Snag characteristics and use as woodpecker drilling sites in harvested and non-harvested northern hardwood forests

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Abstract

Silvicultural practices can modify the availability and quality of essential habitat elements such as snags. In this study, we compared characteristics of snags and their use by woodpeckers (Picidae) as drilling forage in an extensive forest (~ 3600 ha) submitted to single-tree selection cutting and to strip cutting, while the last third was left non-harvested. A third of the 1312 snags (DBH ≥ 5 cm) sampled were used for foraging. Densities of snags (total and used) were 50% higher in the untreated area. Excavated snags had a larger DBH, and were shorter and more decayed than intact snags. Although snag characteristics (diameter, height and decay stage) did not differ among the three treatments, snags in the selection cut were used more often than expected while those in the strip cut were used less than expected. Tree species differed in their proportion of snags used for foraging. Since snag proportion (snags/live trees) also differed among tree species, attention should be given to shifts in composition in planning silvicultural practices if providing snags as good feeding sites for woodpeckers is a considered goal.

Résumé

Les pratiques sylvicoles peuvent modifier la disponibilité et la qualité d'éléments de l'habitat forestier tels les arbres morts. Dans cette étude, nous comparons les caractéristiques des arbres morts et leur utilisation par les pics (Picidae) comme site d'alimentation dans une grande forêt (~ 3600 ha) soumise à une coupe sélective et à une coupe par bandes et où l'on a préservé un tiers de la forêt intacte. Un tiers des 1312 arbres morts (DHP ≥ 5 cm) échantillonnés étaient utilisés pour l'alimentation. Les densités d'arbres morts (totale et arbres utilisés seulement) étaient plus élevées dans le secteur intact. Les arbres morts utilisés avaient un DHP plus grand, étaient plus courts et plus décomposés que les arbres morts non-utilisés. Quoique les caractéristiques des arbres morts (diamètre, hauteur, stade de décomposition) ne différaient pas entre les trois traitements, les arbres morts dans la coupe sélective étaient utilisés plus fréquemment qu'espéré, alors que ceux de la coupe par bande étaient utilisés moins fréquemment qu'espéré. Toutes les espèces d'arbres morts n'étaient pas utilisées dans la même proportion par les pics. Puisque la proportion d'arbres morts (arbre mort/arbre vivant) différait aussi selon les espèces, on devrait se préoccuper des changements dans la composition spécifique des arbres en relation avec les pratiques sylvicoles, si l'on a pour but d'assurer des sites d'alimentation pour les pics.

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Introduction

Snags have been recognized as a critical component of forest ecosystems (Hunter 1990). They are used for nesting, roosting, foraging, singing and hibernating by a variety of wildlife, especially woodpeckers (Conner et al. 1975; Scott 1978; Evans and Conner 1979; Miller and Miller 1980). Many studies have shown a negative impact of forest harvesting on snags. Managing forests for timber harvest can limit populations of cavity-nesting birds by changing either the distribution, abundance or characteristics of snags (Mannan et al. 1980; Dickson et al. 1983; Raphael and White 1984; Zarnowitz and Manuwal 1985; Schreiber and deCalesta 1992). However, few studies have addressed the impact of forest harvesting practices on the use of snags as feeding sites. In fact, several birds prefer snags as feeding sites (Evans and Conner 1979; Conner 1980), particularly those using drilling foraging techniques (Raphael and White 1984).

In hardwood forests of northeastern North America, single-tree selection cutting and strip cutting are both used to regenerate stands (Leak et al. 1987; Hornbeck and Leak 1992). During harvesting operations, many of the standing snags are felled for safety reasons or are knocked over by felling live trees. Consequently, in single-tree selection cutting, the dispersed harvesting of trees can destroy more snags than can local intensive strip cutting. Moreover, the retention of high quality trees associated with selection cutting eliminates defective stems and unhealthy trees which would eventually become snags (Stribling et al. 1990). Strip cutting, like all even-aged silvicultural systems, results in reduced snag size and density because the harvest rotation is shorter than the lifespan of most tree species (Conner and Crawford 1974). It also alters snag spatial distribution. Finally, the species composition of the snag community can also be altered by these forest practices. Selection cutting promotes regeneration of shade tolerant hardwoods, while shade intolerant hardwoods are more likely to become established in a strip cut.

