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Pileated Woodpecker Habitat Ecology In
Boreal Forests - Project Update 1996/97
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Pileated Woodpecker Habitat Ecology In Boreal Forests - Project Update 1996/97

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Pileated Woodpecker Habitat Ecology in Boreal Forests

1996-1997 Progress Report

Preliminary Information - Do not use as Reference

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April 27, 1997

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Introduction

The Foothills Model Forest initiated a pileated woodpecker (Dryocopus pileatus) habitat ecology study in 1993. Most field work ended in 1996, although limited habitat information will be collected in 1997. This report summarizes information and data analysis completed as of March 31, 1997. As data compilation and analysis is still ongoing, preliminary results stated in this report are subject to revision. The final project report is expected to be completed by March 31, 1998.

The purpose of this project is to obtain habitat ecology information for pileated woodpeckers in boreal forest ecosystems. This information is needed to develop forest management plans with conservation strategies for pileated woodpecker, that will in turn help to conserve other cavity-using forest wildlife species.

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Rationale

The pileated woodpecker is the largest woodpecker in North America. It excavates nest cavities in large trees and forages for arthropod food primarily in dead wood (Bull 1987). A new nest cavity is excavated each year, producing a supply of cavities for secondary cavity-using species. For example, 18 of 19 cavities used by nesting boreal owls (Aegolius funereus) in an Idaho study were originally excavated by pileated woodpeckers (Hayward et al. 1993). In northern forests, where natural cavities may be less common, a continuing supply of old pileated woodpecker cavities could be particularly important for large cavity-using wildlife species that cannot enter cavities made by smaller woodpecker species.

Pileated woodpeckers are non-migratory (Hoyt 1957, Bock and Leathien 1975) and have a low reproductive rate (2-3 young/pair/year) compared to other woodpecker species of boreal forests (Short 1982). Life-mated pairs defend large territories all year against other pileated woodpeckers (Kilham 1976, 1979). Pileated woodpeckers are associated with mature and older forests (McClelland 1979, Bull 1987, Renken and Wiggers 1989, Mellen et al. 1992). These characteristics make pileated woodpeckers a suitable species to select for monitoring effects of long-term habitat changes in boreal forests.

In other forest regions, pileated woodpeckers excavate a new nest cavity each year in large trees, roost at night in tree cavities, and feed primarily on carpenter ants and other insects obtained mostly from dead wood (Hoyt 1957, Bull 1987). Little is known about pileated woodpecker habitat ecology in boreal
forests. Differences between boreal forests and more southern forests where most pileated woodpecker research has been conducted are substantial. There are fewer and different tree species, and the average size of trees is smaller. Because natural disturbance regimes are relatively more frequent, the average age of boreal forests is lower. Natural disturbances are dominated by forest fires, and catastrophe-scale fires are the major source of disturbance in terms of area impacted. Winters are long and cold, with extensive periods of snow cover.

The pileated woodpecker is a major predator of wood-boring forest insects, notably carpenter ants (Camponotus spp). This species may be negatively affected by intensified forest management if large trees and dead wood decline in abundance (Bull et al. 1992). For this reason, the pileated woodpecker has been selected as a management indicator species for some forests in the United States as part of the National Forest Management Act, which directs the U.S. Forest Service to manage National Forests for pileated woodpecker habitat sufficient to ensure the continued existence of the species (Bull et al. 1992). In Canada, the pileated woodpecker has been selected for management emphasis in British Columbia (Guy et al. 1994), Alberta (Bonar et al. 1990), Saskatchewan (Anonymous 1991), Manitoba (Millar 1994), Ontario (Naylor et al. 1996), Quebec (Savignac et al. 1996), and New Brunswick (Woodley, 1997).

The United States Fish and Wildlife Service developed a preliminary Habitat Suitability Index (HSI) model for the pileated woodpecker (Schroeder 1983) to evaluate the year-around habitat of the pileated woodpecker. The Foothills Forest Decision Support System includes a wildlife habitat supply analysis module that interprets habitat suitability for individual species based on forecasts of forest inventory information. The module will be used to assess various habitat management alternatives for the pileated woodpecker, one of 35 species included in the module. Wildlife habitat supply analysis will be used in developing the overall management strategy for the Foothills Forest. Because at least 45 other species are associated with pileated woodpecker habitat, validation of the preliminary habitat model is a high priority.

Objectives

Is pileated woodpecker habitat selection, home range size, reproductive success, and adult survival related to the type, density, and interspersion of foraging substrates, nest trees, and roost trees in boreal forests? In wildlife ecology the concept of habitat selection refers to the relative proportion of activity-dependent use of habitat units compared to the relative availability of habitat units. Use depends on activity type and must be defined for each measure of habitat selection. The null hypothesis is that use is comparable to availability (no selection). Positive selection occurs when an animal uses a habitat unit more often than expected and negative selection occurs when an animal uses a habitat unit less often than expected.

In this observational study, scale-dependent relationships between use and availability of three aspects of habitat quality (nest trees, roost trees, and foraging substrates) will be determined. Nest trees, roost trees, and foraging substrates used by pileated woodpeckers more often than expected are assumed to have higher quality than habitat aspects used in proportion to their availability or less often then expected. This relationship depends on the theory that animals will attempt to use the highest quality habitat available to them. Specific objectives are:

1. By season, characterize nest trees, roost trees, foraging substrates, stand-level habitat use, home range size and compare observed characteristics to availability as a measure of habitat quality.
2. By season, compare use of nest trees, roost trees, and foraging substrates within home ranges to availability of potential nest/roost trees and foraging substrates within home ranges.
3. By season, compare use of stands within home ranges in relation to density of foraging substrates and distance from nest/roost trees.

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4. By season, compare home range size with density and location of nest trees, roost trees, and foraging substrates within home ranges.

5. Compare home range size with piliated woodpecker survival and reproductive success.

6. Revise, calibrate and corroborate the Schroeder habitat model, measure habitat use, particularly foraging habitat, by season, at four scales:

- **Landscape** Relative use of forest-level habitat characteristics. Landscape variables include elevation, large-scale ecological classification, broad forest age and species composition (mixedwood, conifer, deciduous, etc), climate/moisture regime, etc.

- **Stand** Relative use of stands within territories. Stand variables include canopy closure, tree species composition, elevation, slope aspect, understory composition, age, height, etc.

- **Element** Relative use of within-stand micro-sites or specific habitat elements. Element variables include foraging site, foraging substrate (log, stump, stub, snag, tree), site-level description, etc.

- **Sub-element** Relative use of habitat element sub-units. Sub-element variables are the same as those of elements, refined by additional description such as position and other measurable variations within the habitat element.

7. Communicate the results to other forest managers and persons interested in forest wildlife habitat ecology.

**Background**

Published information on the piliated woodpecker comes mostly from the United States. Recent research was primarily in the Pacific Northwest (Aubry and Raley 1992, Bull et al. 1992, 1993). At the time this research was initiated, general distribution notes and nest records were the only available information on piliated woodpeckers in Canada. Research programs have since been initiated in British Columbia, Quebec, and New Brunswick.


Pileated woodpeckers occur in forests of North America from northern British Columbia to northern California in the west and Nova Scotia to Florida in the east (Short 1982, Bull and Jackson 1995). In Alberta, the species breeds mainly in the Boreal Forest, Foothills, and Rocky Mountain natural regions, and was recorded in 15.3% of 2206 100 km2 areas surveyed for the Alberta Breeding Bird Atlas (Semenchuk 1992).

Adults average weights are 240-341 g, and males are 5-10 % heavier than females (Short 1982). In addition to other characteristics, malar coloration visibly distinguishes the sexes (red in males, black in females). Habitat use between sexes may not be similar, although this has not been studied in detail (Bull 1980, Mellen et al. 1992). Adults have reached the age of 11 years in the wild (Hoyt 1952).

Pileated woodpeckers are permanent residents and there is evidence that life-mated monogamous pairs defend territories throughout the year against other pileated woodpeckers (Hoyt 1957, Kilham 1976, Bull 1987). A habitat management strategy therefore must accommodate the annual habitat requirements of mated pairs. Annual periods of expected stress are expected to include the nesting period, when birds must produce and feed young, and winter, when the availability of food resources is limited and climatic conditions are most severe.
A new nest cavity is constructed each year, sometimes in the same tree used in previous years. Nest trees selected in other areas are often very large dead trees of coniferous species (Conner et al. 1975, Bull 1987, Harris 1983, McClelland 1979, Mellen 1987). There is also evidence that deciduous species are used (Carriger and Wells 1919, Peck 1983, Harestad and Keisker 1989). Acceptable habitat must therefore include a supply of suitable trees to use for nest cavity excavation.

Pileated woodpeckers roost each night in tree cavities, which include old nest cavities, natural cavities, and cavities excavated exclusively for roosting by the birds. Roosting cavities may provide protection from predators and physiological moderation against the influence of temperature and moisture (Bull et al. 1992). The availability of roost cavities may be particularly important for winter survival in areas with severe winter climate.

Both sexes drum on standing dead wood, probably to establish and defend territories and as part of the courtship process (Hoyt 1957, Kilham 1959, 1979). Drumming takes place all year, but especially marks the pre-breeding period. It seems to proclaim a territory and occurs often at particular drumming trees (Short 1982). Repeated use of drumming trees, particularly those near the boundaries of neighbouring pairs, may be important in defending territories against encroachment by neighbouring pairs.

Pileated woodpeckers feed extensively on wood-boring insects throughout the year (Beal 1911, Hoyt 1957). They specialize on carpenter ants (Bent 1964, Hoyt 1950, Dater 1953, Beckwith and Bull 1985). Foraging methods change seasonally (Hoyt 1957, Conner 1979, McClelland 1979, Bull 1987). In summer, ants and other insects are obtained from the surface of logs, stumps, and standing dead/live trees using pecking and gleaning methods (Jackman 1975). In winter ants are obtained by extensive excavating at the bases of trees, dead and alive, with carpenter ant colonies (Hoyt 1957, McClelland 1979, Bull et al. 1986). Pileated woodpeckers also scale bark to obtain the larvae of wood-boring beetles (Bull 1987, Cannings 1987, Kroll and Fleet 1989), and eat plant foods, especially berries and fruits (Beal 1911, Hoyt 1957, Cannings 1987).

Annual home range estimates are not available. Seasonal home range estimates range from 70 ha in winter (Kilham 1976) to more than 1000 ha during the post-fledging period (Renken and Wiggers 1989, Mellen et al. 1992). Estimates of the minimum forest size needed to support a pair range from 23-260 ha (Tanner 1942, McClelland 1979, Bull and Meslow 1977, Bull 1987).

**Study Area**

Most information, including location and measurement of nest trees and indirect surveys of pileated woodpecker habitat use were made in the 26,000 km2 Foothills Model Forest in west-central Alberta. Nest and roost tree measurements were also obtained on an opportunistic basis throughout the forested areas of central and northern Alberta and parts of northern British Columbia and Saskatchewan through information supplied by cooperators. Detailed habitat ecology information was collected for pileated woodpeckers fitted with radio transmitters within approximately 50 km of Hinton, Alberta.

**Research Strategy**

This study was a mensurative observation of wild pileated woodpeckers and their habitat in boreal forests of northern Alberta. The overall study consists of scale-dependent and inter-related but separate aspects (Appendix 1).

1. By season, characterize nest trees, roost trees, foraging substrates, stand-level habitat use, home range size.
2. By season, compare use of nest trees, roost trees, and foraging substrates within home ranges to availability of potential nest/roost trees and foraging substrates within home ranges.
3. By season, compare use of stands within home ranges in relation to density of foraging substrates...
and distance from nest/roost trees.
4. By season, compare home range size with density and location of nest trees, roost trees, and foraging substrates within home ranges.
5. Compare home range size with pileated woodpecker survival and reproductive success.

