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Snag availability for cavity nesters across a chronosequence of post-harvest landscapes in western Newfoundland

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ABSTRACT

We examined the availability and quality of standing dead trees (snags) for nesting habitat in a harvest chronosequence of boreal forests dominated by balsam fir (*Abies balsamea*) in western Newfoundland. Snag density declined substantially 10–15 years after harvest, then increased to reach its highest level in 81- to 100-year-old forests that had become senescent. Most (55%) of 1260 snags encountered were balsam fir, which contained 41% of the 81 cavities identified. Cavity presence was most strongly positively correlated to snag diameter at breast height (dbh), followed by decay class, time since harvest and height. Less than 40% of snags available throughout the chronosequence had large enough dbh for cavity nesters. Downy Woodpeckers (*Picoides pubescens*) were responsible for 47% of all cavities identified, excavating balsam fir ~50% of the time. Two larger cavity nesters present, Northern Flickers (*Colaptes auratus)* and Three-toed Woodpeckers (*Picoides tridactylus*), were more likely to use large-diameter white birch (*Betula papyrifera*) snags. Northern Flickers excavated the largest cavities, potentially providing habitat for the greatest variety of secondary cavity nesters. Managing for snags with >30 cm dbh, which flickers target for excavation, has the greatest potential to enhance the broader snag cavity-based community in western Newfoundland.

1. Introduction

Standing dead trees (hereafter, snags) are an important but variably available resource for a range of forest birds and mammals (Bull, 1983; Morrison and Raphael, 1993; Martin et al., 2004). Snags support a diverse food base for a host of insectivorous vertebrates, and provide roosting and nesting opportunities for many wildlife species (Bunnell et al., 1999; Spiering and Knight, 2005). Snag availability for wildlife has become a component of forest management decisions (Bull et al., 1997; Garber et al., 2005), yet few studies have reported data on snag availability across periods of time reflecting entire forest rotations. Such decisions require an understanding of snag dynamics and usage by wildlife over time (Garber et al., 2005), especially following disturbances that lead to a major shift in the forest composition and structure.

Prominent among vertebrates using snags are cavity-nesting birds, particularly the woodpeckers (Picidae), which forage on snags but also excavate cavities in both live and dead trees (Raphael and White, 1984; Farris et al., 2004; Remm et al., 2006). As primary cavity nesters, woodpeckers create habitat for other species and play roles in seed dispersal, soil aeration, organic decomposition, and pest control (Everett and Otter, 2004; Farris et al., 2004). Because they excavate new nest cavities each breeding season, there may be a rapid increase in habitat for non-excavating secondary cavity nesters in communities where woodpeckers are present (Martin et al., 2004; Walter and Maguire, 2005; Remm et al., 2006), especially where there is a high density of suitable snags available.

Managing forests with the intent to encourage woodpeckers and secondary cavity nesters involves providing snags appropriate for cavity excavation (Bull et al., 1980; Cimon, 1983). Targeting mature, but pre-senescent, stands for harvest reduces the number and size of snags left on the post-harvest landscape (Cline et al., 1980; Bull et al., 1997; Thompson et al., 1999); this reduces eventual snag availability and, therefore, wildlife abundance and diversity (Haney and Schaadt, 1996; Zack et al., 2002). Woodpeckers select snags with a large diameter at breast height (dbh) to support their nests (Swallow et al., 1986). Although cavity nesters display species-specific differences in their snag size preferences, larger snags are used by more species and tend to stand longer than

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smaller snags (Bull et al., 1980; Schieck and Song, 2006). Cavity-nesting birds also select snags for excavation based on decay class, species, bark cover, and whether the top of the snag is still intact or broken off (Mannan et al., 1980; Raphael and White, 1984; Moorman et al., 1999; Farris et al., 2004). Studies of snags as wildlife habitat have suggested that snag abundance may not be as important as the quality (possessing characteristics necessary for cavity excavation) of snags available (Bull et al., 1997; Imbeau and Desrochers, 2002). Thus, cavity-nesting bird densities are dependent on the availability of quality snags and trees (Runde and Capen, 1987).

