsonicus*	0	1	11	2	6	3	4	1	**14**
Tree Swallow	*Tachycineta bicolor*	0	2	0	0	1	1	0	0	**2**
Barn Swallow	*Hirundo rustica*	1	0	0	0	1	0	0	0	**1**

SPECIES		AGE CLASS				COVER CLASS				
Common name	**Scientific name**	1-10	11-20	21-30	80+	C	CD	DC	UP	**Total**
Ruby-crowned Kinglet	*Corthylio calendula*	2	6	4	21	25	4	4	0	**33**
Golden-crowned Kinglet	*Regulus satrapa*	0	0	1	3	0	1	3	0	**4**
Cedar Waxwing	*Bombycilla cedrorum*	49	26	9	6	28	22	38	2	**90**
Red-breasted Nuthatch	*Sitta canadensis*	28	17	14	28	33	17	36	1	**87**
White-breasted Nuthatch	*Sitta carolinensis*	0	1	1	0	0	1	0	1	**2**
Brown Creeper	*Certhia americana*	0	0	0	2	1	0	1	0	**2**
House Wren	*Troglodytes aedon*	1	0	0	0	0	0	1	0	**1**
Winter Wren	*Troglodytes hiemalis*	35	9	26	15	30	30	25	0	**85**
Swainson's Thrush	*Catharus ustulatus*	70	93	100	71	112	114	106	2	**334**
Hermit Thrush	*Catharus guttatus*	10	15	17	10	22	17	13	0	**52**
American Robin	*Turdus migratorius*	40	22	12	10	26	24	31	3	**84**
Evening Grosbeak	*Coccothraustes vespertinus*	3	0	1	0	0	0	4	0	**4**
Purple Finch	*Haemorhous purpureus*	2	5	3	3	9	4	0	0	**13**
Red Crossbill	*Loxia curvirostra*	0	0	2	0	0	2	0	0	**2**
White-winged Crossbill	*Loxia leucoptera*	144	18	1	4	63	0	100	4	**167**
Pine Siskin	*Spinus pinus*	115	51	49	37	96	57	97	2	**252**
American Goldfinch	*Spinus tristis*	1	4	0	1	0	6	0	0	**6**
Chipping Sparrow	*Spizella passerina*	57	37	29	42	74	61	26	4	**165**
Clay-coloured Sparrow	*Spizella pallida*	71	30	3	1	26	41	38	0	**105**
Dark-eyed Junco	*Junco hyemalis*	9	6	2	25	30	11	1	0	**42**
White-throated Sparrow	*Zonotrichia albicollis*	150	143	96	44	131	144	145	13	**433**
LeConte's Sparrow	*Ammospiza leconteii*	15	2	0	0	2	2	13	0	**17**
Savannah Sparrow	*Passerculus sandwichensis*	5	0	0	0	0	0	5	0	**5**
Song Sparrow	*Melospiza melodia*	7	0	0	1	2	2	4	0	**8**
Lincoln's Sparrow	*Melospiza lincolnii*	139	15	6	6	64	46	56	0	**166**
Swamp Sparrow	*Melospiza georgiana*	5	8	6	3	7	11	4	0	**22**
Red-winged Blackbird	*Agelaius phoeniceus*	2	0	6	0	4	3	1	0	**8**
Brown-headed Cowbird	*Molothrus ater*	0	0	1	0	0	0	1	0	**1**
Common Grackle	*Quiscalus quiscula*	0	0	1	0	0	0	1	0	**1**
Ovenbird	*Seiurus aurocapilla*	19	29	65	40	28	39	76	10	**153**
Northern Waterthrush	*Parkesia noveboracensis*	3	1	9	3	3	9	4	0	**16**
Black-and-white Warbler	*Mniotilta varia*	7	8	29	13	9	19	29	0	**57**
Tennessee Warbler	*Leiothlypis peregrina*	128	192	139	85	154	155	226	9	**544**
Orange-crowned Warbler	*Leiothlypis celata*	2	11	5	0	15	2	1	0	**18**
Connecticut Warbler	*Oporornis agilis*	15	4	1	1	4	6	8	3	**21**
Mourning Warbler	*Geothlypis philadelphia*	20	7	6	14	20	17	10	0	**47**
Common Yellowthroat	*Geothlypis trichas*	55	44	9	7	22	61	32	0	**115**
American Redstart	*Setophaga ruticilla*	2	2	22	3	3	10	16	0	**29**
Magnolia Warbler	*Setophaga magnolia*	3	25	40	12	17	34	26	3	**80**
Bay-breasted Warbler	*Setophaga castanea*	0	0	0	5	1	3	1	0	**5**
Yellow Warbler	*Setophaga petechia*	0	7	7	6	3	10	7	0	**20**
Palm Warbler	*Setophaga palmarum*	0	0	0	3	3	0	0	0	**3**
Yellow-rumped Warbler	*Setophaga coronata*	20	26	42	35	51	44	25	3	**123**
Black-throated Green Warb.	*Setophaga virens*	3	0	2	14	3	7	9	0	**19**
Canada Warbler	*Cardellina canadensis*	3	1	2	5	1	4	5	1	**11**
Wilson's Warbler	*Cardellina pusilla*	0	1	0	0	1	0	0	0	**1**
Western Tanager	*Piranga ludoviciana*	3	1	4	3	4	5	2	0	**11**
Rose-breasted Grosbeak	*Pheucticus ludovicianus*	10	26	27	14	10	28	33	6	**77**
Total number of individuals detected		**1785**	**1349**	**1116**	**730**	**1629**	**1528**	**1728**	**95**	**4980**
Total number of identified species detected		**71**	**63**	**65**	**64**	**73**	**78**	**75**	**28**	**95**
Number of point count stations		**103**	**103**	**98**	**69**	**128**	**115**	**120**	**10**	**373**

Table A2. Previously documented forest age preferences (A), foraging (F), nesting (N), and migratory (M) guilds (see Table 4) used for guild association analyses and percent relative abundance of birds detected ≤ 100 m of site centre, excluding repeat encounters, flyovers, and birds detected in edge habitats. Species in bold-italic and brackets were omitted from calculations of relative abundance for all other species and diversity analyses, but included here for context to guild associations.