Methods

A detailed description of experimental design, methods, and proposed statistical analysis is contained in a research proposal completed in spring 1994 (Bonar 1994).

Telemetry

Adult pileated woodpeckers were captured within the Hinton study area at nest or roost cavities using either a pole-mounted hoop covered with mist netting or a cloth bag, or a board trap. I attempted to capture both members of mated pairs where possible. Board traps consisted of a board mounted on a rat trap attached to the tree over the cavity entrance and manually released by an observer on the ground after a bird had entered the cavity, imprisoning the bird inside (Bull and Pedersen 1978). An observer climbed trees with cavities containing board-trapped birds, removed the bird from the cavity, placed it in a cloth drawstring-equipped bag and lowered the bag to a ground crew. During processing, the bird was held by the legs and a black hood was placed over the bird's head to reduce stress and lessen the possibility of injury to the bird.

Standard aluminum leg bands and plastic colour leg bands were placed on most captured birds to allow visual field recognition of individual birds. Two-stage 12 g1 telemetry transmitters with whip antennas (Holohill Systems Inc) were fitted on each adult using a backpack-style harness made of a single length of ⅛" or 3/8" Teflon™ ribbon. Harness ribbon was sewn together where it crossed at the bird's sternum, and superglue was used to secure the stitching and knots securing the ribbon at the transmitter package. Handling time averaged about 20 minutes from time of capture to time of bird release. Transmitter packages appeared to have minimal impact, if any, on the ability of birds to fly. Birds preened the harness ribbon into their feathers within a few days, and I did not observe any behaviour suggesting discomfort. Transmitter packages were replaced upon failure by recapturing birds, usually at roosts. The nominal battery life was 12 months, but individual packages varied in battery function from 5-13 months.

It was not possible to obtain completely independent samples, which is a common problem with telemetry data (Swihart and Slade 1985). Mellen et al. (1992) failed to demonstrate statistical independence of pileated woodpecker location data as much as 3 days apart. Radio-tagged birds were followed at regular intervals 2-10 days apart for approximately one-half day per follow to minimize autocorrelation effects. Observers used a telemetry receiver to locate the bird and then attempted to remain close enough to the bird to ascertain its location and activity through either direct observation or sound. If the bird moved out of contact, observations were temporarily suspended until contact was re-established. Observers recorded the location, time, and activity of the bird whenever the bird changed locations or activities. Characteristics of the substrate being used by the bird at each location were also recorded (Appendix 1).

Home Range

Home range size was estimated using the non-statistical minimum convex polygon technique for each radio-tagged bird using seasons determined by changes in the status and behaviour of the bird. The number of locations needed to determine home range size was determined by plotting number of

1 The transmitter package is less than 3% of the body weight of adult birds, which is within generally accepted tolerances for transmitter packages on birds established by the U.S. Fish and Wildlife Service and widely accepted in literature reporting field application.
locations against area and calculating the asymptote at which home range size does not increase with more locations.

Survival

Adult survival determined by monitoring survival of all radio-tagged birds was calculated using 2 methods. Simple annual survival in percent was calculated by dividing the number of birds alive at the end of each reproductive year (nesting to nesting) by the number of birds radio-tagged during the period. Adult survival was also calculated as a rate using the Kaplan-Meier method (Pollock et al. 1988). Reproductive success was estimated for each known nesting attempt as the number of young fledged/nesting attempt. The number of young in a nest within 1 week of the expected fledging date was used as an estimate of the number of young that fledged.

Foraging

Foraging substrate use was determined by directly observing foraging activity of radio-tagged birds, direct observations of other pileated woodpeckers, and indirect examination of foraging sites within the Hinton study area. Indirect examinations included foraging sites encountered during other field work and foraging sites measured at habitat characterization plots. Foraging substrate descriptions were obtained for all foraging sites used by each bird on each follow and for all foraging sites encountered during other field work and within habitat characterization plots. Estimated locations of foraging sites were mapped on 1:15,000 scale air photographs or orthophotographs and transferred into a Geographic Information System.

Stand Use

Within home ranges of radio-tagged birds, relative use of stands was estimated using three methods: 1. Number of foraging substrates used/ha estimate obtained by counting used foraging substrates on the habitat characterization plots; 2. The number of radio-telemetry locations in each stand by each bird; 3. The time spent doing each activity by each radio-tagged bird in each stand. Method 2, the number of radio-telemetry locations, is expected to provide the most reliable estimate. Method 1 will be compared to method 2 to see if indirect estimates provide a reasonable estimate of habitat use. If they do, indirect survey data can be used to corroborate telemetry data. Method 3 offers additional insight into activity-related habitat use beyond the location-specific level.

Independent variables were measured in nested circular plots within each home range to estimate population characteristics (availability of habitat). Nest tree and roost tree availability and foraging substrate availability were estimated at each plot. Trees were measured on 0.04 ha plots, and snags, stubs, logs, and stumps were measured on 0.1 ha plots. Plots were allocated using stratified random sampling within stands. The number of plots needed was estimated after a pilot program to determine within-stand variability.

Cavity Trees

Pileated woodpecker nest trees characteristics in boreal forests were unknown before the initiation of this study. Pileated woodpecker nests are difficult to find, and randomized sampling to obtain nest tree data was not logistically feasible. To increase the number of nest trees located, an extensive communications program was developed to ask volunteer cooperators to locate and report nests, and all confirmed nest trees located through any means in boreal forest types within the expanded study area were used in the analysis. Nest trees were located by following unmarked and radio-tagged birds, by searching within active home ranges, by eliciting responses from territorial birds using taped pileated woodpecker calls, and by listening for nestling calls. Evidence for nesting accepted included at least 1 of: eggs observed in

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a nest cavity; live young observed or heard in a cavity; adults repeatedly entering and leaving a freshly-excavated cavity during the nesting season.

Roost trees were located by following radio-tagged adult birds in the evening or locating them in the roost tree after dark, by observations of adults entering cavities in the evening or leaving them in the morning, and by examining cavity trees to see if pileated woodpecker droppings were present in the cavity or on the ground at the base of the tree. Evidence for roosting accepted included observations of birds roosting in a cavity and/or pileated woodpecker droppings in the cavity or on the ground at the base of the tree.

Additional cavity trees containing cavities excavated by pileated woodpeckers but not confirmed as either nests or roosts were located in conjunction with searches for nest and roost trees.

Habitat variables were measured for each cavity tree to facilitate analysis of cavity tree selection and use at different scales (Appendix 1). Tree location and associated site/stand characteristics were recorded to allow later spatial analysis using a GIS. Variables within a 0.04 ha circular plot centered on the cavity tree and a random paired plot within the same stand were measured to examine within-stand site selection. Variables characterizing the cavity tree and any associated cavities were measured to examine tree and cavity site selection.

Analysis

All data were entered into a Microsoft Access database. Spatial information was analyzed with a Geographic Information System, and statistical tests were processed using SAS (ref). A probability level of $P \leq 0.05$ was used to denote significance. Discriminant function analysis (DFA) was used to compare roost tree and nest tree characteristics. Regression was used to examine relationships between continuous variables. Chi-Square Goodness of Fit was used for tests of differences between distributions for available versus observed characteristics of categorical habitat variables, and $t$ - tests were used for continuous variables.

Habitat Suitability Index Model

Evaluation of the pileated woodpecker habitat model is part of the model evaluation package for the habitat supply analysis module of the Foothills Forest DSS framework. Evaluation of habitat models and impacts of timber harvesting are essential to the credibility of DSS initiatives and proposals for management alternatives. The end results will include a revised habitat model, guidelines for habitat management, a better understanding of pileated woodpecker ecology in foothills/boreal forests, and the basis for a long-term monitoring and adaptive management program.

Preliminary Results and Discussion

This section presents preliminary results and a brief discussion of findings to date. There is no statistical analysis, and data for most aspects is incomplete and subject to revision.

Telemetry

Radio transmitters were placed on 33 adult pileated woodpeckers ($F = 17$, $M = 16$) in 14 territories from 1993 to 1996 (Table 1). Transmitters were replaced as necessary, and individual birds were monitored from 5-754 days. Transmitters were removed from 13 of 16 birds still alive at the end of the telemetry study.
Approximately 8500 locations were obtained from 33 radio-tagged pileated woodpecker in 14 pair territories from June 1993 to June 1996. Telemetry location data was supplemented with visual observations of non-marked birds in the territories and by incidental observations of other pileated woodpeckers. Most of the telemetry data is still being compiled for analysis.
Table 1. Radio-tagged pileated woodpeckers in the Foothills Model Forest, Alberta, 1993-1996.

