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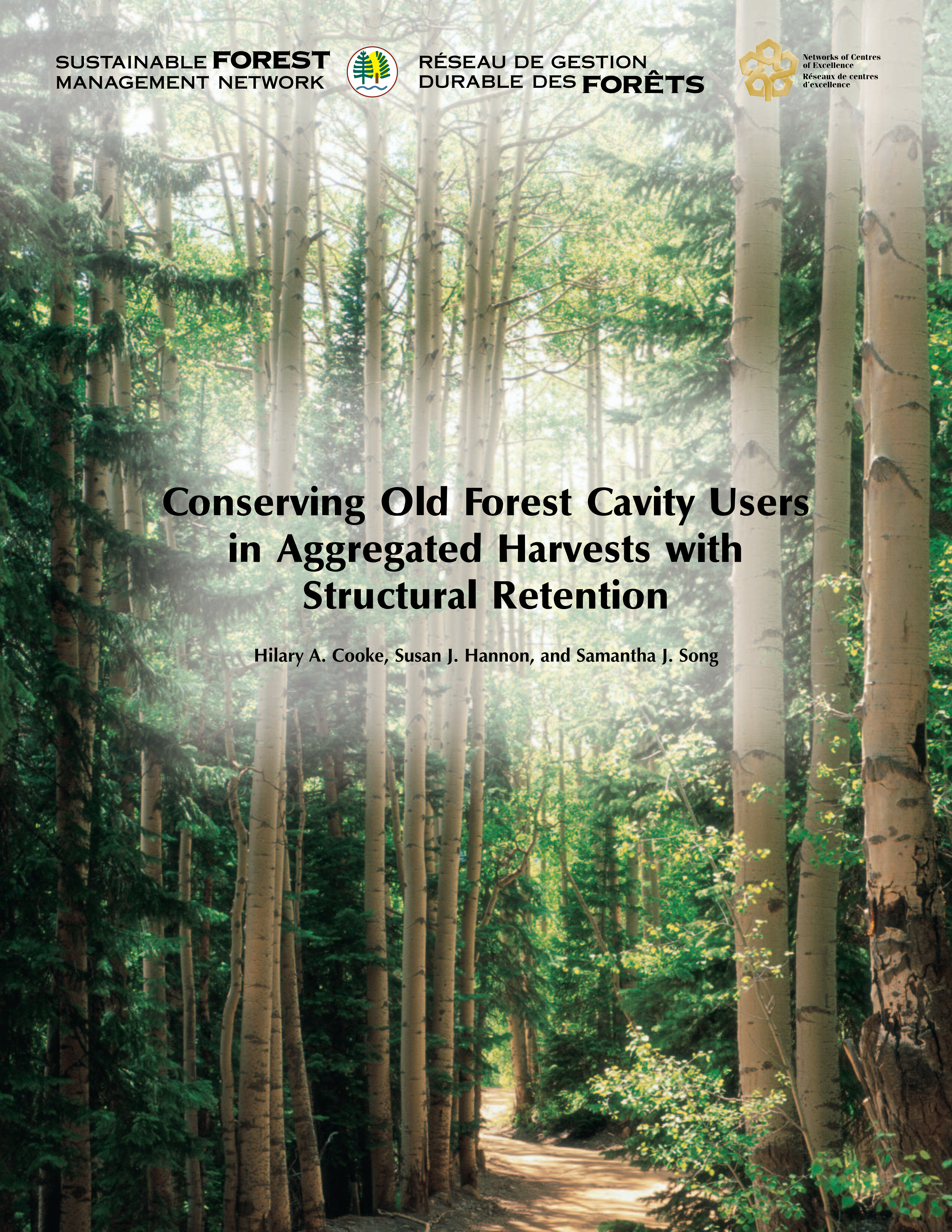

Conserving Old Forest Cavity Users in Aggregated Harvests with Structural Retention

Hilary A. Cooke, Susan J. Hannon, and Samantha J. Song

THE SUSTAINABLE FOREST MANAGEMENT NETWORK

Established in 1995, the Sustainable Forest Management Network (SFM Network) is an incorporated, non-profit research organization based at the University of Alberta in Edmonton, Alberta, Canada.

The SFM Network's mission is to:

- Deliver an internationally-recognized, interdisciplinary program that undertakes relevant university-based research;
- Develop networks of researchers, industry, government, Aboriginal, and non-government organization partners;
- Offer innovative approaches to knowledge transfer; and
- Train scientists and advanced practitioners to meet the challenges of natural resource management.

The SFM Network receives about 60% of its $7 million annual budget from the Networks of Centres of Excellence (NCE) Program, a Canadian initiative sponsored by the NSERC, SSHRC, and CIHR research granting councils. Other funding partners include the University of Alberta, governments, forest industries, Aboriginal groups, non-governmental organizations, and the BIOCAP Canada Foundation (through the Sustainable Forest Management Network/BIOCAP Canada Foundation Joint Venture Agreement).

KNOWLEDGE EXCHANGE AND TECHNOLOGY EXTENSION PROGRAM

The SFM Network completed approximately 300 research projects from 1995 – 2004. These projects enhanced the knowledge and understanding of many aspects of the boreal forest ecosystem, provided unique training opportunities for both graduate and undergraduate students and established a network of partnerships across Canada between researchers, government, forest companies and Aboriginal communities.

The SFM Network's research program was designed to contribute to the transition of the forestry sector from sustained yield forestry to sustainable forest management. Two key elements in this transition include:

- Development of strategies and tools to promote ecological, economic and social sustainability, and
- Transfer of knowledge and technology to inform policy makers and affect forest management practices.

In order to accomplish this transfer of knowledge, the research completed by the Network must be provided to the Network Partners in a variety of forms. The KETE Program is developing a series of tools to facilitate knowledge transfer to their Partners. The Partners' needs are highly variable, ranging from differences in institutional arrangements or corporate philosophies to the capacity to interpret and implement highly technical information. An assortment of strategies and tools is required to facilitate the exchange of information across scales and to a variety of audiences.

The KETE documents represent one element of the knowledge transfer process, and attempt to synthesize research results, from research conducted by the Network and elsewhere in Canada, into a SFM systems approach to assist foresters, planners and biologists with the development of alternative approaches to forest management planning and operational practices.

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Conserving Old Forest Cavity Users in Aggregated Harvests with Structural Retention

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Highlights

- Conservation of old stands of Canada's boreal forest is critical for forest biodiversity. Strategies for achieving regional old forest targets include reduced harvest rates, extended rotations, and reserves.

- Species that use old forests appear to benefit from ecologically sustainable forest management practices that increase heterogeneity within stands and across landscapes. Structural retention within large (1000s ha), spatially-aggregated harvests is one approach to help achieve that heterogeneity.

- In old upland forest in the boreal plains, Yellow-bellied Sapsuckers, Hairy Woodpeckers, Northern Flickers, and Pileated Woodpeckers are key cavity excavators for secondary (non-excavating) birds and mammals such as the Northern Saw-whet Owl, Common Goldeneye, Bufflehead, Red Squirrel and Northern Flying Squirrel.

- In the short term (5 years post-harvest), the key cavity excavators and most secondary cavity users associated with old upland forest are retained in aggregated harvests with structural retention.

- Fine-filter management for old forest cavity users in aggregated harvests depends on retaining the types of trees and patches used for nesting and foraging. Key cavity excavators use live, large (>35 cm DBH) aspen with multiple (~10) fungal conks. Suitable cavity trees should be retained in clumps that include at least one other suitable tree in or within 100 m of large (>5 ha) residual patches.

- Old forest cavity excavators use a variety of foraging substrates, including the bark, trunk and limbs of large-diameter live and dead trees, the foliage of live trees, and small stems of live woody plants. Several old forest cavity excavators prefer foraging substrates in or near (within 50 m of) protective cover.

- To benefit most cavity excavators 20% of the total area of an aggregated harvest landscape should be retained in patches of mature (60-100 year) and old (>100 year) aspen and mixedwood stands. Riparian buffers and other areas unharvested due to operational constraints that are derived from these stand types can contribute to this target.

- Structural retention can help conserve old forest species in aggregated harvests. However, models run over the long-term (150 years) and at a regional (~275,000 ha) scale indicate that structural retention is insufficient when it is the only strategy for conserving old forest species. Thus, additional strategies, such as reduced harvest volumes and extended rotation periods, are critical to conserving old forest species in the boreal plains.

