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Pileated woodpeckers (*Dryocopus pileatus*) and saproxylic beetles in partial cut and uncut bottomland hardwood forests

Patricia Jean Newell

Louisiana State University and Agricultural and Mechanical College

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PILEATED WOODPECKERS (*DRYOCOPUS PILEATUS*) AND SAPROXYLIC BEETLES IN
PARTIAL CUT AND UNCUT BOTTOMLAND HARDWOOD FORESTS

A Thesis
Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in Partial Fulfillment of the
Requirements for the Degree of
Master of Science

in

The School of Renewable Natural Resources

by
Patricia J. Newell
B.S. University of New Brunswick, 1999
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Abstract

Relative abundance and species richness of saproxylic beetles and nesting, roosting, and foraging ecology of pileated woodpeckers were studied in recent partial cuts and uncut forest during the summers of 2006 and 2007 in Louisiana. Relative abundance of saproxylic beetles was greater in one-year-old cuts than uncut forest during 2006 but was not consistent during 2007. The number of dead trees, period of capture, and trapping year also influenced beetle abundance. Species richness was similar in partial cuts and uncut forest.

Characteristics of habitat used by pileated woodpeckers for nesting and roosting in one-year-old and two-year-old partial cuts and uncut forest were similar. Woodpeckers used five species of trees between 42 and 150 cm diameter at breast height (dbh) for nesting ($n = 24$, 60.5 ± 3.02 ; mean \pm SE) and roosting ($n = 15$, 70.3 ± 7.03). Baldcypress (*Taxodium distichum*) was selected in all treatments. Nests (22 of 24) and roosts (12 of 15) were predominantly in boles of live trees (vigorous to decadent). Nest and roost sites contained more trees >50 cm dbh than were available in random plots.

Foraging observations were conducted in 20 territories of radio- and non-radio-tagged pileated woodpeckers. Pileated woodpeckers spent the highest proportion of their foraging time excavating (58%), followed by pecking (14%), gleaning (14%), scaling (7%), berry-eating (4%), and probing (3%). They foraged on live boles (41%), dead branches (27%), live branches (13%), dead boles (10%), and vines (9%). Woodpeckers preferred bitter pecan (*Carya aquatica*), avoided sugarberry (*Celtis laevigata*), and used overcup oak (*Quercus lyrata*) in proportion to availability. They avoided dbh classes 10-20, preferred dbh classes 50-70, and used dbh classes 30-40 in proportion to their availability in most treatments. In partial cuts, extremely large trees (dbh classes 80-90+) were selected. Pileateds either avoided vigorous and

decadent trees for foraging or used them in proportion to their availability. Woodpeckers preferred trees in early stages of decay in all treatments but in two-year-old partial cuts they preferred trees in late stages of decay. Scat of pileated woodpeckers contained seed gathering *Pheidole* ants, carpenter (*Camponotus*) ants, beetles (Coleoptera), and seeds of poison ivy.

Chapter 1: Introduction

The majority of bottomland hardwood (BLH) forests in the Mississippi Alluvial Valley (MAV) were historically influenced by processes that are modified today (Fredrickson 2005). For example, overbank flooding of streams and rivers historically influenced tree composition but is now largely suppressed with levees (Fredrickson 2005). Fluvial geomorphic processes in BLH systems, in most cases, operate at a much slower rate than in the past (Saucier 1994). Management of these systems is required to ensure that the functions and values, including wildlife habitats, can be restored and maintained.

The Lower Mississippi Valley Joint Venture (LMVJV) (2007) recommends a strategy to achieve desired forest conditions (DFCs) in the MAV by actively managing 70-95% of forests. DFCs were developed to benefit species of concern such as Louisiana black bear (*Ursus americanus luteolus*) that require large tracts of extensive forest and ivory-billed woodpecker (*Campephilus principalis*) that require large diameter, recently dead wood. Partial cutting has been suggested as a technique to attain DFC goals. Little is known, however, about the effects of partial cutting on dead wood and species that depend on dead wood.

Saproxyllic beetles are dead-wood dependent and serve many ecological functions, including decomposition of snags and logs by feeding and providing an important source of food for woodpeckers (Bull and Jackson 1995; Hammond et al. 2004). Saproxyllic beetles are known to respond favorably to sun-exposed standing or downed dead wood (Martikainen et al. 1999; Martikainen et al. 2000; Bouget 2005a, b); conditions that partial cutting can create (*LDWF forest prescriptions 1999-2002*). Pileated woodpeckers also depend on dead wood for nesting, roosting, and foraging (Raley and Aubry 2006). Pileated woodpeckers are a keystone species because they create cavities that are used by many other species like ducks, warblers, snakes,

salamanders, squirrels, mice, bats, beetles, and wasps (Raley and Aubry 2006). Pileated woodpeckers could be negatively affected by partial cutting if this technique eliminates structures required for nesting, roosting, and foraging. Harvesting in general is known to reduce the amount of standing dead wood available (Meadows and Goelz 2005). On the other hand, partial cutting techniques can add substantially to coarse woody debris (CWD) (Warriner et al. 2002) and perhaps the standing dead wood component through harvest wounds to residual trees (Nebeker et al. 2005).