<table>
<thead>
<tr>
<th>Territory</th>
<th>Bird#</th>
<th>Sex</th>
<th>Start Date</th>
<th>End Date</th>
<th>Days</th>
<th>End Status</th>
<th>Death Cause</th>
</tr>
</thead>
<tbody>
<tr>
<td>Athabasca</td>
<td>9</td>
<td>F</td>
<td>29-May-94</td>
<td>18-Jun-96</td>
<td>751</td>
<td>alive</td>
<td>goshawk?</td>
</tr>
<tr>
<td>Athabasca</td>
<td>38</td>
<td>F</td>
<td>24-Oct-95</td>
<td>30-Jan-96</td>
<td>98</td>
<td>dead</td>
<td>goshawk?</td>
</tr>
<tr>
<td>Black Cat</td>
<td>15</td>
<td>F</td>
<td>30-May-94</td>
<td>17-Nov-94</td>
<td>171</td>
<td>dead</td>
<td>goshawk</td>
</tr>
<tr>
<td>Black Cat</td>
<td>16</td>
<td>M</td>
<td>02-Jun-94</td>
<td>17-Jun-95</td>
<td>380</td>
<td>dead</td>
<td>goshawk</td>
</tr>
<tr>
<td>Black Cat</td>
<td>30</td>
<td>F</td>
<td>07-Jun-95</td>
<td>08-Jul-96</td>
<td>397</td>
<td>alive</td>
<td></td>
</tr>
<tr>
<td>Bryan Creek</td>
<td>3</td>
<td>M</td>
<td>02-Jun-94</td>
<td>15-Feb-96</td>
<td>623</td>
<td>unkn</td>
<td></td>
</tr>
<tr>
<td>Bryan Creek</td>
<td>4</td>
<td>F</td>
<td>30-May-94</td>
<td>26-Nov-94</td>
<td>180</td>
<td>dead</td>
<td>goshawk?</td>
</tr>
<tr>
<td>Bryan Creek</td>
<td>25</td>
<td>F</td>
<td>17-Apr-95</td>
<td>20-Jun-96</td>
<td>430</td>
<td>alive</td>
<td>goshawk?</td>
</tr>
<tr>
<td>Camp</td>
<td>11</td>
<td>M</td>
<td>28-May-94</td>
<td>15-Feb-95</td>
<td>260</td>
<td>unkn</td>
<td></td>
</tr>
<tr>
<td>Camp</td>
<td>12</td>
<td>F</td>
<td>31-May-94</td>
<td>14-Jun-95</td>
<td>379</td>
<td>dead</td>
<td>goshawk?</td>
</tr>
<tr>
<td>Camp</td>
<td>18</td>
<td>M</td>
<td>10-Jun-93</td>
<td>11-Nov-93</td>
<td>154</td>
<td>dead</td>
<td>goshawk?</td>
</tr>
<tr>
<td>Camp</td>
<td>28</td>
<td>M</td>
<td>30-May-95</td>
<td>18-Jun-96</td>
<td>385</td>
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<td>goshawk?</td>
</tr>
<tr>
<td>Cold Creek</td>
<td>23</td>
<td>F</td>
<td>09-Apr-95</td>
<td>16-Nov-95</td>
<td>222</td>
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<td>mammal?</td>
</tr>
<tr>
<td>Cold Creek</td>
<td>24</td>
<td>M</td>
<td>03-Jun-95</td>
<td>17-Jun-96</td>
<td>380</td>
<td>alive</td>
<td></td>
</tr>
<tr>
<td>East Flats</td>
<td>13</td>
<td>M</td>
<td>31-May-94</td>
<td>04-Oct-94</td>
<td>126</td>
<td>dead</td>
<td>mammal?</td>
</tr>
<tr>
<td>East Flats</td>
<td>14</td>
<td>F</td>
<td>03-Jun-95</td>
<td>15-Mar-95</td>
<td>285</td>
<td>unkn</td>
<td></td>
</tr>
<tr>
<td>Everest</td>
<td>31</td>
<td>F</td>
<td>08-Jun-95</td>
<td>12-Jan-96</td>
<td>218</td>
<td>dead</td>
<td>accident</td>
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<tr>
<td>Everest</td>
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<td>M</td>
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<td>23-Jun-96</td>
<td>388</td>
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<tr>
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<td>10</td>
<td>M</td>
<td>31-May-94</td>
<td>16-Jun-96</td>
<td>749</td>
<td>alive</td>
<td></td>
</tr>
<tr>
<td>Fish Creek</td>
<td>27</td>
<td>F</td>
<td>07-Jun-95</td>
<td>12-Jun-95</td>
<td>5</td>
<td>dead</td>
<td>goshawk</td>
</tr>
<tr>
<td>Gaswell</td>
<td>7</td>
<td>M</td>
<td>31-May-94</td>
<td>23-Jun-96</td>
<td>754</td>
<td>alive</td>
<td></td>
</tr>
<tr>
<td>Gaswell</td>
<td>8</td>
<td>F</td>
<td>29-May-94</td>
<td>07-Jun-94</td>
<td>9</td>
<td>dead</td>
<td>goshawk</td>
</tr>
<tr>
<td>Gaswell</td>
<td>26</td>
<td>F</td>
<td>02-Jun-95</td>
<td>23-Jun-96</td>
<td>387</td>
<td>alive</td>
<td></td>
</tr>
<tr>
<td>Gregg Lake</td>
<td>21</td>
<td>M</td>
<td>29-Mar-95</td>
<td>22-Feb-96</td>
<td>330</td>
<td>dead</td>
<td>goshawk?</td>
</tr>
<tr>
<td>Maxwell Lake</td>
<td>1</td>
<td>F</td>
<td>31-May-94</td>
<td>30-Jun-96</td>
<td>761</td>
<td>alive</td>
<td></td>
</tr>
<tr>
<td>Maxwell Lake</td>
<td>2</td>
<td>M</td>
<td>29-May-94</td>
<td>30-Jun-96</td>
<td>763</td>
<td>alive</td>
<td></td>
</tr>
<tr>
<td>Pedley</td>
<td>17</td>
<td>M</td>
<td>11-Jun-93</td>
<td>26-Jun-93</td>
<td>14</td>
<td>dead</td>
<td>goshawk?</td>
</tr>
<tr>
<td>Pedley</td>
<td>33</td>
<td>F</td>
<td>03-Jun-95</td>
<td>06-Jul-96</td>
<td>399</td>
<td>alive</td>
<td></td>
</tr>
<tr>
<td>Pedley</td>
<td>34</td>
<td>M</td>
<td>08-Jun-95</td>
<td>18-Jun-96</td>
<td>376</td>
<td>alive</td>
<td></td>
</tr>
<tr>
<td>Prest Creek</td>
<td>5</td>
<td>F</td>
<td>30-May-94</td>
<td>20-Jun-96</td>
<td>751</td>
<td>alive</td>
<td></td>
</tr>
<tr>
<td>Prest Creek</td>
<td>6</td>
<td>M</td>
<td>28-May-94</td>
<td>10-Oct-94</td>
<td>135</td>
<td>dead</td>
<td>goshawk?</td>
</tr>
<tr>
<td>Prest Creek</td>
<td>29</td>
<td>M</td>
<td>01-Jun-95</td>
<td>02-Jun-96</td>
<td>367</td>
<td>alive</td>
<td></td>
</tr>
<tr>
<td>Solomon</td>
<td>36</td>
<td>F</td>
<td>22-Jun-95</td>
<td>19-Jul-96</td>
<td>393</td>
<td>alive</td>
<td></td>
</tr>
</tbody>
</table>

Landscape-Scale Distribution

Incidental observations of pileated woodpecker distribution in forested landscapes were obtained during cavity tree searches and as part of a breeding bird atlas program, which used a 5 km by 5 km sampling unit. Recent foraging excavations indicating pileated woodpecker occupation were observed in all locations examined. This leads to the hypothesis that pileated woodpecker pair territories may be more or less contiguous and cover most forested landscapes in the Foothills Model Forest study area. Sampling was primarily in the Upper Foothills, Lower Foothills, and Montane Natural Regions.

 Territory size

Although there were some minor differences, the minimum convex polygon (MCP) territory size of the male and female of each territorial pair was similar. Preliminary cumulative MCP areas for 13 pair territories ranged from 1000-4050 ha and averaged 2310 ha (Table 2).
Table 2. Pileated woodpecker pair territory size in the Foothills Model Forest, Alberta, 1993-1996.

<table>
<thead>
<tr>
<th>Territory</th>
<th>Number of Locations</th>
<th>Cumulative Territory Size (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Athabasca</td>
<td>530</td>
<td>2050</td>
</tr>
<tr>
<td>Black Cat</td>
<td>493</td>
<td>4050</td>
</tr>
<tr>
<td>Bryan Creek</td>
<td>344</td>
<td>1675</td>
</tr>
<tr>
<td>Camp</td>
<td>707</td>
<td>1725</td>
</tr>
<tr>
<td>Cold Creek</td>
<td>159</td>
<td>2100</td>
</tr>
<tr>
<td>East Flats</td>
<td>245</td>
<td>1000</td>
</tr>
<tr>
<td>Everest</td>
<td>71</td>
<td>2200</td>
</tr>
<tr>
<td>Fish Creek</td>
<td>453</td>
<td>2525</td>
</tr>
<tr>
<td>Gaswell</td>
<td>382</td>
<td>2175</td>
</tr>
<tr>
<td>Gregg Lake</td>
<td>101</td>
<td>1950</td>
</tr>
<tr>
<td>Maxwell Lake</td>
<td>264</td>
<td>3800</td>
</tr>
<tr>
<td>Prest Creek</td>
<td>413</td>
<td>3475</td>
</tr>
<tr>
<td>Solomon Creek</td>
<td>105</td>
<td>1300</td>
</tr>
</tbody>
</table>

I divided each year into periods that reflected changes in the annual cycle of pileated woodpeckers to examine seasonal territory size, but have not yet undertaken that analysis. Following are descriptions of the cycle changes that will be used to define seasonal territory size.

**Territory Affirmation/nest excavation**
Active territory affirmation behaviour started each year late February and early March when rates of calling and drumming by both sexes increased. Both individual birds and the pair often flew “circuits” along the boundaries of their territories, stopping to call and drum every 100-200 m. Encounters with neighbours always resulted in vocal and active skirmishes but did not seem to change territory boundaries.

Nest excavation started in the last 2 weeks of March and continued until late April or early May. Most pairs started multiple nest excavations each year. Drumming, calling, and circuits of territory boundaries decreased markedly as the nest cavity neared completion.

**Nesting**
Both birds tended to remain in the vicinity of the nest from cavity completion until just before the nestlings fledged. Adults rarely travelled more than 1 km from the nest, and 1 adult was usually at the nest or in the immediate vicinity. Throughout this period the adult pileated woodpeckers used an area that was much smaller than the territory they had just recently affirmed and would use after young fledged and throughout the winter.

**Family Groups**
The largest seasonal territory size was during the period when family groups were together after young had fledged and before young birds dispersed in late summer. During this period there was often overlap between adjacent territories. However, if birds from one territory were “caught” within the territory of a neighbour there was always a skirmish, and the intruding birds were chased until they returned to their own territory area.

**Winter**
The area used during the winter period was generally similar to the Family Groups/Territory Affirmation period. However, adult birds rarely strayed into neighbouring territories during the winter.
Table 3. Pileated woodpecker seasonal pair territory size in the Foothills Model Forest, Alberta, 1993-1996.

<table>
<thead>
<tr>
<th>Season</th>
<th>Time Interval</th>
<th>Number Pairs</th>
<th>Range</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Territory Affirmation</td>
<td>Mar 1 - Apr 15</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nesting</td>
<td>Apr 16 - Jul 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Family Groups</td>
<td>Jul 1 - Sep 30</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winter</td>
<td>Oct 1 - Feb 28</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Territory Description

Forest Cover
The percentage of forest cover within telemetry pair territories near Hinton varied from approximately 50-90% (rough analysis). The amount of forest cover necessary to support pileated woodpeckers may be much lower. Five instances of successful reproduction were documented in areas with less than 10% forest cover. Evidence of pileated woodpecker occupation was observed in all forest landscapes inspected, including areas where almost all mature forest had been logged and areas where minor amounts of forest cover remained in predominately agricultural landscapes.

Pileated woodpeckers do not appear to be sensitive to relative amount and configuration of forest cover when moving around their territories. They flew below forest canopies when making short local movements, but flew above the canopy when moving longer distances. Radio-tagged birds often flew several kilometers in the space of a few minutes, moving in a straight line over extensive non-forested areas.

Forest Age
All pileated woodpecker territories had at least some mature forest cover, and most territories had substantial amounts of mature/old forest. However, there were also territories with substantial amounts of young forest originating from both logging and forest fires. Age classification analysis within telemetry territories will be used to investigate relationships between age of forest and territory size.

Tree Species Composition
Forests in pileated woodpecker territories ranged from almost pure conifers dominated by combinations of lodgepole pine, white spruce, black spruce, and subalpine fir to almost pure deciduous forests dominated by aspen and balsam poplar. All territories had at least some amount of deciduous cover, although deciduous cover was very sparse at times. One territory contained only 27 mature aspen trees, all in one clump. Not surprisingly given the evidence that pileated woodpeckers nest mostly in mature aspens, this clump of aspens was used for nesting in both years that the pair was monitored. This pair also used conifer snags and living balsam poplars as cavity trees.

Cavity Trees
From 9-48 cavity trees (average 19) were found in 19 pileated woodpecker pair territories. It is probable that observed differences were partly due to sampling intensity, because the number of trees found per territory continued to increase with the length of time radio-tagged birds were monitored and was still increasing at the end of the study. The best-known territories had the most known cavity trees.

Cavity trees tended to be clumped in distribution but groups of trees and individual trees were often scattered throughout each pair territory and might be several kilometers apart. With a few exceptions, cavity trees within a pair territory were used only by the territorial pair and individual non-breeding birds, which were observed in at least 5 territories. Some cavity trees located near a boundary between neighbouring territorial pairs were used by birds from both adjacent territories.
Survival

Fourteen birds died during the study period (Table 1), and 3 birds disappeared while their transmitters were inoperative. I suspect that these birds also died because their place within their territories was quickly taken by other birds. Simple annual survival calculated assuming these 3 birds died was 0%, 56.3% and 61.9%, in 1993-94, 1994-95 and 1995-96, respectively, and averaged 56.4% for all three years. Two instances of severed pair-bonds were recorded, where 1 member of a mated pair left the territory while the other bird was still alive. It is therefore possible that the 3 birds with unknown fates also left the territory, and did not die. If so, simple annual survival was 68.8% in 1994-95, 66.7% in 1995-96, and the 3-year average was 64.1%. Statistical significance and survival rates using the Kaplan-Meier method have not yet been calculated. I will also test for an inverse relationship between adult survival and the relative amount of habitat fragmentation within pileated woodpecker territories.