1.0 Introduction

The importance of old forests

Old forest stands are critical components of boreal ecosystems. They are often characterized by a multi-layered canopy, large trees and snags, and high amounts of coarse woody debris (Kneeshaw and Gauthier 2003). The vertical and horizontal structural complexity of old stands provides habitat for numerous boreal species that may be absent or at low abundances in younger stands (Stelfox 1995, Spence *et al*. 1996, Niemi *et al*. 1998, Song 2002).

In western boreal forests of Canada, numerous bird species are at their highest abundances in the oldest seral stage (Schieck and Song 2006). In particular, cavity-using birds, such as Yellow-bellied Sapsuckers (see Appendix 1 for Latin names of birds and mammals) and Pileated Woodpeckers, rely on structures characteristic of old stands (large dead and decaying trees) and are often at their highest abundances in old stands (Schieck and Song 2006). Old boreal stands also support the highest abundances of several mammals, including Red Squirrels, Northern Flying Squirrels, Red-backed Voles, American Marten, and several bat species (McDonald 1995, Roy *et al*. 1995, Crampton and Barclay 1998, Fisher and Wilkinson 2005). Lichens, fungi, mosses, and arthopods such as carabid beetles (food for many species) are all more diverse and more abundant in old stands in the boreal plains (Stelfox 1995, Spence *et al*. 1996). Given their importance to forest biodiversity, old stands should be priorities for conservation in Canada's boreal forest.

Old stands are a conservation priority in Canada's boreal forest.

The changing face of forest management

Conventional harvest practices in Canada's boreal forest involve clearcutting of small (generally <100 ha) cutblocks over multiple passes (Sougavinski and Doyon 2005). This practice results in loss of heterogeneity at both stand and landscape scales (Bergeron *et al*. 2002, Lindenmayer and Franklin 2002). Clearcutting removes mature and old forest and simplifies structure in regenerating stands. The harvest of many small cutblocks that are dispersed across the landscape results in fragmentation of remaining forest into small patches. In combination with short rotation periods, these harvest practices result in significant declines in old forest over the long term (Burton *et al*. 1999). Evidence from the boreal forests of Finland and Sweden suggests these changes will be accompanied by declines in old forest biota (Berg *et al*. 1994, Hanski 2000).

In boreal and other regions, concern over the impact of conventional harvest practices on forest biodiversity has led to the development of sustainable forest management (Haila 1994, Franklin *et al*. 1997, Lindenmayer and Franklin 2002, Vaillancourt *et al*. 2009). This approach aims to maintain ecosystem function and biodiversity while sustaining forest productivity and economic values. Central to this new management paradigm are harvest practices that increase heterogeneity within stands and across landscapes (Hansen *et al*. 1991, Franklin *et al*. 1997, Bergeron *et*

In recent decades there has been a shift in forest management paradigms to incorporate greater stand and landscape heterogeneity in harvested areas.

al. 2002, Lindenmayer and Franklin 2002). Structural heterogeneity characterizes natural forests and is required to support forest biodiversity. Natural forest stands also vary in type, size and spatial distribution across a landscape. Thus, forest biodiversity may be better conserved if harvest practices maintain this variability.

Structural retention within cutblocks may act as lifeboats for old forest species and provide legacies of old forest structure.

Greater structural heterogeneity within stands is achieved by retaining green (live) trees and patches of trees. Retained trees and patches provide refugia for old forest biota in regenerating stands (lifeboats), enhance habitat connectivity, and structurally enrich regenerating stands with old forest structures (legacies) (Franklin *et al*. 1997). Forest managers who employ structural retention in cutblocks (also known as partial harvesting and variable retention harvesting) must decide what structure to retain, how much to retain, and the spatial distribution of structure (Lindenmayer and Franklin 2002).

Structural retention may be targeted to achieve specific management objectives, such as providing habitat for species of concern (Franklin *et al*. 1997, Bunnell 1999, Serrouya and D'Eon 2004, Sougavinski and Doyon 2005). Structural retention within cutblocks may also be modelled on the unburned structure that remains after fire (Hunter 1993, Bergeron *et al*. 2002, Lindenmayer and Franklin 2002). Lee *et al*. (2002) and Serrouya and D'Eon (2004) summarize characteristics of post-fire residuals that can be used as a template for post-harvest residuals in boreal forests of Canada. Many forestry companies operating in Canada's boreal forest combine these coarse-filter (natural disturbance model) and fine-filter (species-specific management targets) approaches (Sougavinski and Doyon 2005; e.g. Canfor 2003, Weyerhaeuser 2005).

Figure 1. Aerial view of large, spatially aggregated harvest with structural retention in the boreal plains.
Photo credit: Steve Van Wilgenburg, Environment Canada

At the landscape scale, forestry companies maintain heterogeneity by harvesting along existing stand boundaries and increasing the range of cutblock sizes (Sougavinski and Doyon 2005). Natural disturbances can provide the template for harvest patterns at the landscape scale (Hunter 1993, Bergeron *et al*. 2002, Lee *et al*. 2002, Dzus *et al*. 2009). Fires covering thousands or tens of thousands of hectares are responsible for most of the area burned in Canada's boreal forest (Bergeron *et al*. 2002, Schneider 2002). However, very large harvests are generally socially unacceptable. Thus, most forestry regulations place limits on cutblock size (up to 1,500 ha across Canada; Sougavinski and Doyon 2005). Large harvest disturbances are also achieved by spatially aggregating cutblocks into very large (10,000s ha) harvests (see Figure 1) (Lee *et al*. 2002, Dzus *et al*. 2009).

Impacts of management changes on cavity users

For many birds and mammals associated with old boreal forest, residual trees and patches offer habitat in small, recently harvested (<10 years) cutblocks (Serrouya and D'Eon 2004, Fisher and Wilkinson 2005, Schieck and Song 2006). Large live and dead trees and patches of trees retain cavity-using birds (e.g. Yellow-bellied Sapsucker, Downy and Hairy Woodpeckers, Black-capped Chickadee), bark-foraging birds (e.g. Red-breasted Nuthatch), shrub- and tree nesting birds (e.g. Swainson's Thrush, Yellow-rumped warbler, Warbling Vireo, Western Tanager, among others), and several mammals (e.g. Red Squirrel, Northern Flying Squirrel, Southern Red-backed Vole, *Myotis* spp, American Marten) (Hogberg *et al*. 2002, Serrouya and D'Eon 2004, Fisher and Wilkinson 2005, Sullivan *et al*. 2008, Zwolak 2009). These species vary in their response to retention level, patch size, and/or the spatial distribution of residuals (Song 2002, Serrouya and D'Eon 2004).

In general, as more forest is retained within small cutblocks, the abundance of old forest birds increases. Retention levels greater than 40% and patches >10 ha are likely required to retain most old forest birds in western boreal forests (Schieck and Song 2006). For some old forest species, such as cavity-using birds, aggregation of trees into patches is preferred over structure dispersed throughout a cutblock (Serrouya and D'Eon 2004). See Song (2002), Serrouya and D'Eon (2004), Fisher and Wilkinson (2005), Schieck and Song (2006) for detailed reviews of the response of forest biota to structural retention in small cutblocks in western boreal forests.

Compared with small cutblocks, large planning units can accommodate a greater range of residual patch sizes (from single trees to 100s ha) (Lee *et al*. 2002). This may affect the value of retained structure for old forest biodiversity. For example, species with large home ranges, such as woodpeckers, may benefit from retention of large patches of suitable habitat. However, our understanding of the use of residual structure by old forest species in small cutblocks may not be applicable to large, aggregated harvests. Many forestry companies in the boreal plains are incorporating larger cutblocks and spatial aggregation of cutblocks but there is little information on the implications for old forest species.

Large (1000s ha), spatially-aggregated harvests can accommodate a wide range of residual patch sizes (up to 100s ha).