					AGE AND COVER CLASS (*pi* %)												
SPECIES	**GUILD**				**1-10**			**11-20**				**21-30**			**80+**		
Common name	**A**	**F**	**N**	**M**	**C**	**CD**	**DC**	**C**	**CD**	**DC**	**UP**	**C**	**CD**	**DC**	**C**	**CD**	**DC**
Mallard	A	O	G	SD	(0.4)	0	0	0	0	0	0	0	0	(0.3)	0	0	0
Bufflehead	A	O	Ct	SD	0	0	0	0	0	0	0	0	0	0	0	(0.4)	0
Common Goldeneye	A	O	Ct	SD	0	0	0	0	0	0	0	0	0	0	0	(0.9)	0
Ruffed Grouse	Y	SF	G	R	0	0	0	(0.4)	(0.6)	(1.3)	(1.8)	0	(2.6)	0	(2.3)	(0.4)	(0.5)
Common Nighthawk	Y	AI	G	LD	0	0	0.5	0	0	0	0	0	0	0	0	0	0
Sora	A	SF	G	LD	0	0	0	0	(0.3)	0	(0.3)	0	0	0	0	0	0
Killdeer	Y	GG	G	SD	0	(0.7)	(0.9)	0	0	0	0	0	0	0	0	0	0
Wilson's Snipe	Y	GG	G	SD	(1.6)	(4.6)	(2.2)	(0.4)	(1.9)	0	(2.4)	(1.0)	(0.3)	(0.3)	0	0	0
Solitary Sandpiper	Y	GG	Cp	LD	0	(0.4)	(1.3)	0	0	0	(0.5)	0	0	0	0	0	0
Lesser Yellowlegs	Y	GG	G	LD	0	0	(0.9)	0	0	0	0	0	0	0	0	(0.4)	0
Greater Yellowlegs	Y	GG	G	LD	(1.6)	0	0	0	(0.3)	0	0	0	0	0	0	0	0
Franklin's Gull	Y	O	G	LD	0	0	0	0	0	0	0	0	(0.6)	0	0	0	0
Common Loon	A	O	G	SD	0	0	0	0	0	0	0	(0.3)	0	0	0	0	0
Sharp-shinned Hawk	O	O	Cp	LD	0	(0.4)	(0.4)	0	0	0	0	0	(0.3)	0	0	0	0
Great Gray Owl	O	O	Cp	R	0	0	0	0	0	0	0	0	(0.3)	0	0	0	0
Yellow-bellied Sapsucker	O	BG	Ct	SD	0	0	0	1.8	0	1.4	0	0	0.3	0	0	0.5	0
American Three-toed Wo.	Y	BG	Ct	R	0	0	0	0.4	0	0	0	0	0	0	0	0	0
Black-backed Wood.	Y	BG	Ct	R	0	0	0	0	0	0	0	0	0	0	1.3	0	0
Downy Woodpecker	G	BG	Ct	R	0	0	0	0	0	0	0	0	0.6	0	0	0.5	1.0
Hairy Woodpecker	O	BG	Ct	R	0.8	0	0	0.7	0.3	0	0	0	0	0	2.5	0	0.5
Northern Flicker	Y	BG	Ct	SD	1.3	0.4	0	0.4	0.3	0	0.6	0	0	0	0.6	0	0.5
Pileated Woodpecker	O	BG	Ct	R	0	0	0	0	0.6	0	0.6	0.3	0.3	0	0.6	0	0
American Kestrel	Y	O	Ct	LD	(0.4)	0	0	0	0	0	0	0	0	0	0	0	0
Merlin	G	O	Cp	LD	0	0	(0.4)	0	0	0	0	0	0	0	0	0	0
Olive-sided Flycatcher	Y	AI	Cp	LD	0	0.4	0	0	0	0	0	0	0	0	0	0	0.5
Western Wood-Pewee	O	AI	Cp	LD	0	0	0	0.4	0.3	0	0.6	0	0	0	0	0	0
Alder Flycatcher	Y	AI	S	LD	16.0	14.1	13.2	11.3	13.5	5.5	13.2	2.4	2.2	4.1	0	0.5	1.0
Least Flycatcher	O	AI	S	LD	0.8	1.1	1.5	2.2	0.6	0	0.6	0.3	0	0.9	0	0	2.0
Blue-headed Vireo	O	FG	Cp	LD	0	0	0	0	0	0	0	0.7	0.3	0	0	0.5	0
Philadelphia Vireo	O	FG	Cp	LD	0	0.4	0.5	0.4	0	2.7	1.1	0	1.3	0	0	1.0	1.0
Warbling Vireo	O	FG	Cp	LD	0.4	0	0	2.9	0.6	0	1.4	2.1	0	0.3	0.6	0.5	0
Red-eyed Vireo	G	FG	S	LD	5.0	8.0	1.5	5.1	15.1	12.3	9.5	14.7	15.1	18.2	2.5	2.9	9.0
Canada Jay	O	O	Cp	R	0.8	0.4	0	4.0	1.0	0	1.4	1.0	2.2	0.3	3.2	2.4	0
Blue Jay	Y	O	Cp	R	0	0.4	1.0	0.7	0	0	1.1	0.7	0.6	0	0.6	0	0
American Crow	Y	O	Cp	SD	0	0.4	0	0.4	0	0	0.3	0	0.3	0.6	0.6	1.0	0
Common Raven	O	O	Cp	R	0	0	0	0.7	0	0	0	0	0	0	0	1.0	0
Black-capped Chickadee	G	BG	Ct	R	0	0	0	0.4	0	0	0.6	1.4	0.9	0.3	0	0	1.5
Boreal Chickadee	O	FG	Ct	R	0	0	0	0	0	1.4	0	1.7	0.6	1.3	0.6	0.5	0
Ruby-crowned Kinglet	O	FG	Cp	SD	0.4	0	0	1.8	0	0	0.3	0.3	0	0.9	10.1	1.9	0
Golden-crowned Kinglet	O	FG	Cp	SD	0	0	0	0	0	0	0	0	0.3	0	0	0	1.5
Cedar Waxwing	Y	SF	Cp	SD	1.3	3.1	7.1	0.7	0.6	2.7	0.8	0.7	0.3	1.6	1.3	0.5	0.5
Red-breasted Nuthatch	O	SF	Ct	R	0	0.4	0	2.9	0.3	1.4	0.3	2.1	0	0.9	1.9	4.8	5.0
White-breasted Nuthatch	O	BG	Ct	R	0	0	0	0	0	1.4	0	0	0.3	0	0	0	0
Brown Creeper	O	BG	Ct	R	0	0	0	0	0	0	0	0	0	0	0.6	0	0.5
Winter Wren	O	GG	G	SD	0.8	2.7	1.0	1.1	0.6	0	0.6	3.5	1.6	0.9	2.5	1.4	1.5

