Characteristics of habitat used by pileated woodpeckers in Great Lakes–St. Lawrence forest region of Ontario

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Abstract: We documented habitat used by pileated woodpeckers for foraging in Great Lakes – St. Lawrence forests of Ontario of central Ontario at the tree and stand scales. At the tree scale, we found that the pileated woodpeckers used a range of tree species and used trees that were generally larger than other trees available at the site. We also found that pileated woodpeckers used a higher portion of snags compared to live trees. All five snag classes were used, but classes 4 and 5 (higher decayed classes) were used more than expected. At the stand scale, we developed a habitat suitability index (HSI) model that predicted the presence of pileated woodpecker foraging activity based on forest-type, stand age, and canopy closure. Foraging use by pileated woodpeckers appeared to peak in stands ca. 120–150 years of age and with a canopy closure of approximately 60%. Foresters are encouraged to set management objectives at both the tree and stand scales. At the tree scale, it is important to retain larger trees (i.e. > 25 cm dbh), especially snags, of a variety of species for foraging opportunities. At the stand scale, a variety of forest types can provide pileated woodpecker foraging habitat. Our findings suggest that pileated woodpeckers may not be ‘old-growth obligates’ but actually prefer foraging in forests mature in development with a partly open canopy (i.e. approximately 60% canopy closure).

Key words: Dryocopus pileatus, foraging, forest management, pileated woodpecker, habitat supply modeling, HSI, Ontario.

Introduction

The pileated woodpecker (*Dryocopus pileatus*) is the largest woodpecker in North America, averaging 42 cm in length (Kilham 1983). The species is widely distributed throughout forested regions in North America from Great Slave Lake to Texas and Florida (Dance, 1987). In Ontario, the pileated woodpecker favours forested areas south of the Hudson Bay Lowland (Speirs 1985). Pileated woodpeckers are strong excavators and feed primarily on ants (especially carpenter ants *Camponotus* spp.) nesting in dead wood (i.e. snags) or living trees with advanced heartwood decay (Hoyt 1957, Bonar 2001). Pileated woodpeckers are most often associated with large tracts of old forests (e.g. Bull and Meslow 1977, Renken and Wigers 1989, Bull and Holthausen 1993, Conner et al. 1994, Flemming et al. 1999, and Lemaitre and Villard. 2005).

Several jurisdictions across North America (including Ontario) have identified the pileated woodpecker as an umbrella species for forest management because its habitat needs are believed to encompass those of a larger group of wildlife species that require mature and old forest with abundant cavity trees, snags, and downed woody debris (Bull and Meslow 1977, Koven and Martel 1994, Aubry and Raley 2002). For example, the pileated woodpecker provides excavated cavities that are in turn used by a number of other species such as the boreal owl (*Aegolius funereus*), screech owl (*Otus asio*), saw-whet owl (*Aegolius acadicus*), wood duck (*Aix sponsa*), common merganser (*Mergus merganser*), American kestral (*Faco sparverius*), common flicker (*Colaptes auratus*), northern flying squirrel (*Glaucomys sabrinus*), and American marten (*Martes americana*) (McClelland 1977, Bonar 2000).

To develop effective guidelines to help forest managers conserve habitat for this species, it is important to identify the forest habitat characteristics used by the pileated woodpecker. Little is known about pileated woodpecker habitat use in the Great Lakes-St. Lawrence (GLSL) forest of eastern North America. Differences in forest types and timber harvesting systems between western North America, where a majority of research has taken place, and Ontario (where little has taken place) make it difficult to transfer existing knowledge of pileated woodpecker habitat use to the GLSL. Conservation of pileated woodpecker habitat requires the understanding and protection of forest at two scales: the tree and stand. At the tree-scale, it is important to identify the tree characteristics (e.g. certain types and sizes of trees, snags, etc.) of used habitat, in order for them to be managed during harvest activities. At the broad scale, forest managers need to identify the types, ages, and structure of forest stands used by the pileated woodpecker. Forest managers can then analyse habitat supply to evaluate different forest management regimes, and ensure that a certain amount of pileated woodpecker habitat is conserved across the broad forest landscape.