We conducted this study in order to investigate the effect of two harvesting practices, single-tree selection cutting and strip cutting, when applied to an extensive forest landscape, on: (1) snag density, (2) snag characteristics, (3) proportion of snags per tree species, and (4) snag use by woodpeckers as drilling foraging sites.

Study Area

Field work was conducted in southwestern Québec, 65 km north of Ottawa (4545'N, 7605'W), in the Gatineau Experimental Forest, a 36 km^2 forest, during summer 1993 and 1994. The landscape is characteristic of the Precambrian shield and elevations range from 675 to 1125 m. In this extensively (95%) forested region, the forest is composed of sugar maple (*Acer saccharum*), beech (*Fagus grandifolia*), yellow birch (*Betula alleghaniensis*), basswood (*Tilia americana*) and white ash (*Fraxinus americana*) with hemlock (*Tsuga canadensis*) on acid rock glacial tills. Mixedwood (*Abies balsamea* and *Picea glauca*) stands are found on fluvio-glacial deposits in the lowlands, and red oak (*Quercus rubra*) stands on the thin upland deposits. Early-succession stands are usually composed of red maple (*Acer rubrum*) associated with trembling (*Populus tremuloides*) and largetooth aspens (*Populus grandidentata*), and white birch (Betula papyrifera). Pileated Woodpeckers (*Dryocopus pileatus*) and Hairy Woodpeckers (*Picoides villosus*) are the main snag drillers in these forests, although Downy Woodpecker (*P. pubescens*) and Yellow-bellied Sapsucker (*Sphyrapicus varius*) occasionally excavate some snags for foraging.

At the beginning of the 20th Century, easily accessible, high quality timber trees might have been harvested by surrounding villagers who had the right at that time to harvest trees on crown lands for their personal use. Although the extent of this exploitation is not known, it was probably limited. During the same period, many fires occurred and approximately a third of the forest burned, mainly in the present day strip cut and untreated forest areas. After these fires, no major natural or artificial disturbance events occurred. In the early 1970s, the forest became the Gatineau Provincial Experimental Forest. This experimental forest has two parts: the Doyley Lake Forest (1100 ha) is about 8 km north of the Isabelle Lake Forest (2500 ha). Between 1982 and 1985, the Doyley Lake Forest was strip cut and about half of Isabelle Lake Forest was selection cut (single-tree). In the strip cut forest all stems with diameter at breast height (DBH, 1.3 m) 10 cm were to be removed in one of three strips every 30 years. At the time of our study, only one strip had been cut. Single-tree selection cutting varied in intensity between 15 and 30% of the basal area, removing trees from all merchantable (DBH 10 cm) diameter classes. Trees to be harvested were culled according to their ability to stay vigorous until the next entry (15-20 years later) and the quality of the stem, regardless of species. No specific guidelines for snag retention were given during either harvest operations. Although only a few snags were

Table 1. Proportion of sampling plots in the Gatineau Experimental Forest by habitat type, and availability of habitat types, prior to treatment.

	Strip cutting	**Selection cutting**	**Untreated**	**Total**
Habitat types	Plots % (availability %)	Plots % (availability %)	Plots % (availability %)	Plots % (availability %)
Shade-tolerant hardwood	54 (32)	74 (66)	64 (38)	64 (47)
Shade-intolerant hardwood	30 (45)	13 (12)	17 (22)	20 (25)
Mixedwood-conifer	16 (23)	13 (22)	19 (40)	16 (28)

deliberately cut for safety reasons, logging operations caused many to fall down (D. Joanisse, Québec Ministry of Natural Resources, pers. comm.).

Methods

Sampling

The forest was first stratified into shade tolerant hardwood, intolerant hardwood and mixedwood-conifer habitats, using forest cover maps (Gouvernement du Québec 1986; Majcen et al. 1986). Sampling plots were then randomly located across the treatment forests while trying to keep the habitat types balanced. However, proportion of habitat types differed between the three forests, mainly because the early century fires had increased the proportion of intolerant hardwood habitat in the strip cut and the untreated forests (Table 1). Because of that, and because the plots had to be 250 m apart and 100 m from any water body or wetland, the distribution of the plots is not totally balanced across the habitat types in the three treatments (Table 1), although not too far from it. We believe this sampling design ensures that differences will be attributed to the treatments instead of pre-treatment forest conditions.