Disturbance can greatly alter the landscape and, consequently, the availability of snags for cavity-nesting birds, however depending on the source of the disturbance (natural vs. human caused), the outcome may be very different in terms of stand structure. Fire is the main natural disturbance in many forest systems, but in much of the boreal region of North America, harvesting is becoming increasingly prevalent (Simon et al., 2002). Concomitant with the rising demand for wood products, harvesting levels in Canadian forests (largely boreal) have increased to approximately 1 million ha per year (Howard et al., 2004). Until recently, the prominent use of clearcutting in these harvest operations left landscapes with very few snags or living trees (Simon et al., 2002), creating post-harvest landscapes very different from post-fire systems in terms of the amount of snags and deadwood remaining (Schieck and Song, 2006). In their review of studies on post-harvest and post-fire landscapes in western Canada, Schieck and Song (2006) identified significant differences between these landscapes in bird community composition during the years immediately following disturbance. Cavity-nesting birds were abundant in post-fire disturbance sites while the bird communities of post-harvest landscapes were dominated by open-meadow or shrubby habitat bird species. However, they also found that with time the physical and community differences between disturbance types lessened, leading to old-forest stands with similar structural and avifaunal community characteristics (Schieck and Song, 2006). These findings indicate that management for cavity nesters and other wildlife in post-harvest landscapes may be most critical in the years immediately following harvesting, rather than later successional stages, at least in boreal North America. It remains unclear whether attempts to mimic natural disturbance with modified forest harvest techniques will help retain the expected early seral-stage avifaunal community in general (Schieck and Song, 2006). Nor is it known what the general nature of the post-harvest cavity-nesting community is in the forests of eastern boreal North America (e.g., Newfoundland), where fire is less prevalent and the scale of natural disturbance is smaller. This aim of this study was to determine the availability and quality of snags for cavity-nesting birds and other wildlife in post-harvest balsam fir-dominated boreal forests of western Newfoundland, Canada. We predicted that snag availability would decrease below 10 snags/ha around the mid-rotation stage of the forest rotation following harvesting. We also predicted that very few large diameter snags would be available for cavity-nesting species.

2. Methods

2.1. Study area and site selection

Our study was conducted in the Western Newfoundland Ecoregion (Forest Section B28b) of the Canadian Boreal Forest (Rowe, 1972) on the west coast of Newfoundland, Canada. The mean July and January daily temperatures are 17 and −6 °C, respectively, with a mean precipitation of ~1200 mm/year, of which a large proportion occurs as snow (Damman, 1983; Snyder, 1984). Fire in this region is limited, and insect outbreaks are the dominant natural disturbance (Thompson et al., 2003). Study sites were located within forest management district 15 (Fig. 1), which covers an area of 562 533 ha (Govt. of Newfoundland and Labrador, 2003). Selected stands were dominated by balsam fir, with scattered black spruce (*Picea mariana*), depending on site characteristics (Damman, 1983). Other species, including white spruce (*Picea glauca*), white birch (*Betula papyrifera*), white pine (*Pinus strobus*), red maple (*Acer rubrum*), and eastern larch (*Larix laricina*), occur at low densities except at scattered locations where site characteristics favor greater abundance. The dbh (at 1.3 m) in balsam fir-dominated forests is generally <30 cm, and stands rarely reach 100 years old before senescence begins (Moroni, 2006). The forest rotation in Newfoundland has been 80–120 years (Setterington et al., 2000), but the harvest rotation is currently as short as 60 years where productivity is high (S. Balsom, Corner Brook Pulp and Paper, Ltd., personal communication, 2006) and clearcutting is the primary method of harvesting in the region (Whitaker and Montevecchi, 1999).