SPECIES	GUILD				AGE AND COVER CLASS (*pi* %)													
					1-10			**11-20**				**21-30**			**80+**			
Common name	**A**	**F**	N	M	**C**	**CD**	**DC**	**C**	**CD**	**DC**	**UP**	**C**	**CD**	**DC**	**C**	**CD**	**DC**
Swainson's Thrush	O	IX	G	LD	1.3	2.7	2.0	12.4	9.3	2.7	5.0	10.8	10.1	10.1	8.9	11.0	15.0
Hermit Thrush	G	GG	G	LD	0	0	0	2.6	1.0	0	0	0.7	2.2	2.5	1.9	2.9	0.5
American Robin	Y	GG	Cp	SD	1.7	3.1	3.0	1.5	1.0	4.1	1.4	1.7	0.3	1.9	0.6	1.9	0.5
Purple Finch	O	SF	Cp	SD	0	0	0	1.1	0.3	0	0	0.7	0.3	0	1.3	0	0
Red Crossbill	O	SF	Cp	I	0	0	0	0	0	0	0	0	(0.6)	0	0	0	0
White-winged Crossbill	O	SF	Cp	I	(0.8)	0	0	0	0	(5.1)	0	(0.3)	0	0	0	0	0
Pine Siskin	O	SF	Cp	I	0	(1.4)	(6.2)	(0.7)	(0.9)	0	(1.3)	(4.3)	(2.9)	(1.2)	(8.0)	(4.0)	(1.0)
American Goldfinch	Y	SF	S	SD	0	0	0	0	0	0	0	0	0	0	0	0.5	0
Chipping Sparrow	G	GG	S	SD	6.3	5.0	1.5	3.3	2.9	5.5	2.5	5.2	2.8	0.6	12.0	7.6	1.0
Clay-coloured Sparrow	Y	GG	G	SD	10.1	7.3	11.2	0.7	5.1	0	2.2	0	0	0.9	0	0.5	0
Dark-eyed Junco	G	GG	G	SD	1.3	1.5	0	2.2	0	0	0	0.7	0	0	10.1	2.9	0
White-throated Sparrow	G	SF	G	SD	13.9	14.1	8.6	10.6	11.6	17.8	10.6	8.0	8.5	11.3	3.2	7.6	6.0
LeConte's Sparrow	Y	GG	G	SD	0.8	0	6.1	0	0.6	0	0	0	0	0	0	0	0
Savannah Sparrow	Y	GG	G	SD	0	0	2.5	0	0	0	0	0	0	0	0	0	0
Song Sparrow	Y	GG	G	SD	0.4	0.8	2.0	0	0	0	0	0	0	0	0.6	0	0
Lincoln's Sparrow	Y	GG	G	SD	20.2	12.6	21.8	1.1	2.6	0	0.8	0.3	0.3	0.6	1.9	0	0
Swamp Sparrow	Y	GG	G	SD	0.8	0	0	0.4	1.3	0	0.3	0.3	1.3	0.3	0.6	0	0.5
Red-winged Blackbird	A	GG	S	SD	0	0.4	0	0	0	0	0	1.0	0	0.3	0	0	0
Brown-headed Cowbird	Y	GG	P	SD	0	0	0	0	0	0	0	0	0	0.3	0	0	0
Ovenbird	G	GG	G	LD	0	1.1	0	0	0.3	12.3	2.8	3.8	5.7	7.9	1.9	4.8	12.0
Northern Waterthrush	Y	GG	G	LD	0.4	0	0.5	0	0	0	0.3	0	2.2	0.6	0	0.5	0
Black-and-white Warbler	Y	BG	G	LD	0.4	1.5	0	0.4	0.3	0	1.7	2.1	3.2	4.1	0.6	1.9	4.0
Tennessee Warbler	G	FG	G	LD	6.7	5.0	7.1	14.2	12.9	12.3	26.6	17.1	13.6	11.9	8.9	15.7	15.5
Orange-crowned Warbler	Y	FG	G	LD	0.4	0	0	3.3	0	0	0.3	1.0	0.6	0	0	0	0
Connecticut Warbler	G	GG	G	LD	0	0	2.0	0	0	2.7	0	0.3	0	0	0	0.5	0
Mourning Warbler	Y	GG	G	LD	0.8	1.9	0.5	2.6	0	0	0	1.4	0.6	0	2.5	1.4	3.5
Common Yellowthroat	Y	FG	S	LD	6.3	8.8	4.1	0	9.3	0	3.4	0.3	1.3	0.9	1.3	0.5	0.5
American Redstart	Y	IX	S	LD	0.4	0.4	0	0	0.6	0	0	0.7	1.9	4.4	0	0.5	1.0
Magnolia Warbler	Y	FG	S	LD	0	0.4	0	0.4	2.3	4.1	3.4	3.5	5.7	3.5	1.9	3.8	0.5
Bay-breasted Warbler	O	FG	Cp	LD	0	0	0	0	0	0	0	0	0	0	0.6	1.4	0.5
Yellow Warbler	Y	FG	S	LD	0	0	0	0	1.6	0	0.6	0.7	0.6	0.9	0.6	1.4	1.0
Palm Warbler	Y	GG	G	LD	0	0	0	0	0	0	0	0	0	0	1.3	0	0
Yellow-rumped Warbler	O	FG	S	SD	0	1.1	0.5	4.7	1.3	2.7	1.4	4.5	6.0	3.1	8.9	6.7	2.5
Black-throated Green Wa.	O	FG	Cp	LD	0	0	0	0	0	0	0	0	0	0.3	0	2.9	3.0
Canada Warbler	O	IX	G	LD	0	0	0	0	0	1.4	0	0	0.3	0.3	0	1.4	1.0
Wilson's Warbler	Y	FG	G	LD	0	0	0	0.4	0	0	0	0	0	0	0	0	0
Western Tanager	O	FG	G	LD	0	0	0	0	0	0	0	0	0.9	0.3	0.6	0.5	0.5
Rose-breasted Grosbeak	G	SF	S	LD	0	0.8	0	0	1.6	5.5	3.9	2.4	4.1	2.2	0	1.9	5.0
Total number of individuals					**250**	**283**	**225**	**278**	**324**	**381**	**78**	**304**	**343**	**324**	**176**	**224**	**203**
Species richness, observed					**32**	**35**	**30**	**39**	**36**	**38**	**21**	**40**	**45**	**38**	**38**	**44**	**36**
Species richness, all exclusions					**27**	**30**	**23**	**36**	**31**	**33**	**19**	**36**	**38**	**35**	**36**	**39**	**34**
Number of point count stations					**36**	**34**	**31**	**33**	**28**	**32**	**10**	**32**	**33**	**33**	**24**	**20**	**22**