We sampled 270 plots (91 in strip cut, 95 in selection cut, and 84 in untreated forest). Each plot consisted of five 80-m^2 circular micro-plots, located at the four corners and at the centre of a 60 m X 60 m square. Because of the random nature of the sampling design, some micro-plots in the two harvested forests were in cut areas, some were in uncut areas, and some straddled the two. In these micro-plots, we recorded the species and DBH of all living ($\geq$ 10 cm DBH) and dead trees ($\geq$ 5 cm DBH), with a caliper. Snag species were identified by their remaining bark and branching architecture. Using a clinometer, snag height was recorded by 3 m classes, except for the first 3 m which was split into two classes (0-1.5, 1.5-3 m). We categorized snags in 5 decay classes according to the characteristics listed in Table 2.

Table 2. Snag characteristics used to assign decay classes.

Decay class	**Snag characteristics**
1	tree has recently died; bud, twigs, fine branches still apparent
2	bud, twigs, fine branches gone; bark deteriorating, loosening, beginning to slough off; sapwood still hard
3	only the limbs remain; tree top is broken; bark is extensively sloughed off; sapwood starting to soften and decay
4	only stubs of limbs remain; bark practically absent; most of sapwood is decayed; heartwood starting to soften; height significantly reduced
5	wood is completely rotten; vegetation has started to colonize snag; organic matter accumulated at base of snag

Evidence of foraging was noted according to three levels of feeding use: none (level of feeding = 0), few signs (0-3 signs, level of feeding = 1), abundant signs (>3 signs, level of feeding = 2), using binoculars when needed. Signs of foraging by sapsuckers were not included. Evidence of foraging was related to height areas (0-3 m, 3-9 m, 9-15 m, >15 m, top-3 m). The area use index (AUI) was then computed for each snag using the following equation [1]:

[1] AUI = Σ (area height section x level of feeding use of that section).

The area of each section was obtained using the conic area formula, based on tree diameter and height. For snags with broken tops, previous height was estimated using a diameter-height regression from dendrometrical studies made in these forests (Majcen et al. 1984, 1985; Majcen and Richard 1989; Majcen et al. 1992). Total Area Use Index (TAUI) was obtained by adding all AUIs of each snag in the plot.

Data Analysis

Snag characteristics per individual (DBH, height, decay stage and AUI) and per plot (density, basal area, TAUI) were compared among the three treatments and between used and unused snags using ANOVA (DBH, density, basal area, height classes, decay classes). Treatment effect on AUI and TAUI was tested with Kruskal-Wallis test. Comparisons among species were performed for diameter using ANOVA, and for height and decay using Kruskal-Wallis tests. When a significant effect was found, *a posteriori* tests were conducted to detect significant differences among levels (Bonferonni for ANOVA and SNK for Kruskal-Wallis). Snags used versus availability was compared with χ^2 using a confidence interval method (Neu et al. 1974) for each characteristic class (DBH, height, decay), in order to identify preference (Byers and Steinhorst 1984). Diameter classes used were 5-9.9 cm, 10-14.9 cm, 15-24.9 cm, 25-49.9 cm and ≥50 cm. We used the Spearman correlation coefficient to examine relationships among DBH, height and decay.

Snag proportion (snag versus living tree) and snag use (used versus unused snags) were compared among the three forest treatments using contingency analysis. In order to control for the tree species composition, snag proportion and snag use were modeled with a log-linear model (Agresti 1990), using tree species and forest treatments as independent variables. Infrequent tree species were removed until the contingency table had less than 20% of its cells with expected frequency < 5. Consequently, the tree species variable has 14 species categories for the snag proportion model and 12 for the snag use model. The model was fitted with the fewest number of parameters through backward hierarchical selection (SPSS Inc. 1988). Parameter estimates of the model were tested at the .05 level using their Z-value.