The objective of this study was to document habitat use by pileated woodpeckers in central Ontario at the tree and stand scales and to use this information to develop a habitat suitability index (HSI) model that could be used to conduct habitat supply analyses across the broad landscape. The focus of the paper is on quantification of foraging habitat; however we also present some descriptive and qualitative data on nest and roosts to provide a complete compilation of pileated habitat use identified in this study.

Study Area

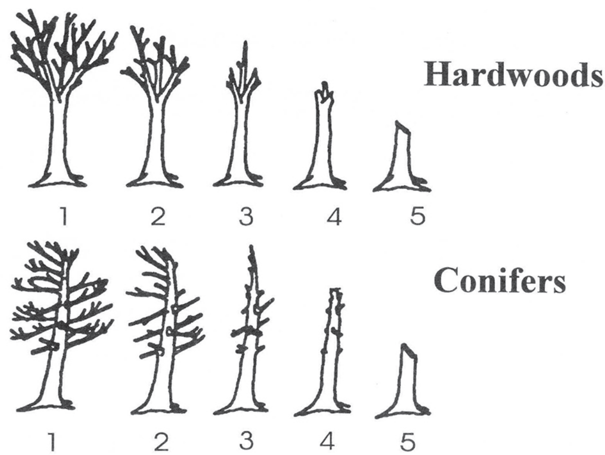
We conducted our study of pileated woodpecker habitat use within the GLSL forest region (Rowe 1972) of central Ontario, Canada. The region extends from 45°N to 47°N and from 78°W to 85°W. This forest is a transition zone between the conifer-dominated boreal forest to the north and the hardwood-dominated deciduous forest to the south. The hardwood forest in this region include both tolerant hardwood forest (forests that are tolerant to shade) and intolerant hardwood forest (forests that like full sun exposure or intolerant to shade). Overall the forest cover in the GLSL is characterized by sugar maple (*Acer saccharum*), yellow birch (*Betula alleghaniensis*), American beech (*Fagus grandifolia*), eastern hemlock (*Tsuga canadensis*), eastern white pine (*Pinus strobus*), and red pine (*Pinus resinosa*) (Chambers et al. 1997). The area has a temperate continental climate with cool winters and warm summers. Elevation ranges from 150 m above sea level (asl) along the shores of the Great Lakes and the Ottawa River to 575-600 m asl on the Algonquin Dome and the eastern shores of Lake Superior (Chambers et al. 1997).

Methods

Study sites were selected from sample plots established for the purpose of developing a forest ecosystem classification (FEC) for central Ontario by the Ontario Ministry of Natural Resources. The FEC defines 25 dominant forest community types (referred to as 'ecosites') within the GLSL forest of central Ontario based on analysis of data from a network of 1539 sample plots (Chambers et al. 1997). The FEC sample plots were located in forest stands with uniform site characteristics, species composition, stand structure, and had no disturbance (e.g. from fire, wind, or timber harvesting) within the past 25 years (Chambers et al. 1997). Each FEC sample plot covers 0.04 ha. Information on vegetation community type (ecosite), species and size of all standing or leaning trees (live and dead), overstory age (age of stratrum of tress above other vegetation in the uppermost canopy), and overstory canopy closure had already been collected for the majority of plots (although some snag data were determined to be missing after we visited the sites and was re-measured). From these original 1539 plots used in the creation of the FEC, we used stratified-random sampling on FEC type to select our subset of study sites. In total, we visited and surveyed 466 plots during May through August 1995. Each tree and snag (free standing or leaning) in each plot was surveyed for evidence of foraging, roosting, or nesting activity by pileated woodpeckers. Foraging by pileated woodpeckers was distinguished from other species by noting holes that were at least 5 cm in depth and/or 5 cm in length (Bull et al. 1990). Nest holes were distinguished by dome-shaped entrance 10 – 13 cm high and 7 – 10 cm wide (Bull et al. 1990) and appeared to open up from the entrance. Roast activity was distinguished by 2 of more holes similar to nesting holes (although often more round than dome-shaped) and usually 30 – 60 cm from each other (Bull et al. 1990).