This study sought to understand the effects of partial cutting on species that are thought to require dead wood; the pileated woodpecker and species of saproxylic beetles. In the following chapters, I report the results of three studies that compare responses of species in partial cuts to uncut forest. They include the effects of partial cutting on saproxylic beetles, on nesting and roosting of pileated woodpeckers and on the foraging ecology of pileated woodpeckers.

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Chapter 2: Relative Abundance and Species Richness of Saproxylic Beetles in Partial Cut and Uncut Bottomland Hardwood Forests

Introduction

Beetles that depend on dead, moribund, or dying wood for some part of their life cycle are referred to as saproxylic (Speight 1989). Saproxylic beetles serve many ecological functions, including decomposition of snags and logs by feeding, pollinating herbaceous and woody plants, and influencing activities of fungi (Hanula 1996; Warriner et al. 2002; Hammond et al. 2004). Larval and adult saproxylic beetles are also an important source of food for woodpeckers (Conner et al. 1994; Bull and Jackson 1995; Fayt 1999) and some families of saproxylic beetles such as the Cleridae and Trogossitidae are predators of other saproxylic beetles (Hammond et al. 2004).

Saproxylic beetle species are sensitive to forest management like clearcutting because dead wood availability is often reduced during harvest (Økland et al. 1996; Hammond et al. 2004; Gibb et al. 2006). Studies from northern Europe have shown significant negative effects of forest management on dead wood (Fridman and Walheim 2000; Siitonen et al. 2000; Gibb et al. 2005) and saproxylic beetles (Kouki 1994; Siitonen and Martikainen 1994; Kouki et al. 2001; Siitonen 2001), as management often reduces dead wood volume (Grove 2002; Hjalten et al. 2007) and alters dead wood tree species (Jonsell et al. 1998), diameter and decay class (Økland et al. 1996), and condition (snag versus log) (Jonsell & Weslien 2003). As a result, managed forests generally support fewer individuals, fewer species, and different assemblages of saproxylic beetles compared to primary or old-growth forests (Ehnstrom 2001; Grove 2002).

In contrast to northern Europe and some areas of the United States, the saproxylic beetle fauna of the southern United States and their response to forest management are poorly understood. This is especially true for bottomland hardwood (BLH) forests of which only 25-50% of the original pre-settlement area still exists (Smith 1993). Bottomland hardwood forests

are alluvial wetlands that typically flank river systems and are some of the most productive ecosystems on earth due to overbank flooding and subsequent deposition of nutrient rich sediments (Mitsch and Gosselink 2000).

Forests in Louisiana were traditionally clearcut or high-grade harvested. In the last ten to fifteen years, however, forest management on Louisiana public lands has been transitioning to uneven-aged partial cutting that improves vertical structure, benefitting migrant and resident songbirds (Hamilton et al. 2005). Vertical structure is created by introducing canopy gaps through the use of single-tree and group cut harvesting (Hamilton et al. 2005). Single-tree partial cuts result in gaps that are up to 0.24 ha while group cuts usually result in openings 0.5 ha or larger. Either of these methods may be well suited for bottomlands since these forests are naturally adapted to small-scale disturbances (Hamilton et al. 2005).

Since the rediscovery of the ivory-billed woodpecker (Fitzpatrick et al. 2005), broader ecological objectives, such as dead wood maintenance and improvement, have been developed for BLH forests (LMVJV 2007). Partial cutting can help attain some of these objectives since it has the potential to create dead wood (Jonsson et al. 2005; Shoch 2005). For example, mature trees can be retained in partial cuts to generate large dimension snags for the future (Shoch 2005) and standing dead wood can increase due to harvest-wounded residual trees that eventually die (Meadows and Stanturf 1997). Partial cutting can cause widespread damage to residual trees with from 60-84% being damaged (Meadows and Stanturf 1997; Nebeker et al. 2005).

In addition, the harvest itself can create dead wood in the form of residual logging slash (Warriner et al. 2002). High concentrations of sun-exposed recently dead wood are attractive to many saproxylic organisms (Martikainen et al. 1999; Martikainen et al. 2000; Simila et al. 2003; Bouget 2005a, b). Adult saproxylic beetles like Cerambycidae and Buprestidae were more abundant in dead-wood laden windthrow gaps in the first or second year after windstorm

disturbance (Wermilinger et al. 2002; Bouget and Duelli 2004; Bouget 2005a; Bouget 2005b); beetle abundance in man-made gaps in the overstory have shown the same response when logging slash is left behind (Grove 2002; Warriner et al. 2002; Ulyshen et al. 2004). Although gaps are beneficial to saproxylic beetles, the influence of gap size (between 0.13 and >1 ha) on relative abundance and species richness of saproxylic beetles may be negligible (Ulyshen et al. 2004; Bouget 2005b).