Results

Snag density

We measured 6708 live trees and 1312 snags representing 25 tree species. Snag density and basal area were higher in the untreated forest than in treated forests, for all and used snags only (Table 3). Although tree density was 10% lower in the strip cut and 21% lower in the selection cut forest areas, when compared to the untreated forest area, snag densities were as much as 24% and 38% lower in the strip cut and the selection cut respectively (Table 3). The selection cut forest had a significantly lower snag density than the untreated one for the first two diameter size classes (5-9.9 cm and 10-14.9 cm) while the inverse was true for the largest diameter class (25 cm); the strip cut forest had significantly a lower density than the untreated. Density did not differ between the three forests for the 15-24.9 cm class. Of the only 8 snags ≥ 50 cm sampled, 5 were in the untreated, 2 in the selection cut , and 1 in the strip cut forest. TAUI differed among forest treatments (Table 3). However, even though the lowest snag density occurred in the selection cutting area, TAUI did not differ between the selection and the untreated forest.

Snag Characteristics

Characteristics of used and unused snags did not differ among the three forest treatments (Table 4). Used snags had larger diameter, smaller height, and were more decayed than unused snags. We observed a greater percentage of use as the diameter increased (Figure 1A). Snags with DBH < 10 cm were under-used while those between 15 and 50 cm were over-used (p (χ^2) < 0.05, Bonferonni corrected). Indeed, nearly 70% of snags > 25 cm DBH were used for foraging. Snags taller than 6 m, were under-used (~25 %) whereas shorter ones were over-used (~50%) (Figure 1B). Snag diameter and height were not highly correlated (rs=0.11, p=0.001). Finally, use increased with the degree of snag decay (Figure 1C). Use of snags increased when they reached the third decay class. Decay was negatively correlated with height (rs = -0.58, p < 0.001) but very weakly with diameter (rs = 0.12, p < 0.001).

Snag Proportion

The proportion of snags over live trees differed among the three forest treatments (Strip=19%, Selection=18%, Untreated=22%; 2=13.4, df=2,

Table 3. Tree density, snag density by DBH class, snag basal area, and Total Area Use Index (TAUI).

Treatment **Sample size**		**Strip cut** **n = 91**	**Selection cut** **n = 95**	**Untreated** **n = 84**	**p**
Tree density (no./ha)		626±25A[a]	548±21B	698±21C	0.0001
Snag density (no./ha)					
DBH class	5-9.9 cm	52±4.9AB	40±5.3A	6.7±6.1B	0.002
	10-14.9 cm	32±3.6AB	24±2.9A	40±4.3B	0.006
	15-24.9 cm	29±3.5	22±3.0	33±4.8	0.087
	≥ 25 cm	6±1.4A	9±1.9AB	15±2.4B	0.004
All		118±8.2A	94±8.8A	156±10.5B	0.001
Used		39±4.1A	36±3.8A	56±4.5B	0.001
Snag basal area (m^2/ha)	All	2.0±0.3A	2.1±0.3A	3.3±0.3B	0.001
	Used	1.0±0.2A	1.1±0.2A	1.8±0.2B	0.014
TAUI[b] (m^2/m^2)	All	0.22±0.04A	0.28±0.04B	0.39±0.05B	0.022

[a] Mean ± 1 standard error. Means followed by different letters within each row are significantly different ($p < 0.05$).
[b] Total Area Use Index (level of use * m^2/m^2).

p=0.001). It was lower than expected in the selection cut area and higher than expected in the untreated area (p (χ^2) = 0.05, Bonferonni corrected). However, when the effect of tree composition was controlled, snag proportion differed among the three forest treatments for only four species (red maple, ironwood, trembling aspen and balsam fir) with a significant interaction term (Table 5). When looking at the species effect only, snags of balsam fir, red maple, white birch, large-toothed aspen and trembling aspen were over-represented, when compared to their proportion as live trees, while species like beech, white spruce, basswood and eastern hemlock were under-represented (Table 5).