Mortality Causes

Raptor predation was the confirmed or probable cause of death for 11 of 14 pileated woodpeckers whose radio transmitters were recovered. Evidence accepted as indicating raptor predation included pileated woodpecker carcasses in active raptor nests, intact carcasses with talon puncture wounds, partially plucked carcasses, piles of plucked feathers, bones or skeletons with flesh torn from bones, raptor droppings, and snow sign.

Five adult radio-tagged pileated woodpeckers were killed by raptors in June while both woodpeckers and raptors were feeding nestlings. Two carcasses were found in active northern goshawk nests, and an agitated adult northern goshawk flushed from the immediate vicinity of a 3rd freshly-killed carcass as the observer approached. A 4th partially plucked and slightly eaten carcass was recovered from fairly heavy cover, suggesting accipiter predation. The 5th carcass was recovered at the base of a stub along an edge of a linear opening. This bird had been plucked elsewhere, and the head and feet were also absent. The raptor had perched on the stub and dropped the de-fleshed skeleton at the base.

Nine pileated woodpeckers died during winter. Two of these birds may have been killed by mammalian predators. In both cases, only the transmitter package was found, and there were tooth-like marks in the potting material. The harness material was also missing, in contrast to remains found at avian predation sites. Recent snowfall had obscured the transmitter recovery site in one instance, and the other transmitter was recovered in a snow-free period from underneath a 26 cm diameter log that was approximately 30 cm above the ground. One female was killed when the tree she was roosting in split and broke off during a severe windstorm. The 6 remaining winter-killed birds were killed by raptors. The 3 birds with unknown fates also disappeared in winter. Northern goshawks were the only accipiter species present in the study area during winter.

Other raptor species present in the study area that are known to kill pileated woodpeckers (Bull and Jackson 1995) were red-tailed hawk *Buteo jamaicensis* (summer), Cooper's hawk *Accipiter cooperi* (summer), great horned owl *Bubo virginianus* (resident), and barred owl *Strix varia* (resident). Northern goshawks and red-tailed hawks were observed in all 14 pileated woodpecker pair territories within the study area. Great horned owls were observed or heard calling in 8 territories, and barred owls were observed or heard calling in 4 territories. Cooper's hawks were observed in 2 territories. Both owl species are unlikely pileated woodpecker predators because owl and woodpecker activity periods have little overlap. The owls are primarily nocturnal, and pileated woodpeckers are strictly diurnal, entering and leaving roost cavities in trees before and after main periods of owl activity.

Four unsuccessful predation attempts by northern goshawks on pileated woodpeckers were observed. Two of these attempts were almost identical in sequence and outcome. An adult northern goshawk was first observed in close pursuit of an adult pileated woodpecker, flying through fairly open forest. In both instances, the woodpecker evaded the goshawk by flying to a tree, landing on the trunk, and dodging
around the trunk. Once on the tree, the woodpecker easily avoided the still-flying goshawk, which quickly broke off the attack and left the area. In the 3rd attempt, an adult northern goshawk flew at a pileated woodpecker which was foraging approximately 50 cm from the ground on a 30 cm dbh aspen snag. The woodpecker saw the goshawk coming at the last instant and dodged around the tree trunk. The goshawk perched approximately 30 m away and watched the woodpecker for 12 minutes. The woodpecker remained very still and silent until the goshawk left the area, and it then resumed excavating. In the 4th attempt, the observer saw a northern goshawk arrive in the area and perch approximately 50 m from a pileated woodpecker that was foraging at the base of a living lodgepole pine. The woodpecker was aware of the goshawk and remained very still and quiet for approximately 20 minutes. The goshawk then flew toward the woodpecker, which quickly dodged around the trunk, evading the goshawk, which then left the area. The woodpecker resumed excavating within a few minutes.

Although most transmitters recovered from predator-killed pileated woodpeckers appeared to have been moved from the kill site, we believe we found 3 actual raptor kill sites. At 2 sites, pileated woodpeckers were apparently killed while foraging at the bases of trees within forest stands, and at the 3rd site a pileated woodpecker was apparently killed while foraging on a stump approximately 30 m from a forest edge in a 15 year-old clearcut. At each site, fresh pileated woodpecker excavation chips and droppings were present at the tree and stump bases.

Red-tailed hawks or Cooper's hawks may have been responsible for 2 of 5 pileated woodpecker predator deaths during the months when these migratory species are present.

Nesting

I located 133 nests used by pileated woodpeckers between 1982 and 1996 (Table 4). Ninety-two nests were found within the Foothills Model Forest study area, including 45 nests from 14 pileated woodpecker territories used by radio-tagged birds.

Table 4. Pileated woodpecker nests located in Alberta and northern British Columbia, 1982-1996.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Foothills Model Forest</td>
<td>4</td>
<td>7</td>
<td>12</td>
<td>20</td>
<td>23</td>
<td>27</td>
<td>92</td>
</tr>
<tr>
<td>Other Alberta Areas</td>
<td>7</td>
<td>1</td>
<td>6</td>
<td>9</td>
<td>9</td>
<td>6</td>
<td>38</td>
</tr>
<tr>
<td>British Columbia</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>11</td>
<td>8</td>
<td>18</td>
<td>29</td>
<td>33</td>
<td>34</td>
<td>133</td>
</tr>
</tbody>
</table>

Clutch size

Clutch size determined for 57 nests varied from 3-5 eggs (Table 5). Most nests (93%, N=53) had 4 eggs and there was little year-to-year variation. Although not yet tested, it appears unlikely that any relationship exists between clutch size and habitat quality variables.

Nest success

The number of fledged young was estimated for 78 nests that fledged at least 1 young (Table 5). Although most clutches were of 4 eggs, there were no instances of 4 fledged young, and 4 live nestlings were not observed in any nest at any time. I suspect that this is either because 1 egg does not hatch, or because 1 egg hatches slightly after the others and the last nestling cannot compete with its siblings and quickly dies. I was unable to determine exactly what happened, because adults removed unhatched eggs, egg shells, and dead nestlings within a few days of egg hatching. There were 3 nestlings in 14 nests and 2 nestlings in 2 nests, all inspected within approximately 5 days of hatching, and 3 newly
hatched nestlings and a single egg in 8 nests that had either just hatched or were in the process of hatching. The 8 just-hatched nests had 3 nestlings when inspected 2-4 days later, and no eggs, egg shells or dead nestlings. It appears from this evidence that most clutches of 4 eggs are reduced to 3 (or, rarely, 2) nestlings within a few days of hatching.

Table 5. Pileated woodpecker clutch size and number of fledged young in Alberta, 1990-1996.

<table>
<thead>
<tr>
<th>Year</th>
<th>Clutch size 3</th>
<th>Clutch size 4</th>
<th>Clutch size 5</th>
<th>Clutch size 0</th>
<th>Number of Fledged young 2</th>
<th>Number of Fledged young 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>2</td>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1991</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1992</td>
<td>2</td>
<td></td>
<td></td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>1993</td>
<td>2</td>
<td></td>
<td></td>
<td>2</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>1994</td>
<td>13</td>
<td></td>
<td></td>
<td>8</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>1995</td>
<td>3</td>
<td>17</td>
<td></td>
<td>4</td>
<td>6</td>
<td>13</td>
</tr>
<tr>
<td>1996</td>
<td>19</td>
<td>1</td>
<td>2</td>
<td>9</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>3</td>
<td>53</td>
<td>1</td>
<td>6</td>
<td>24</td>
<td>54</td>
</tr>
</tbody>
</table>

Additional mortality of nestlings after the first several days from hatching is apparently low if both parents survive until the young fledge. Either 2 (31%) or 3 (69%) young were observed in 78 nests inspected within a week of expected fledging (Table 5). As it was difficult to determine if there were 2 or 3 young in nests inspected from the ground, some of the nests counted as having 2 nestlings may actually have had 3 nestlings. Annual differences in number of young fledged have not been tested, but do not appear to be significant (Figure 1)

Fig. 1 Number of Fledged Young

Most nests were found after eggs had been laid or hatched, so the number of nesting attempts that produced fledged young could only be estimated using radio-tagged birds that were followed for successive years. In 1995 4 of 14 nesting attempts failed, and in 1996 2 of 14 nesting attempts failed. In 3 of the failures, eggs were laid but later disappeared from the nest. There were no egg shell fragments in or near these nests when they were inspected 10, 12 and 15 days after egg presence was confirmed. I suspect that these nests were abandoned after one of the adult birds died. For the 1st nest, an unmarked female disappeared from the territory of a radio-tagged male. The male made no other nesting attempts and was not observed with a female for approximately 4 weeks after the nest failure. For the 2nd nest, a radio-tagged male with a non-functioning transmitter disappeared from his territory after eggs had been laid in his nest. This bird did not subsequently use any of his known roost trees, supporting my belief that he died before the eggs had hatched. For the 3rd nest, an unmarked male
disappeared from the territory of a radio-tagged female, who made no attempt to renest and was not observed again with a male during the nesting period.

The remaining 3 nests failed within 2-7 days after eggs had hatched. In each instance, the nestlings died of suspected hypothermia within 1-2 days after one of the adult birds was killed. The nestlings were probably not capable of thermoregulation and were left exposed when the remaining adult was forced to leave them to forage.

One nest failed after both adult birds died. The female died as a result of an injury sustained during capture approximately 10 days after eggs hatched, with 3 healthy nestlings in the nest. The male continued to feed the nestlings. The smallest nestling died within 3-4 days, possibly of starvation. The carcass remained in the nest cavity. The 2 remaining nestlings were very close to fledging when the adult male was killed by a northern goshawk. The failure of this nest was not used in estimating nest success because of observer influence, but it indicates that one adult may be able to successfully feed at least 2 young if they are old enough to thermoregulate when the other adult dies.

No instances of nest predation were observed or suspected. Several intra-specific interactions at active nests were observed between pileated woodpeckers and 3 potential nest predator species (red squirrel, saw-whet owl, boreal owl) but none involved apparent predation attempts. In each instance, adult pileated woodpeckers harassed the interloper until it left the area.

Nesting Ecology

The earliest date observed for initiation of nest cavity excavation was March 8 and the latest date observed for completion of nest cavity excavation was May 15. Most nest cavity excavation activity occurred in April. Copulation was observed from April 7-24. Excavations were started by both sexes, although males started more excavations than females (M=18, F=8). Most excavation starts were quickly abandoned after just a few minutes of excavation, and many started/abandoned excavations were found in any year. The maximum number of fresh abandoned excavation starts observed for a single pair in a single year was 17. I tested 22 fresh abandoned excavation starts with an increment borer and found that tree heartwood decay at the start was either absent (N=15) or incipient (N=7) and apparently was not advanced sufficiently to suit the birds.

Pileated woodpeckers usually nested in cavities that were newly excavated by the mated pair in the year they were used for nesting (N=117). However, at least 14 nest cavities were completed excavations started and abandoned in previous years, and pileated woodpeckers were frequently observed excavating at previously-started cavities. There were 2 instances of renesting in previously-used cavities without further excavation. Radio-tagged birds from 2 separate territories renested in a cavity excavated and used for nesting in the preceding year. Both of these pairs had first completed and then abandoned a new cavity in a separate tree within their territory.

Although reuse of cavities was rare, reuse of nest trees was common. More than half (N=73) of all nest cavities were new cavities excavated in trees with 1-6 previously-completed cavities. Previous nesting use of multiple-cavity nest trees was confirmed for 15 trees, and pileated woodpeckers nested in one tree in each of 3 consecutive years.