The effects of harvesting on saproxylic beetles have been studied elsewhere but no research has been conducted in partial cuts in Louisiana BLH. Consequently, the current practices of partial cut harvesting in BLH forests needs to be evaluated. My objectives were to: (1) compare relative abundance and species richness of saproxylic beetles among one-year-old and two-year-old partial cuts and uncut controls; (2) determine local stand characteristics that explain differences in relative abundance and species richness of beetles; and (3) determine if the decay class of a tree is affected by harvest wounding. To reach these objectives, I captured adult beetles in Sante traps (canopy traps designed for intercepting flying insects) and measured tree characteristics in a 0.04 ha plot at each trap. I expected that I would collect a higher abundance and species richness of beetles in partial cuts due to fresh logging slash left behind from harvest and that plot characteristics pertaining to dead wood would be good predictors of beetles. I also expected that trees with large residual harvest wounds would be further along in decay classes than trees with small wounds.

Study Area

During 2006, trapping was conducted on Louisiana Department of Wildlife and Fisheries (LDWF) Three Rivers/Red River and Big Lake Wildlife Management Areas in east central and northeastern Louisiana respectively (Fig. 2.1). In 2007, Bayou Cocodrie National Wildlife Refuge (NWR) was added as a site (Fig. 2.1).

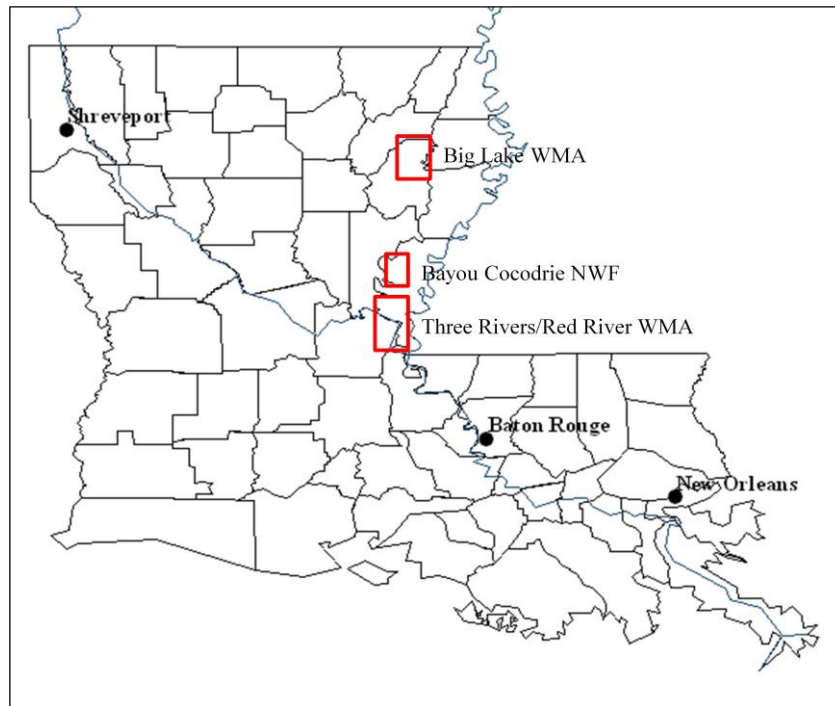


Figure 2.1. Sante trap study sites in Louisiana. Red boxes indicate approximate locations of Three Rivers/Red River WMA, Bayou Cocodrie NWR, and Big Lake WMA.

The study sites were located in backwater swamps on Sharkey clay soils of poor drainage and high fertility that were frequently ponded for short periods of time in the winter. Partial cuts in Red River and Three Rivers WMAs consisted of the overcup oak-bitter pecan (*Quercus lyrata/Carya aquatica*) association before and after harvest. One control site in Red River was composed of the sugarberry (*Celtis laevigata*)-overcup oak association and the other of the overcup oak-bitter pecan association while Three Rivers WMA controls were composed of the sugarberry-overcup oak association. The partial cut and control in Bayou Cocodrie NWR were at a higher elevation and the species were of the sweetgum (*Liquidambar styraciflua*)-willow oak (*Quercus phellos*)-Nuttall oak (*Quercus nuttallii*) association. Big Lake WMA partial cuts and controls were composed of the American elm (*Ulmus americana*)-green ash (*Fraxinus pennsylvanica*)-sugarberry-Nuttall oak association.

Methods

Study Design

To determine the early effects of partial cutting on saproxylic beetles, beetles were sampled in group or single tree partial cuts (a total of six cuts harvested in the summer or fall of 2005 or 2006) and uncut control forest in Three Rivers/Red River and Big Lake WMAs and Bayou Cocodrie NWR (Table 2.1).

