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SNAG USE BY FORAGING BLACK-BACKED WOODPECKERS (*PICOIDES ARCTICUS*) IN A RECENTLY BURNED EASTERN BOREAL FOREST

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Abstract.—We studied snag use for foraging by Black-backed Woodpeckers (*Picoides arcticus*) one year after a fire in an eastern black spruce (*Picea mariana*) boreal forest in Quebec, Canada. We searched for signs of foraging (bark flaking and excavation holes) by Black-backed Woodpeckers on 6,536 snags sampled in 56 plots located in portions of the burned forest that had not been salvage logged. A logistic regression model was developed based on the presence or absence of foraging signs. Results showed that Black-backed Woodpeckers used larger snags that were less deteriorated by fire (qualified as high-quality snags). Direct field observations of individuals foraging on 119 snags also indicated that used snags corresponded to those of high predicted quality. Finally, we assessed the relationship between food availability and snag characteristics by measuring the density of wood-boring beetle larvae holes on 30 snags of different size and deterioration classes. High-quality snags contained higher prey densities (wood-boring beetle holes) than smaller and more deteriorated snags. We recommend that forest blocks characterized by large and less deteriorated trees be preserved from salvage logging in recently burned boreal forests in northeastern North America. *Received 6 December 2001, accepted 14 December 2002.*

Résumé.—Nous avons étudié l'utilisation des chicots à des fins d'alimentation par le Pic à dos noir (*Picoides arcticus*) un an après feu dans une pessière noire (*Picea mariana*) de l'est de la forêt boréale au Québec, Canada. Nous avons cherché des marques d'alimentation (écorce soulevée et trous d'excavation) de Pics à dos noir sur 6,536 chicots échantillonnés dans 56 placettes situées dans des portions de forêts brûlées préservées de la coupe de récupération. Un modèle de régression logistique a été développé basé sur la présence ou l'absence de marques d'alimentation. Nos résultats ont montré que les Pics à dos noir utilisaient les chicots de plus gros diamètre et moins détériorés par le feu (qualifiés de chicots de haute qualité). Des observations directes d'individus s'alimentant sur 119 chicots ont également montré que les caractéristiques des arbres utilisés correspondaient à celles déterminées par le modèle pour des chicots de haute qualité. Finalement, nous avons examiné la relation entre la disponibilité alimentaire et les caractéristiques des chicots en mesurant la densité de trous de larves de longicorne pour 30 chicots de différentes classes de diamètre et de détérioration. Les chicots de haute qualité contenaient de plus fortes densités de proies (trous de longicornes) que les chicots de plus faible diamètre et plus détériorés. Nous recommandons que des blocs de forêts contenant des chicots de large diamètre et moins détériorés par le feu soient préservés de la coupe de récupération dans les forêts boréales récemment brûlées du nord-est de l'Amérique du Nord.

The Black-backed Woodpecker (*Picoides arcticus*) has been closely associated with recently burned conifer forests in several studies (Hutto 1995, Murphy and Lehnhausen 1998, Hoyt and Hannon 2002). The high number of recently dead trees represents high-quality habitat for nesting, but especially for foraging because of the increased availability of wood-boring (*Cerambycidae* and Buprestidae) and bark (Scolytidae) beetles (Murphy and Lehnhausen 1998, Powell et al. 2002). In the boreal black spruce (*Picea mariana*) forest of eastern Canada where fire is the major natural disturbance (Rowe and Scotter 1973, Bergeron et al. 2002), early postfire forests may be quite important for that species. Old-growth forests contribute very little to availability of snags compared to burned forests, and insect outbreaks that kill large numbers of mature trees are scarce

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(Imbeau et al. 1999, Nappi 2000, Drapeau et al. 2002). Although burned boreal forests are becoming more accessible for salvage logging (Murphy and Lehnhausen 1998, Purdon et al. 2002), a crucial need exists to provide science-based guidelines for management of those forests to provide appropriate habitat conditions for burn-associated species such as the Black-backed Woodpecker.

Foraging behavior of Black-backed Woodpeckers and the characteristics of trees used for foraging have been documented in different forest cover types (Goggans et al. 1989, Villard and Beninger 1993, Villard 1994, Murphy and Lehnhausen 1998). In postfire habitats, we still lack information on snag use by Black-backed Woodpeckers and more precisely, on the relationship between snag selection, insect prey abundance, and snag characteristics such as size, decay, and fire severity.