We initially attempted to estimate the age of the foraging activity but ultimately pooled data for analysis due to sample size. However, very old holes (i.e. those with dark wood or with moss growing inside) were not recorded because they may have been created when the forest stand had rather different characteristics than at the time of the survey. The intensity of foraging was also considered. Trees with up to four small holes (5-15 cm long), or one large hole (>15 cm long) were classed as having low intensity. Those with five to ten small holes or two to four large holes were classed as having medium intensity. Trees with five or more large holes were considered to have high intensity. Snags were classified into one of five decay class categories (Hayden et al. 1995), with class 1 being the least decayed and class 5 being the most decayed (Figure 1). The foraging location was recorded in one of four categories: stump (0-1.3 m height), bole (main trunk above 1.3 m), dead branches, or crotch (where two or more large branches meet the trunk).

In addition to feeding holes, excavated nest holes and roost holes were recorded. After each plot was completely surveyed, four transects were walked to locate additional nests and roosts in an attempt to augment habitat selection data. Transects were 40 m in length and radiated from the center of each plot in the four cardinal directions. Transects were restricted to this size in an attempt to stay within the original forest stand-type of the



Decay Class 1 - Tree is recently dead. Top is intact. Most fine branching is still present. Bark is intact.

Decay Class 2. Top is intact. Most of the fine branches have dropped. More than 50% of the coarse branches are left. Bark may begin to loosen.

Decay Class 3 - Top is intact. Fewer than 50% of the coarse branches are left. Depending on the species, bark may (e.g. white pine) or may not (e.g. white brich) have sloughed off.

Decay Class 4- Top is broken. No coarse branches remain. Bark may or may not have sloughed off. Height at least 6 m.

Decay Class 5 - (stub) Top repeatedly broken. No coarse branches remain. Bark may or may not have sloughed off. Height less than 6 m.

Note: Trees that have died before attaining a height of 6 m should be assessed using the diagrams. They are not automatically classified as Decay Class 5. Similarly, if the tree in question has never attained a height of 6m, it cannot be coded as a Decay Class 4.

Figure 1: *Snag decay classes (Hayden et al. 1995).*

sample plot (i.e. the 0.04 ha). All visible nests from the transect line within approximately 10-15 m were recorded.

Statistical Analyses

We used descriptive statistics to characterize foraging activity at tree and stand scales. We performed chi-square goodness-of-fit tests to determine if foraging was distributed among tree species in proportion to their availability. We then followed techniques described by Neu et al. (1974) to determine which sites were selected, avoided, or used in proportion to their availability. Because tree dbh was not normally distributed, we used the nonparametric paired Wilcoxon test to compare the trees used for foraging with the average dbh of trees in the stand. We also used the nonparametric Mann-Whitney U test to compare the intensity of use between live trees and snags. We used chi-square tests to determine if foraging differed between groups of foraging trees (e.g. conifers and hardwoods, live and dead trees). We also used chi-square tests to compare the intensity of foraging and location of use on the tree with that which was randomly expected. Because of the small sample size of nests and roosts located in and around the plots, we developed only descriptive statistics for these data.

For the stand-scale analysis, we developed descriptive statistics of foraging use by FEC ecosite type. We performed chi-square goodness-of-fit tests to determine if foraging was distributed among habitats (i.e. FEC ecosites) in proportion to their availability. We then followed techniques described by Neu et al. (1974). When the chi-square tests determines a difference in usage, a Bonerroni z-statistic is used to determine which sites were selected, avoided, or used in proportion to their availability.

We used stepwise logistic regression analysis to develop a model to predict the probability of encountering pileated woodpecker foraging activity. We used stepwise because we wanted to predict a dichotomous dependant variable (i.e. present/absence of foraging activity) and we wanted to do exploratory analysis of variables relationships rather than theory testing (Manard 2002). Some pitfalls in using the stepwise logistic regression approach have been identified in the literature and should be considered interpretation of our results including: bias in parameter estimation, inconsistencies among model selection algorithms, and inappropriate reliance on the best model (Whittingham et al. 2006, Mundry and Nunn 2006). We acknowledge that variables in the model identified may not be causing the pileated woodpecker foraging presence, but maybe valuable variables for forest managers to use in the predicting of pileated woodpecker foraging presence. Habitat variables were used in a logistic regression, with foraging activity as our dependent variable, with ±-to-enter = 0.5 and ±-to-remove = 0.10, using the computer program SAS (SAS Institute, 1990). For the logistic regression model results we presented the likelihood ratio test (chi-square difference) and the predicted classification of the original categories. All of other results are presented as mean $\pm$ SE. P-values $\leq$0.05 were considered significant.