Appendix B.

Locations of all sites surveyed (WGS84 ± 10 m)

Site	Latitude	Longitude	Site	Latitude	Longitude	Site	Latitude	Longitude	Site	Latitude	Longitude
1	55.27881	-114.1433	131	55.30698	-114.1041	179	55.41482	-113.6539	228	55.41351	-113.6710
2	55.28061	-114.1431	132	55.42973	-114.6437	180	55.41402	-113.6511	229	55.42450	-113.6918
22	55.11270	-114.1193	133	55.42989	-114.6298	181	55.41738	-113.6528	230	55.54819	-115.1082
23	55.11419	-114.1124	134	55.43032	-114.6261	182	55.42284	-113.6540	231	55.54667	-115.1052
24	55.11735	-114.1060	135	55.43193	-114.6132	183	55.42029	-113.6518	232	55.54503	-115.1032
26	55.11524	-114.1054	136	55.43251	-114.6169	184	55.42315	-113.6640	233	55.54571	-115.1084
38	55.27354	-113.9988	137	55.43446	-114.6153	185	55.42392	-113.6682	260	55.27834	-113.9848
55	55.28540	-114.1176	138	55.43430	-114.6452	186	55.42594	-113.6691	261	55.28125	-113.9832
56	55.28751	-114.1202	139	55.43355	-114.5844	187	55.42198	-113.6797	262	55.28298	-113.9823
57	55.28770	-114.1246	140	55.43572	-114.5909	188	55.42228	-113.6757	263	55.28559	-113.9744
80	55.14214	-114.1195	141	55.43737	-114.5859	189	55.42651	-113.6851	267	55.28875	-113.9746
82	55.14755	-114.1165	142	55.43106	-114.5767	190	55.42713	-113.6821	268	55.29034	-113.9778
83	55.14432	-114.1205	143	55.43110	-114.5720	191	55.42553	-113.6791	269	55.28975	-113.9816
84	55.14032	-114.1192	144	55.43652	-114.5776	192	55.54661	-114.0020	270	55.29280	-113.9827
85	55.29159	-114.0666	145	55.44139	-114.5085	193	55.54374	-114.0002	271	55.29414	-113.9870
86	55.29505	-114.0663	146	55.44552	-114.5098	194	55.54870	-114.0027	272	55.29550	-113.9843
89	55.26453	-114.0160	147	55.44322	-114.5092	195	55.54852	-114.0161	273	55.29781	-114.0708
90	55.26878	-114.0243	148	55.44969	-114.5225	196	55.54468	-114.0236	274	55.54537	-113.9925
91	55.26870	-114.0212	149	55.45302	-114.5288	197	55.54912	-113.9806	275	55.55007	-113.9889
92	55.26855	-114.0149	150	55.45369	-114.5320	198	55.54796	-113.9782	276	55.55048	-113.9853
93	55.27065	-114.0273	151	55.44373	-114.5334	199	55.54618	-113.9787	277	55.54848	-113.9857
94	55.27057	-114.0242	152	55.44194	-114.5250	200	55.55961	-115.0912	278	55.54404	-113.9788
95	55.27034	-114.0148	153	55.44218	-114.5283	201	55.55839	-115.1011	279	55.54226	-113.9799
96	55.27947	-114.0204	154	55.44554	-114.5292	202	55.56100	-115.0992	280	55.54303	-113.9891
97	55.28516	-114.0325	155	55.44773	-114.5312	203	55.54855	-115.0983	281	55.54232	-113.9861
98	55.28102	-114.0178	156	55.44918	-114.5286	204	55.42026	-113.6459	282	55.54144	-113.9832
100	55.27954	-114.0101	157	55.45038	-114.5313	205	55.42026	-113.6426	283	55.53903	-113.9755
101	55.27769	-114.0045	158	55.41700	-113.6928	206	55.41332	-113.6418	284	55.53985	-113.9724
102	55.27332	-114.0274	159	55.41748	-113.6961	207	55.41526	-113.6435	285	55.54523	-114.0447
103	55.27662	-114.0239	160	55.56403	-115.0957	208	55.43238	-113.6751	286	55.54420	-114.0414
104	55.26792	-114.0115	161	55.56390	-115.0898	209	55.43236	-113.6712	287	55.52331	-113.9726
105	55.26612	-114.0091	162	55.56461	-115.0927	210	55.43031	-113.6722	288	55.52212	-113.9696
110	55.28411	-114.0288	163	55.56678	-115.0813	211	55.42943	-113.6755	289	55.52316	-113.9428
111	55.28601	-114.0288	164	55.56564	-115.0788	212	55.42981	-113.6789	290	55.52727	-113.9336
112	55.28671	-114.0306	165	55.56433	-115.0830	213	55.55586	-115.1055	291	55.52319	-113.9337
113	55.28144	-114.1021	166	55.56503	-115.0865	214	55.41814	-113.6848	292	55.52081	-113.9347
117	55.30993	-114.0714	167	55.56274	-115.0868	215	55.41957	-113.6828	293	55.52245	-113.9388
120	55.31074	-114.0790	168	55.40081	-113.6615	216	55.41559	-113.6783	294	55.51853	-113.9359
121	55.30938	-114.0826	169	55.40086	-113.6581	217	55.41399	-113.6751	295	55.51663	-113.9393
122	55.30782	-114.0808	170	55.39920	-113.6569	218	55.41303	-113.6787	296	55.51610	-113.9428
123	55.30548	-114.0996	171	55.39765	-113.6601	220	55.40635	-113.6923	297	55.51443	-113.9410
124	55.30713	-114.0967	172	55.39718	-113.6569	221	55.40691	-113.6953	298	55.51375	-113.9373
125	55.30844	-114.0996	173	55.41749	-113.6640	222	55.41382	-113.6955	299	55.51144	-113.9376
126	55.31003	-114.0976	174	55.41457	-113.6626	223	55.41292	-113.6907	303	55.51349	-113.8771
127	55.30780	-114.1090	175	55.41286	-113.6606	224	55.41210	-113.6941	304	55.51060	-113.8835
128	55.30593	-114.1082	176	55.41073	-113.6588	225	55.42303	-113.6892	305	55.51021	-113.8803
129	55.30212	-114.1050	177	55.41581	-113.6569	226	55.41128	-113.6679	306	55.50862	-113.8821
130	55.31208	-114.0711	178	55.41592	-113.6509	227	55.40974	-113.6647	307	55.50870	-113.8776