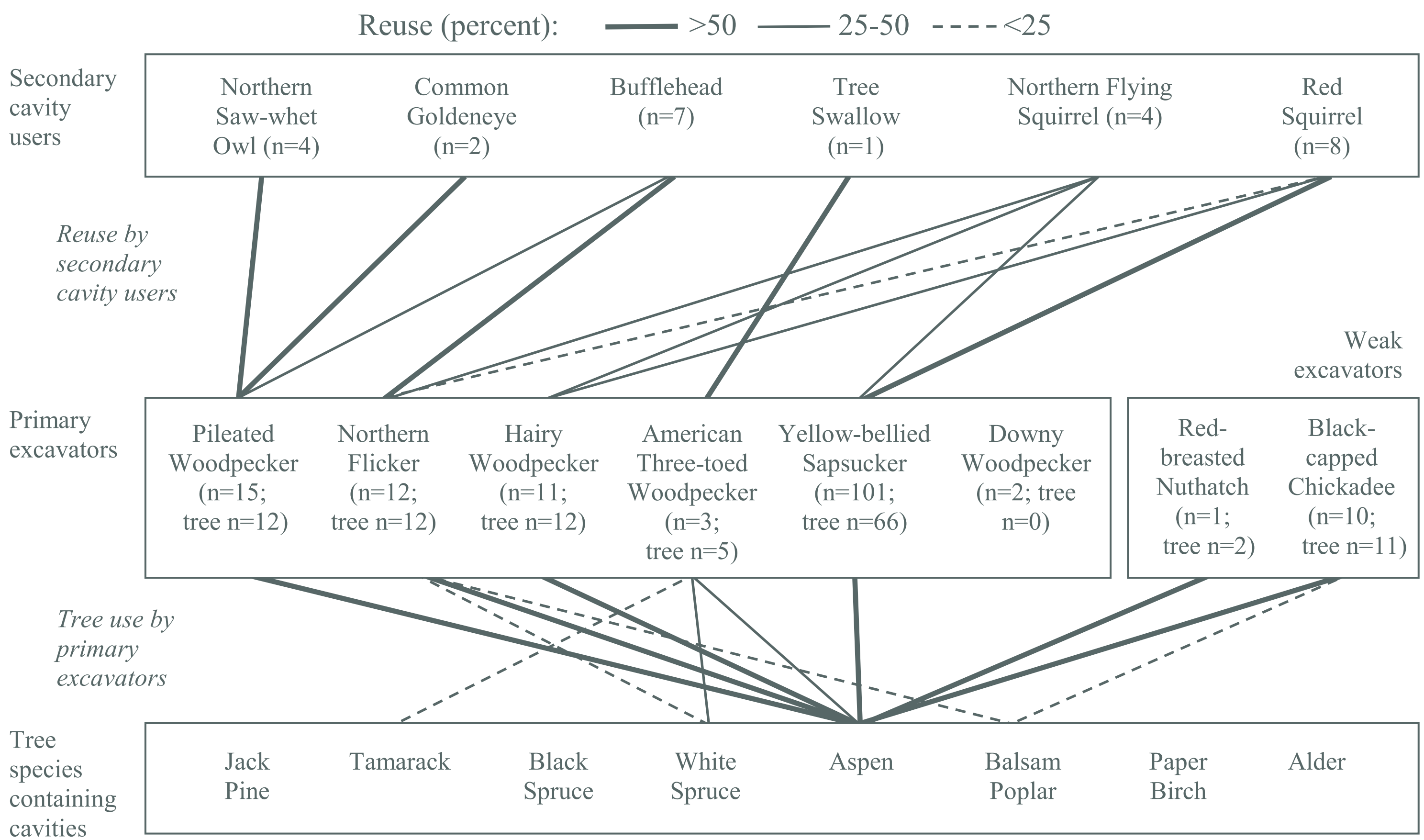
This report synthesizes current knowledge of the value of residual structure within aggregated harvests as habitat for cavity-using species associated with old upland forest in the boreal plains. The primary source of this information is a study of old forest cavity users in two intact and two aggregated harvest landscapes in the boreal plains of Alberta (AB) and Saskatchewan (SK) (see Cooke 2009 for a detailed description of this study). In each province a spatially-aggregated harvest was paired with a nearby unharvested landscape. The area of each study landscape was ~1600 ha in AB and ~3500 ha in SK. All landscapes were composed primarily of mature (60-100 year) and old (>100 year) upland stands. Upland stands in this region were dominated by deciduous (primarily aspen, *Populus tremuloides*) or coniferous (primarily white spruce, *Picea glauca*) species or a mix of deciduous and coniferous trees. Cutblocks in the aggregated harvests were harvested between 2000 and 2004. Residual forest structure covered approximately 35% of each harvested landscape (includes island and peninsular patches, existing riparian buffers, visual buffers, and inoperable areas; patches are derived from merchantable and non-merchantable stands). Residual structure ranged from single trees to very large (>600 ha) patches.

2.0 Cavity web and key cavity excavators in old upland forest in the boreal plains

One or a few cavity excavators may produce the majority of cavities reused by other species so their conservation is critical.

Cavity-using birds and mammals were studied because they are sensitive to intensive harvest practices (Angelstam and Mikuskinski 1994, Imbeau *et al*. 2001) and have a strong association with old forest in the boreal plains (Schieck and Song 2006). Cavity-using birds and mammals are a unique group of forest species that use holes in trees for nesting or roosting. Cavity users differ in their ability to excavate a cavity. Woodpeckers (known as primary cavity users) excavate their own tree cavity. Secondary cavity users (including ducks, owls, squirrels, bats) are unable to excavate a cavity. These species must reuse cavities excavated by woodpeckers or created naturally through decay processes in trees. Weak cavity users (chickadees, nuthatches) may excavate or may use existing cavities. A map of the links between species producing cavities and those reusing cavities is called a 'cavity web' (Martin and Eadie 1999). Conservation of non-excavating species in the cavity web depends on conserving species that produce cavities. In particular, one or a few cavity excavators may produce the majority of cavities reused by other species and thus their conservation is critical.

In old upland forest in the boreal plains, the cavity web is organized around cavities excavated in aspen by four woodpeckers: Yellow-bellied Sapsucker, Hairy Woodpecker, Northern Flicker, and Pileated Woodpecker (see Figure 2; Cooke 2009). Yellow-bellied Sapsuckers are the most common woodpecker of old stands in this region and thus produce the most cavities in old upland forest (Schieck and Song 2006, Cooke 2009). In contrast, Hairy and Pileated Woodpeckers and Northern Flickers occur at low densities, even in old upland stands. Downy Woodpeckers and American Three-toed Woodpecker produce very few cavities in old upland stands.



Interpreting the cavity web: Lines indicate the flow of cavities from the tree species that contain the cavities through woodpeckers, chickadees, and nuthatches that produce the cavities to the secondary (non-excavating) species that reuse the cavities. Sample sizes in parentheses below each species. Tree species and reuse not determined for all cavities. Thus, sample size for tree species may include more or fewer cavities than reuse sample. Line width reflects the percentage of all secondary reuse events occurring in the cavity of the linked excavator or the percentage of all cavities occurring in linked tree species.

Figure 2. Cavity web for unharvested landscapes of mature and old upland forest

Pileated Woodpeckers, Northern Flickers, Yellow-bellied Sapsuckers, and Hairy Woodpeckers are key cavity excavators in old upland forest in the boreal plains.

The cavities of Northern Flickers and Pileated Woodpeckers are reused by at least five secondary cavity users (Northern Saw-Whet Owl, Common Goldeneye, Bufflehead, Northern Flying Squirrel, and Red Squirrel). Only two species, Red Squirrel and Northern Flying Squirrel, are known to reuse Yellow-bellied Sapsucker and Hairy Woodpecker cavities. These small-bodied mammals use the cavities of all four excavators whereas the large-bodied Northern Saw-whet Owl, Common Goldeneye, and Bufflehead rely exclusively on the cavities of Northern Flickers and Pileated Woodpeckers.

Given their importance to most secondary cavity users, Yellow-bellied Sapsuckers, Hairy Woodpeckers, Northern Flickers, and Pileated Woodpeckers are the foundation of the cavity web of old upland forest in the boreal plains. These four key excavators are therefore priorities for conservation in managed forests. The reliance of the large-bodied secondary users on cavities produced by Pileated Woodpeckers and Northern Flickers make these two woodpeckers critical for conservation of this assemblage.

3.0 Cavity web and key cavity excavators in aggregated harvests with retention

Many cavity-using birds and mammals associated with old upland forest were retained in large (1000s ha), spatially-aggregated harvests.