Snag Use

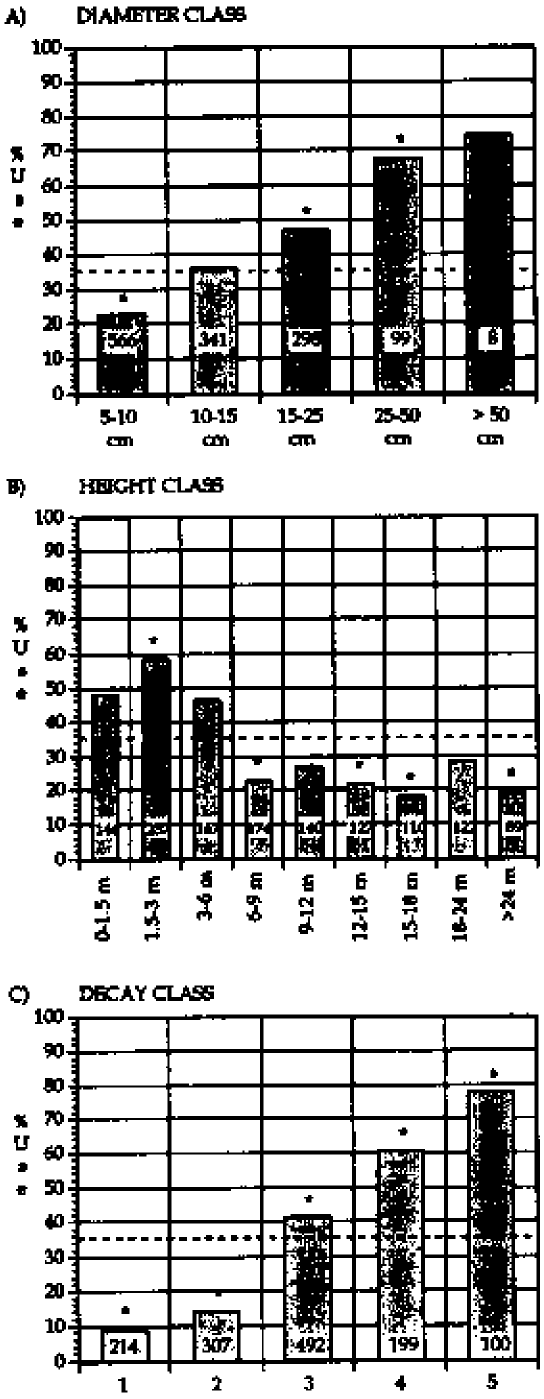
Approximately 37% of sampled snags had been used, at least slightly, as drilling forage by woodpeckers. Intensity of use per individual snag as expressed by the

Table 4. Snag characteristics in a strip cutting, selection cutting, and untreated hardwood forest, southwestern Québec.

		Harvesting practice			**Effects**		
	Snag	Strip cutting	Selection cutting	Untreated	HP[a]	U[b]	HP x U
No. of snags	Unused	289	221	336			
	Used	142	136	188			
DBH (cm)	Unused	11.2±0.3A[c]	12.1±0.5A	11.9±0.4A	NS	0.001	NS
	Used	16.3±0.7B	16.9±0.9B	16.9±0.8B			
Height class	Unused	5.0±0.2A	5.4±0.2A	5.1±0.2A	NS	0.001	NS
	Used	3.4±0.2B	3.6±0.2B	4.0±0.2B			
Decay class	Unused	2.3±0.1B	2.3±0.1A	2.5±0.1A	NS	0.001	0.013
	Used	3.6±0.1B	3.3±0.1B	3.4±0.1B			
AUI[d]	Used	2.3±0.3	3.1±0.3	2.8±0.3	NS		

[a] Harvesting practice; [b] Use; [c] Mean ± 1 standard error; means followed by different letters within each row and column for each parameter are significantly different ($p < 0.05$); [d] Area Use Index (level of use * m^2).

Figure 1. Percentage of snag use by (A) diameter class, (B) height class, and (C) decay class (1 (least) to 5 (most) decayed). A star over the bar indicates over- or under-use (χ^2, $p<0.05$, Bonferonni corrected), compared to the total percentage of use (dashed line). The number within each bar indicates the frequency of that class.



AUI did not differ among the three forest treatments (p=0.140, Table 3). Proportion of snags used did not differ among the three forest treatments (Strip = 33%, Selection = 38%, Untreated = 36%; $\chi^2 = 2.3$, df = 2, p = 0.32). However, after controlling for the composition effect, snags were used less often in the strip cut area, and significantly more in the selection cut area, as expressed by the multiplicative coefficient (Table 5). Four species, beech, large-toothed aspen, trembling aspen and basswood, had foraging evidences more often than randomly expected while four species (balsam fir, red maple, sugar maple and ironwood) were less used (Table 5).