Cavity Trees

A total of 519 pileated woodpecker cavity trees have been located but not all measurements have been obtained yet. Of this total, 133 trees were confirmed nest trees, 127 trees were confirmed roost trees, and 350 cavity trees were not confirmed as either nest trees or roost trees. Many trees were used for both nesting and roosting.
Tree Species

Although statistical analysis has not been done, it is apparent that pileated woodpeckers show strong selection for nest tree species (Figure 2). Ninety-eight percent of nest trees were trembling aspen, which comprised only 10% of available trees in the study area. The amount of aspen as a proportion of tree species composition increased at each scale of habitat selection.

A slightly lower proportion of roost trees were aspen (91% - Figure 3). Almost all nest trees were also used for roosting, but pileated woodpeckers also roosted in trees that may not have been used previously for nesting. In particular, roost trees entrances in balsam poplar sometimes accessed an internal hollow that probably resulted from natural decay and not from excavation by pileated woodpeckers.

The proportion of all pileated woodpecker cavity trees that were aspen paralleled the proportion for roost trees (Figure 4). Pileated woodpeckers in the study area appear to show positive selection of aspen for both nesting and roosting.
Tree Condition

Ninety-two percent of nest trees and 89% of available trees were living (Figure 7). This finding will be tested to see if pileated woodpeckers select for nest tree condition. If they do, selection may be for living trees.

Although pileated woodpeckers nested almost exclusively in living trees, they did not nest in healthy living trees. All nest trees had heartwood decay at the cavity site. Confirmed or potential external indicators of heartwood decay were present on most nest trees. Conks of the false tinder fungus *Phellinus tremulae*, which are conclusive evidence of heartwood decay, were present on 61% of nest trees (Figure 8). Conks were present on 18% of available trees (aspen >25 cm dbh) in nest tree stands.

Roost trees and cavity trees were more likely to be dead trees (snags and stubs) than either nest trees or available trees. I suspect this is because cavities are used as roosts for many years after they are first excavated, and many trees die during this period.

Tree Size

Mean diameter at breast height and distribution of trees in diameter classes for nest trees, roost trees, and cavity trees was similar (Table 6, Figure 9). Most cavity trees (80%) were 35-55 cm dbh, but only 33% of available trees (>25 cm dbh) were in the 35-55 cm dbh range.
Table 6. Pileated woodpecker cavity tree diameter range in Alberta and northern British Columbia, 1982-1996.

<table>
<thead>
<tr>
<th>Category</th>
<th>Number of Trees</th>
<th>Diameter Range in cm</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nest Trees</td>
<td>98</td>
<td>29.1 - 60.0</td>
<td>44.0</td>
</tr>
<tr>
<td>Roost Trees</td>
<td>111</td>
<td>30.2 - 76.1</td>
<td>46.2</td>
</tr>
<tr>
<td>Cavity Trees</td>
<td>459</td>
<td>23.2 - 76.4</td>
<td>45.2</td>
</tr>
</tbody>
</table>

Fig. 9. Diameter at breast height of nest trees, roost trees, cavity trees, and available trees in cm.
Tree Location

Remarks in this section are anecdotal because I haven't yet done any analysis of cavity tree spatial relationships.

Pileated woodpecker cavity trees were often located within or on the edge of a small opening in a stand. I expect both tree density and basal area will be lower at cavity tree sites than at random locations within cavity tree stands. Cavity trees were also often found on the edges of stands, and there were so many trees found on stand edges that I expect selection for within-stand openings and stand edges will be evident when data are analyzed. Cavity trees were also found in single trees and small patches of trees completely surrounded by openings, including clearcuts. Pileated woodpeckers seem to select at least a small open area immediately adjacent to the cavity tree. They do not appear to be sensitive to human activity. Many nest trees, roost trees, and cavity trees were found in areas of high activity (eg close to residences, edges of busy roads, in busy campgrounds).

Pileated woodpeckers show strong philopatry. They frequently excavate more than 1 cavity in each cavity tree. Philopatry was also apparent in locations of cavity trees, which were often clumped within favoured cavity tree stands. For example, 1 stand of 85 aspen trees had 33 pileated woodpecker cavities in 18 different trees, and another stand of 27 aspens had 15 cavities in 8 trees.

Cavity trees were found in a wide variety of landscape positions, and primarily on mesic sites. There are no obvious patterns related to landscape position and site based on a preliminary qualitative review of data.

Cavity Location on Tree

Cavity entrances were found as low as 2.8 m and as high as 20.0 m above the ground (Figure 10). Seventy-eight percent of cavities were in the 5.0 - 12.5 m height class. This pattern indicates that selection for height was occurring, when compared to an expected random distribution of equal number of cavities in each height class. Nest height may be weakly related to tree dbh (Figure 11), but there does not appear to be a strong relationship. The most likely reason for the observed distribution of nest height is the location of decay on the tree trunk. Cavities were always located at areas of decay, most of which appeared to be caused by Phellinus tremulae, a heartrot fungus that usually occurs at least 2 m above the ground and below the live crown of a tree.

Fig. 10 Cavity Height

![Cavity Height Chart]

Number of Cavities
Cavity entrance orientation was not random (Figure 12). Sixty percent of entrances faced either southwest, south, or south-east. I suspect that entrance orientation is related to the position of the cavity tree related to adjacent open areas, but have not yet tested this hypothesis.

**Drumming Trees**

Drumming tree information has not yet been analyzed. Pileated woodpeckers used a variety of trees for drumming and did not appear to select for tree species. The most common type of tree was a snag or the dead top of a living tree. Birds drummed on the trunk and also on limbs. Preferred sites were dry, sound wood without bark. Another favoured drumming site was just below the entrance to an old cavity in a dead tree, where the cavity served as a resonating chamber. Some drumming trees were used repeatedly, especially those near the nest tree or the boundary of a pair territory.

**Foraging**

This section presents preliminary analysis of the foraging substrate used by pileated woodpeckers. Analysis of foraging position (the location on the substrate), foraging method, food category, and stand-
level selection has not been started yet. Additional caution in interpreting these results is warranted because only about half the foraging substrate data has been analyzed, and seasonal use of substrates will likely be influenced by the order in which data have been entered.

**Fig. 12 Foraging Substrates**

- Live: 46%
- Stump: 2%
- Log: 10%
- Stub: 13%
- Snag: 29%

**Fig. 13 Available Substrates**

- Live: 69%
- Stump: 3%
- Log: 18%
- Stub: 5%
- Snag: 5%

**Substrates**

Pileated woodpeckers foraged almost exclusively on and in living and dead wood. A few instances of foraging at ant hills were recorded. I did not observe pileated woodpeckers foraging on berries in this study, although they have been observed foraging on saskatoons (J. Beck, personal communication) and pin cherries (B. Stelfox, personal communication) in Alberta and use of berries in other areas is well-documented.

Dead wood substrates comprised 54% of all substrates (Figure 13), but only 31% of available foraging substrates (Figure 14). Considering all species and decay/defect classes, snags and stubs were used at higher proportions than availability, while logs, stumps, and live trees were used at lower proportions than availability. I have not analyzed the decay/defect data, but I expect that relationships will show a greater than expected use of living trees with decay/defect than availability, and similar patterns for logs in the first 3 decay classes, which seemed to be the preferred types of foraging logs. Pileated woodpeckers seem to prefer foraging on living trees with defects/decay, and on dead snags, stubs, logs, and stumps that are in the early or middle stages of decay. Foraging on apparently healthy trees and on very rotten dead wood was rarely observed.

Pileated woodpeckers foraged on substrates of all available tree species (Figure 14). I plan to do use-availability comparisons by tree species when data on tree species availability are analyzed, but I do not expect to see much selection for foraging tree species.

The observed selection for dead wood appears to hold for all tree species (Figure 15). Sample sizes for subalpine fir were small, but only about 6% of subalpine firs used as foraging substrates were living.
Seasonal Changes
Pileated woodpeckers made seasonal changes in foraging substrate selection (Figures 16 and 17). Use of logs increased during snow-free months and use of living trees peaked in mid-summer and mid-winter, with declines in spring and fall. Use of snags was also highest in mid-winter. Use of conifers was highest during winter, and use of deciduous tree species peaked during summer.

Most winter foraging was by excavating into relatively sound wood at the bases of living trees, snags, and stubs with carpenter ant colonies. Pileated woodpeckers returned to carpenter ant foraging sites at regular intervals throughout the winter, enlarging their excavations into the ant colony chamber at each visit.

In spring, pileated woodpeckers started excavating in softer wood as soon as snow melted enough to allow access to soft wood substrates and insect activity in these substrates increased with moderating temperatures. Carpenter ants were important sources of food throughout the year, but carpenter ants were obtained during snow-free periods primarily by gleaning at existing hard-wood excavations and excavating into soft wood substrates. Excavation into hard wood was confined almost exclusively to winter months.
Use of other ant species and other arthropod foods increased in spring and continued until late fall. Ants were the most common prey item identified by observing foraging pileated woodpeckers and examining fresh foraging sites. Ants of species living in soft wood were targeted prey items. Pileated woodpeckers appeared to show preference for ant pupae when they were successful in breaking into ant brood chambers.

Although most foraging throughout the year was by excavating/gleaning at a specific site on a foraging substrate (Figure 18), pileated woodpeckers also gleaned arthropod food off the surface of tree trunks, particularly during the summer. The usual method was to hitch upward on a tree trunk or hop along a log, gleaning insects off the surface of the bark, with occasional blows to knock off bark or other obstructions. Pileated woodpeckers were also observed scaling bark off trees to access food items between the bark and tree trunk.
**Stand-level Habitat Use**

Detailed analysis of stand-level habitat use will start after a new stand inventory using Alberta Vegetation Inventory specifications is completed in September 1997. Pileated woodpeckers used all available stand types within their territories during snow-free months. In general, stand use appeared to be related to availability of individual foraging substrates and not to factors such as tree species composition, tree density, or stand age, although these factors may be related to stand use insofar as they are related to availability of foraging substrates.

As previously noted, stand use during the nesting period was partially related to the position of the nest tree within the territory. Stands more than approximately 1 km from the nest were not used or were used infrequently, while stands close to the nest tree were used more than similar stands farther away. Outside the nesting season, the proximity of roost trees did not appear to influence use of nearby stands.

Pileated woodpeckers were observed foraging on stumps, logs, and residual trees in recent clearcuts. Clearcuts without residual trees were used, but most activity in these was within approximately 100 m of adjacent tree cover. Use of clearcut areas appeared to be facilitated by the presence of residual trees, which were used as foraging substrates and bases from which birds foraged on nearby logs and stumps. Residual trees in clearcuts probably also serve as escape trees in the event of raptor attack and may facilitate use of larger clearcut areas by pileated woodpeckers.

Winter habitat use was primarily in forested areas and not in recent clearcuts unless there were sufficient residual trees to provide foraging opportunities.

Pileated woodpeckers foraged both within stands and at stand edges. Stand edges adjacent to open areas often had relatively more foraging sites than stand interiors because wind-thrown trees and damaged trees seemed to be more abundant along stand edges.

**Habitat Suitability Index Model**

**Schroeder (1993) HSI Model**

I evaluated the pileated woodpecker HSI model developed by Schroeder (1983) for applicability in the study area. The Schroeder model was developed to evaluate the year-round habitat of the pileated woodpecker and to apply to the entire range of the pileated woodpecker. Snag variable diameters differ between the eastern and western portions of the range. The Schroeder model combines food, cover,
and reproduction into a single component. Based on a preliminary evaluation, the Schroeder (1993) HSI model is not appropriate for the pileated woodpecker in northern forest types.