Many of the cavity-using birds and mammals associated with old upland forest in the boreal plains were retained in the large, spatially-aggregated harvests in the short term (within 5 years of harvest) (Cooke 2009). All four of the key cavity excavators of intact old upland forest were retained (Figure 3). However, Yellow-bellied Sapsuckers occurred less frequently and Northern Flickers occurred more frequently in aggregated harvests compared with unharvested forest. These differences in abundance were expected. Yellow-bellied Sapsuckers have their highest abundance in old upland forest and thus are expected to decline with the loss of forest cover. In contrast, Northern Flickers occur in old forest but are more abundant in open habitats with suitable nest sites (Schieck and Song 2006).

The effect of aggregated harvesting on the abundance of Hairy Woodpeckers and Pileated Woodpeckers is uncertain. These species occur at low densities in the boreal plains and thus differences in abundance were difficult to detect. However, it is likely that these species increased their home range to accommodate the loss of forest cover in harvested landscapes (Bull *et al*. 2007). Thus, they likely occurred at even lower abundances in aggregated harvests compared with intact forest landscapes. Active nests of Pileated Woodpeckers were not found in the aggregated harvests but individuals have been observed on surveys. Finally, the two weak cavity excavators, Black-capped Chickadee and Red-breasted Nuthatch, were also retained in aggregated harvests but there is no information on their abundance compared to unharvested landscapes.

Five secondary cavity users associated with old upland forest in the boreal plains occurred in aggregated harvests with structural retention: Northern Saw-Whet Owl, Common Goldeneye, Tree Swallow, Red Squirrel, and Northern Flying Squirrel (Figure 3; Cooke 2009). These species use cavities excavated in residual

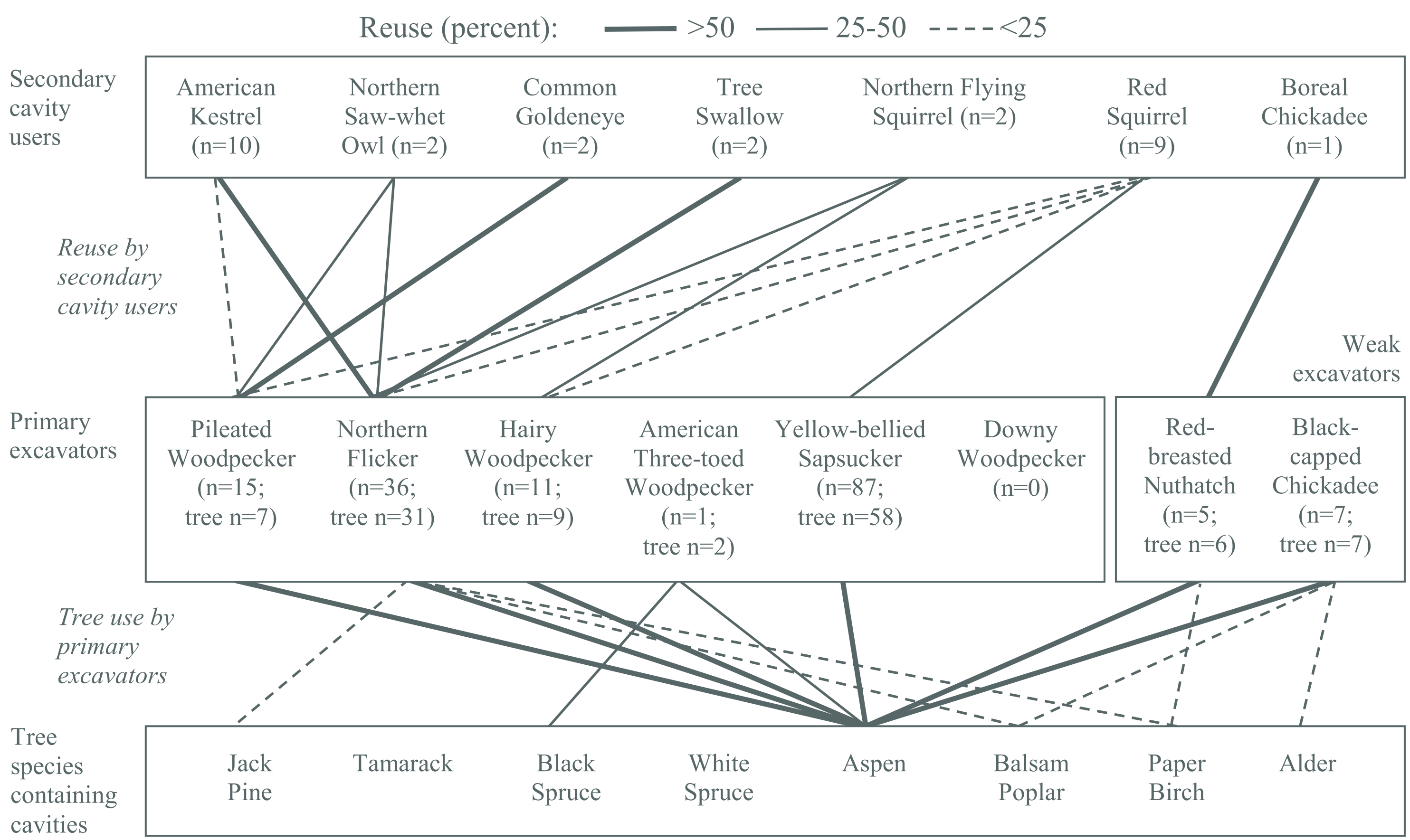


Figure 3. Cavity web for aggregated harvests with structural retention

trees by the same excavators that are most important in unharvested forest. The study found that cavities excavated by Northern Flickers were reused primarily by Bufflehead in intact landscapes and by American Kestrels in harvested landscapes. Bufflehead were found using Northern Flicker and Pileated Woodpecker cavities near water bodies in old upland forest but were not observed in aggregated harvests. Bufflehead may be absent from aggregated harvests if suitable nest sites within these harvests are farther than 500 m from water (Gauthier 1993). American Kestrel were prevalent in aggregated harvests but were not found nesting in unharvested forest. Like Northern Flickers, Kestrels are an open-woodland species that occur predominantly in early successional post-fire and post-harvest habitats in the boreal plains (Hannon and Drapeau 2005, Schieck and Song 2006). Kestrels occur rarely in mature or old stands. Thus, their positive response to the cutblock-forest patch mosaic of aggregated harvests is expected.

Although most old forest cavity users were retained in large aggregated harvests with structural retention in the short term, reproductive success and survival may be lower compared to intact forest landscapes (Hinsley 2000, Bull *et al*. 2007). Further information on reproductive success and other population parameters is required.

4.0 Habitat requirements of old forest cavity excavators in the boreal plains

Managers who want to target old forest cavity users for conservation in aggregated harvests in the short term (<5 years post-harvest) need information on the types of forest structure that should be retained. Conserving the non-excavating species depends on retaining the nesting and foraging habitats of cavity excavators. This section describes the habitat requirements of seven cavity excavators in the boreal plains: Yellow-bellied Sapsuckers, Hairy Woodpeckers, Northern Flickers, Pileated Woodpeckers, Black-capped Chickadees, Red-breasted Nuthatches, and American Three-toed Woodpeckers. This section describes the forest characteristics necessary to conserve habitat for these species, including the characteristics of:

- cavity trees,
- cavity tree clumps,
- foraging substrates, and
- residual patches within aggregated harvests.

4.1 Cavity trees

Tree species

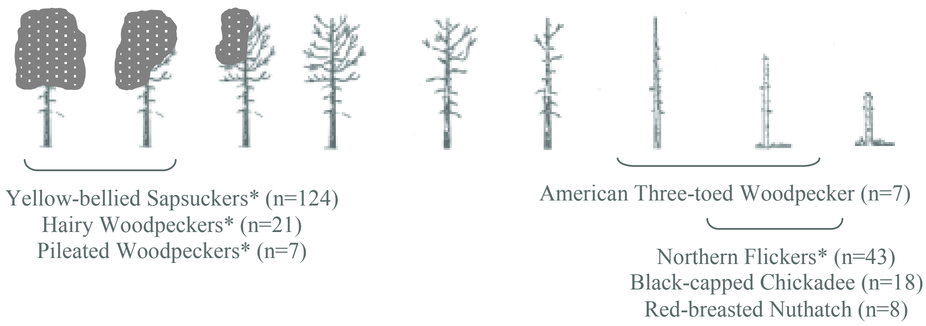
Trembling aspen was the primary tree species used by all excavators in intact landscapes of old upland forest and in aggregated harvests (Figures 2 & 3; Cooke 2009). All excavators, except American Three-toed Woodpecker, used aspen more than 70% of the time. Three of the key cavity excavators—Yellow-bellied sapsuckers, Hairy Woodpeckers, and Pileated Woodpeckers—used aspen exclusively. Other tree species used by Black-capped Chickadees, Red-breasted Nuthatch, and Northern Flicker included balsam poplar *(Populus balsamifera)*, alder *(Alnus sp)*, and paper birch *(Betula papyrifera)*. In addition to aspen, American Three-toed Woodpeckers used tamarack *(Larix larcina)*, black spruce *(Picea mariana)*, and white spruce *(Picea glauca)*.