Table 2.1. Number of traps during 2006 and 2007 per Site and Harvest Year, Harvest Type, and size of cut block. Site = Red River WMA (RR), Three Rivers WMA (TR), Big Lake WMA (BL), or Bayou Cocodrie NWR (BC); Harvest type: group cut (GR), single tree cut (ST), or unharvested control (CON); Cut Area = size of the harvest block; Harvest Date = months in which harvesting occurred.

Site and Harvest Year	Harvest Type	Cut Area (ha)	Harvest Date	Number Traps 2006	Number Traps 2007
RR 2005	GR	85	Oct-Nov	6	3
RR 2006	GR	50	May-Jul	n/a	3
RR	CON	n/a	n/a	7	3
TR 2005	ST	145	Sep-Dec	6	3
TR 2006	GR	25	Oct-Nov	n/a	3
TR	CON	n/a	n/a	5	3
BL 2005	ST	75	Nov-Dec	6	3
BL	CON	n/a	n/a	2	2
BC 2006	GR/ST	113	Aug-Oct	n/a	3
BC	CON	n/a	n/a	n/a	1

The selection of cut sites was only a result of what was available on public lands and was not designed to compare different types of partial cuts; group or single tree. Approximately 30-40% of the basal area (BA) was removed in each treatment according to prescriptions to promote advanced regeneration, create white tailed deer (*Odocoileus virginianus*) browse and cover, and maintain and provide vertical structure for Neotropical migratory birds and wild turkey (*Meleagris gallopavo*) (LDWF forest prescriptions 1999 to 2002). Gaps created by single tree cuts were 0.02-0.08 ha (Meadows and Stanturf 1997) while group cutting created openings that

were 0.4-2 ha (*LDWF forest prescriptions 1999 to 2002*). Baldcypress (*Taxodium distichum*), large overcup oak (>70 cm dbh), and cavity trees were avoided for harvest and 50% of declining trees were left for addition to the standing dead wood component (*LDWF forest prescriptions 1999 to 2002*). Logging slash was left on-site and a portion of residual trees were wounded during harvest (Fig. 2.2).



Figure 2.2. Partial cut characteristics. Left: Group cut at Red River WMA with logging slash piled on-site. Right: Typical logging wound on an overcup oak tree. Red arrow points to medium-sized wound.

Sante traps were used to intercept flying adult beetles one and two years post harvest in partial cuts as well as in uncut controls to compare relative abundance and species richness of saproxylic beetles. Each Sante trap was equipped with a collection vessel at the top and bottom of the trap that allowed for the capture of beetles that respond to interception by dropping as well as rising (Hutcheson and Kimberley 1999; Ulyshen et al. 2004) (Fig. 2.3). Traps were deployed from April to July, 2006 and 2007, and were rotated every 14 days among Three Rivers/Red River WMA, Big Lake WMA, and Bayou Cocodrie NWR (2007). This resulted in three (14-day) sampling periods for each trap in an approximately one month period of time; Period 1, Period 2, and Period 3 (Table 2.2).



Figure 2.3. Characteristics of Sante traps. Top: Sante trap used in the study with top and bottom collection vessels. Bottom: Relative position in the canopy of Sante trap.

Table 2.2. Sampling dates for Sante traps in the study. Note: 2006 traps took two days to rotate among WMAs, therefore, 2006 dates include the duration of all traps in that period.

Year	Site (WMA or NWR)	Period	Date
2006	Red River/Three Rivers	1	April 19-May 4
2006	Big Lake and Red River/Three Rivers	1	May 5-May 20
2006	Red River/Three Rivers	2	May 24-June 8
2006	Big Lake and Red River/Three Rivers	2	June 10-June 25
2006	Red River/Three Rivers	3	June 26-July 11
2006	Big Lake and Red River/Three Rivers	3	July 11-July 25
2007	Red River/Three Rivers	1	April 16-April 30
2007	Bayou Cocodrie/Big Lake	1	May 2-May 16
2007	Red River/Three Rivers	2	May 18-June 1
2007	Bayou Cocodrie/Big Lake	2	June 2-June 16
2007	Red River/Three Rivers	3	June 17-July 1
2007	Bayou Cocodrie/Big Lake	3	July 1-July 15

During 2006, 32 Sante traps were set up in partial cuts that were either group or single tree partial cut in 2005 (CUT1) as well as in uncut controls (CON). Eighteen Sante traps in one-year-old partial cuts (CUT1) and 14 in uncut controls (CON) were sampled three times throughout the summer resulting in 93 total samples. Three samples were destroyed and values for relative abundance and species richness were interpolated with averages for these samples. In 2007, the 2005 partial cuts were re-sampled (CUT2) and new partial cuts that were harvested during 2006 (CUT1) as well as controls (CON) were sampled. Therefore, there were two 2006 treatment types and three 2007 treatments (Table 2.1). During 2007, 27 Sante trap locations were sampled, nine in each of the one-year-old partial cuts (CUT1), two-year-old partial cuts (CUT2) and controls (CON) that were sampled three times throughout the summer resulting in 81 total samples.