Site	Latitude	Longitude
308	55.50789	-113.8742
309	55.49803	-113.8509
310	55.49716	-113.8431
311	55.49538	-113.8435
312	55.49354	-113.8437
313	55.49494	-113.8393
314	55.49703	-113.8394
315	55.49467	-113.8356
316	55.49680	-113.8358
317	55.49544	-113.8325
318	55.49662	-113.8842
319	55.49012	-113.8848
320	55.48818	-113.8845
321	55.54112	-114.0393
322	55.53793	-114.0347
323	55.53785	-114.0307
324	55.53583	-114.0307
325	55.53403	-114.0306
326	55.53213	-114.0304
327	55.49697	-114.0864
328	55.50197	-114.0715
329	55.40230	-113.6556
330	55.40049	-113.6524
331	55.39808	-113.6518
332	55.40264	-113.6615
333	55.41731	-113.6764
334	55.41659	-113.6722
335	55.41607	-113.6688
336	55.41521	-113.6659
337	55.41121	-113.6776
338	55.40935	-113.6752
339	55.41974	-113.6776
340	55.41956	-113.6729
341	55.41008	-113.6882
342	55.40822	-113.6888
343	55.40479	-113.6893
344	55.40434	-113.6943
345	55.40807	-113.6983
346	55.40978	-113.6999
347	55.41120	-113.6975
348	55.30923	-114.1047
349	55.30363	-114.1033
350	55.23690	-114.7018
351	55.23616	-114.6980
352	55.23842	-114.6985
353	55.22392	-114.6336
354	55.22431	-114.6298
355	55.22704	-114.6137
356	55.22567	-114.6065
357	55.22475	-114.6032
358	55.22418	-114.5851

Site	Latitude	Longitude
359	55.22672	-114.5823
360	55.22750	-114.5796
361	55.22594	-114.5779
362	55.22674	-114.5751
363	55.22848	-114.5744
364	55.22838	-114.5709
365	55.23736	-114.6952
366	55.22938	-114.6137
367	55.25062	-114.5787
368	55.23200	-114.6038
369	55.49462	-113.8498
400	55.44425	-114.6234
401	55.44376	-114.6271
402	55.51565	-113.9561
403	55.51593	-113.9524
404	55.51603	-113.9492
405	55.51553	-113.9461
406	55.51360	-113.9448
407	55.51450	-113.9481
408	55.51463	-113.9514
409	55.51857	-113.9493
410	55.50972	-113.9627
411	55.50795	-113.9620
412	55.26132	-114.0817
413	55.26025	-114.0863
414	55.25887	-114.0871
415	55.25888	-114.0840
416	55.25709	-114.0845
417	55.25410	-114.0784
418	55.25198	-114.0792
419	55.25146	-114.0823
420	55.24847	-114.0755
421	55.27032	-114.0403
422	55.27197	-114.0419
423	55.27404	-114.0437
424	55.27576	-114.0381
425	55.27492	-114.0338
426	55.52027	-113.9309
427	55.52826	-113.9569
428	55.24625	-114.0716
429	55.24640	-114.0671
430	55.27754	-114.0321
3531	55.22812	-114.6160
3541	55.22639	-114.6169
L1	***55.41685***	***-114.5277***
L2	***55.41688***	***-114.5246***
L3	***55.41686***	***-114.5214***
L4	***55.41684***	***-114.5182***
L5	***55.41686***	***-114.5151***
L6	***55.41688***	***-114.5119***
L7	***55.41687***	***-114.5086***