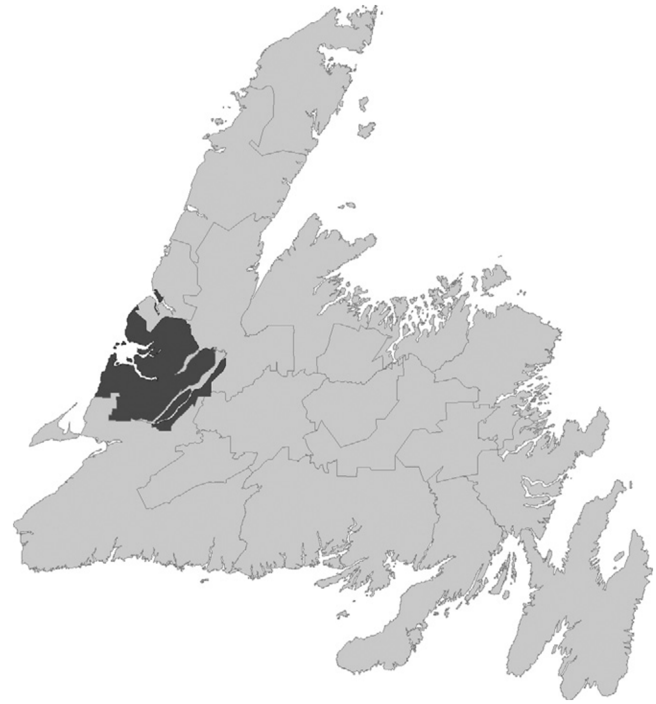

Fig. 1. Newfoundland, with Forest Management District 15 shaded.

We selected 15 sites for each of 15 age classes in a chronosequence ranging from 1 year since harvest (YSH) to 81–100 YSH, for a total of 225 sites. Age classes were divided into three stages of the forest rotation (and reflect the nature of stand-aging data available from provincial agencies): recently harvested from 1 to 7 YSH in 1-year increments; early regeneration from 9 to 20 YSH, with four age classes in 2-year increments; and mid- to late-rotation from 21 to 100 YSH, with four age classes in 20-year increments (Fig. 2). All sites selected were on harvest blocks >2 ha in size, composed of >75% balsam fir, with 50–100% crown closure, and having medium or good site quality (based on merchantable volume). For two age classes, 4 and 81–100 YSH, the sites chosen were clustered geographically because of limited availability in the forest management district.

2.2. Field measurements and data collection

Fieldwork was conducted from 1 June to 31 August 2006. At each site, beginning 50 m from the access road and at the cut block

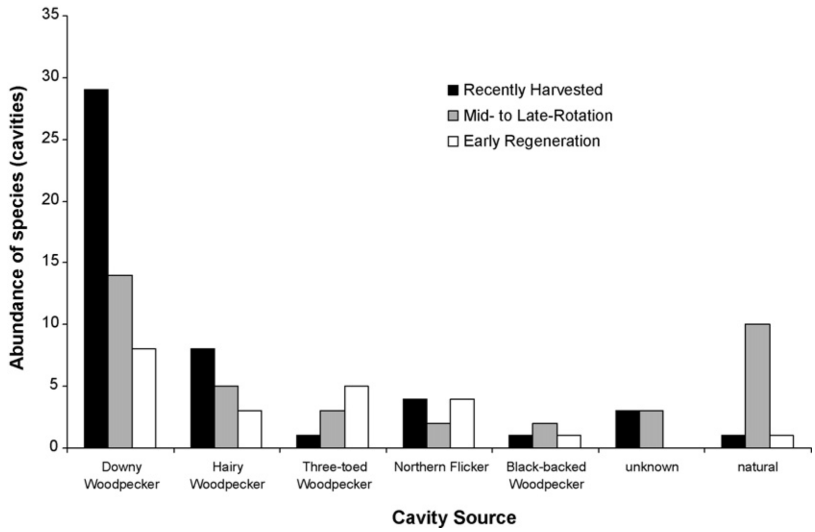

Fig. 2. Breakdown of abundance of each species recorded in recently harvested (1–7 YSH), early regeneration (9–20 YSH) and mid- to late-rotation (21–100 YSH).