We examined use of snags for foraging by Black-backed Woodpeckers in a first year post-fire forest. First, we determined the characteristics of trees used for foraging on the basis of the presence or absence of foraging signs on snags. Second, we validated our results by direct observations of Black-backed Woodpeckers foraging on snags. Finally, we assessed the relationship between food availability and snag characteristics by measuring the density of wood-boring beetle larvae holes, an indirect measure of a major prey in the Black-backed Woodpecker diet.

METHODS

Study area.—The study area was located at the Ontario–Quebec border near Val-Paradis, in northwestern Quebec (49°02′N to 49°12′N; 78°22′W to 79°32′W). That area is representative of the black spruce–moss bioclimatic domain (Saucier et al. 1998), with gently rolling terrain composed of 4 to 5% slopes. Between 5 and 12 June 1997, a fire burned 12,540 ha of forest in an area that last burned in 1911 (Bordeleau 1998, Bergeron et al. 2001). The forest was composed mainly of jack pine (*Pinus banksiana*) and black spruce. Salvage logging began during the same summer as the fire and covered 64% of the burned area, mostly in the jack pine stands (Purdon et al. 2002). Snags were not retained within the harvested blocks. The unsalvaged stands were composed mainly of black spruce (85%) and jack pine (13%). Remnant patches were very similar in structure, tree composition, and mean diameter (~9 cm). All patches from 4 to 100 ha were systematically surveyed for woodpeckers and snags, for a total of 22 patches. In 1998, standing snags and woodpecker foraging signs were sampled in 56 triangular plots (700 m^2), separated by at least 400 m, and located within the 22 survey patches.

Characteristics and use of snags.—A snag was defined as any dead tree (no green needles) at least 2 m tall. Within each plot, we recorded diameter (±0.5 cm) at breast height (DBH) and species for each snag >5 cm. We also described deterioration of each snag using five characteristics based on a modified version of the wildlife tree classification normally used for unburned trees (British Columbia Ministry of Forests 1998). "Visual appearance" variable described the general condition of the snag (1 = recently dead tree to 6 = standing stump >2 m tall). "Crown condition" variable referred to remaining quantity of twigs and branches on the snag (1 = some or all foliage lost; 2 = no foliage, up to 50% of twigs lost; 3 = no foliage or twigs, up to 50% of branches lost; 4 = most branches gone, some branch stubs remain; 5 = no branches, some branch stubs; 6 = no branches or stubs). "Bark retention" variable represented proportion of bark still present on the trunk surface (1 = all bark present; 2 = <5% lost; 3 = 5–25% lost; 4 = 26–50% lost; 5 = 51–75% lost; 6 = 76–99% lost; 7 = no bark). "Wood condition" variable reflected the internal and external decay of the snag (1 = no decay; 2 = probable limited internal decay; 3 = limited decay; 4 = decay spreading; 5 = balance of hard and soft wood; 6 = more soft than hard wood; 7 = no more hard wood; 8 = hollow shell). We also evaluated percentage of the trunk surface that was burned with the "bark burn severity" variable (1 = unburned; 2 = <5% burned; 3 = 6–40% burned; 4 = 41–60% burned; 5 = 61–95% burned; 6 = 96–99% burned; and 7 = totally burned). Those characteristics allowed us to determine the severity of fire at each tree and its decay state prior to fire. We also calculated snag density by DBH class (5–9.5 cm; 10–14.5 cm; 15–19.5 cm; >20 cm) in each plot.

Black-backed Woodpecker foraging signs were determined by presence of flaked bark or foraging excavations. Those signs correspond to foraging techniques used by woodpeckers to extract wood-boring and bark beetles under the bark or within the wood (Villard 1994, Murphy and Lehnhausen 1998). Previous studies found some overlap in foraging techniques (pecking, flaking, excavating) used by Black-backed, Three-toed (*P. tridactulus*), and Hairy (*P. villosus*) woodpeckers (Villard 1994, Murphy and Lehnhausen 1998). In the northeastern boreal forest, those species may co-occur in burns. However, a simultaneous study showed that the Black-backed Woodpecker was, by far, the most abundant species in the Val-Paradis postfire forest (Nappi 2000). Thus, foraging signs were assumed to represent evidence of Black-backed Woodpecker foraging activities. Because our study was conducted the year after the fire, foraging signs were an appropriate indirect measure of effective use of snags by woodpeckers.

Model development.—On the basis of presence or absence of foraging signs, we used logistic regression with a stepwise procedure to determine which set of explanatory variables best predicted snag use by foraging Black-backed Woodpeckers (Hosmer and Lemeshow 2000). We included 11 variables in the model: DBH, tree species, visual appearance, crown condition, bark retention, wood condition, bark burn severity, and snag density (four DBH classes). Snag observations within each plot were not independent. We therefore statistically weighted the number of snags per plot so that each plot contributed to only one degree of freedom in the model (Desrochers 1992). That technique allowed us to use all observations while avoiding pseudoreplication (Machlis et al. 1985).