Site	Latitude	Longitude
L11	***55.41460***	***-114.5120***
L12	***55.41471***	***-114.5152***
L13	***55.41478***	***-114.5186***
L14	***55.41475***	***-114.5215***
L15	***55.41471***	***-114.5247***
L16	***55.41470***	***-114.5280***
L17	55.41293	-114.5214
L18	55.41115	-114.5213
L19	55.40934	-114.5212
L20	55.40902	-114.5245
L21	55.41112	-114.5246
L22	55.41293	-114.5247
M1	***55.51272***	***-113.9990***
M2	***55.51462***	***-113.9982***
M3	***55.51639***	***-113.9990***
M4	***55.51846***	***-113.9996***
M5	***55.52009***	***-113.9996***
M6	***55.52190***	***-113.9998***
M7	***55.52320***	***-114.0002***
M8	***55.52557***	***-114.0001***
M9	***55.52560***	***-114.0040***
M10	***55.52380***	***-114.0039***
M11	***55.52201***	***-114.0038***
M12	***55.52016***	***-114.0036***
M13	***55.51851***	***-114.0035***
M14	***55.51687***	***-114.0030***
M15	***55.51488***	***-114.0032***
M16	***55.51329***	***-114.0031***
O1	***55.61673***	***-113.9332***
O2	***55.61584***	***-113.9355***
O3	***55.61496***	***-113.9387***
O4	***55.61400***	***-113.9414***
O5	***55.61292***	***-113.9440***
O6	***55.61209***	***-113.9466***
O7	***55.61113***	***-113.9489***
O8	***55.61017***	***-113.9522***
O9	***55.60824***	***-113.9496***
O10	***55.60904***	***-113.9470***
O11	***55.61014***	***-113.9442***
O12	***55.61115***	***-113.9415***
O13	***55.61199***	***-113.9397***
O14	***55.61295***	***-113.9370***
O15	***55.61383***	***-113.9343***
O16	***55.61502***	***-113.9313***
O17	55.61602	-113.9284
O18	55.61765	-113.9305
O19	55.61949	-113.9305
O20	55.61945	-113.9271
O21	55.61761	-113.9272
S1	***55.76239***	***-115.5970***
S2	***55.76032***	***-115.5949***

Site	Latitude	Longitude
S3	***55.75934***	***-115.5970***
S4	***55.75681***	***-115.5958***
S5	***55.75520***	***-115.5964***
S8	***55.75884***	***-115.6008***
S9	***55.76020***	***-115.6008***
S10	***55.76234***	***-115.6008***
S11	***55.76370***	***-115.6009***
S12	***55.76605***	***-115.6011***
S13	***55.76772***	***-115.6011***
S14	***55.76773***	***-115.5975***
S15	***55.76588***	***-115.5968***
S16	***55.76402***	***-115.5970***
X1	***55.13240***	***-114.0986***
X2	***55.13140***	***-114.1010***
X3	***55.13053***	***-114.1037***
X4	***55.12945***	***-114.1062***
X5	***55.12837***	***-114.1089***
X6	***55.12728***	***-114.1115***
X7	***55.12632***	***-114.1144***
X8	***55.12542***	***-114.1171***
X9	***55.12709***	***-114.1188***
X10	***55.12785***	***-114.1160***
X11	***55.12868***	***-114.1131***
X12	***55.12963***	***-114.1105***
X13	***55.13042***	***-114.1079***
X14	***55.13138***	***-114.1050***
X15	***55.13245***	***-114.1022***
X16	***55.13324***	***-114.0998***

Bold-italicized *sites were resampled from periodic breeding bird surveys (established 2001). Some of these sites may have moved ≤ 50 m from original locations to maintain sampled habitat type after recent disturbances.*

Appendix C.

Scientific names and presence by cover class of dominant plant species

Table C1. Number of sites where each species was listed as one of the top five dominant understory species representing 97.5% of records. In many cases vegetation could only be identified to family. Fewer than five dominant species were recorded at 11% of surveyed sites such that 1,194 observations of a possible 1,340 (n = 368 sites * 5 observations per site) are summarized below. Common names derived from Johnson et al. (1995). "Unid" short for "unidentified".

UNDERSTORY SPECIES		AGE CLASS				COVER CLASS				
Common name	**Scientific name**	1-10	11-20	21-30	80+	C	CD	DC	UP	**Total**
	TREES									
White Spruce sapling	*Picea glauca*	56	50	79	23	66	68	74	0	**208**
Black Spruce sapling	*Picea mariana*	6	6	3	28	33	9	1	0	**43**
Unid. Spruce sapling	*Picea sapling*	4	7	0	0	1	6	3	1	**11**
Jack Pine sapling	*Pinus banksiana*	3	2	0	0	0	3	2	0	**5**
Lodgepole Pine sapling	*Pinus contorta*	5	9	3	0	17	0	0	0	**17**
Unid. Pine sapling	*Pinus sp.*	3	7	1	1	8	2	2	0	**12**
Balsam Fir sapling	*Abies balsamea*	8	0	3	9	6	11	3	0	**20**
Tamarack sapling	*Larix laricina*	1	3	0	2	3	0	3	0	**6**
Balsam Poplar sapling	*Populus balsamifera*	32	10	7	4	13	18	22	0	**53**
Trembling Aspen sapling	*Populus tremuloides*	75	40	41	19	41	58	70	6	**175**
Paper Birch sapling	*Betula papyrifera*	37	72	65	28	79	55	65	3	**202**
	SHRUBS									
Water Birch	*Betula occidentalis*	0	0	0	3	3	0	0	0	**3**
Swamp Birch	*Betula pumila*	0	1	0	0	1	0	0	0	**1**
Green Alder	*Alnus crispa*	14	30	16	29	34	20	34	1	**89**
Beaked Hazelnut	*Corylus cornuta*	1	2	0	0	1	0	0	2	**3**
Wolf Willow	*Elaeagnus commutata*	0	0	0	1	1	0	0	0	**1**
Unid. Willow sp.	*Salix sp.*	49	56	78	20	56	65	80	2	**203**
Red-osier Dogwood	*Cornus stolonifera*	2	5	8	0	2	1	12	0	**15**
Buffaloberry	*Shepherdia canadensis*	0	5	0	0	1	0	4	0	**5**
Saskatoon	*Amelanchier alnifolia*	1	9	1	0	2	0	7	2	**11**
Pin Cherry	*Prunus pensylvanica*	0	0	0	0	0	0	0	0	**0**
Unid. Cherry sp.	*Prunus sp.*	1	2	1	0	2	2	0	0	**4**
Unid. Rose sp.	*Rosa sp.*	0	3	2	0	2	2	1	0	**5**
Common Wild Rose	*Rosa woodsii*	4	7	5	0	6	1	3	6	**16**
Wild Red Raspberry	*Rubus idaeus*	6	3	3	2	5	1	7	1	**14**
Northern Black Currant	*Ribes hudsonianum*	0	1	1	0	1	0	1	0	**2**
Wild Red Currant	*Ribes triste*	0	0	1	0	1	0	0	0	**1**
Gooseberry	*Ribes lacustre/oxyacanthoides*	0	0	1	0	1	0	0	0	**1**
Unid. Currant sp.	*Ribes sp.*	2	15	5	2	4	9	8	3	**24**
Low-bush Cranberry	*Viburnum edule*	0	2	1	0	1	0	0	2	**3**
High-bush Cranberry	*Viburnum opulus*	0	1	6	0	1	1	4	1	**7**
Unid. Cranberry sp.	*Viburnum sp.*	0	0	1	0	0	0	1	0	**1**
Common Snowberry	*Symphoricarpos albus*	0	6	0	1	0	4	2	1	**7**
Twining Honeysuckle	*Lonicera dioica*	1	0	0	0	0	0	1	0	**1**
Bracted Honeysuckle	*Lonicera involucrata*	1	13	7	2	6	4	10	3	**23**
Labrador Tea	*Ledum groenlandicum*	0	1	1	0	1	0	0	1	**2**
	Total species identified / generalizations (Top 5)	18/5	20/6	18/6	13/3	23/6	14/6	18/6	10/3	**27/7**
	Number of point count stations	**101**	**103**	**98**	**66**	**125**	**115**	**118**	**10**	**368**