Results

Foraging Tree Selection:

We located 312 trees with foraging evidence from the 466 plots. The majority of the trees used for foraging were snags (75%), followed by live trees (25%). Foraging trees represented a low percentage of the available live trees (0.6%) and snags (10.7%, n = 299 plots). Eighteen tree species were used, with aspen (*Populus* spp.) being used most frequently (35.9%). Hardwoods (n = 182) were used more than conifers (n = 128) (X^2 = 10.05, P = 0.02). We found that frequency of foraging activity was not independent of tree species (X^2 = 236.7, df = 17, $P < 0.001$). Of the 18 tree species used, we found six to be used more than expected: aspen, white pine, sugar maple, white cedar (*Thuja occidentalis*), white birch (*Betula papyrifera*), and balsam fir (*Abies balsamea*). Black ash (*Fraxinus nigra*), white ash (*Fraxinus americana*), American beech, yellow birch, hemlock, red pine, black spruce (*Picea mariana*), and white spruce (*Picea glauca*) were used less than expected. We also found that two species, ironwood (*Ostrya viriniana*) and basswood (*Tilia americana*), were not used for foraging at all, despite being common within plots (> 75 trees).

Foraging trees averaged 24.5 $\pm$ 0.6 cm dbh (range 9.5-62.7 cm). Snags were used more than live trees (X^2 = 78.0, $P < 0.001$). Snags used for foraging were on average 23.1 $\pm$ 0.7 cm dbh and were significantly larger than available snags (n = 163, Z = -6.4, $P < 0.001$). Live trees used for foraging averaged 28.3 $\pm$ 1.2 cm dbh and were significantly larger than the average of live trees in the same plot (n = 78, Z = -5.3, $P < 0.001$). All five snag classes were used (Table 1), but classes 4 and 5 were used more than expected (X^2 = 13.2, df = 2, P = 0.001), and represented 70% (164 of 222) of the standing snags used. There were 1.2 standing snags used per plot (226 standing snags from 187 plots) which represents 30 standing snags used per ha.

Table 1: *Characteristic of dead trees (snags) used for foraging by Pileated Woodpeckers in central Ontario.*

Snag Decay Class	Used Trees (%)	Mean dbh (cm)
Class 1	4.3	22.8
Class 2	0.3	25.7
Class 3	10.3	24.9
Class 4	34.2	24.9
Class 5	35.9	19.8
Total/mean	**234 trees**	22.4

The majority of trees used for foraging had a low intensity of foraging activity (*n* = 176), followed by medium intensity (*n* = 105) and high intensity (*n* = 31). Trees with higher intensity use had larger dbh (X^2 = 13.2, *df* = 2, *P* = 0.001) (Table 2). Snags had significantly higher intensity of foraging compared to live trees (*U* = 6972, *P* < 0.001).

Table 2: *Frequency of foraging on trees by Pileated Woodpeckers.*

Frequency of Use	Number ofTrees	Mean dbh (cm)	Snags	Live Trees
Low	176 (56.4%)	21.4	118	58
Medium	105 (33.7%)	23.6	90	15
High	31 (9.9%)	29.7	26	5
Total/Mean	312	23.2	234	78

Pileated woodpeckers appeared to forage equally within the tree, between the stump (*n* = 124) and the bole (*n* = 111) (X^2 = 0.7, *df* = 1, *P* = 0.396), with 68 trees exhibiting foraging both on the stump and the bole. There was also some foraging on dead branches (*n* = 7) and in tree crotches (*n* = 2). When we examined conifers separately, there was a preference for foraging at the base on the stump (n = 75) compared to the bole (n = 26) (X^2 = 23.7, *df* = 1, *P* < 0.001). Conversely, there appeared to be more foraging on the bole (n = 84) of hardwoods (X^2 = 9.2, *df* = 1, *P* = 0.002) compared to the stump (n = 49).