boundary, a 100 m long transect was established running toward the interior of the cut block to create a plot 20 m wide. Data were recorded for all snags inside the plot having a dbh $\geq$9 cm and a height >1.5 m. Snags were tallied within the plot to determine snag density per hectare for each site. Data recorded for each snag included GPS waypoint, species, dbh, height, decay class, bark cover, and top presence (see Smith et al., submitted for publication, for details). Bird and wildlife data recorded for each snag included number of cavities present, species of woodpecker that created each cavity, presence of foraging and excavation, and any animals occupying the cavity.

Nest cavities were attributed to primary excavators based on cavity dimensions characteristic to each species. The species of woodpeckers found in western Newfoundland include Downy Woodpeckers (*Picoides pubescens*), Hairy Woodpeckers (*Picoides villosus*), Black-backed Woodpeckers (*Picoides arcticus*), Three-toed Woodpeckers (*Picoides tridactylus*), and Northern Flickers (*Colaptes auratus*). Downy Woodpeckers are commonly found in deciduous, riparian, and mixed forest, and nest in either snags or live trees with advanced heart rot and an average dbh >25 cm (Setterington et al., 2000; Jackson and Ouellet, 2002). Downy Woodpecker cavities were easily distinguished from other potential excavators by the circular shape of the entrance compared with the distinctly oval cavity openings of other species; the entrance has an average diameter of 3 cm (Jackson and Ouellet, 2002). Hairy Woodpeckers are known to use both deciduous and coniferous trees for nesting (Saab et al., 2004); they will nest in snags but prefer live trees with advanced heart rot and a dbh >25 cm (Jackson et al., 2002). The dimensions of a Hairy Woodpecker cavity entrance average 4.8 cm high and 3.8 cm wide (Jackson et al., 2002). Three-toed Woodpeckers are associated with mature forest and nest in either coniferous or deciduous snags, but prefer a dbh >27 cm; the average diameter of their cavity entrance, which may be irregularly shaped, is between 3.8 and 4.5 cm (Leonard, 2001). Black-backed Woodpeckers are strongly associated with fire-disturbed forest in most parts of the boreal as well as in the forests of the western United States (Hutto, 1995; Hoyt and Hannon, 2002) but are also known to use old-growth forest in places such as western Newfoundland (Thompson et al., 1999). They nest in live trees and snags of various species having an average dbh of approximately 27 cm (Dixon and Saab, 2000; Setterington et al., 2000). Black-backed Woodpeckers have a cavity entrance that is 4.4 cm in diameter, with a flattened sill-like spot on the bottom (Dixon and Saab, 2000). Northern Flickers prefer open forest landscapes, and excavate their cavities in dead trees with sufficient decay to provide soft wood and an average dbh >30 cm. Flickers have the largest cavity entrance among these species, approximately 8 cm high and 7.4 cm wide (Moore, 1995).

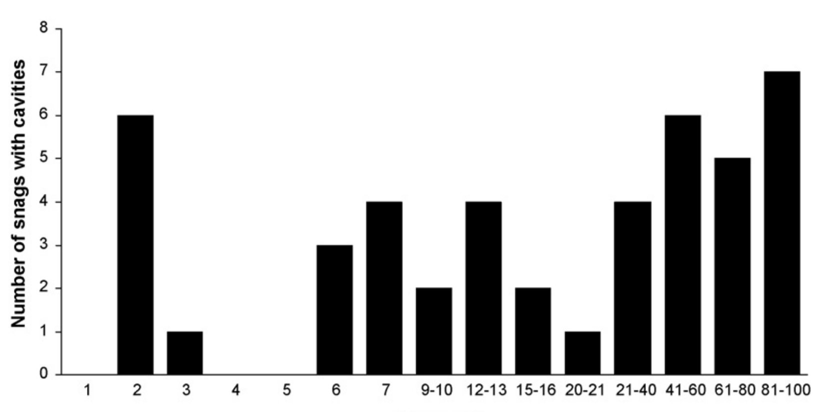

Fig. 3. Total of snags with cavities found in each age class; total snags = 45 (note changing scale of *x*-axis).