Model validation.—We subsequently tested the validity of our model using an independent data set obtained by direct observations of Black-backed Woodpeckers foraging on snags. During June 1998, we conducted field observations of unmarked individuals in the largest unsalvaged section of the burn (100 ha). Foraging woodpeckers were detected by walking during morning hours (0500 to 1200 hours EST) along five linear transects located 200 m apart and totaling 6.7 km. On each transect, a 2 min stop was made every 100 m to increase the chance of detecting Black-backed Woodpeckers. Each day, surveying began at the point where the previous survey ended. During the breeding season, the entire area was surveyed five times, a cumulative effort of 39.5 h of surveying. During those surveys, we located 15 active Black-backed Woodpecker nests. Rather than following the same individual for a long period we conducted shorter focal surveys. That approach increased the probability of following different individuals (maximum of 30 individuals) for which foraging observations were conducted. When a bird was found, it was followed for a maximum period of 10 min, or until it flew out of sight. During those periods, each tree used for foraging was marked, and the same characteristics as those recorded for the snag sampling were subsequently noted. Deterioration values and DBH were used to derive the probability that a tree should have been used (from 0 = unused to 1 = used) according to the logistic regression model based on woodpeckers' foraging signs. The mean probability was calculated for each observation bout (Σ of probability of each tree/total number of used trees during the bout). Finally, we looked at the percentage of observation bouts that were classified in the high-quality snag class (predicted value >0.5).

Predicted snag quality and wood-borer activity.—In the summer of 1999 (two years after the fire), we measured the number of entrance and emergence holes of wood-boring beetle larvae as an indirect measure of insect prey abundance in snags of varying size (5.5 to 18 cm) and deterioration class (crown condition = 1 to 3). The use of those two snag characteristics was based on our observations from the previous year (see below). We entered the DBH and deterioration values of trees into the regression model to determine if a snag was of high (predicted value >0.5) or low-quality (predicted value <0.5) foraging substrate. A total of 30 snags were selected for insect sampling: 16 high-quality and 14 low-quality snags.

Several species of wood-boring (Cerambycidae, Buprestidae) and bark (Scolytidae) beetles may colonize burned trees (Ross 1960, Murphy and Lehnhausen 1998, Hanks 1999). However, studies conducted in recently burned forests suggest that large wood-boring beetles represent the main prey of Black-backed Woodpeckers in those forests (Villard and Beninger 1993, Murphy and Lehnhausen 1998, Powell et al. 2002). Large wood-borers, such as some *Monochamus* spp., excavate galleries when they reach the third-instar stage (before the first winter following hatching) and emerge two or three years after oviposition (Rose 1957). We thus assume that measuring the number of wood-borer holes (entrance and emergence holes) provides an index of abundance of large wood-boring beetle larvae (Rose 1957, Ross 1960, Zhang et al. 1993). During that period, larvae come back to the surface to feed (Rose 1957, Hanks 1999). Thus, both larvae at the surface or within the sapwood are available for Black-backed Woodpeckers, which use both bark flaking and excavating foraging techniques.

For each snag, we measured the total number of larval entrance and emergence holes in the wood in the first meter above ground and for all subsequent 2 m sections up to the crown. Larval entrance holes (small, oval shaped holes surrounded by eaten wood surface resulting from larval feeding) were distinguished from exit holes (larger and rounder). We also recorded the total number of foraging excavations made by woodpeckers to assess intensity of their foraging on each section of the tree. On the basis of DBH, we used a stem profile model calibrated for black spruce (Zakrzewski 1999) to estimate diameter of the trunk at different heights and surface area of each section. We then calculated density (number per square meter) of wood-boring beetle holes and woodpecker foraging holes for each tree section, which was then used to calculate the mean density per tree. Characteristics of each snag were also recorded, using the snag sampling methodology.

We compared the density of larval entrance holes, larval emergence holes and foraging excavations of woodpeckers between high- and low-quality snags using Mann-Whitney *U*-tests. Spearman's correlations were used to examine relationship between densities of larval entrance holes, emergence holes and foraging excavations of woodpeckers using tree sections as sampling unit. Within each of the high- and low-quality snag classes, we compared larval entrance hole density among height sections using the Wilcoxon signed ranks test.

RESULTS

Snag characteristics and Black-backed Woodpecker use.—A total of 6,536 snags were measured during snag sampling including 2,518 (39%) with signs of foraging by woodpeckers. Among the used snags, 58% had bark flaking signs only ($n = 1{,}461$), whereas 40% ($n = 1{,}010$) had signs of both bark flaking and foraging excavation. Few snags that had only foraging excavations ($n = 47$) were not considered in the analysis because they might have represented snag use prior to fire.