Nests and Roosts Description:

From transects surrounding the plots and from within the plots, we found eight pileated woodpecker nest trees and 17 roost trees (Table 3). Of the eight nests, all were in hardwoods, with trembling aspen (*Populus tremuloides*) used most commonly (*n* = 5), followed by beech (*n* = 2), and sugar maple (*n* = 1). Live trees were primarily used for nesting (7 of 8). Nest trees averaged 44.2 $\pm$ 3.0 cm dbh (range 29.2-58.5 cm). Roosts were also mostly in hardwood trees, with trembling aspen again the most commonly used species (*n* = 8), followed by sugar maple (*n* = 4), yellow birch (*n* = 2), beech, (*n* = 1), white ash (*n* = 1), and white cedar (*n* = 1). Both snags (*n* = 8) and live trees (*n* = 9) were used for roosts. The roost trees averaged 45.7 $\pm$ 3.8 cm dbh (*n* = 16, range 24.0-74.4 cm).

Stand-Scale Selection:

Of the 466 plots surveyed, 187 had at least one tree with some pileated woodpecker foraging activity. All forest ecosite types (and groups) had some evidence of foraging activity (Table 4). We found that foraging trees were not distributed among ecosites in proportion to their availability (X^2

Table 3: *Characteristics of trees used for nesting and roosting by Pileated Woodpeckers in central Ontario.*

Activity	Tree	Tree Condition	Snag Class	DBH (cm)	Plot or Transect
Nest	Aspen	Snag	3	29.2	Transect
Nest	Aspen	Live		41.5	Transect
Nest	Aspen	Live		44.5	Transect
Nest	Aspen	Live		46.9	Transect
Nest	Aspen	Live		58.5	Transect
Nest	Beech	Live		38.7	Transect
Nest	Beech	Live		45.9	Transect
Nest	Sugar Maple	Live		48	Transect
Roost	Aspen	Snag	4	24	Transect
Roost	Aspen	Snag	3	29	Transect
Roost	Aspen	Snag	3	31	Transect
Roost	Aspen	Snag	3	31.9	Transect
Roost	Aspen	Snag	4	33.5	Transect
Roost	Aspen	Snag	4	42	Plot
Roost	Aspen	Snag	4	47	Transect
Roost	Aspen	Live		54	Transect
Roost	Sugar Maple	Snag	3	47	Transect
Roost	Sugar Maple	Live		44.5	Transect
Roost	Sugar Maple	Live		63.3	Transect
Roost	Sugar Maple	Live		70.9	Transect
Roost	Yellow Birch	Live		60	Transect
Roost	Yellow Birch	Live		74.4	Transect
Roost	White Ash	Live		34	Transect
Roost	Beech	Live		45	Plot
Roost	White Cedar	Live		undeter.	Transect

= 71.1, *df* = 24, *P* < 0.001). Of the 25 ecosite types, we found three to be used more than expected: ES14 (White Pine-Largetooth Aspen-Red Oak), ES19 (Aspen-Jack Pine-White Spruce-Black Spruce), and ES34 (White Cedar-Lowland Hardwoods). We also found that ES25 (Sugar Maple-Beech-Red Oak), ES26 (Sugar Maple-Basswood), ES28 (Sugar Maple-Hemlock-Yellow Birch, and ES30 (Hemlock-Yellow Birch) were used less than expected, while all other ecosites were used in proportion to their availability.

We further examined stand-scale selection with logistic regression analysis to build models to predict the presence of Woodpecker activity based on plot age, canopy closure, and dummy variables representing ecosite type. We initially tried dependent variables of differing amounts of use (i.e. plots with high versus low use considering the number of trees and intensity), but ultimately found that a dependent variable reflecting

Table 4: *Evidence of foraging activity by Pileated Woodpeckers within 25 forest community types (Ecosites) in central Ontario.*