2.3. Statistics

We used backward stepwise selection to determine the best model with an α value of 0.15 being required to enter or leave the model; no interactions qualified to be in the model, nor did snag species. We then ran a binary logistic multiple regression to assess which parameter(s) (from among snag dbh, decay class, age class, and height) were the best predictor of cavity presence in a snag (Minitab Inc, 2006). Logistic regression applies maximum-likelihood estimation after transforming the dependent into a logit value; it does not require normally distributed variables. An α level of 0.05 was used to determine significance for all statistical tests.

3. Results

Data for 1260 snags from 225 sites covering 15 age classes were collected; there were a total of 81 cavities contained in 45 snags. Cavity presence was positively correlated with dbh (binary logistic regression: $z = 8.47$, $p < 0.0001$), increasing in occurrence as dbh increased. Cavity presence was also positively correlated with, decay ($z = 2.98$, $p = 0.003$), and age class ($z = 2.13$, $p = 0.033$), reaching its highest level in the oldest age class (Fig. 3). There was a negative correlation between cavity presence and height ($z = -2.13$, $p = 0.033$), with cavities occurring less often in taller snags. There were no significant interaction effects.

Average snag dbh remained relatively constant at ~17 cm throughout the rotation, with an increase of about 10 cm by 41–60 YSH (Fig. 4). However, 62% of all snags had a dbh between 10 and 20 cm, and average dbh was 19.4 ± 0.72 cm (mean ± S.D.; Fig. 5). In contrast, snags with cavities had an average dbh of 30.7 ± 1.37 cm, and cavity nesters seem to prefer snags with a larger dbh (Fig. 5). Approximately 70% of cavities recorded were in decay class 3 snags; but only 463 of the 1260 snags encountered had decayed enough for potential excavation (decay class 2 or 3), and in addition, had a dbh >20 cm. Thus, there were fewer than two snags/ha on average per study site with a dbh >20 cm available for cavity excavation. The average height of snags containing cavities was 5.68 ± 0.28 m, compared with 5.34 ± 0.07 m for all other snags.

Snag species was not a useful predictor of cavity presence in a snag and woodpeckers appeared to create cavities in snags based largely on availability. Balsam fir was the most abundant snag-forming species (669, 53%) followed by white birch (266, 21%), white pine (175, 14%), black spruce (134, 11%), and white spruce (16, 1%). Overall, 41% of cavities were in balsam fir, 29% in white

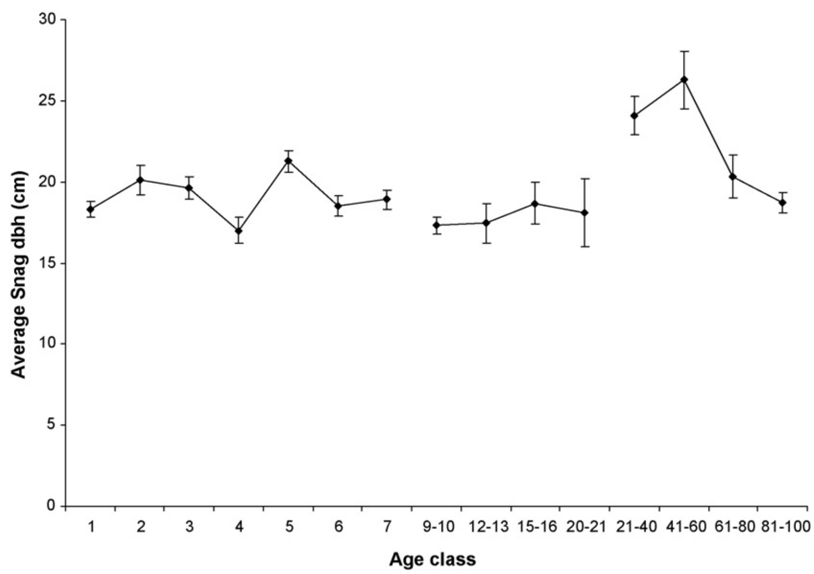

Fig. 4. Average snag dbh by age class (mean ± S.E.; $n = 15$; note changing scale of x-axis).