Snag characteristics differed among species. With the exception of the basswood, selected species usually had larger diameter and were more decayed (Table 6). Height was not as good in discriminating selected species and only differed between yellow birch and sugar maple, ironwood and balsam fir.

Discussion

Forest cutting practices have considerably reduced snag abundance. In fact, snag density was proportionally more reduced than tree density in the two harvested forests, suggesting an accentuated detrimental effect of harvest on snags. However, this density reduction, although important (33%), might not have strongly affected the woodpecker community since snag densities (DBH ≥ 10 cm) in the untreated forests were actually higher than what has been observed in many other untreated hardwood forests in North America (McComb and Noble 1980; Carey 1983; McComb and Muller 1983; Chadwick et al. 1986; Sedgwick and Knopf 1986; Rosenberg et al. 1988). Indeed, even considering the lowest density observed among the three forests, snag availability was sufficient for maximum population density of small (Downy Woodpecker) and medium-sized woodpeckers (Hairy Woodpecker and Yellow-bellied Sapsucker) according to Evans and Conner (1979). However, nesting and foraging snag resources in treated forests might not be sufficient to support a healthy Pileated Woodpecker population which requires snags with DBH ≥ 50 cm, but our sampling method was not well designed to determine an accurate estimation of snag density of that size (Bull et al. 1990).

Globally, snag proportion (10.0%, DBH ≥ 10 cm, all three forests together) was within the range (4.5 - 10.2%) observed in other hardwood forests (McComb and Muller 1983; Chadwick et al. 1986; Conner et al. 1994). Like McComb and Muller (1983), we found that beech and red oak were poorly represented as

Table 5. Effects of tree species and harvesting practices on snag proportion and snag use proportion as expressed by the parameter coefficients of log-linear models.

Parameter (abbreviation)	Snag proportion[a]		Snag use[b]	
	Multiplicative Coefficient [c]	Z-value	Multiplicative Coefficient [c]	Z-value
Constant (K)	0.1655	-28.78	0.6618	-4.06
SPECIES EFFECT (SP)				
American beech (Fag)	0.6610	-3.01	2.8344	4.21
Balsam fir (Abb)	2.3101	7.56	0.4299	-4.25
Basswood (Tia)	0.5265	-2.5	3.3489	2.77
Eastern hemlock (Tsc)	0.2667	-2.79	0.3935	-1.76
Ironwood (Osv)	0.7176	-1.46	0.1631	-3.17
Large-toothed aspen (Pog)	2.0431	5.53	2.3099	4.32
Paper birch (Bep)	1.7245	3.58	1.3895	1.45
Red oak (Qur)	0.7917	-1.07	0.9280	-0.19
Red maple (Acr)	1.3062	2.71	0.4961	-3.85
Sugar maple (Acs)	1.0973	1.13	0.6414	-3.05
Trembling aspen (Pot)	1.7417	2.73	2.5877	2.87
White ash (Fra)	1.4623	1.21		
White spruce (Pig)	0.4827	-2.67		
Yellow birch (Bea)	1.3222	1.97	1.5556	1.79
HARVESTING PRACTICE EFFECT (HP)				
Strip cutting (SC)	0.8501	-1.67	0.77	-2.76
Selection cutting (SeC)	1.0116	0.13	1.2913	2.64
Untreated (UT)	1.1629	1.89	1.0058	0.07
INTERACTION EFFECT[d]				
Abb x SC	0.6777	-2.28		
Acr x SC	1.6144	3.51		
Acr x UT	0.7007	-2.67		
Osv x SeC	2.1845	2.85		
Pot x SeC	2.2470	2.63		

[a] Snag proportion log-linear model: Snag/living tree = K + Sp + HP + Sp*HP, G = 0.000, df = 0, p = 1.000.

[b] Snag use selected log-linear model: Used/unused = K + Sp + HP, G = 13.47, df = 21, p = 0.891.

[c] Estimates significantly different from 1 at $p < 0.05$ are underlined.

[d] Only parameter coefficients significantly different from 1 are shown.

Table 6. Mean diameter (cm), height class and decay class of snags in southern Québec.