Ecosite type	Sites Sampled	Sites With Foraging	Percent	Number of Trees Used	Utilization Availability
White and Red Pine Group					
ES11 (White Pine-Red Pine)	19	13	68.40%	20	Proportional
ES12 (Red Pine)	8	3	37.50%	6	Proportional
ES13 (Jack Pine-White Pine-Red Pine)	19	9	47.40%	13	Proportional
ES14 (White Pine-Aspen-Red Oak)	33	22	66.70%	41	Selected
Jack Pine and Black Spruce Group					
ES15 (Jack Pine)	8	2	25.00%	4	Proportional
ES16 (Black Spruce-Pine)	19	8	42.1	16	Proportional
Intolerant Hardwoods and Mixedwoods Group					
ES17 (Aspen-White Birch)	11	6	54.50%	9	Proportional
ES18 (Aspen-White Birch-White Spruce- Balsam Fir)	25	12	48	19	Proportional
ES19 (Aspen-Jack Pine-White Spruce-Black Spruce)	11	7	63.60%	16	Selected
ES20 (White Pine-Red Pine-White Spruce-White Birch-Trembling Aspen)	6	3	50.00%	5	Proportional
Tolerant and Mid-Tolerant Hardwoods Group					
ES21 (White Cedar-White Pine-White- Birch-White Spruce)	6	2	33.30%	3	Proportional
ES22 (White Cedar-Other Conifer)	9	2	22.20%	3	Proportional
ES23 (Red Oak-Hardwood)	19	7	36.3	11	Proportional
ES24 (Sugar Maple-Red Oak-Basswood)	23	8	34.80%	10	Proportional
ES25 (Sugar Maple-Beech-Red Oak)	21	6	28.6	7	Avoided
ES26 (Sugar Maple-Basswood)	14	4	38.6	4	Avoided
ES27 (Sugar Maple-White Birch-Aspen-White Pine)	43	16	37.2	21	Proportional
ES28 (Sugar Maple-Hemlock-Yellow Birch)	23	7	30.4	8	Avoided
ES29 (Sugar Maple-Yellow Birch)	23	6	26.1	12	Proportional
ES30 (Hemlock-Yellow Birch)	25	4	16	7	Avoided
Conifers and Hardwood Lowlands Group					
ES31 (Black Spruce-Tamarack)	14	3	21.4	5	Proportional
ES32 (White Cedar-Black Spruce- Tamarack)	20	8	40	15	Proportional
ES33 (White Cedar-Other Conifer)	10	5	50	12	Proportional
ES34 (White Cedar-Lowland Hardwoods)	31	16	51.6	33	Selected
ES35 (Lowland Hardwoods)	26	8	30.8	11	Proportional
Totals	466	187	40.1	311	

presence or absence of feeding activity performed the best. The final model included age, age^2, canopy closure (cc), canopy closure^2, and dummy variables for 14 of the 25 ecosites. The equation was significant ($X^2 = 39.4$, $df = 18$, $P < 0.003$) and correctly classified 57.7% of the original plots. The equation form is represented by P (Y) = $1/1+^{e-Y}$ where P (Y) = probability of the plot being used and Y= intercept + 3.9691* age - 1.9764* age^2+ 4.1486* cc - 3.2455* cc^2. P(Y) provides an HSI score for a forest stand ranging from 0 to 1. The intercept terms are ecosite-specific (Table 5). Because of the

Table 5: *Ecosite-specific intercepts for the non-spatial HSI model.*

Ecosite type	Intercept
ES11 (White Pine-Red Pine)	-2.196
ES12 (Red Pine)	-3.3
ES13 (Jack Pine-White Pine-Red Pine)	-3.3
ES14 (White Pine-Largetooth Aspen-Red Oak)	-2.276
ES15 (Jack Pine)	-4.123
ES16 (Black Spruce-Pine)	-3.3
ES17 (Aspen-White Birch)	-2.759
ES18 (Aspen-White Birch-White Spruce-Balsam Fir)	-3.3
ES19 (Aspen-Jack Pine-White Spruce-Black Spruce)	-2.475
ES20 (White Pine-Red Pine-White Spruce-White Birch-Trembling Aspen)	-3.3
ES21 (White Cedar-White Pine-White Birch-White Spruce)	-3.3
ES22 (White Cedar-Other Conifer)	-3.3
ES23 (Red Oak-Hardwood)	-3.3
ES24 (Sugar Maple-Red Oak-Basswood)	-3.647
ES25 (Sugar Maple-Beech-Red Oak)	-3.931
ES26 (Sugar Maple-Basswood)	-3.896
ES27 (Sugar Maple-White Birch-Aspen-White Pine)	-3.3
ES28 (Sugar Maple-Hemlock-Yellow Birch)	-3.71
ES29 (Sugar Maple-Yellow Birch)	-4.264
ES30 (Hemlock-Yellow Birch)	-3.897
ES31 (Black Spruce-Tamarack)	-4.593
ES32 (White Cedar-Black Spruce-Tamarack)	-3.684
ES33 (White Cedar-Other Conifer)	-3.3
ES34 (White Cedar-Lowland Hardwoods)	-3.3
ES35 (Lowland Hardwoods)	-3.734

* Note higher intercept value = higher preference

For Ecosite definitions see Chambers et al. (1997)

quadratic terms in the model, HSI scores increase initially with stand age up to ca. 120 - 150 years but then decline (Figure 2). Similarly, HSI scores increase with increasing canopy closure to about 60%, and then decline (Figure 2).