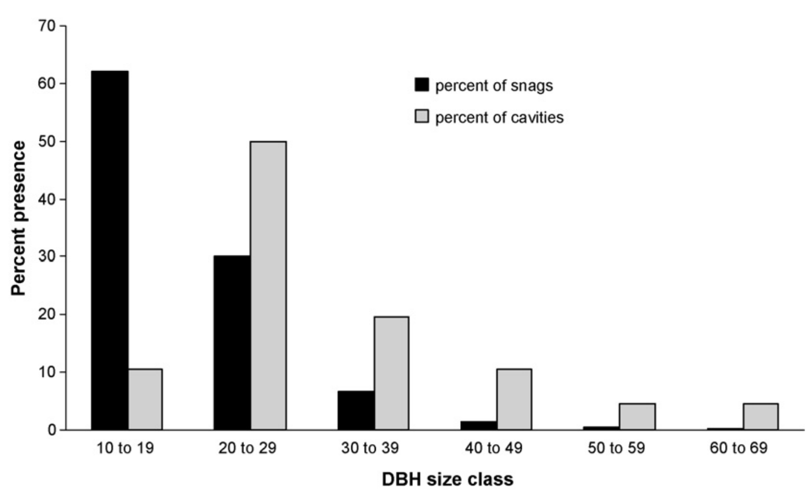

Fig. 5. Percentages of overall snags and cavity snags by dbh size class.

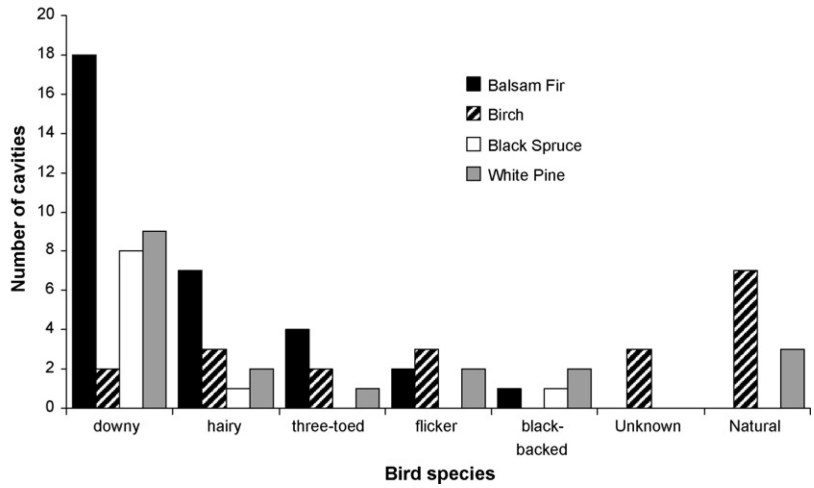

Fig. 6. Totals of cavity snags of each tree species as used by each woodpecker species.

pine, 21% in birch, and 9% in black spruce. The largest proportion of cavities was excavated by Downy Woodpeckers (47%), and although most prominent on recently harvested (1–7 YSH) sites, Downy Woodpeckers were responsible for about one third of cavities in early regeneration, as well as mid-to-late successional stands (Fig. 3). Hairy Woodpecker cavities were the second-most abundant and showed little change in abundance over time, a pattern similar to Black-backed woodpecker cavities, which were the least abundant overall. Northern Flicker cavities reached a maximum in early regenerating forest, and were least abundant in the older sites where canopy closure inhibited their activities and snags containing flicker cavities excavated early in the rotation fell to the forest floor. Three-toed Woodpecker cavities were rare early in the forest rotation, but became the second-most abundant during the mid to late phase of the forest rotation.