Aspen is the most important cavity tree species for woodpeckers, chickadees, and nuthatches of old upland forest in the boreal plains.

Tree decay stage

Woodpeckers, chickadees, and nuthatches used trees in a range of decay stages (Figure 4) (Cooke 2009). Hairy Woodpeckers, Pileated Woodpeckers, and Yellow-bellied Sapsuckers preferred live aspen trees, including those with signs of decay (i.e. dead branches in canopy). Northern Flickers, Black-capped Chickadees, and Red-breasted Nuthatches primarily use broken-top aspen snags (dead trees). Snags used by these species tended to be of moderate hardness (i.e. bark has fallen off but wood is not yet crumbling). American Three-toed Woodpeckers also nested in snags.

Live aspen with early signs of decay are preferred by several key woodpeckers of old upland forest.



Brackets indicate decay classes with greater than 20% of observations.
*Key cavity producers for cavity-using ducks, owls, and squirrels.

Management recommendation: Retain aspen in a range of decay stages. Live aspen, including those with **signs of decay,** are preferred by 3 of 4 key cavity excavators. Decay in live trees is indicated by dead branches in the canopy. **Broken-top snags** (dead trees) are preferred by several excavators.

It is important to note that snags and "wolf trees" (dead trees with extensive branching) are not preferred nest trees of the key cavity producers of old deciduous and mixedwood stands in the boreal plains. Snags and stumps may be used for foraging by some cavity users. For species that use broken-top snags, those created by "topping" live trees are not suitable in the short term.

Figure 4. Decay stages of cavity trees

DBH (cm)	Black-capped Chickadee (n=18)	Red-breasted Nuthatch (n=8)	Yellow-bellied Sapsucker (n=124)	American Three-toed Woodpecker (n=7)	Hairy Woodpecker (n=21)	Northern Flicker (n=43)	Pileated Woodpecker (n=7)
12.0 - 14.9							
15.0 - 19.9							
20.0 - 24.9	mean=22	mean=24					
25.0 - 29.9							
30.0 - 39.9			mean=34	mean=31	mean=31	mean=3	
40.0 - 49.9							mean=44
50.0 - 59.9							

Shaded boxes encompass the 25-75% percentiles for tree DBH.

Management recommendation: Retain aspen in a range of size classes. Small-diameter (>20 cm DBH) aspen are used by Black-capped Chickadees and Red-breasted Nuthatches. However, **large-diameter (>35 cm DBH) aspen are most important** as these are selected by the four key cavity excavators. In particular, **aspen greater than 45 cm DBH** should be retained for Pileated Woodpeckers.

Figure 5. Cavity tree diameter at breast height (DBH)

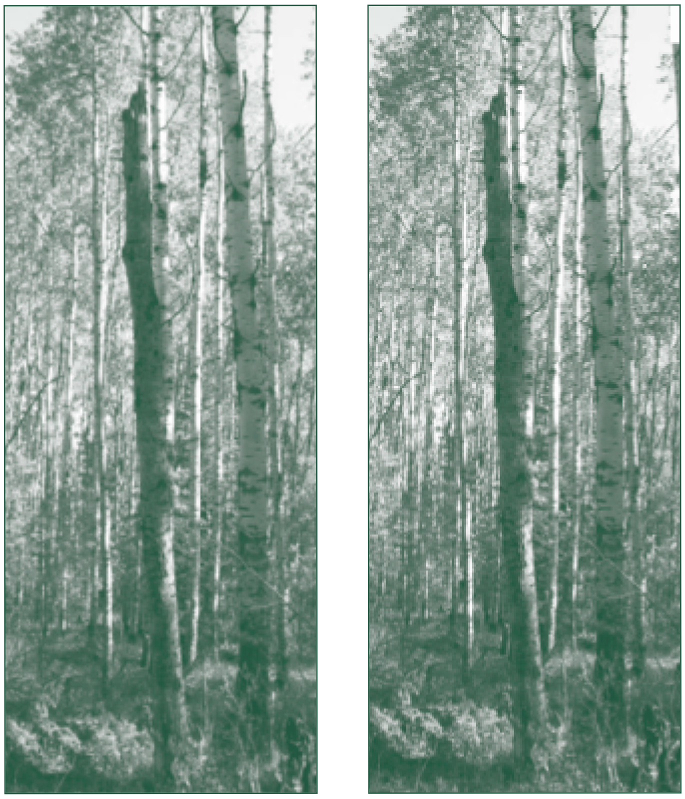
Tree diameter

Cavity excavators used trees that range in diameter at breast height (DBH) from 15 to 60 cm (Figure 5) (Cooke 2009). Cavity tree diameter increases with body size of the excavating species. Black-capped Chickadees and Red-breasted Nuthatches use the smallest (>20 cm DBH) trees. Hairy Woodpeckers and American-Three Toed Woodpeckers use trees greater than 30 cm DBH, on average. Yellow-bellied Sapsuckers and Northern Flickers use aspen greater than 35 cm DBH. Pileated Woodpeckers use very large (>45 cm DBH) aspen.

Large (>35 cm diameter at breast height) aspen are required by key cavity excavators of old upland forest.

Tree height

Cavity tree height was related to decay stage: tree height averaged ~10-15 m for species that selected broken-top snags (Black-capped Chickadee, Red-breasted Nuthatch, American Three-toed Woodpecker, Northern Flicker) and ~25 m for species using live or early decay trees (Yellow-bellied Sapsucker, Hairy and Pileated woodpeckers) (Figure 6).



Yellow-bellied Sapsucker
Hairy Woodpecker
Pileated Woodpecker

Northern Flicker
Black-capped Chickadee
Red-breasted Nuthatch

Height of a cavity tree is related to tree diameter & decay stage. **Management recommendation: Retain tall (>25 m), large (>35 cm DBH), live aspen** (left picture) and **short (~10 m), medium diameter (>20 cm DBH) aspen snags** (right picture).

Figure 6. Height of cavity trees

Fungal conks

Fungal conks were a key tree characteristic for woodpeckers selecting live aspen for cavity excavation. In particular, the cavity trees of Yellow-bellied Sapsuckers, Northern Flickers, and Hairy and Pileated Woodpeckers had on average, more than 10 conks of the fungus *Phellinus tremulae,* or false tinder conk (Figure 7) (Cooke 2009). Conks appear on the outside of the tree and are the site of spore production and release. Conks may not appear until several years after initial infection by the fungus (Anderson and Schipper 1978).

Numerous (>10) false tinder conks on an aspen is the most important indicator of a good cavity tree for several key woodpeckers.

Phellinus tremulae rots the heartwood of aspen. The number of conks is a direct indicator of the amount of heart rot because heart rot extends approximately 3-4m above and below each conk (Hinds 1963). A high (~10) number of conks on woodpecker cavity trees indicates the tree is severely decayed and may be non-merchantable (Hinds 1963, Maier and Darrah 1989).

False tinder conk *(Phellinus tremulae)* is a heartrot fungus that infects aspen and is critical for facilitating cavity excavation. The conk can be identified by the reddy-brown underside. Conks occur primarily on the trunk and often appear under branch scars.