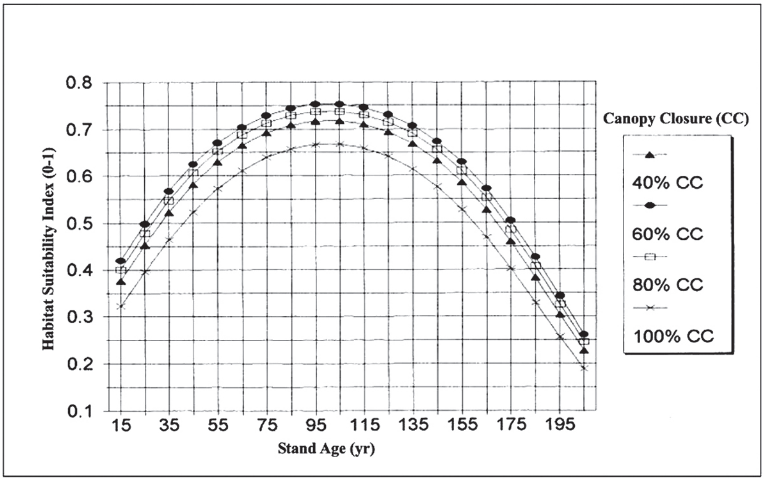


Figure 2: *HSI scores for Ecosite 11 as a function of stand age and canopy closure.*

Discussion

Foraging Tree Selection:

In central Ontario, pileated woodpeckers used a range of foraging trees, including 18 species of both living and dead trees of differing decay classes. However, our findings suggest that pileated woodpeckers select foraging trees with from there options in an unequal non-random manner. Pileated woodpeckers foraged on live trees and snags that were larger on average than those available in the stand. Several authors have also found a preference for foraging on larger trees (Bull and Meslow 1977, Bull and Holthausen 1993, Flemming et al.1999, Bonar 2001, Lemaitre and Villard 2005). The larger trees in our study also experienced higher foraging intensity. This may suggest that pileated woodpeckers are getting an even larger portion of their diet from larger trees. Pileated woodpeckers appeared to forage more frequently at the bases on coniferous trees, as compared to the boles of hardwood trees. Bonar (2001) found pileated woodpeckers foraged more frequently at lower heights on conifer trees, but attributed some of this foraging position difference to seasonal behaviour (with more foraging at the base during the winter). Our finding of increased foraging occurring on snags (75%). versus live trees is high compared to existing literature (e.g. Bull 1987, Millar 1992, Conner et al. 1994, Bull and Holthausen 1993, Lemaitre and Villard 2005).

Stand-Scale Selection:

Results from the availability analysis (Neu et al. 1974) helped us identify the forest types that had a higher use based on their availability. Considering of sampling design of forest plots in all forest types across the broad region, this information can help identify the forests that are more likely to be used across the landscape. Forest types that were rated preferred in central Ontario included those dominated by white and/or red pine, white cedar, upland black spruce, intolerant hardwoods, mixes of intolerant and tolerant hardwoods, and mixes of intolerant hardwoods and various conifers. Although we did find some foraging in all forest types, we would not go as far as calling pileated woodpeckers a habitat generalist at the stand, as Bonar (2001) did. It rather appears that pileated prefer a number of forest types and yet avoid others. These preferred forest types may be more likely to have the tree foraging characteristic identified either and the stand-scale characteristics (e.g. canopy closure) identified in the logistic regression analysis.