Downy Woodpecker and Hairy Woodpecker cavities were most common in balsam fir snags, which contained 50% of these cavities (Fig. 6). Northern Flickers and Three-toed Woodpeckers constructed their cavities in birch snags ~50% of the time. Most cavities that were formed naturally or of unknown creation were found in birch snags. Black-backed Woodpeckers excavated four of the cavities recorded, and two were found in white pine snags.

Of the 1260 snags recorded in the study, only 12% showed no evidence of foraging, with high levels of foraging occurring throughout all age classes.

4. Discussion and conclusions

The loss of snags soon after harvest typically leads to a dramatic change on the landscape for cavity-nesting species (Haney and Schaadt, 1996; Zack et al., 2002; Schieck and Song, 2006). Previously (Smith et al., submitted for publication), we found that snags in post-harvest landscapes of western Newfoundland were generally short lived. Many (either existing before, or created during, harvest) were quickly lost to windthrow and domestic harvest for firewood, with the few remaining individuals falling within 10–15 years after harvest (Smith et al., submitted for publication). The small stature of the predominant but short-lived balsam fir contributed to the overall short lifespan of snags on this landscape. The most common hardwood in the study area, white birch (Smith et al., submitted for publication), would be expected to have enhanced longevity because of its dense tissue (Cline, 1977; Garber et al., 2005). However, in western Newfoundland, the targeting of birch for domestic harvest and its apparent heightened susceptibility to windthrow immediately after harvest (Smith et al., submitted for publication) have meant a relatively limited presence among snags during the early post-harvest period. Similar to other studies (see Schieck and Song, 2006), we found that snag density increased in the latter stages of the forest rotation when senescence occurred. Understanding the time frame of these processes is important for managing habitat availability for cavity-nesting species (Walter and Maguire, 2005). Snags left at the time of harvest may only be available for a short period in the entire forest rotation (Bull et al., 1980) unless care is taken to protect snags with characteristics that enhance their potential longevity.

Larger diameter snags are the most valuable for wildlife habitat because of their longevity (Morrison and Raphael, 1993; Ganey and Vojta, 2005; Russell et al., 2006). When snag density was at its lowest during our study (15–60 YSH), the average dbh was at its highest point, indicating that larger snags survived longest after harvest and consequently provided habitat for the greatest period of time (Fig. 4). Consistent with this finding, over half (62%) the snags encountered in our study were <20 cm in diameter, whereas 90% of the snags containing cavities were >20 cm in diameter (four Downy Woodpecker cavities were in trees with dbh between 15 and 20 cm). Thus, similar to other studies (e.g., Swallow et al., 1986), not only do large dbh snags last longer, but they have a greater likelihood of being chosen for cavity excavation. Similar results have been found for woodpeckers excavating in lodgepole pine *(Pinus contorta) and* ponderosa pine (*Pinus ponderosa*) forests, with no cavities found in snags <25 cm dbh (Bull, 1983). Hairy Woodpeckers have been reported to require a minimum dbh of 25 cm whereas Black-backed woodpeckers and Three-toed Woodpeckers have been reported to require a minimum dbh >30 cm (Bull et al., 1980; Leonard, 2001; Jackson et al., 2002). We would caution however that while small-diameter snags (<20 cm) would appear to have little value for nesting, they were still heavily used by woodpeckers for foraging (evidence found on ~90% of snags in this study).