Table C2. Number of sites where each species was listed in the top eight dominant ground cover species representing 94.5% of records. Fewer than eight dominant species were recorded at 21% of surveyed sites.

GROUND COVER SPECIES		AGE CLASS				COVER CLASS				
Common name	**Scientific name**	1-10	11-20	21-30	80+	C	CD	DC	UP	**Total**
	TREES									
White Spruce seedling	*Picea glauca*	11	5	3	3	7	4	11	0	**22**
Black Spruce seedling	*Picea mariana*	0	1	0	10	7	4	0	0	**11**
Unid. Spruce seedling	*Picea sp.*	7	0	0	0	2	1	4	0	**7**
Jack Pine seedling	*Pinus banksiana*	1	0	0	0	0	1	0	0	**1**
Lodgepole Pine seedling	*Pinus contorta*	1	0	0	0	1	0	0	0	**1**
Balsam Fir seedling	*Abies balsamea*	0	0	0	1	0	1	0	0	**1**
Balsam Poplar seedling	*Populus balsamifera*	2	0	0	2	2	1	1	0	**4**
Trembling Aspen seedling	*Populus tremuloides*	15	0	0	2	3	10	4	0	**17**
Paper Birch seedling	*Betula papyrifera*	3	0	0	0	0	2	1	0	**3**
	SHRUBS									
Swamp Birch	*Betula pumila*	0	0	1	0	0	1	0	0	**1**
Green Alder	*Alnus crispa*	4	0	0	2	1	2	3	0	**6**
Beaked Hazelnut	*Corylus cornuta*	0	1	0	0	0	0	1	0	**1**
Unid. Willow sp.	*Salix sp.*	7	3	0	2	3	4	5	0	**12**
Red-osier Dogwood	*Cornus stolonifera*	1	1	2	0	0	1	3	0	**4**
Buffaloberry	*Shepherdia canadensis*	0	1	0	0	0	0	1	0	**1**
Saskatoon	*Amelanchier alnifolia*	0	1	0	0	0	0	0	1	**1**
Prickly Wild Rose	*Rosa acicularis*	5	3	2	0	3	7	0	0	**10**
Common Wild Rose	*Rosa woodsii*	27	14	16	1	13	12	32	1	**58**
Unid. Rose Sp.	*Rosa sp.*	14	14	33	21	18	34	30	0	**82**
Western Mountain Ash	*Sorbus scopulina*	1	0	0	0	1	0	0	0	**1**
Wild Red Raspberry	*Rubus idaeus*	67	38	27	11	40	51	50	2	**143**
Unid. Raspberry sp.	*Rubus sp.*	1	6	12	11	6	10	14	0	**30**
Northern Black Currant	*Ribes hudsonianum*	4	0	5	0	5	4	0	0	**9**
Wild Red Currant	*Ribes triste*	1	5	1	1	3	0	5	0	**8**
Gooseberry	*R. lacustre/oxyacanthoides*	1	17	3	0	3	7	11	0	**21**
Unid. Currant sp.	*Ribes sp.*	18	14	21	21	17	26	31	0	**74**
Low-Bush Cranberry	*Viburnum edule*	5	10	33	11	8	27	22	2	**59**
High-Bush Cranberry	*Viburnum opulus*	1	3	12	8	7	9	8	0	**24**
Unid. Cranberry sp.	*Viburnum sp.*	3	1	6	2	4	4	4	0	**12**
Common Snowberry	*Symphoricarpos albus*	2	11	1	3	2	3	10	2	**17**
Twining Honeysuckle	*Lonicera dioica*	2	0	0	0	0	0	2	0	**2**
Bracted Honeysuckle	*Lonicera involucrata*	8	14	21	19	15	19	28	0	**62**
Unid. Honeysuckle sp.	*Lonicera/Symphoricarpos sp.*	1	3	1	0	0	0	5	0	**5**
Bearberry	*Arctostaphylos uva-ursi*	4	8	6	0	16	0	1	1	**18**
Lingonberry	*Vaccinium vitis-idaea*	0	4	2	23	20	6	3	0	**29**
Common Blueberry	*Vaccinium myrtilloides*	0	1	0	0	0	0	1	0	**1**
Dwarf Blueberry	*Vaccinium caespitosum*	1	0	0	0	1	0	0	0	**1**
Unid. Blueberry sp.	*Vaccinium/Arctostaphylos sp.*	5	10	4	8	21	2	4	0	**27**
Labrador Tea	*Ledum groenlandicum*	7	18	8	26	46	7	6	0	**59**
Red Elderberry	*Sambucus racemosa*	2	0	0	0	2	0	0	0	**2**
	HERBACEOUS									
False Solomon's-seal	*Maianthemum racemosum*	0	0	2	0	1	1	0	0	**2**
Wild Lily-of-the-valley	*Maianthemum canadense*	1	6	4	1	1	5	5	1	**12**
Shepherd's Purse	*Capsella bursa-pastoris*	3	4	2	0	0	5	3	1	**9**
Bishop's Cap	*Mitella nuda*	3	2	17	4	3	15	7	1	**26**
Marsh Marigold	*Caltha palustris*	0	0	0	1	0	1	0	0	**1**
Tall Buttercup	*Ranunculus acris*	1	0	0	0	1	0	0	0	**1**