Management recommendation: The key cavity excavators of old upland forest prefer **live aspen with ~10 fungal conks** (pictured left) on the trunk. **Any aspen with fungal conks should be targeted for retention.**

Figure 7. Fungal conks on cavity trees
Photo credit: Chris Kolaczan

4.2 Cavity tree clumps

In both intact forest landscapes and aggregated harvests, cavity tree selection may be influenced by the clump of trees immediately surrounding (i.e. within ~10 m of) a suitable cavity tree (e.g. Savignac *et al*. 2000, Mahon *et al*. 2007, Norris and Martin 2008). The cavity trees of Black-capped Chickadees, Red-breasted

Nuthatch, Hairy Woodpeckers, and Yellow-bellied Sapsuckers in the boreal plains were surrounded by ~25-30 trees >12 cm DBH (Cooke 2009). Northern Flicker and American Three-toed Woodpecker cavity tree clumps differed from the other excavators by containing fewer (~10-15) trees. Black-capped Chickadees and Red-breasted Nuthatches preferred cavity tree clumps without any live, large conifers. Chickadees and Nuthatches may benefit from nesting in clumps without large conifers because of reduced predation risk from red squirrels, which forage on conifer seeds (Fisher and Wiebe 2006).

In aggregated harvests, Hairy Woodpeckers, Yellow-bellied Sapsuckers, and Northern Flickers all selected cavity trees surrounded by other apparently suitable cavity trees: aspen larger than 25 cm DBH with false tinder conks. These multiple potential nest trees may swamp predators with suitable trees to search for prey (Norris and Martin 2008, Saab *et al*. 2009). Selection for clumps of suitable cavity trees in harvests may also reflect an avoidance of open areas (i.e. avoidance of trees in cutblocks with no or few nearby trees).

4.3 Foraging substrates

Snags, stumps, and logs

Dead woody substrates are used for foraging by several cavity excavators.

Hairy Woodpeckers and American Three-toed Woodpeckers forage on insects, primarily the larvae of bark- and wood-boring beetles (Murphy and Lehnhausen 1998, Leonard 2001, Jackson *et al*. 2002, Morrissey *et al*. 2008). In most regions, Three-toed Woodpeckers prefer to forage on the trunks of dead conifers (Leonard 2001, Imbeau and Desrochers 2002, Gagne *et al*. 2007, Morrissey *et al*. 2008). Three-toed Woodpeckers in Canada's boreal forest primarily use spruce, tamarack and jack pine snags (Villard 1994, Imbeau and Desrochers 2002, Gagne *et al*. 2007). Relatively sound snags are preferred by Three-toed Woodpeckers over highly decayed snags and logs (Imbeau and Desrochers 2002, Gagne *et al*. 2007). In recently harvested boreal landscapes, Three-toed Woodpeckers preferred to forage in the interior of remnant forest patches (i.e. >40 m from the forest patch-clearcut edge), despite a high density of high-quality foraging substrates along the edge (Gagne *et al*. 2007).

Across their range, Hairy Woodpeckers use diverse foraging substrates (Leonard 2001). In the boreal plains, Hairy Woodpeckers have been observed foraging on dead limbs, trunks of dead trees, and stumps and logs in intact forests and in harvested areas (Cooke, *unpublished data;* H.D. Clarke, *personal communication*). Pileated Woodpeckers forage primarily for carpenter ants (*Camponotus spp*) in large (>25 cm dbh) woody substrates, including snags, logs and stumps (Bull and Jackson 1995, Flemming *et al*. 1999, Bonar 2001, Lemaitre and Villard 2005, Raley and Aubry 2006). In western boreal forests, Pileated Woodpeckers forage on white spruce, lodgepole pine *(Pinus contorta)*, balsam fir *(Abies balsamifera),* aspen, and balsam poplar (Bonar 2001, Cooke, *unpublished data,* H.D. Clarke, *personal communication*). They prefer soft (i.e. highly decayed) substrates in the summer and hard substrates (injured live trees or hard snags) in the winter (Bonar 2001).

Foraging habitat for several woodpeckers includes clumps of large-diameter (>25 cm DBH) conifer and deciduous snags in or within 50 m of residual forest patches.

Pileated Woodpecker, American Three-toed and Hairy Woodpeckers all forage on large snags and live trees (Bull and Jackson 1995, Imbeau and Desrochers 2002, Covert-Bratland *et al*. 2006, Raley and Aubry 2006, Gagne *et al*. 2007). This preference for large trees may reflect preferences of the prey and/or higher prey abundance in large substrates (Bull and Jackson 1995, Lemaître and Villard 2005, Raley and Aubry 2006). Pileated Woodpeckers avoid using foraging substrates located in open areas (e.g. clearcuts) without protective cover within ~50 m (Bonar 2001, Raley and Aubry 2006). Pileated Woodpeckers also prefer to forage in areas with high densities of suitable foraging substrates (Savignac *et al*. 2000, Raley and Aubry 2006).

Live trees

Although American Three-toed Woodpeckers and Hairy Woodpeckers generally prefer snags or dead limbs, live trees are also important foraging substrates (Jackson *et al*. 2002, Gagne *et al*. 2007). Hairy Woodpeckers and Pileated Woodpeckers have been observed foraging on live trees in intact forest and in harvested areas in the boreal plains (Cooke, *unpublished data;* H.D. Clarke, *personal communication*). Live trees used by Hairy Woodpeckers in the boreal plains include aspen and balsam poplar. Pileated Woodpeckers have been observed foraging at the base of live aspen, balsam poplar, white spruce, and balsam fir in the boreal plains (Cooke, *unpublished data;* H.D. Clarke, *personal communication*).

Yellow-bellied Sapsuckers drill sapwells in small stems of birch, willow, alder, aspen, and spruce.

Yellow-bellied Sapsuckers forage primarily on sap in the breeding season, which they access by drilling small sapwells in live, woody plant stems (Walters *et al*. 2002, Savignac and Machtans 2006). Sapsuckers in old upland stands in the boreal plains have been observed drilling sapwells in small stems of birch, willow (*Salix* spp), white spruce and aspen (Cooke, *unpublished data;* H.D. Clarke, *personal communication*). Sapsuckers also forage on insects in the breeding season, which may be captured on the trunk or in the crown of a tree (Walters *et al*. 2002).

Black-capped Chickadees forage primarily on caterpillars and other insects during the breeding season and on insects and seeds during the winter (Smith 1993). Chickadees use a range of foraging substrates, including the branches, twigs, bark, and foliage of deciduous and coniferous trees (Smith 1993, Hartung and Brawn 2005, Mills 2007). Despite high energetic costs and predation risk, Chickadees will forage in open areas up to 40 m from forest cover when other foraging opportunities are limited (Turcotte and Desrochers 2003). Red-breasted Nuthatches forage for seeds and a range of adult and larval arthopods in the bark and foliage of live and dead coniferous and deciduous trees (Ghalambor and Martin 1999).

Other

The Northern Flicker is unique among North American woodpeckers in that it forages, almost exclusively, for ants on the ground (Moore 1995). Flickers prefer to forage in areas with short vegetation, bare ground, and numerous small anthills (Elchuk and Wiebe 2003). Foraging sites within 10 m of a tree are also preferred.

4.4 Residual patches in aggregated harvests

Within spatially-aggregated harvests there are two types of residual patches: planned and operator. Planned residual patches (also known as polygon residuals) are areas delineated for retention at the planning stage of aggregated harvests (Lee *et al*. 2002, Dzus *et al*. 2009). These patches tend to be large (>5 ha) and may be islands (completely surrounded by harvested areas) or peninsulas (attached to contiguous forest area on the edge of an aggregated harvest). Operator residual patches are delineated for retention during harvest operations. These patches are also known as "in-block" or "logger's choice" residuals (Lee *et al*. 2002, Al-Pac 2004). These patches are small, ranging from single trees to generally <5 ha (Lee *et al*. 2002). Three characteristics of residual patches that are important to old forest cavity excavators are:

- stand type,
- patch size, and
- patch isolation.

Stand type

Yellow-bellied Sapsuckers selected to nest in areas with significantly greater cover derived from mature and old aspen and mixedwood stands than is typically available across the harvested landscapes (Cooke 2009). Within a 75-m radius of Sapsucker cavity trees (representing a core-use area for this species), cover by mature and old aspen and mixedwood stands as both planned and operator patches is ~20-50% (range in median values). Due to small sample sizes, information on residual patch selection in aggregated harvests is limited for the other old forest cavity excavators. However, preferences for patches based on stand type can be inferred from their association with stand types in unharvested forest.