Sante traps were spaced at least 120 m from each other to avoid pseudo-replication since Sante traps draw insects from 84 m to 100 m (Dugdale and Hutcheson 1997; Hutcheson and Kimberley 1999) and were positioned at least 100 m from major edges (i.e. roads, agriculture

fields, or other forest types). Traps were suspended from branches of random trees and the bottom of each trap was secured two meters from the ground (Hutcheson and Kimberley 1999).

A 100% ethanol solution was used to attract beetles to the collection vessels to kill them and store them until they were taken to the lab. All beetles ≥ 6 mm in length were extracted, pinned, and identified to species. All Cerambycidae captured were ≥ 6 mm so data includes all cerambycids captured. Saproxylic beetles were separated into two groups; (1) Cerambycidae; and (2) Non-Cerambycidae. Most cerambycids were identified using the “Field Guide to Northeastern Longhorned Beetles (Coleoptera: Cerambycidae)” by Yanega (1996). Non-cerambycids were identified with the help of Louisiana State Arthropod Museum (LSAM) staff and graduate students. To confirm identifications, I compared specimens to those in LSAM. Voucher specimens were deposited at LSAM.

Vegetation Sampling

To determine if abundance and richness of beetles were related to Sante trap site characteristics, trees at Sante trap locations were measured in 0.04 ha plots with the Sante trap tree as the center. For each tree in the plot ≥ 10 cm, species, diameter at breast height (dbh), decay class, vine class, and wound class were recorded. Ten decay classes were used to describe the stage of decomposition, with tree conditions from vigorous trees to downed logs (Foti et al. 2005) (Table 2.3). Five wound classes were developed to categorize the extent of harvest wounds on trees (Table 2.4). In 2007, the percent of downed coarse woody debris (CWD) with a diameter ≥ 5 cm was measured at each Sante trap plot.

Statistical Analyses

The Sante trap data were discrete count data and a Poisson distribution was assumed for all analyses. I used Generalized Linear Mixed Model (PROC GLIMMIX in SAS 9.1) to determine if the treatment or covariables predicted relative abundance and species richness of

Table 2.3. Tree condition and description of decay classes (Foti et al. 2005).

Decay Class	Tree Condition	Description
1	Vigorous	Live tree, live crown
2		<1/3 crown dieback
3		1/3-2/3 crown dieback
4	Decadent	>2/3 crown dieback
5		Recently dead
6	Early Stage of Decay	Retains only large limbs
7		Only bole ≥ 8 m
8	Late Stage of Decay	Only bole <8 m
9		Only stump
10	Downed	Log

Table 2.4. Description of harvest wound classes of trees in partial cuts.

Wound Class	Description	Length of Longest Side
0	None	n/a
1	Small	<20 cm
2	Medium	21-50 cm
3	Large	51-100 cm
4	Extra large	>100 cm

cerambycid and non-cerambycid beetles. Non-cerambycid families were classified into one of three functional groups: (1) predominately rotting wood families; (2) predominately fresh dead wood families; and (3) predator families (Stehr 1991; Arnett et al. 2002). The functional groups were statistically analyzed together since the number of species and individuals was too low in each group for robust analysis. Since the number of 2006 treatments were different (CUT1 and CON) from 2007 (CUT1, CUT2, and CON), I analyzed data separately for each year. Site and harvest type were added as random effects in all models, and were assumed to not be significant sources of variation.

The total number of either cerambycid or non-cerambycid beetles collected in each Sante trap sample was considered the relative abundance response, and species richness was calculated

simply as the number of species caught per Sante trap (a sample). I chose not to standardize sample species richness according to sample abundance using rarefaction because I had a standard trapping effort in all three treatment types. However, I did use rarefaction curves from the program EstimateS (Colwell 2006) to compare the total number of species detected between years and among treatment types since sampling design was different between years.

The covariables (SBA, BA, NUMSP, DBH50, CWD, Decadent, Totdead, Period, and the interaction between Treatment and Period) were chosen based on specific hypotheses I wished to test. Basal area of sugarberry (SBA) was used as a covariable since it was found to be higher in controls than partial cuts and I wanted to ensure that any difference detected in responses among partial cuts and controls was due to the treatment and not to differences in sugarberry. Other covariables included plot basal area (BA) to test the hypothesis that beetles are more abundant and species rich with less basal area (i.e. in sun-exposed open areas); the number of different tree species (NUMSP) to test the hypothesis that beetles are more abundant and species rich with more richness in trees; the number of trees ≥ 50 cm dbh (DBH50) to test the hypothesis that beetle abundance and richness increases with large diameter trees, and CWD to test if beetles increase with increasing CWD in a plot. To test the hypothesis that beetles were influenced by decay class, I collapsed decay classes into two groups I thought may be important; (1) the number of decadent trees in a plot (trees in decay classes 3 and 4 (Decadent), and (2) the total number of dead trees in a plot (decay classes 5 to 9) (Totdead). I also included the period of capture (Period).