The 1st variable in the Schroeder (1993) HSI model is percent tree canopy closure. This variable relates to documented preference by pileated woodpeckers for dense stands in other areas. In the Schroeder (1993) model, stands <25% canopy closure have a value of 0, and stands >75% canopy closure have a value of 1. In the Foothills Model Forest study area, I regularly observed pileated woodpeckers using stands with very open canopies, and rarely using stands with very dense canopies. Although not yet analyzed, I suspect that tree canopy closure may not be a useful variable to describe pileated woodpecker habitat use in the Foothills Model Forest.

The 2nd variable in the Schroeder (1993) HSI model is number of trees >51 cm dbh/0.4 ha. In the Schroeder (1993) model, this variable relates to the availability of trees for nesting/roosting and large trees, which are considered to have greater value for foraging. Stands with <4 trees have a value of 0, and stands >30 trees are considered to have a value of 1. In the Foothills Model Forest study area, 78% of cavity trees were <51 cm dbh and 96% of foraging substrates were <51 cm dbh.

The 3rd variable in the Schroeder (1993) HSI model is number of tree stumps >0.3 m in height and >18 cm diameter. This variable relates to observed use of stumps for foraging in other areas. In the Schroeder (1993) model, stands with no stumps have a value of 0.3 and stands with >10 stumps have a value of 1. In the Foothills Model Forest study area, only 15% of foraging substrates were stumps/stubs, and 11% of stumps/stub foraging substrates were <18 cm diameter.

The 4th variable in the Schroeder (1993) HSI model is number of snags >38 cm dbh/0.4 ha. This variable relates to the observed preference for large diameter snags for foraging. In the Schroeder (1993) model, stands with no large snags have a value of 0 and stands with >15 snags/0.4 ha have a value of 1.0. In the Foothills Model Forest study area, 28% of foraging substrates were snags, and 88% of foraging snags were <38 cm dbh. The average density of all snags in nest tree stands was 15.7 snags/0.4 ha, and the average density of snags >38 cm dbh was 1.3 snags/0.4 ha.

The 5th variable in the Schroeder (1993) HSI model is average dbh of snags >38 cm dbh. This variable relates to observed preference for large diameter snags for foraging by pileated woodpeckers in other areas. In the Schroeder (1993) model, stands with an average large snag dbh of 38 cm have a value of 0.25 and stands with an average large snag dbh of >54 cm have a value of 1.0. In the Foothills Model Forest study area, only 8% of snags were >38 cm dbh, and only 12% of foraging on snags was on snags >38 cm dbh.

Preliminary Foothills Forest HSI Model

The specifications in the Schroeder (1993) HSI Model do not match observed pileated woodpecker habitat ecology in the Foothills Model Forest. A new preliminary HSI model to apply to the Foothills Model Forest was developed using local information (Bonar 1995) and revised in 1996 (Bonar and Bessie 1996). The preliminary model has been revised again to incorporate new information (Bonar 1997, Appendix 2).

I assume that the limiting habitat factor for pileated woodpeckers in western boreal forests is probably not the availability of trees for nesting and roosting. Large aspen trees with fungal heart-rot are abundant in these forests, and most areas of forest large enough to contain a pair territory (2000 ha) will probably contain enough trees to provide nesting and roosting opportunities.

I also assume that the availability of food during the nesting period is probably not a limiting habitat factor. Pileated woodpeckers use a much smaller area during this period than during other seasons, and appear to be able to easily find enough food from the small area to feed nestlings and themselves.
I assume that the availability of food during winter is probably the major limiting habitat factor for pileated woodpeckers in this area. Winter food is mostly carpenter ants found in colonies at the bases of sound dead trees and living trees with some defect. Birds must have access to enough carpenter ant colonies to survive relatively long and cold winters. I hypothesize that the reason pileated woodpeckers establish and defend large territories but don't use the entire territory area during the nesting season is because they need to protect an area large enough to supply enough food to survive the winter season.

Preliminary Forest Management Guidelines

Pileated woodpeckers appear to be resident in most forest types in the study area and do not seem to be sensitive to forest fragmentation. The large size of pair territories mean that it's likely pileated woodpeckers will continue to use most forest areas so long as trees for nesting/roosting and winter foraging are present in sufficient quantity to meet their needs. It seems that they are quite flexible in selecting both cavity trees and foraging substrates at the site, stand, and landscape levels of selection, so long as the characteristics of the tree/substrate are suitable. It also seems that they can continue to persist in areas that have relatively low amounts of forest cover.

Cavity tree suggestions
1. Protect known existing cavity trees and cavity tree stands - consider incorporating known cavity tree stands or individual trees into reserve areas, small patches within harvest areas, or individual trees retained within harvest areas.
2. Plan opportunities for future cavity tree supply - consider retaining some individual trees, patches, or stands with large aspens containing fungal conks, or younger aspens that will develop into suitable trees in the future.
3. It may be particularly important to retain aspen when aspen is rare in the landscape.

Foraging substrate suggestions
1. Actions to provide current and future cavity tree opportunities would also help to provide foraging substrates.
2. Trees with existing defects are the highest priority for retention - consider retaining dead trees and living trees that have existing pileated woodpecker foraging excavations, or cutting these trees off (high-stump).
3. Retain residual trees and logs during harvesting to provide future foraging substrates.
4. Stands, patches, and individual trees retained in forest landscapes for any reason should also provide pileated woodpecker foraging opportunities.

It's possible that pileated woodpeckers would continue to use recently-harvested areas with no specific management actions to conserve habitat. However, implementing these guidelines at any level should help to maintain current habitat conditions suitable for pileated woodpeckers during forest harvesting, and also increase the suitability of future habitat conditions.

References


Beckwith, R.C., and E.L. Bull. 1985. Scat analysis of the arthropod component of pileated woodpecker


Bonar, R. et al 1990


Savignac, C. 1994. Selection de l'habitat par le gran pic (Dryocopus pileatus) selon differentes echeles spatiales. Universite Laval, Montreal, Quebec.


Woodley, S. 1997. Pileated woodpecker study - project summary (Internet reference)
Appendix

Appendix 1 Dependent and Independent Variables

Dependent Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nest Tree</td>
<td>Trees used as nests.</td>
</tr>
<tr>
<td>Roost Tree</td>
<td>Trees used as roosts.</td>
</tr>
<tr>
<td>Cavity Tree</td>
<td>Trees with cavities excavated by pileated woodpeckers but confirmed as either nest trees or roost trees</td>
</tr>
</tbody>
</table>

Foraging Substrate

<table>
<thead>
<tr>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foraging substrate used by pileated woodpeckers.</td>
</tr>
</tbody>
</table>

Stand-level Habitat Use

<table>
<thead>
<tr>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area weighted use/availability ratio for a habitat unit, calculated as observed use divided by expected use. Observed use for a unit is the number of sample observations for a bird in the unit divided by the total number of observations for the bird. Expected use is the area of the unit divided by the total area used by the bird and multiplied by the total number of observations for the bird.</td>
</tr>
</tbody>
</table>

Home Range Size

<table>
<thead>
<tr>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area in ha of seasonal home range for each bird using Minimum Convex Polygon (MCP) method. Seasons defined by changes in annual reproductive cycle.</td>
</tr>
</tbody>
</table>

Adult Survival

<table>
<thead>
<tr>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survival rate of adult birds expressed as a proportion and determined through analysis of telemetry data using Kaplan-Meier method (Pollock et al. 1988).</td>
</tr>
</tbody>
</table>

Reproductive Success

<table>
<thead>
<tr>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of young observed in nest within 1 week of expected fledging date.</td>
</tr>
</tbody>
</table>

Independent variables for cavities.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entrance height</td>
<td>Height of entrance to 0.1 m</td>
</tr>
<tr>
<td>Entrance aspect</td>
<td>Aspect of entrance to closest 10°</td>
</tr>
<tr>
<td>Entrance DBH</td>
<td>Tree diameter at entrance to 0.1 m</td>
</tr>
<tr>
<td>Sapwood Decay Class</td>
<td>Decay class of sapwood at cavity entrance</td>
</tr>
<tr>
<td>Heartwood Decay Class</td>
<td>Decay class of heartwood at cavity</td>
</tr>
<tr>
<td>Cavity dimensions</td>
<td>Depth and diameter of cavity to 0.1 cm</td>
</tr>
</tbody>
</table>

Randomized variables that may influence pileated woodpecker habitat selection but are beyond the scope of this study include: physiography (aspect, slope, elevation), climate (weather, snow depth and persistence), age of birds, predation, food density, human disturbances, effects of radio-transmitters.
## Independent Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foraging Substrate Density</td>
<td>Density calculated by dividing number of substrates in a habitat unit by the areas in ha of the unit. Substrates types used by pileated woodpeckers include trees, snags, stubs, stumps, logs, and anthills.</td>
</tr>
<tr>
<td>Season</td>
<td>Spring (start of territory affirmation to cavity completion). Nesting (cavity completion date to fledging date). Summer (fledged young with adults). Winter (after young have dispersed in late summer). Seasons will vary for each bird according to changes in the annual reproductive cycle.</td>
</tr>
<tr>
<td>Location</td>
<td>The location of all foraging sites, nest trees, and roost trees will be entered on a GIS for analysis of distances.</td>
</tr>
<tr>
<td>Tree Species</td>
<td>White spruce/Engelmann spruce - Sw; Black spruce - Sb; Lodgepole pine - Pl; Sub-alpine/balsam fir - Fa; Trembling aspen - Aw; Balsam poplar - Pb; Paper birch - Bw; Tamarack - Lt.</td>
</tr>
<tr>
<td>Stem Type</td>
<td>Live - any standing tree with green needles or leaves or live buds (deciduous in winter). Snag - any dead tree with an intact trunk (no broken top). Stub - any dead tree with a broken top - applies to all heights. Stump - any sawn stump - does not apply to short stubs (natural breaks). Log - applies to all stems on the ground, not leaning trees.</td>
</tr>
<tr>
<td>DBH</td>
<td>Diameter at breast height, measured to 0.1 cm at 1.3 m above point of tree origin. Measure diameter at base for stubs &lt;2 m tall, stumps, and logs and estimate DBH using taper equations.</td>
</tr>
<tr>
<td>Height</td>
<td>Height to 0.1 m, estimated with clinometer for trees, snags, and stubs, measured with loggers tape for logs.</td>
</tr>
<tr>
<td>Defect</td>
<td>Stem defect: includes broken top (BT), dead top (DT), forked top (FT), fungal conks (CK), frost cracks (FC), base damage (BD), fire scar (FS), mammal damage (MD).</td>
</tr>
<tr>
<td>Decay Class</td>
<td>Applies to all dead stems. Categories: Class 1: Wet - Recently dead, may still have brown needles or leaves, sap still present, often infested with bark beetles, still moist between bark and sapwood. Class 2: Hard - Main stem dried out, fine branches still present, most of bark still present and firmly attached. Class 3: Hard - Fine branches gone, major branches still present, stem mostly sound, variable bark depending on species. Class 4: Hard - Few or no branches, stem mostly intact but may be starting to soften, variable bark depending on species. Class 5: Soft - No branches, stem starting to decompose (noticeably punky), bark variable depending on species. Class 6: Decomposed - No branches, stem very punky or rotten, bark mostly absent.</td>
</tr>
<tr>
<td># Cavity Entrances</td>
<td>Number of pileated woodpecker cavity entrances in tree.</td>
</tr>
<tr>
<td>Live Crown Height</td>
<td>Height to live crown to 0.1 m, estimated with clinometer.</td>
</tr>
<tr>
<td>Foraging Position</td>
<td>Foraging location on substrate. Root (RO), Base of trunk (first 2 m) (BA), Trunk (TR), Top of Trunk (last 2 m) (TO), Branch (BR).</td>
</tr>
<tr>
<td>Foraging Age</td>
<td>Fresh (F) - Bird observed foraging or other evidence for freshness (&lt;1 week old) such as wet droppings, disturbed insects, crushed vegetation, etc. Recent (R) - Between last leaf fall or green up and survey date. Chips on top of leaf fall or green up.</td>
</tr>
</tbody>
</table>
Appendix 2 Preliminary HSI Model

PILEATED WOODPECKER (*Dryocopus pileatus*)

HABITAT SUITABILITY INDEX (HSI) MODEL

Model last modified: April 26, 1997

Richard L. Bonar, Weldwood of Canada Ltd., 760 Switzer Drive, Hinton, Alberta. T7V 1V7


1. INTRODUCTION

1.1 HSI MODELS

Habitat Suitability Index models predict the suitability of habitat for a species based on an assessment of habitat attributes such as habitat structure, habitat type and spatial arrangements between habitat features. This HSI model for the pileated woodpecker applies to forests of the Foothills Model Forest in west central Alberta. The intended use is to predict habitat suitability at landscape scales and over long-term periods. The model will be used to determine potential changes in pileated woodpecker habitat area and carrying capacity throughout an entire forest management cycle (250 - 300 years). The model was developed using literature review and preliminary information from a habitat ecology study of pileated woodpeckers in the Foothills Model Forest, and will be evaluated using data from the study.