In general, Yellow-bellied Sapsuckers, Hairy Woodpeckers, and Pileated Woodpeckers all had their highest abundances in old aspen, mixedwood, and white spruce stands and use these stands for nesting in the boreal plains (reviewed in Cooke 2009). They also use the mature seral stages of these stand types. Black-capped Chickadees have high abundance in both mature and old upland stands. Red-breasted Nuthatches and American Three-toed Woodpecker use older seral stages of upland forest but prefer conifer stands. For most old forest cavity excavators, patches derived from mature and old aspen, mixedwood, and white spruce stand types are likely preferred over younger (<60 year) stands and non-merchantable stand types (e.g. black spruce).

In aggregated harvests, Yellow-bellied Sapsuckers select to nest where 20-50% of a 75-m radius area is residual cover derived from mature and old aspen and mixedwood stands. Other old forest excavators likely also benefit from high retention of these stand types.

Patch size

Yellow-bellied Sapsuckers selected to nest in or near (within 25 m of) planned patches that are primarily greater than 5 ha and, on average, are greater than 15 ha (Figure 8). In contrast, Northern Flickers selected to nest in open areas of aggregated harvests. Flickers selected to nest away from planned patches and used single trees or small (<0.5 ha) operator patches for nesting.

Planned patch = delineated for retention at planning stage.

Operator patch = selected for retention by logger.

75-m radius buffer at Yellow-bellied Sapsucker cavity trees

Management recommendation: Planned patches of residual structure should be at least 5 ha. Many patches should be greater than 15 ha and some patches should be greater than 100 ha. Larger patches can be composed of both merchantable and non-merchantable stand types. However, **at least 20% of the area of mature and old aspen and mixedwood stands within the planning unit should be retained as operator and planned patches.** Higher (up to 50%) retention levels should occur in some blocks.

Figure 8. Use of planned patches by nesting Yellow-bellied Sapsuckers in an aggregated harvest.

The following describes the characteristics of residual patches used in aggregated harvests. Black-capped Chickadees nests were in residual patches >10 ha (n=6; Cooke 2009). Of four Red-breasted Nuthatch nests found in aggregated harvests, one occurred in a patch of 36 ha and three occurred in a patch of ~250 ha (Cooke 2009). Sample sizes were too small to determine if these patches were selected for nesting based on their size.

Old forest cavity excavators nesting in aggregated harvests can likely incorporate multiple residual patches into their home range. However, reproductive success may be greatest if an individual can contain their home range within a single patch of suitable habitat (Hinsley 2000, Bull *et al*. 2007, Hinam and St. Clair 2008). For example, Pileated Woodpeckers nesting in landscapes modified by forestry have declining reproductive success with increasing area of regenerating forest in their home range (Bull *et al*. 2007). This pattern is likely a result of greater distances travelled between patches of foraging habitat when a home range includes recently harvested areas (Hinsley 2000). Thus, preferred patch sizes for cavity users in aggregated harvests may be inferred from their breeding season home range. Based on estimates from other regions, Black-capped Chickadees likely have the smallest home range at ~5 ha. Pileated Woodpeckers likely have the largest home range: in the boreal foothills they require approximately 250 ha in the breeding season (Bonar 2001). Thus, patch sizes required by old forest cavity users likely vary from 5 ha to several hundred hectares. See Cooke (2009) for a review of home range sizes for all species.

Yellow-bellied Sapsuckers prefer to nest in or near large (>15 ha) residual patches in aggregated harvests. For other cavity excavators, preferred patch sizes may be inferred from their breeding season home range.

Patch isolation

In addition to residual patch size, old forest cavity users may be sensitive to the spatial distribution of residual patches in an aggregated harvest. A patch of suitable habitat that is completely surrounded by recently harvested areas may be functionally isolated for cavity users and other old forest species. Studies of cavity users in other landscapes of fragmented forest cover suggest an individual may be willing to cross an open gap if the distance between forest patches is small enough (Desrochers and Hannon 1997, St. Clair *et al*. 1998, Belisle *et al*. 2001, Belisle and Desrochers 2002, Hadley and Desrochers 2008a).

There is no information on the sensitivity of cavity users to gaps between forest patches in aggregated harvests. Thus, we summarize information from gap-crossing and movement studies in other landscapes to provide insights into the maximum distance each species may travel across recently harvested blocks (see Cooke 2009 for detailed review). Black-capped Chickadees and Red-breasted Nuthatches are reluctant to cross gaps across recently harvested areas that are >100 m. Although no studies of gap-crossing behaviour have been conducted on Sapsuckers, evidence from woodpeckers of similar size suggests they may be reluctant to cross gaps in forest cover >200 m. Based on a gap-crossing study of wintering Hairy Woodpeckers in an agricultural landscape, the median within-home-range gap-crossing distance for this species is estimated at 400 m. No studies on gap-crossing behaviour have been conducted for Pileated Woodpeckers. However, based on a study of another large woodpecker (Northern Flicker), it is likely Pileated Woodpeckers can easily cross large (<600 m) gaps in forest cover.

Patches of suitable habitat greater than 100m from other forest cover may be functionally isolated for small old forest cavity excavators.

5.0 Guidelines for structural retention in aggregated harvests in the boreal plains

Information on multi-scale habitat requirements of old forest cavity excavators (see previous section) was used to derive guidelines for structural retention in aggregated harvests in the boreal plains (see Table 1). These guidelines are

Table 1. Guidelines for the use of structural retention in aggregated harvests in the boreal plains to conserve old forest cavity users.

	What?	Where?	How much?
Live Trees	Aspen: live; large (>35 cm DBH); multiple (>10) false tinder conks (nesting). Other tree species: all sizes and decay stages (foraging).	In clumps or patches, especially in or near (within 75 m of) large (>5 ha) patches. Note: Single trees in open areas of cutblocks are *not* suitable for nesting or foraging.	Include as part of overall retention level (see Patches of Trees).
Snags	Broken-top aspen snags >20 cm DBH (nesting). Large (>25 cm DBH) coniferous and deciduous snags (foraging). Note: Broken-top snags created by topping live, healthy aspen are *not* suitable for nesting or foraging in the short term.	In clumps and in or near (within 50 m of) large (>5 ha) residual patches.	Include as part of overall retention level (see Patches of Trees).
	Large (>25 cm DBH), highly decayed snags and stumps (foraging). Wolf trees (with extensive branching) are generally not suitable for nesting but may provide foraging substrates	In clumps and in or near (within 50 m of) large (>5 ha) residual patches.	Include as part of overall retention level (see Patches of Trees).
Clumps of Trees (<10 stems)	Clumps should include several suitable cavity trees (e.g. live large aspen) and/or several suitable foraging trees (both merchantable and non-merchantable live trees and snags).	*Variable:* Retain clumps of trees close to large patches (for nesting) and distributed throughout the harvest area (for connectivity). Connectivity will be facilitated if clumps and patches are within 100 m of each other.	Include as part of overall retention level (see Patches of Trees).
Patches of Trees (>10 stems)	Mature (60-100 years) and old (>100 years) aspen-dominated and mixedwood (i.e. merchantable) stands should be targeted for inclusion in both operator and planned patches.	*Variable:* Retain patches of merchantable forest adjacent to non-merchantable areas, riparian buffers and inoperable areas to increase overall patch size. Distribute patches throughout the harvest area to facilitate connectivity. Connectivity will be facilitated if clumps and patches are within 100 m of each other.	Planned patches (merchantable & non-merchantable): at least 5 ha, with most >15 ha and some >200 ha. See Lee *et al.* (2002) for guidelines. At least 20% of the landscape area should be covered by residual patches derived from mature and old aspen and mixedwood stands.

intended to facilitate fine-filter management targeting retention of cavity users associated with old forest in the short term (i.e. <5 years post-harvest). These guidelines are relevant for upland forest in the boreal plains, especially aspen and mixedwood stands. Note that the habitat requirements of Northern Flickers were not included in these guidelines as this species responds positively to the loss of tree cover associated with aggregated harvests.

Secondary cavity-using species will benefit if cavity excavators are retained in aggregated harvests. However, secondary cavity users may respond differently to the types, amount, and distribution of residual trees and patches. For example, Northern Flying Squirrels are very sensitive to forest connectivity. They are reluctant to travel across gaps and through young forest for distances greater than 25 m (Cooke 2009). Thus, additional information is required to manage for specific secondary cavity users.