Regression analysis was conducted on 6,489 snags (weighted for 56 plots). From the 11 variables introduced into the model, two were significant predictors of snag use for foraging: DBH ($P < 0.01$) and crown condition ($P < 0.05$). The crown condition variable best described snag deterioration and will be hereafter called "deterioration". Probability that a snag was used increased with a higher DBH and a lower deterioration value (Fig. 1). The "tree species" variable was not a significant predictor of snag use. However, jack pine snags were larger in DBH (49% of jack pines had a DBH >10 cm) than black spruce (24% had a DBH >10 cm).

We followed male Black-backed Woodpeckers 14 times, females 8 times, and birds of unidentified sex 4 times. A total of 119 trees, mostly black spruce (93%), were used for foraging by those focal individuals (1 to 19 snags per observation bout). Deterioration values and DBH of those trees were used to evaluate the accuracy of the logistic regression model. According to the predictions of our model, Black-backed Woodpeckers used snags of high predicted quality (mean value >0.5) during 20 (77%) of the 26 observation bouts.

Wood-borer activity.—Snags of high predicted quality contained higher densities (mean per snag) of larval entrance holes (Mann-Whitney *U*-test, $Z = -2.7$, $n = 30$, $P < 0.01$), larval emergence holes (Mann-Whitney *U*-test, $Z = -2.6$, $n = 30$, $P < 0.01$) and foraging excavations of woodpeckers (Mann-Whitney *U*-test, $Z = -2.0$, $n = 30$, $P < 0.05$) than snags of low predicted quality (Fig. 2). Density of larval entrance holes was highly correlated to density of exit holes ($r_s = 0.83$, $n = 170$, $P < 0.001$) and density of foraging excavations of woodpeckers ($r_s = 0.69$, $n = 170$, $P < 0.001$). Among snags of high predicted quality, entrance hole density was significantly higher for the 1–3 m section than for the 0–1 m section (Wilcoxon signed ranks test; $Z = -2.0$, $n = 16$, $P < 0.05$). Among snags of low predicted quality, entrance hole density was significantly higher in the 0–1 m (Wilcoxon signed ranks test; $Z = -2.3$, $n = 14$, $P < 0.05$) and the 1–3 m section (Wilcoxon signed ranks test; $Z = -2.3$, $n = 14$, $P < 0.05$) than the 3–5 m section.

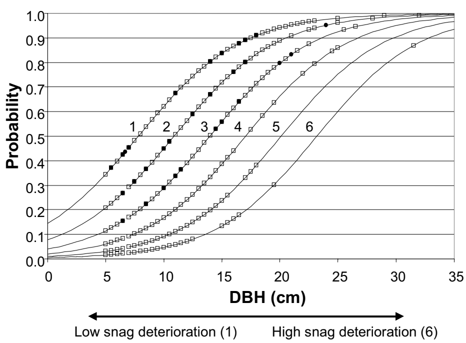

FIG. 1. Logistic regression models showing probability of snag use for foraging by Black-backed Woodpeckers (0 = unused snag, 1= used snag) in relation to DBH for different snag deterioration classes (from 1 = less deteriorated snag to 6 = most deteriorated snag) in the burned forest landscape near Val-Paradis, Quebec ($n = 6{,}489$ snags). Squares represent categories that were sampled for the vegetation sampling. Filled circles and squares represent categories for which insect sampling was done

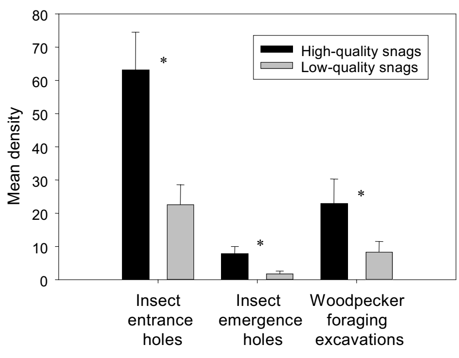

FIG. 2. Mean densities (number per square meter; +1 SE) of wood-boring beetle larval entrance holes (insect entrance holes), wood-boring beetle larval emergence holes (insect emergence holes), and foraging excavations of Black-backed Woodpeckers (woodpecker foraging excavations) for high-quality and low-quality snags in the burned forest landscape near Val-Paradis, Quebec ($n = 30$ snags). Asterisks show statistically significant differences.