Before conducting parametric analyses with the beetle abundance and richness data, I determined if the explanatory variable (Treatment) or covariables (SBA, BA, NUMSP, DBH50, CWD, Decadent, and Totdead) showed multicollinearity. If variables were correlated (Pearson Correlation Coefficients $r \geq 0.4$), I eliminated one of the correlated variables based on biological

significance. I chose $r \geq 0.4$ to compromise between retaining variables that may be correlated and consequential loss of statistical power and throwing out variables that may have been important to the model. Generally, $r < 0.4$ have weak correlations where $r \geq 0.6$ are strongly correlated (Graham 2003). Although the covariable 'Period' was included in beetle analyses, it was not included in the correlation analysis. Period is a time variable and was not expected to be correlated with any of the variables since plot variables were only measured once and would not be expected to change with time.

I used model selection with corrected pseudo Akaike's information criterion (AIC_C) suitable for small sample sizes and non-normal distributions as the selection criteria for the most informative model (Hobbs and Hilborn 2006). I adapted some rules for assessing the models in each set relative to each other: (1) two models with $AIC_C \Delta < 2$ were essentially the same in explanatory power; (2) those with $AIC_C \Delta 2-4$ were less likely to be the same; while (3) models having $\Delta 4-10$ were quite different in explanatory power (Burnham and Anderson 2001). AIC_C supports models with fewer variables so if two models were about the same ($AIC_C \Delta < 2$), I chose the model with fewer variables. I also used Akaike weights (w_i) from 0-1 to gauge which model would emerge as the best model given repetition (Burnham and Anderson 2001)).

Tukey's post hoc multiple comparisons were used to test for differences in levels of class variables or covariables that were selected for the best model with adjusted p-values for multiple comparisons.

To determine the effect of Treatment, Period and plot characteristics on the abundance of individual saproxylic species I first used Principal Components Analysis (PCA) (PROC FACTOR in SAS 9.1) to group species (cerambycid and non-cerambycid combined) to reduce dimensionality in the data (Quinn and Keough 2002). To avoid a large number of zero data in the PCA, species with low frequency, ($< 1\%$ of total) were removed from analyses. A scree plot

was used to determine the number of meaningful principal components. I then used Multivariate Analysis of Variance (MANOVA) to test whether the explanatory variables Treatment, Period and plot characteristics explained variation in the principal components of species from the Principal Component Analysis.

Harvest Wounds

I hypothesized that if harvest wounds to residual standing trees weakened trees, then trees with wounds large enough to harm the tree should be in later decay classes compared to trees with wounds too small to affect the tree, especially by year two post-harvest. To test this, I compared the decay classes of trees with large wounds (wound class 3 and 4) to decay classes of trees with small wounds (wound classes 1 and 2) using a Generalized Linear Mixed Model with a multinomial distribution for class response variables with PROC GLIMMIX in SAS 9.1. Trees with small wounds were used instead of trees without wounds because I wanted to ensure the trees used in the analysis were trees that were subject to wounding, (i.e. to ensure similar species composition and diameter class distribution). I included trees in all stages of decay except decay class 10 (logs) since wounded trees were expected to still be standing (Conner et al. 1983; Aulen 1991; Farris et al. 2002). Trees from 2005 and 2006 harvests were combined for analyses. A positive relationship was determined to be significant with a p-value <0.05.

Results

Study Areas

Differences between partial cuts and controls were consistent among sites; partial cuts had lower plot basal area and lower basal area of sugarberry than controls (Table 2.5). Species composition in partial cuts varied among treatments and study sites, though oak species predominated in all sites in all treatments and sugarberry and bitter pecan were the next dominant species. Oak, sugarberry, and bitter pecan comprised between 74% to 99% (89 ± 3.9)

of BA in Red River and Three Rivers WMAs but only 64% to 71% (67 ± 1.5) in Big Lake WMA and Bayou Cocodrie NWR. CWD was higher in partial cuts than controls in all sites (Table 2.5). Decadent trees were more abundant than dead trees in all treatments in all sites but variation existed in the decadent to dead tree ratio among sites (Fig. 2.4). Decadent and dead trees were more abundant in the smaller dbh classes (Fig. 2.4). The diameter class distribution of trees was different between partial cuts and controls (Fig. 2.5).

Table 2.5. Characteristics of partial cuts and controls of sites in the Sante trap study. Figures are based on Sante trap plot data collected during 2006 and 2007: Site and Year of harvest; RR = Red River WMA, TR = Three Rivers WMA, BL = Big Lake WMA, BC = Bayou Cocodrie NWR; CWD = average plot laying coarse woody debris; Decadent trees/ha = number of trees measured in decay classes 3 or 4/ha; Dead Trees/ha = number of trees measured in decay classes 5-9/ha; BA = basal area; SB = sugarberry, BP = bitter pecan.