		DBH		Height class		Decay class	
Species[a]	**n**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
American beech +	75	18.6 A[b]	0.9	3.7 AB	0.3	3.0 AB	0.1
Balsam fir -	166	13.8 BCD	0.6	4.8 B	0.2	2.9 AD	0.1
Basswood +	21	13.5 ABCD	1.8	4.1 AB	0.6	3.1 ABCDE	0.2
Eastern hemlock	18	18.4 AB	1.9	4.6 AB	0.7	2.1 BCDE	0.3
Ironwood -	27	9.5 CD	1.6	5.5 B	0.5	2.2 DE	0.2
Large-toothed aspen +	131	18.2 A	0.7	4.2 AB	0.3	3.3 A	0.2
Paper birch	83	13.8 BCD	0.9	5.3 AB	0.3	2.9 ABCDE	0.1
Red maple -	210	11.0 D	0.6	4.7 AB	0.2	2.5 BCDE	0.1
Red oak	25	14.2 ABCD	1.6	5.4 AB	0.6	2.9 ABCDE	0.2
Sugar maple -	374	11.4 D	0.4	4.8 B	0.2	2.5 CE	0.1
Trembling aspen +	36	18.5 AB	1.4	3.9 AB	0.5	3.1 AC	0.2
White spruce	15	12.6 ABCD	2.1	4.6 AB	0.7	1.8 E	0.3
Yellow birch	67	15.5 ABC	1.0	3.7 A	0.4	3.5 A	0.1

[a] + (more) or - (less) used than expected for foraging (Table 5).

[b] Numbers in a column sharing the same letter are not significantly different ($p < 0.05$).

snags, when compared to live stems. On the other hand, unlike these authors, we found red maple snags were over-represented. Over- and under-representation result from species longevity, fate of dying stems (Tyrell and Crow 1994), snag durability (Morrison and Raphael 1993) and forest practices. For example, despite good snag durability resulting from high wood density, American beech's great longevity impedes snag formation. Inversely, many of the 10-15 cm balsam fir trees were attacked by *Scolytus* spp. (F. Doyon, pers. obs.), reducing their longevity and therefore promoting snag formation of small DBH (Table 6). However, we are aware that over-representation of species producing small DBH snags like balsam fir, paper birch and red maple could have also resulted from the fact that we have not sampled the live trees in the 5-9.9 cm class. Trembling aspen snag representation was affected by selection cutting practices as expressed by a strong positive interaction between trembling aspen and selection cutting (Table 5). Indeed, this species, based on the marking rules, was preferentially culled so as not to waste high quality stems between the last and the next entry. Residual unhealthy and poor quality live aspens were likely to become snags, whereas vigorous live trees had been considerably reduced by the harvest, leading to snag over-representation. Finally, long-lived and easily uprooting species, like eastern hemlock (Tyrell and Crow 1994) and white spruce, are more likely to be under-represented in snags, as we observed.

Twelve years after treatment, forest harvesting practices did not alter snag population characteristics (diameter, height and decay). Only a few other studies have considered this aspect in response to forest practices. In their comparison between thinned and unthinned stands, Welsh et al. (1992) did not find a difference in snag diameter. However, in that case, thinning was executed with den and cavity tree retention guidelines. Hagan and Grove (1996) also did not see any difference in maximum snag DBH between a virgin hardwood forest and forests having been selection cut with different numbers of entries. In the strip cut forest, most of the snags were in the remaining intact green strips. Very few were observed in the strip cuts. Consequently, it is not surprising that the actual snag population still reflects the past distribution of the snag characteristics. In the selection cut, we expected that remaining snags, left after the selection cut, would be less decayed as a result of the application of tree felling security norms (Gouvernement du Québec 1981; Picher 1992) and the sanitation removal of some decayed snags, a practice generally included in the operations of this silvicultural system (Creha et al. 1987). Apparently, snag felling indifferently occurred in all characteristic classes.

Larger snags were used to a greater degree. In our study, snags with a diameter over 20 cm were clearly selected, as reported in several other studies (Bull and Meslow 1977; Brawn et al. 1982; Raphael and White 1984; Rosenberg et al. 1988; Swallow et al. 1988). According to our results, this could not be attributed to a positive correlation between diameter and decay stage. One hypothesis is that larger snags offer more foraging area, more prey per tree and thus more food per unit area (Mannan et al. 1980; Raphael and White 1984) but our data did not allow us to test this hypothesis. It may be worthwhile to examine how the 20-cm threshold relates to prey density and optimal foraging bio-energetics.