The pileated woodpecker is often considered a species reliant on or characteristic of ‘old-growth’ forest (Bull and Holthausen 1993, McClelland and McClelland 1999). While our HSI model results suggest that habitat use generally does increase with increased forest age, they also demonstrate that pileated woodpeckers will forage in forest of a wide range of ages. This supports the contention of Bonar (2001) that most ages of forests are used. Moreover, use eventually appeared to decline as the forest approaches ‘old-age’ (Figure 2). This may reflect the loss of relatively short-lived intolerant hardwoods (i.e. aspen) that were found to be preferred foraging trees.

The pileated woodpecker also is typically considered a species of dense forest (Renken and Wiggers 1989, Bull et al. 1992). Bull and Holthausen (1993) suggested that a canopy closure of 60%+ was optimal for nesting and roosting in Oregon. High canopy closure is likely beneficial as it may reduce the hunting efficacy of the pileated woodpecker’s primary predator, the northern goshawk (*Accipiter gentilis*) (Auser 1989). Our HSI model results also suggest that 60% crown closure is optimal, but that use may actually decline if forest is denser (Figure 2). Similarly, Bonar (2001) found that stands with > 70% canopy closure were not preferred. Denser stands have microclimates that are less suitable for carpenter ants which are the pileated woodpeckers' primary prey (Bonar 2001).

Nests and Roosts Description:

Considering the caveat of our small sample size, nest and roosts tree selection did show some similarity to the foraging tree selection. Nest and roost trees were larger-sized trees, with a variety of tree-species and both live and dead trees being used. Bonar (2000) also found similar patterns for nest and roost tree selection to forage tree selection at both the tree and stand-scale. This supports forest and wildlife managers modelling habitat selection on more easily obtainable local foraging selection data than nesting/roosting selection data. The descriptive results of nest and roost tree selection provides an important baseline data not previous collected for this region.

Management Considerations:

This study has provided some important understanding of pileated woodpeckers habitat use but can also provide some important information for forest and wildlife managers to consider. Managing habitat for pileated woodpeckers will require both the provision of tree-scale and stand-scale habitat features. At the tree scale, it is important to retain larger trees (i.e. > 25 cm dbh) of a variety of species for foraging opportunities. Larger trees in this study provided higher frequency foraging. Although we did find evidence of foraging on trees as small as 9.5 cm, managers should be careful about applying minimum size standards (based on minimum field value) and would do better to consider mean values (Conner 1979, McClelland and McClelland 1999). Managers often apply minimum dbh size retention in forest harvest blocks (as foraging or nest trees for pileated woodpecker) based on smallest recorded dbh (McClelland and McClelland 1999). Loggers may opt to leave more of smaller sized (slightly above the minimum) than the higher volume (more timber valuable) larger trees. This may be detrimental to pileated woodpecker populations. Mean values of dbh (tree > 25 cm) may provide more optimal foraging opportunities for pileated woodpeckers.

Standing dead trees (the most-used tree in this study) should be retained where they do not pose a safety risk to forest workers during harvesting, site-preparation, or other field activities. Special attention should be given to the retention of standing snags in advanced stages of decay, which represented 70% of the snags used for foraging in our study.

Bonar (2000) provided an extensive list of species that use pileated woodpecker cavity trees. Interestingly, we observed a red-breasted nuthatch (*Sitta canadensis*) and a flying squirrel using cavities found in this study. Although our sample size of nest and roosts trees was small, based on the results obtained we recommend that those trees retained to be potential cavity trees be at least 45 cm dbh.

At the stand scale, forest managers should consider that a variety of forest types can provide pileated woodpecker foraging habitat. Our findings suggest that pileated woodpeckers may not be 'old-growth obligates' but prefer foraging in forests mature in development with a partly open canopy (i.e. 60% canopy closure).

We feel our HSI habitat model has an advantage to local managers over others pileated wood pecker models available (e.g. Schroeder, 1983) because this model has gone through calibration and verification (Brooks 1997). Our model was first calibrated by being designed to fit local forests and local forest classification (i.e. FEC). The model was then verified based on pileated woodpecker use at 466 sites. The model has also gone through separate landscape validation (Bush 1999) where the increases in the total amount and core areas of preferred habitat (as described by model in this paper) were positively correlated with pileated woodpecker presence. Our HSI model has also been adapted into a categorical (i.e. preferred, suitable, unsuitable) habitat supply model that is used in forest management planning activities in Ontario (Kloss 2002). Other jurisdictions can adapt our findings and/or approach to local forest types.

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