Site and Harvest Year	CWD (%)	Decadent Trees/ha	Dead Trees/ha	Total BA/ha	BA/ha Oak	BA/ha SB	BA/ha BP
RR 2005	18.8	21	13	25.4	20.0	0.4	2.4
RR 2006	17.8	67	8	20.6	12.3	2.5	1.7
RR	8.0	32	14	33.8	14.7	13.3	3.3
TR 2005	15.6	38	21	20.8	10.5	2.4	2.5
TR 2006	11.2	192	8	23.0	13.7	5.9	3.1
TR	9.0	30	20	23.8	11.5	7.3	3.9
BL 2005	16.7	63	4	21.1	8.4	2.8	2.7
BL	6.2	50	25	25.7	9.0	2.8	6.4
BC 2006	24.0	125	58	27.0	11.5	5.7	0
BC	7.0	150	100	43.0	17.0	9.3	2.5

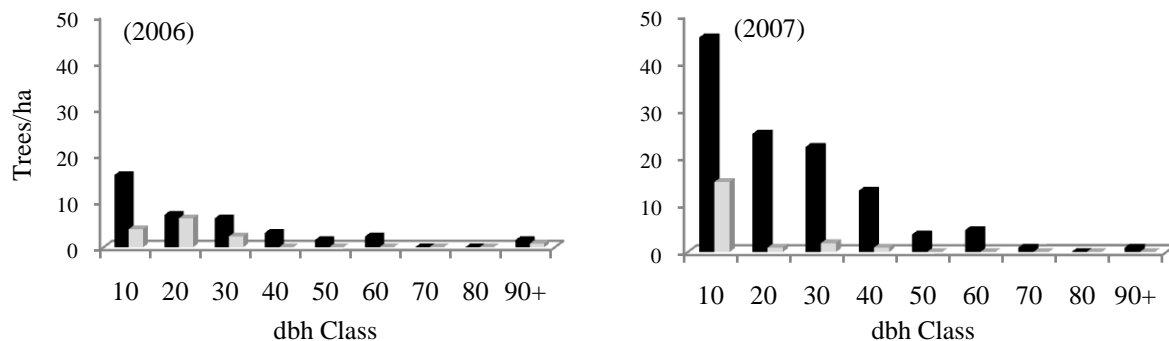


Figure 2.4. Diameter class distribution (dbh class) of decadent (black) and dead trees (grey) in 2006 and 2007 Sante plots.

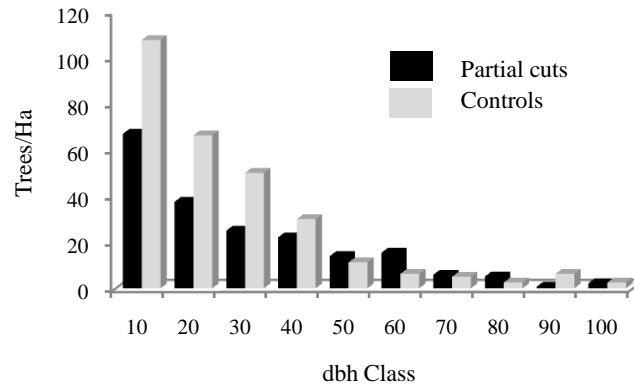


Figure 2.5. Diameter class distribution of 2005 and 2006 partial cuts (black) vs. uncut control forest measured in the same year (grey). Data is from 34 Sante trap plots in partial cuts and 20 in uncut controls.

Covariables

According to Pearson Correlation Coefficients SBA, NUMSP, CWD, and DBH50 were correlated with other covariables (Tables 2.6a, b). SBA was correlated with treatment in 2006 models but not in 2007 models. Because I hoped to establish that SBA was not driving response variables, I included it in 2007 analyses since SBA was not correlated, to indicate whether SBA affected response variables. NUMSP was correlated with two covariables and CWD was correlated with Treatment so they were removed as covariables. DBH50 was considered a redundant variable with BA since BA increased with increasing trees ≥ 50 cm dbh in this dataset.

Saproxylc Beetles

I captured a total of 5503 saproxylc beetles greater than six millimeters in length representing 96 species. A total of 65 species of cerambycids and 33 non-cerambycids were identified. The Cerambycidae represented 71% of saproxylc beetles captured, the Cleridae; 9%, Elateridae; 8%, Buprestidae; 5%, Eucnemidae; 5% and other; 2%.