1.2 SPECIES DESCRIPTION AND DISTRIBUTION

The pileated woodpecker is the largest North American woodpecker species and 6th largest woodpecker species in the world. Adults are “crow-sized” (40-49 cm long) and average weights are 240-341 g, and males are 5-10 % heavier than females (Short 1982, Bull and Jackson 1995). Body and upper wing feathers are black to very dark charcoal grey, and there is an oval white patch on the underside of the wings. Both sexes have prominent red crests (larger in the male), and a prominent white line extends from the base of the bill down each side of the neck to the shoulders. The bill is long and chisel-shaped. In addition to other characteristics, malar coloration visibly distinguishes the sexes (red in males, black in females). Adults have reached the age of 11 years in the wild (Hoyt 1952). The most common calls are a series of loud “cucks” and a higher, rolling series of cuks fairly similar to the call of a northern flicker, but shorter and less mechanical sounding. Both sexes drum using a distinctive “slow sonorous drum-roll” (Ellison 1992).

Pileated woodpeckers occur in forests of North America from northern British Columbia to northern California in the west and Nova Scotia to Florida in the east (Short 1982, Bull and Jackson 1995). In Alberta, the species breeds mainly in the Boreal Forest, Foothills, and Rocky Mountain Natural Regions, and was recorded in 15.3% of 2206 100 km2 areas surveyed for the Alberta Breeding Bird Atlas (Semenchuk 1992).

Pileated woodpeckers are associated with mature and older forests (McClelland 1979, Bull 1987, Renken and Wiggers 1989, Mellen et al. 1992). They are non-migratory (Hoyt 1957, Bock and Lepthien 1975) and have a fairly low reproductive rate (2-3 young/pair/year) (Bull and Jackson 1995). Life-mated pairs have large home ranges that are defended all year against other pileated woodpeckers (Kilham 1976, 1979). Pileated woodpeckers excavate a new nest cavity each year in large trees, roost at night in tree cavities, and feed primarily on carpenter ants and other insects obtained mostly from within dead rotted wood (Hoyt 1957, Bull 1987).
The tree cavities which the pileated woodpecker excavates each year are in turn used by other cavity-using forest wildlife species. For example, 18 of 19 cavities used by nesting boreal owls (Aegolius funereus) in an Idaho study were originally excavated by pileated woodpeckers (Hayward et al. 1993). In northern forests, where natural cavities may be less common, a continuous supply of old pileated woodpecker cavities could be particularly important for maintaining populations of large cavity-using wildlife species that cannot get into cavities made by smaller woodpecker species.

### 1.3 FOOD

Wood-dwelling insects are the primary diet of pileated woodpeckers throughout the year, and carpenter ants are a major food in all seasons (Bent 1939, Hoyt 1957, Beckwith and Bull 1985, Bull et al. 1992b). Carpenter ants are particularly important in winter, when they form the bulk of the diet. Other ant species (especially thatching ants (Formica spp), and seasonally abundant insects obtained from soft wood are eaten in spring, summer, and fall (Hoyt 1957, Bull et al. 1992b). Thatching ants comprised approximately 60% of the summer diet in an Oregon study (Bull et al.1992b).

Pileated woodpeckers show a seasonal change in foraging methods and diet that appears to be related to the availability of arthropod food (Hoyt 1957, Conner 1979, 1981, Bull and Holthausen 1993). In winter, the main foraging method is deep excavation into fairly sound wood to access carpenter ant colonies. Excavation is the primary winter foraging method, but pileated woodpeckers take opportunistic advantage of bark beetle outbreaks and may temporarily shift much of their foraging to scaling bark from trees to access bark beetle larvae (Kroll and Fleet 1979, Bull 1987). In summer, excavations into sound wood are mostly replaced by excavations into soft wood, surface gleaning and probing. The variety of arthropod foods used increases in summer, but ants are still the dominant food item. Pileated woodpeckers opportunistically exploit seasonally abundant food sources such as western spruce budworm (Choristoneura occidentalis) larvae (Bull et al. 1992b) and berries, nuts, and fruits of many species (Hoyt 1957, Bent 1939).

The seasonal change in foraging methods is accompanied by a seasonal change in foraging substrates which also appears to be related to food availability. Summer food is abundant at or near the wood surface so birds do not need to expend energy in deep excavations through sound wood to obtain food. Winter food is only obtainable by deep excavation or scaling, and many of the foraging substrates used in summer such as stumps and logs may be covered by snow. This is particularly true in areas with deep and extensive winter snow cover (McClelland 1977).

Pileated woodpeckers do not use habitat randomly at the stand-level of selection. Selection appears to be related mostly to the availability of food (Conner 1979, Renken and Wiggers 1989, Mellen et al. 1992, Bull et al.1993). Food is primarily obtained from dead wood, and forest characteristics related to the availability of dead wood are correlated with pileated woodpecker home range size (Renken and Wiggers 1989) and use of forest stands (Mellen et al. 1992, Bull and Holthausen 1993). Density and characteristics of foraging substrates vary among stand types.

### 1.4 COVER AND ROOSTING

Cover is associated with both food and predator avoidance. Pileated woodpeckers are closely associated with tree cover for nesting, roosting, and foraging. In spring, summer, and fall they forage in both open and closed canopied areas. In winter, logs and stumps are mostly unavailable due to snow cover, particularly in open areas, and as a consequence use of open areas declines. Tree cover is also important for predator avoidance, particularly from avian predators. Pileated woodpeckers foil avian predation attempts by dodging around tree trunks (Lima 1993, Bonar 1997). The major predator of pileated woodpeckers appears to be the northern goshawk (Bull et al. 1993, Bull and Jackson 1995, Bonar 1997).

Pileated woodpeckers roost at night in tree cavities that reduce predation risk and offer protection from poor weather (Bull et al. 1992a). Members of mated pairs usually have separate roost trees, although they occasionally occupy different cavities in the same tree. Some roost cavities are used by both birds, but never at the same time. Each bird uses several roost trees, and birds disturbed after they have
entered a roost fly directly to an alternate tree. Roost cavities include cavities excavated and used previously as nests (Hoyt 1957, Kilham 1979, McClelland 1979, Bull 1987, Mellien 1987), natural cavities (hollow trees) with entrances excavated by the birds (Bull et al. 1992a), and natural cavities with entrances not excavated by the birds (Aubry and Raley 1992). Roost trees often have two or more entrances that connect an internal hollow (Bull et al. 1992a).

1.5 REPRODUCTION

Eggs are laid in late April or early May and hatch after a 14-18 day incubation (Short 1982, Bull and Jackson 1995). The parents brood the young for the first few weeks and both adults carry food which is fed to the young by regurgitation. When they are about 12 days old, the young birds climb to the nest entrance and the parents feed them from there instead of going inside. By this stage, the young make the typical woodpecker “churring” sound when the parents are at the nest, and most will fledge within another 2 weeks. Fledged young remain with the parents for most of the summer and disperse from the parent territory leave in August or September.

For reproduction to occur, a territory must contain at least some trees suitable for nesting. With a few very rare exceptions, pileated woodpeckers nest only in tree cavities that they excavate themselves. New cavities are usually excavated each year, but a few instances of old cavity reuse have been reported (Hoyt 1957, Bull 1987, R. Bonar unpublished data). More commonly, new cavities are excavated in previously-used nest trees and nest-tree stands (Bull 1987, Bull et al. 1992a, R. Bonar unpublished data). Cavity excavations are frequently started and then abandoned, and some of these are completed in later years and used for nesting or roosting (Bull and Jackson 1995, Bonar 1997).

Cavities are almost always excavated in the main trunk of the nest tree. Only trees big enough to hold a large cavity relatively high above the ground are used for nesting. The largest available trees of suitable species seem to be preferred. To accommodate the large cavities excavated by pileated woodpeckers, the minimum DBH of trees used for nesting appears to be about 33 cm (Conner et al. 1976). In Alberta pileated woodpeckers have successfully nested in trees as small as 29 cm DBH (Bonar 1997).

Nest cavities are usually located at least 4 m from the ground, and are often much higher on the branch-free portion of the trunk (Bent 1939). Pileated woodpeckers may prefer high cavities to "hide" the nest from ground-based predators and also to make it harder for them to reach the nest. Branches may interfere with cavity excavation or movement of adult birds flying to and from the nest.

Pileated woodpeckers use many tree species for nest trees, according to geographic location and available tree species composition. Hoyt (1957) reported nests in 12 different tree genera. In Virginia, Conner et al. (1976) found nests in oaks (Quercus spp) and hickories (Carya spp); in the interior conifer forests of Oregon ponderosa pine (Pinus ponderosa), western larch (Larix occidentalis), and Douglas fir (Pseudotsuga menziesii) were the primary species used for nest trees (McClelland 1979, Bull 1987); in the coastal rain-forests of Washington, most nests are in western hemlock (Aubry and Raley 1992). In Alberta and northeastern British Columbia, 113 of 115 nests were in living trembling aspen (Populus tremuloides), 1 was in a balsam poplar (Populus balsamifera) snag, and 1 was in a white spruce (Picea glauca) snag (Bonar 1997).

Both living and dead trees are used for nesting, but dead trees are used more often in many areas (Hoyt 1957, Conner et al. 1976, McClelland 1979). However, it seems that the species of tree and whether it is alive or dead may be less important than the physical characteristics of the tree. Pileated woodpeckers are capable of excavating a cavity in sound, dense wood (Bull 1987), and nest trees almost always have sound sapwood at the cavity entrance. This lessens the chance that the tree will break at the cavity and makes it harder for predators to break into the nest.

Pileated woodpeckers show a preference for trees with fungal-softened heartwood at the cavity location (Conner et al. 1976, McClelland 1979). Softer hardwood is easier to excavate, and fungal respiration may heat the cavity (Conner et al. 1976). In boreal forests, aspen, balsam poplar, paper birch (Betula papyrifera), and balsam/subalpine fir (Abies spp) are species where heartwood decay occurs high on the trunk.
1.6 TERRITORIES AND INTERSPERSION

Pileated woodpecker pairs generally mate for life and actively defend their territories against other pileated woodpeckers throughout the year. There have been only two studies that provide year-around territory size information. In Oregon, territory size of individual birds was 200 - 1586 ha, and pair territories were slightly larger than the territory of either partner (Bull and Holthausen 1993). The territories of birds in Alberta are considerably larger, ranging from approximately 1000 - 4000 ha and averaging 2000 ha (Bonar, 1997).