6.0 Conserving old forest cavity users at larger scales and over the long term

Old forest conservation strategies have been developed by provincial governments and forestry companies operating in the boreal plains (e.g. Canfor 2003, Al-Pac 2004, Weyerhaeuser 2005, Sougavinski and Doyon 2005, Dzus *et al*. 2009). These strategies generally involve setting targets for the amount of old forest within management units and achieving these targets through harvest planning at a regional scale. One way companies achieve these targets is to permanently protect areas such as riparian buffers and inoperable areas from harvest (Dzus *et al*. 2009). Old forest targets are also achieved by reductions in harvest volume and extended rotation periods. However, structural retention within harvests may also contribute to a regional old forest conservation strategy.

The short-term (i.e. within 5 years post-harvest) value of structural retention for old forest species has been determined by field studies (e.g. Cooke 2009). However, evaluating the contribution of retained structure to old forest conservation and habitat over the long term (>100 years) is more difficult. Spatial landscape simulation tools can model forest succession, natural disturbance, and forest harvest over large areas and long time periods (Larson *et al*. 2004). Thus, they are useful for exploring possible outcomes of forest management alternatives.

Simulations of forest management conducted across ~275,000 ha of boreal forest in northeast Alberta suggested that structural retention within aggregated harvests can lead to greater conservation of old upland forest over the long term (Cooke 2009). After 150 years of simulated forest management, retention of 5-20% of the merchantable stands within large (15,000 ha) harvests resulted in ~32-42% more area of old upland forest than aggregated harvest without retention. Despite this improvement, significant (at least 40%) losses of old upland forest still occurred at a regional scale and over the long term. Without reductions in the annual harvest volume, high retention of old forest within harvests simply shifted the harvest pressure to mature forest stands. The consequence was that mature forest was lost when old forest was conserved and vice versa.

For species that can use both old and mature upland stands (e.g. cavity users), greater availability of old forest habitat within harvests was offset by loss of mature forest habitat elsewhere. Thus, at a regional scale, 20% retention performs similarly as 5% retention at conserving habitat for Yellow-bellied Sapsuckers and Black-capped Chickadees. At a regional scale, high structural retention within aggregated harvests can also result in fragmentation of remaining old forest patches. This means fewer large (>100 ha) patches are available for species that prefer large, contiguous patches of mature and old upland forest, such as Pileated Woodpeckers. Structural retention is an important strategy for conserving old forest species in regenerating stands and is an improvement on traditional, clear-cut harvesting. However, additional long-term strategies are needed for conserving old forest species regionally.

Over the long term (150 years) and at a larger regional scale, 20% structural retention may conserve more old upland forest than low (5%) and no retention. However, fewer large patches and less mature forest, and thus overall less habitat for old forest cavity users, will be conserved.

In addition to providing refugia for old forest species in recently harvested areas, structural retention is also important for the development of late-successional forest characteristics in regenerating stands (Lindenmayer and Franklin 2002). Small-diameter trees retained at harvest presumably develop into large trees and large snags before the regeneration cohort reaches maturity. Thus, stands with structural retention may support cavity users and other old forest species at an earlier stage of succession compared with stands regenerating from clearcuts. However, there is currently no information on the types of aspen that should be retained at harvest in order to ensure trees develop the characteristics (e.g. numerous fungal conks) preferred by old forest excavators. It has been identified that aspen retained along the windward edge of planned patches may experience more limb breakage and subsequent infection by heartrot spores (Jackson and Jackson 2004). Susceptibility of aspen to heartrot is also genetic (Hiratsuka and Loman 1984). Thus, regenerating clones of infected aspen are more likely to develop into suitable cavity trees. Finally, retaining aspen with conks ensures a source of spores in the regenerating stand.

7.0 Conclusions

In the short term (within 5 years of harvest), residual patches within aggregated harvests can provide habitat for many of the cavity-using birds and mammals associated with old upland forest in the boreal plains. Trees and patches that are legacies of mature and old upland forest are lifeboats for the key cavity excavators of old upland forest: Yellow-bellied Sapsucker, Hairy Woodpecker, Northern Flicker, and Pileated Woodpecker. In turn, these excavators provide the cavities necessary for secondary cavity-using birds and mammals to occupy the harvested landscapes.

Although most old forest cavity users were retained in aggregated harvests, there are some differences compared to unharvested forest. Yellow-bellied Sapsuckers were at a lower abundance and Northern Flickers were at a higher abundance in aggregated harvests. Despite abundant Flicker cavities, Bufflehead were not observed nesting in aggregated harvests. This may be because water bodies within ~500 m of potential nest sites were lacking in the harvests. Finally, one open-woodland species, American Kestrel, was absent from intact upland forest but was an important occupant of Flicker cavities in aggregated harvests.

Old forest cavity users may be best conserved in aggregated harvests in the short term if at least 20% of the landscape is covered by residual structure derived from mature and old upland stands (including riparian buffers and other operational deletion areas). Small (>5 ha) patches may be sufficient for small cavity excavators, like Black-capped Chickadees. However, large (>15 ha) patches are preferred by at least one old forest excavator (Yellow-bellied Sapsucker). Very large (>200 ha) patches may be required by Pileated Woodpeckers. With large cutblocks and spatial aggregation of cutblocks, planners can achieve a greater range of patch sizes and thus accommodate the large patch size requirements of some old forest woodpeckers. One strategy for achieving larger patch sizes is to incorporate merchantable and non-merchantable stands into planned patches and to instruct operators to retain clumps adjacent to planned patches. These recommendations may be combined with the patch size distribution suggested by Lee *et al*. (2002). They recommended that 63% of the area of residuals in large aggregated harvests be in patches from 5 ha to >80 ha, with half of that area (29% of the total area) in patches >20 ha.

At the tree scale, cavity excavators associated with old upland forest in the boreal plains use aspen almost exclusively for nesting. In particular, many woodpeckers use live aspen. Thus, the common view of snags as 'cavity trees' is not appropriate in the boreal plains. In order to retain the key cavity producers of this system, operators should be directed to include live, large (>35 cm DBH) aspen in clumps of trees or as part of residual patches. Broken-top aspen snags are used for nesting by some species. A range of live and dead, small and large-diameter, coniferous and deciduous trees are used as foraging substrates by cavity users.

Guidelines for structural retention based solely on cavity tree requirements ignore other habitat needs that are critical to population persistence. There has been little research on habitat requirements of old forest cavity users in the boreal plains. Thus, we supplemented our information on tree and patch selection with information on foraging substrates, home range size, and sensitivity to patch connectivity from other regions. Given that these habitat requirements have not been tested in the boreal plains, we suggest caution in applying all structural guidelines. We recommend a policy of 'don't do the same thing everywhere'. This 'risk-spreading' approach is also recommended given the absence of information for many other old forest species in the boreal plains.

This study demonstrated that old forest cavity users can be retained in aggregated harvests in the short term. However, landscape simulations suggested that the cumulative loss of old upland forest that occurs after one complete rotation through a region will result in significant losses of habitat for these species. Thus, at the regional scale, structural retention needs to be combined with other old-forest conservation strategies, such as reduced harvest volumes and extended rotation ages.

Given the uncertainty in habitat requirements of all old forest species in the boreal plains, a policy of 'don't do the same thing everywhere' is recommended.

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Appendix 1 Common name and Latin name for species referenced in the text.

Species	*Latin*
Bufflehead	*Bucephala albeola*
Common goldeneye	*Bucephala clangula*
American kestrel	*Falco sparverius*
Northern saw-whet owl	*Aegolius acadicus*
Yellow-bellied sapsucker	*Sphyrapicus varius*
Downy woodpecker	*Picoides pubescens*
Hairy woodpecker	*Picoides villosus*
American three-toed woodpecker	*Picoides dorsalis*
Northern flicker	*Colaptes auratus*
Pileated woodpecker	*Dryocopus pileatus*
Tree swallow	*Tachycineta bicolor*
Black-capped chickadee	*Poecile atricapillus*
Boreal chickadee	*Poecile hudsonica*
Red-breasted nuthatch	*Sitta canadensis*
Swainson's Thrush	*Catharus ustulatus*
Yellow-rumped Warbler	*Dendroica coronata*
Western Tanager	*Piranga ludoviciana*
Northern flying squirrel	*Glaucomys sabrinus*
Red squirrel	*Tamiasciurus hudsonicus*
Southern Red-backed vole	*Clethrionomys gapperi*
American marten	*Martes americana*

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