Others attribute this relationship to a bias: large snags stand for a longer period of time than small ones, and evidence of foraging is more likely to occur on them (Cline et al. 1980; Dickson et al. 1983). This was probably also true in our study, however, most of the snags that had been excavated in the past usually still had fresh foraging signs, which suggests a positive feedback between excavating, wood decaying and prey density. Even if large diameter snags were selected for foraging, it does not dismiss small diameter snags as an important resource. We found that 23% of the snags in the 5-9.9 cm diameter class, which comprised 43% of all the snags, had foraging evidences. Rosenberg et al. (1988) had similar statistics.

Shorter snags were used more than expected and under-use significantly appeared for snags over 6 m high (Figure 1B). When a snag decays, it loses its branches and the top often breaks, reducing its height. The base and top of snags are used more often than any other height section (Conner et al. 1994). These two extremities are also more likely to be well-decayed, and therefore contain a higher arthropod biomass (Conner et al. 1994). Therefore, shorter snags should comprise a greater proportion of that high quality substrate, which requires less effort in order for woodpeckers to find prey. The large significant negative correlation between height and decay supports this explanation.

Foraging preference on oak (Conner 1980; Brawn et al. 1982; Conner et al. 1994) and elm snags (Swallow et al. 1988) has been observed, but never for beech, basswood, trembling aspen or large-toothed aspen, species that were significantly more used in our area. Under-use of red maple in foraging has also been noticed elsewhere (Conner 1980; Conner et al. 1994). Aspens have thin bark and low wood density (large-toothed aspen and trembling aspen green wood specific gravity are 0.36 and 0.35, respectively (U.S. Forest Products Laboratory 1974)). These characteristics allow easy invasion by disease and decay organisms (Loehle 1988). Indeed, low wood density has been found to be inversely correlated with the number of foraging signs (Conner et al. 1994). Despite a high wood density (0.56), beech is frequently subject to beech bark disease (*Cryptococcus fagi*/*Nectria coccinia* var. *faginata*) and to frost split, causing the bark to crack. In addition to creating new microhabitats for insects, they expose sapwood to fungi invasion. In fact, snags of beech and aspens (trembling or large- toothed) were indeed more decayed than other species (Table 6). They were also larger, another feature of selected snags. Even if yellow birch was not selected more than expected at $\alpha=0.05$ level (Table 5), it was not too far from it ($p = 0.073$). Since it has all the desired characteristics of forage snags (Table 6) and is one of the few that is long enough lived to provide very large (DBH $\geq$50 cm) snags, yellow birch should be considered an important snag-providing species. On the other hand, basswood snags, which were also more selected than randomly expected, were not larger or more decayed than other snags. Its very low wood density (0.32) probably gives it a softness similar to decayed denser wood.

Conclusions

We have compared snag density, characteristics, and their use as forage sites by excavation by woodpeckers in two harvested forests and one left intact. Twelve years after a first entry, strip and selection cutting have had a strong impact on snag density but not on snag characteristics and tree species snag proportion. If the differences in snag density we observed after the first entry between the treated forests and the untreated one can be mainly attributed to harvest practices, as we believe, we are seriously concerned that such a reduction will bring snag density under some critical threshold after the next entry, if no retention guidelines are provided. Large diameter snags (DBH $\geq$50 cm), already rare, are likely to be extirpated, especially in the strip cut where recruitment will occur only in the last remaining green strip. We caution practitioners that a simple proportion calculation from tree density reduction to predicted residual snag density cannot be made. The felling of trees is critical in retention practices and recommendations should be given to woodcutters to maintain marked snags (Naylor et al. 1996). Our results suggest preferential retention of basswood, beech, aspen and yellow birch snags over 20 cm DBH, as favorable drilling forage for excavators. Greater consideration should be given to the dynamics of basswood and beech trees and snags, because these overused snags were proportionally poorly represented. Also, more quantitative information about foraging and nesting requirements for snag-dependent species is needed. Coupled with snag dynamics models (Morrison and Raphael 1993), snag density and quality could be managed through time in order to minimize the impact on snag-dependent species.

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