The territory of the pileated woodpecker must contain both feeding and nesting/roosting opportunities. The ratio of nesting/roosting area to feeding area must be \( \geq 1:100 \).

2. HSI MODEL DEVELOPMENT

2.1 MODEL APPLICABILITY

Species: Pileated Woodpecker (\textit{Dryocopus pileatus})

Habitat Evaluated: Nesting, Roosting, and Winter Food Habitat

Geographic Area: This model is applicable to the Foothills Model Forest in west-central Alberta.

Seasonal Applicability: This model was developed to evaluate year-round habitat.

Cover Types: This model applies to all forest and non-forest habitat areas of the Lower Foothills, Upper Foothills, Montane and Subalpine Natural Regions of Alberta (ref). The model should also be broadly applicable to other habitat areas dominated by similar tree species, including boreal deciduous, mixedwood and coniferous forest types.

Minimum Habitat Area: Pileated woodpeckers have large territories and are highly mobile. There is no minimum habitat area for nesting, roosting, or foraging. It is assumed that birds will readily use a single tree, snag, or stub for these activities, regardless of the location of the substrate.

Model Output: This model will produce habitat units (HU) for all cover types for their suitability as (1) nesting/roosting habitat; and (2) winter foraging habitat. The performance measure for the model is potential carrying capacity (pileated woodpecker pairs per hectare). Model output (HU) must be correlated to estimates of carrying capacity to verify model performance.

Carrying Capacity: Each pair of pileated woodpeckers is assumed to use a territory of at least 500 ha, so the number of pairs per hectare where HSI = 1.0 is 0.002.

Verification Level: This model is based on the U.S. Fish and Wildlife Service HSI model (Schroeder 1983), literature review, and preliminary results from an ongoing research study on pileated woodpecker habitat ecology in the Foothills Model Forest (Bonar 1997). It has been reviewed by several biologists but not by recognized species experts.

Application: This HSI model is designed to assess habitat suitability for relatively large forest landscapes using generalized species-habitat relationships and stand-level vegetation inventory. Its purpose is to predict relative changes in pileated woodpecker habitat supply at the landscape level over long time periods (250 - 300 years), for integration with forest management planning. It is not designed to provide accurate prediction of suitability or use at the stand level. Approximate population size can be calculated by assuming linear habitat-population relationships, but
the model is not designed to provide accurate population density estimates. Any attempt to use the model in a different geographic area or for other than the intended purpose should be accompanied by model testing procedures, verification analysis, and other modifications to meet specific objectives.

2.2 MODEL DESCRIPTION

Forested habitat provides nest trees, roost trees, food, cover, and opportunities to escape raptor predation, which are assumed to be the major habitat needs of the pileated woodpecker. Food and cover needs are found to some extent in all forest types except very young stands and in scattered timber, while nest/roost trees are found only in stands which have trees or snags of the correct size, species, and decay characteristics. Food and nesting/roosting habitat are considered to be the limiting life requisites on which the HSI for the pileated woodpecker is based. Raptor escape opportunities are assumed to be present in all habitat that provides food and nesting/roosting opportunities.

2.2.1 Habitat Variables and HSI Components:

A. Nesting/Roosting

In Alberta, pileated woodpecker nest trees (N = 115) ranged in size from 29.1-60.08 cm and averaged 44.0 cm dbh (Bonar 1997). Roost trees have similar size characteristics. Although most nest and roost trees are in living trembling aspen, some dead trees were used, and cavities were found in conifer snags (lodgepole pine, white spruce, subalpine fir). The model assumes that the availability of suitable nest trees will also provide suitable trees for roosting, and therefore availability of roost trees is not a limiting factor. Although pileated woodpeckers will nest in a stand with a single suitable tree, greater numbers of suitable trees will provide a continuing supply of nest trees for long-term use. All trees of suitable species do not provide suitable nest sites because of the association between heart-rot fungal decay and nest tree selection.

Suitable trees for nesting are defined as living deciduous trees or conifer snags ≥ 35 cm dbh (Table 1). Although pileated woodpeckers will nest in smaller trees, the 35 cm dbh limit is set because smaller trees are less likely to have fungal infections and are more likely to break at the cavity site than larger trees. Conifer snags > 35 cm dbh are currently not available in the habitat yield curve data set, so they are calculated as follows:

\[
\text{Snags} \geq 35 \text{ cm dbh} = 0, \text{ if } \text{mean dbh} < 35 \text{ cm;}
\]
\[
\text{Snags} \geq 35 \text{ cm dbh} = (\text{snags} > 16 \text{ cm dbh/ha})(\text{conifers/ha})/(\text{total trees} + \text{snags/ha}), \text{ if } \text{mean dbh} \geq 35 \text{ cm.}
\]

B. Winter Food

Pileated woodpeckers obtain most of their food in winter by excavating at the base of living trees, snags, and stubs of all tree species to access carpenter ant colonies. Most carpenter ant colonies are found in larger trees, at least 16 cm dbh. Snags and stubs are selected over living trees by both carpenter ants and pileated woodpeckers, and conditions are considered optimal when >8 snags/stubs >16 cm dbh are present per hectare. However, snags and stubs are not essential, because pileated woodpeckers also forage on living trees. Conditions are considered unsuitable when the average dbh of overstorey trees is <10 cm dbh, and optimal when the average dbh is >16 cm dbh. The components \(S_2\) and \(S_3\) are defined to relate mean DBH and number of snags and stubs to winter food, respectively (Table 1). The fourth component \(S_4\) is set so that the model only provides food values in stands with a sufficient cover of trees, and it also decreases the suitability in very dense stands.

2.2.2 Graphical HSI Component Relationships

\(S_1\)  If no suitable deciduous trees or conifer snags (≥ 35 cm dbh) are present, the nesting/roosting component, \(S_1 = 0\). \(S_1\) then increases to 1 when there are 30 or more suitable trees or snags per hectare (Figure 1a).
The value of $S_2$ is 0 at all values up to and including 10 cm dbh, and then increases to 1 at 16 cm (Figure 1b).

Since snags are not the only potential food source, their absence cannot drive the food value to zero. The minimum value of $S_3$ is set at 0.2 and then increases to 1 at 8 snags/stubs per hectare (Figure 1c).

The value of $S_4$ is 1 for canopy closure classes A, B, and C, and 0.75 for canopy closure class D. $S_4$ is reduced in D density stands (> 85 % crown closure) to reflect observed reductions in pileated woodpecker use of dense stands (Figure 1d).

Table 1. Relationships of HSI components to habitat requisites and the habitat variable each is predicted from, in the pileated woodpecker HSI model. Each variable is then explicitly defined.

<table>
<thead>
<tr>
<th>HSI Component</th>
<th>Habitat Requisite</th>
<th>Predictive Variable</th>
<th>Habitat Variable Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>$S_1$ Nesting/Roosting Cover</td>
<td>Deciduous Trees &amp; Conifer Snags $\geq$35 cm DBH (ha$^{-1}$)</td>
<td>Number of deciduous trees $\geq$35 cm dbh per hectare + conifer snags $\geq$ 35 cm dbh. The latter component is calculated as described in the text above.</td>
<td></td>
</tr>
<tr>
<td>$S_2$ Winter Food</td>
<td>Mean Overstorey DBH (cm)</td>
<td>Mean diameter at breast height of all canopy level (dominant and codominant) trees.</td>
<td></td>
</tr>
<tr>
<td>$S_3$ Winter Food</td>
<td>Snags and Stubs $\geq$ 16 cm DBH (ha$^{-1}$)</td>
<td>Density of dead and broken topped trees $\geq$ 16 cm dbh.</td>
<td></td>
</tr>
<tr>
<td>$S_4$ Winter Food</td>
<td>Tree Canopy Closure</td>
<td>Projected horizontal coverage of the entire crown area of canopy and sub-canopy trees.</td>
<td></td>
</tr>
</tbody>
</table>

![Graph S1](image1.png)

![Graph S2](image2.png)
Figure 1. Graphical relationships between habitat variables and HSI components in the pileated woodpecker model.

2.3 MODEL ASSUMPTIONS

1. Winter is the limiting season, because food resources are more restricted than in summer. The territory used in winter includes the territory used in summer, so the model applies to year-around habitat.

2. All conifer snags and large aspens have the same potential value for nest/roost construction. The availability of suitable nest trees is not normally a limiting factor in boreal forests because of large territory size and preferred use of relatively abundant living aspen with heart-rot fungal infection for nest trees.

3. Cover and water needs are provided by food and nesting habitat.

4. Roosting habitat needs are provided by nesting habitat.

5. Pileated woodpecker habitat use is not limited by proximity to human activities or roads or by the spatial arrangement of habitat.

2.4 EQUATIONS:

A. Nesting

HSI Nesting is the value of $S_1$ (the number of large deciduous trees or dead conifer snags) determined for each stand. There is compensation built directly into the component since deciduous trees and conifer snags can both serve as this resource.

$$\text{HSI (Nesting)} = S_1$$

B. Winter Food

The three HSI components $S_2$, $S_3$ and $S_4$ are considered equal and non-compensatory, so they are multiplied directly together. Only $S_2$ and $S_4$ can ever be equal to 0, so these are critical for determining suitability. $S_3$ is a modifying component and never decreases below 0.2.

$$\text{HSI (Winter Food)} = S_2 \times S_3 \times S_4$$

2.5 HSI DETERMINATION AND MODEL USE

In this section, the steps required to use the HSI models within the Foothills Model Forest habitat supply modeling system are briefly described. The Habitat Supply Analysis (HSA) software developed by Beck and Beck (1995) calculates Habitat Units (HU) for forest areas made up of many stands. The HSA software is first used to calculate the non-spatial components of the HSI models based on stand attribute data. Spatial elements are then implemented sequentially, by the calculation of distances to different
block types by use of a set of set-size grids overlaid on a GIS data layer to adjust the results of the non-spatial analysis. The resulting Habitat Units are the product of the HSI model scores and the area in hectares. The assumption is then made that the relationship between habitat suitability and carrying capacity is isometric; the HU are multiplied by the wildlife species carrying capacity for a hectare of HSI = 1 forest area and the values are summed among all hectares in the forest area. This allows changes in potential population densities to be tracked throughout the forest cycle.

To use the pileated woodpecker HSI model:

1. Calculate HSI (Nesting) for all stands using the HSI (Nesting) equation.
2. Calculate HSI (Winter Food) for all stands using the HSI (Winter Food) equation.
3. Combine the two HSI results in the following manner. Using a 1000 ha moving window, multiply the HSI (Nesting) value for each stand times the stand area and sum the totals. If the sum over 1000 ha is < 10, HSI (Nesting) is assumed to be the limiting factor and:
   \[ HU = \frac{\sum \text{HSI Nesting}}{10} \times \text{HSI Food}, \text{for each hectare.} \]
4. If the sum from above \( \geq 10 \), then HSI (Nesting) is assumed to not be the limiting factor and
   \[ HU = \sum \text{HSI Food}, \text{for each hectare.} \]

4. SOURCES OF OTHER HSI MODELS

The United States Fish and Wildlife service developed the original HSI model for pileated woodpeckers (Schroeder 1983). This model has since been modified for use in other areas including Quebec (LaFleur and Blanchette 1993), Manitoba (Millar 1994), Ontario (Bush and Naylor 1996) and Saskatchewan (Anon. 1991). Kirk and Naylor (1996) provide a summary and comparison of these models.

4. REFERENCES