GROUND COVER SPECIES		AGE CLASS				COVER CLASS				
Common name	**Scientific name**	1-10	11-20	21-30	80+	C	CD	DC	UP	**Total**
Unid. Buttercup sp.	*Ranunculus sp.*	5	0	1	0	0	5	1	0	**6**
Tall Larkspur	*Delphinium glaucum*	1	0	0	0	1	0	0	0	**1**
Veiny Meadow Rue	*Thalictrum venulosum*	0	0	1	0	0	0	1	0	**1**
Cloudberry	*Rubus chamaemorus*	0	0	0	1	1	0	0	0	**1**
Dewberry	*Rubus pubescense*	12	7	2	2	11	7	5	0	**23**
Dwarf Raspberry	*Rubus acaulis*	1	0	0	1	1	1	0	0	**2**
Unid. Strawberry sp.	*Fragaria sp.*	25	24	30	2	19	25	32	5	**81**
Woodland Strawberry	*Fragaria vesca*	0	0	1	0	0	1	0	0	**1**
Wild Vetch	*Vicia americana*	3	6	3	0	4	4	4	0	**12**
Creamy Peavine	*Lathyrus ochroleucus*	9	8	10	0	8	7	10	2	**27**
Alsike Clover	*Trifolium hybridum*	1	3	1	0	1	2	2	0	**5**
Unid. Clover sp.	*Trifolium sp.*	1	2	7	0	0	3	7	0	**10**
Unid. Violet sp.	*Viola sp.*	4	6	1	4	1	6	8	0	**15**
Unid. Pea sp.	*Fabaceae sp.*	0	1	6	0	1	1	5	0	**7**
Fireweed	*Epilobium angustifolium*	55	27	37	5	48	27	48	1	**124**
Cow Parsnip	*Heracleum lanatum*	3	0	2	3	1	2	5	0	**8**
Common Pink Wintergreen	*Pyrola asarifolia*	0	0	4	0	1	1	2	0	**4**
Starflower	*Trientalis borealis*	3	2	4	2	5	0	6	0	**11**
Common Dandelion	*Taraxacum officinale*	6	5	9	0	7	6	7	0	**20**
Perennial Sow-thistle	*Sonchus arvensis*	2	0	0	0	1	0	1	0	**2**
Canada Thistle	*Cirsium arvense*	1	0	0	1	0	2	0	0	**2**
Common Yarrow	*Achillea millefolium*	6	0	0	0	1	1	4	0	**6**
Unid. Aster sp.	*Erigeron sp.*	1	0	0	0	1	0	0	0	**1**
Palmate-leaved Coltsfoot	*Petasites palmatus*	8	9	31	1	17	14	16	2	**49**
Stinging Nettle	*Urtica dioica*	2	0	0	1	1	1	1	0	**3**
Pink Corydalis	*Corydalis sempervirens*	4	0	0	0	2	1	1	0	**4**
Wild Sarsaparilla	*Aralia nudicaulis*	13	17	25	20	14	30	26	5	**75**
Bunchberry	*Cornus canadensis*	26	36	50	22	52	36	37	9	**134**
Common Harebell	*Campanula rotundifolia*	0	1	0	0	0	1	0	0	**1**
Tall Lungwort	*Mertensia paniculata*	21	7	33	8	18	23	28	0	**69**
Unid. 'Bluebell' sp.	*C. rotundifolia/ M. paniculata*	15	8	2	0	5	9	11	0	**25**
Common Plantain	*Plantago major*	3	0	0	0	1	0	2	0	**3**
Unid. Bedstraw sp.	*Galium sp.*	19	14	8	1	9	13	17	3	**42**
Twinflower	*Linnaea borealis*	0	3	1	0	0	1	0	3	**4**
Common Cattail	*Typha latifolia*	4	1	0	0	2	3	0	0	**5**
Pond Lily	*Nuphar variegatum*	0	1	0	0	0	1	0	0	**1**
Unid. Sedge sp.	*Cyperaceae sp.*	0	5	0	0	0	0	4	1	**5**
Unid. Cotton-grass sp.	*Eriophorum sp.*	1	0	0	0	0	1	0	0	**1**
Unid. Rush sp.	*Juncaceae sp.*	1	0	0	0	1	0	0	0	**1**
Hairy Wild Rye	*Leymus innovatus*	1	0	0	0	0	1	0	0	**1**
Unid. Grass sp.	*Poaceae sp.*	97	87	83	35	94	99	104	5	**302**
Unid. Reedgrass sp.	*Calamagrostis sp.*	3	0	0	0	2	1	0	0	**3**
Unid. Fern Sp.	*fern sp.*	7	4	4	14	10	4	15	0	**29**
Common Horsetail	*Equisetum arvense*	1	0	0	0	1	0	0	0	**1**
Woodland Horsetail	*Equisetum sylvaticum*	4	0	3	2	4	4	1	0	**9**
Unid. Horsetail sp.	*Equisetum sp.*	65	55	57	30	67	61	76	3	**207**
MOSSES AND LICHENS										
Knight Plume Moss	*Ptilium rista-castrensis*	0	0	0	1	1	0	0	0	**1**
Unid. Moss sp.	*Bryophyte sp.*	6	20	19	31	46	16	16	0	**76**
Unid. Lichen sp.	*Lichen sp.*	0	1	1	0	2	0	0	0	**2**
Total species identified / generalizations (Top 8)		53/21	38/19	38/18	31/15	52/20	50/21	45/19	15/5	**70/26**
Number of point count stations		**101**	**103**	**98**	**66**	**125**	**115**	**118**	**10**	**368**