The largest dbh trees observed during this study were white pine and white birch. The white pine is a slow-growing species that is no longer common in Newfoundland because of intensive harvesting in the past and expansion of the white pine blister rust disease (*Cronartium ribicola*) (Rajora et al., 2002), making it difficult to manage. In contrast, white birch is common on the landscape and is frequently left standing after harvest. The potential contribution of these trees to the snag population would be enhanced if birch were managed to: (1) survive their increased susceptibility to windthrow (Bebber et al., 2005), and (2) exclude them from domestic harvest (Smith et al., submitted for publication). Managing white birch to maximize snag recruitment would require selective retention of large dbh individuals that were already snags at the time of harvest, but also the creation of snags through the topping and trimming of live trees (e.g., Bull and Partridge, 1986). Thus, wildlife habitat availability could be improved both immediately after harvest through retention/ protection of the extant white birch snag population, and (based on the prominence of birch snags in the low-density 21–40 YSH age class; Smith et al., submitted for publication) perhaps beyond 20 years into the post-harvest rotation based on the creation of new snags at the time of harvest.

Maintaining white birch on the landscape would directly support species associated with deciduous trees such as Downy and Hairy Woodpeckers, as well as Northern Flickers (Setterington et al., 2000). The increase of large diameter trees left behind on the landscape would also increase overall cavity excavation. Given that ~50% of Northern Flicker cavities were in white birch, and flickers used birch for cavities roughly in proportion to availability, we would predict that cavity creation (particularly in the more open landscapes favored by this species) would increase along with Northern Flicker numbers. As a keystone excavator (Martin et al., 2004), greater Northern Flicker populations would have the potential to provide more breeding habitat for a variety of secondary cavity-nesting species, including large-bodied species such as Northern Hawk Owls (*Surnia ulula*), American Kestrels (*Falco sparvenius*), and Boreal Owls (*Aefolius funereus*), all of which make use of cavities in snags left behind on clearcuts in Newfoundland (Gosse and Montevecchi, 2001).

4.1. Management implications

The quality (both diameter and state of decay) of snags on the landscape may be more important than the overall abundance in terms of supporting cavity-nesting birds (Farris et al., 2004). In western Newfoundland, however, forest management practices have provided an average of <2 snags per cutover with adequate dbh (>20 cm) and sufficient decay for cavity excavation. Two factors acting against the creation of such quality snags are clearcut harvesting, which tends to decrease the number of large trees and snags retained on the landscape (Simon et al., 2002), and short harvest rotations (<100 years), which prevent forests from senescing and producing larger snags (Imbeau and Desrochers, 2002). Together, these factors may be the reason why post-harvest landscapes in Newfoundland have limited cavity-nesting populations immediately following harvest. It may also explain the absence of Black-backed Woodpeckers during late-successional stages on these post-harvest landscapes due to their preference in western Newfoundland for old-growth forest (>80 years) (Thompson et al., 1999; Setterington et al., 2000). Implementing management to retain greater numbers of quality snags on post-harvest landscapes would narrow the gap in differences between natural disturbances and harvesting (Schieck and Song, 2006). Although, as evident in the widespread occurrence of foraging activity on snags of all sizes, caution must be exercised to leave not only potential nesting habitat but also foraging trees.

By focusing on the protection or creation of high-quality snags at the time of harvest, it may be possible to greatly extend the availability of nesting habitat for primary and secondary cavity nesters. Where necessary, live white birch could be killed to create snags that would remain on the landscape longer into the forest rotation (Moorman et al., 1999). Bull and Partridge (1986) found that topping was the most effective method for creating snags as it reduces susceptibility to wind and allows faster fungal and decomposing bacteria invasion. Snags created by this method were also most frequently used for nesting and foraging (Bull and Partridge, 1986; Hallet et al., 2001).

Managing for large-cavity excavators, such as Northern Flickers, and the associated range of secondary nesters would be greatly facilitated through the retention and/or creation of larger diameter white birch snags in Newfoundland. Current forestry guidelines in this jurisdiction suggest that ten snags/ha are to be left following harvest (following Cline et al., 1980). It would be more appropriate to leave ten high-quality snags/ha, i.e., snags with a large enough dbh to be potential cavity-nesting trees for the largest species in the region.

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