Discussion

In eastern boreal forest landscapes, where fire is the major natural disturbance, recently burned forests offer abundant foraging opportunities for Black-backed Woodpeckers. However, not all postfire snags have the same foraging potential. Foraging signs and direct observation of Black-backed Woodpeckers clearly indicate that both snag size and deterioration influence their selection for foraging. Moreover, our results show that selection of larger and less deteriorated snags is linked to a higher availability of insect prey. The strong correlation between densities of woodpecker foraging holes and wood-boring beetle larval holes suggests that snag selection is not random: Woodpeckers tended to select snags and portions of snags that contained higher densities of wood-boring insects.

Our results support previous studies that showed that larger snags are preferred by woodpeckers for foraging activities (Mannan et al. 1980, Raphael and White 1984, Goggans et al. 1989). Mannan et al. (1980) suggested that woodpeckers might use larger snags more frequently because they may have more adult or larval insects than smaller ones. We found that larger snags had indeed higher densities of wood-boring beetle larva entrance holes than smaller snags.

Previous studies showed that Black-backed Woodpeckers select a wide variety of tree species for foraging (Apfelbaum and Haney 1981, Goggans et al. 1989, Villard and Beninger 1993, Hutto 1995, Murphy and Lehnhausen 1998). In our study, black spruce and jack pine—the two main tree species present—were used in proportion to their respective availability.

Our study also pointed out that for the same DBH, a less-deteriorated snag had a higher probability of use than did a more deteriorated one. Among the variables used to describe snag deterioration, crown condition was the best predictor of use by foraging Black-backed Woodpeckers. Deterioration of snags in postfire forests may reflect either mortality prior to fire or mortality as a consequence of fire. High deterioration values (4, 5, 6) corresponded to snags that were already dead and considerably decayed prior to fire whereas low values (1, 2, 3) represented trees killed by the recent fire. Differences within low deterioration values are linked to burn severity. Hence, snags with lower values were burned less severely, had a more intact, crown and more needles and small branches compared to snags with higher values (A. Nappi pers. obs.). Surprisingly, the variable of bark burn severity which also represents severity of the fire did not come out in the logistic regression model. That may be explained by the little variability shown by that variable; the Val-Paradis fire entirely consumed the bark for an important proportion of snags.

Snag deterioration combined with DBH influenced density of wood-boring beetle larvae. Woodpeckers avoided more degraded snags (prefire or severely burned postfire snags) in which wood-borers probably oviposited less and where larvae were more susceptible to desiccation (Rose 1957, Ross 1960, Murphy and Lehnhausen 1998). In a recently burned spruce forest in Alaska, Murphy and Lenhausen (1998) also found that abundance of cerambycid eggs was initially low on heavily scorched spruces and that larval survival was poor as a consequence of rapid sapwood desiccation.

Snags of high predicted quality harbored an important density of potential prey insects in the first 1–5 m of the trunk, which roughly corresponded to the zone where Black-backed Woodpeckers have been observed foraging (Villard and Beninger 1993). Nevertheless, low-quality snags may offer favorable microhabitat for wood-boring beetles, but more at the base of trees (lowest first meters) where trunk size is bigger and where bark thickness favors higher moisture levels.

Differences among studies of the attributes associated with the use of snags by Black-backed Woodpeckers in stand-replacing fires may reflect the complex interactions between tree species, tree size, burn severity, time since fire, and colonization and survival rates of wood-borer insect prey (Villard and Beninger 1993, Murphy and Lehnhausen 1998, Powell et al. 2002). Thus, importance of postfire forests as a foraging habitat for the Black-backed Woodpecker may vary in regards to prefire characteristics of trees and conditions induced by fire.

In North American boreal forests, large burned areas are becoming more accessible as road networks develop, resulting in a considerable increase of salvage logging. In Quebec, for example, recent modifications of legislation and regulations provide incentives to increase salvage logging on public lands (Quebec Government 2002). Those regulations do not include any management recommendations for snag retention in salvaged cutover areas. Considering that Black-backed Woodpeckers are sensitive to salvage logging (Saab and Dudley 1998), retention of unsalvaged tracts within recently burned forests may be important for maintaining regional populations. That is especially crucial, if Black-backed Woodpecker populations are maintained by a patchwork of recently burned forests, as suggested by Hutto (1995) and Murphy and Lenhausen (1998). Snag retention within those tracts should include trees of high quality as foraging substrate (large DBH and low deterioration) that still have a commercial value. Future studies should aim at determining the size and spatial arrangement of retention blocks of unsalvaged snags in recently burned forests. More knowledge on the spatial relationship between woodpeckers and their prey should provide insightful information on how much and where unsalvaged habitat should be set aside in salvaged logged forests.

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