Table 2.6. 2006 (a) and 2007 (b) Pearson Correlation Coefficients (r) for covariables tested in Generalized Linear Mixed Models. Values ≥ 0.4 were considered for removal. TREAT = treatment (CUT1 vs. CUT2 vs. CON), BA = basal area, SBA = basal area of sugarberry, NUMSP = number of different tree species, DBH50 = number of trees ≥ 50 cm dbh, DECADENT = number of trees counted in decay classes 3 and 4, TOTDEAD = total number of trees counted in decay classes 5 to 9, and CWD = downed coarse woody debris.

a)	TREAT	BA	SBA	NUMSP	DBH50	DECADENT	TOTDEAD
TREAT	1						
BA	0.11	1					
SBA	0.54	0.25	1				
NUMSP	-0.17	0.03	-0.2	1			
DBH50	-0.2	0.72	0.05	0.08	1		
DECADENT	-0.1	-0.12	0.02	0.40	-0.08	1	
TOTDEAD	0.12	-0.11	0.2	-0.16	-0.18	0.01	1

b)	TREAT	BA	SBA	NUMSP	DBH50	DECADENT	TOTDEAD	CWD
TREAT	1							
BA	0.24	1						
SBA	-0.0024	0.15	1					
NUMSP	0.06	0.25	-0.14	1				
DBH50	0.31	0.71	-0.12	0.15	1			
DECADENT	-0.32	0.12	0.12	0.04	-0.12	1		
TOTDEAD	-0.23	0.24	-0.10	0.54	0.13	0.13	1	
CWD	-0.40	-0.11	-0.19	-0.02	-0.14	0.41	0.07	1

The top five most abundant families were the same in both years (Table 2.7). Rotting wood families included Eucnemidae, Elateridae, Synchroidea, Lymexylidae, and Mordellidae. Fresh dead wood families included Brentidae, Bostrichidae, and Buprestidae, and predator families were Cleridae, Trogossitidae, and Passandridae.

During 2006, 93 samples yielded a total of 2387 saproxylic beetles (25.7/sample) of which 1752 beetles were Cerambycidae (Table 2.7). During 2007, 81 samples yielded a total of 3116 saproxylic beetles (38.5/sample) of which 2128 beetles were Cerambycidae (Table 2.7).

Thirteen percent more saproxylic beetles were captured during 2007 ($n = 3116$) than 2006 ($n = 2387$) even though there were 13% fewer 2007 samples ($n = 81$) as 2006 ($n = 93$). These differences can be attributed to a few families that were more abundant in 2007. More

Table 2.7. Number (n), percent (%), rank, and larval habitat niches of families of beetles caught in Sante traps during 2006 and 2007. Top five ranks of families are bolded in red.

Family	2006			2007			Larval Niche*
	n	%	rank	n	%	rank	
Cerambycidae	1752	73.4	1	2128	68.3	1	Weakened, dying, recently dead, and moribund trees
Elateridae	215	9	2	222	7.1	3	Decayed to rotting wood
Buprestidae	175	7.3	3	107	3.4	5	Inner bark of dead and dying hardwoods
Cleridae	106	4.4	4	367	11.8	2	Predaceous on wood boring beetle larvae
Eucnemidae	52	2.2	5	209	6.7	4	Newly dead to rotting trees
Mordellidae	22	0.9	6	16	0.5	7	Decaying wood
Staphylinidae	22	0.9	6	11	0.4	8	Predaceous on wood boring beetle larvae
Trogossitidae	18	0.8	7	26	0.8	6	Predaceous on wood boring beetle larvae
Brentidae	11	0.5	8	14	0.4	8	Inner bark of recently felled trees
Synchroidae	6	0.3	9	6	0.2	9	Under bark of dead hardwood trees
Lymexylidae	5	0.2	10	3	0.1	10	Decaying wood
Passandridae	3	0.1	11	6	0.2	9	Predaceous on wood boring beetle larvae
Bostrichidae	-	-	-	1	0.03	11	Heartwood of recently felled trees
	2387			3116			

*(Arnett et al. 2002; Stehr 1991)

species of saproxylic beetles were captured in 2007 (n = 86) compared to 2006 (n = 76). Eleven unique cerambycid species were collected during 2007 and eight during 2006; nine unique non-cerambycid species were collected during 2007 and two during 2006.

Top vessels were more effective in capturing adult cerambycids during 2006 (n = 1530) and 2007 (n = 1964) than bottom vessels (n = 222 and 164 respectively). Top vessels were also more effective in capturing the non-cerambycids during 2006 (n = 488) and 2007 (n = 753) compared to bottom vessels (n = 147 and n = 235 respectively). Ninety percent of total cerambycids and 76% of total non-cerambycids were captured in top vessels. No saproxylic species with abundance greater than one were only captured in bottom vessels.

Cerambycidae

Fifty-two species of Cerambycidae were captured during 2006 and 55 during 2007 (Table 2.8). The seven most abundant species were the same in both years although ranking changed within. Of the top ten most abundant species, *Parelapthidion aspersum* Haldeman and *Eburia*

quadrigeminata (Say) were the only species to conspicuously decrease rank from 2006 to 2007 and *Anelaphus villosus* (F.) conspicuously increased (Table 2.8).

Table 2.8. Number (n), percent (%), and rank of Cerambycidae caught with Sante traps during 2006 and 2007 ordered from most abundant to least abundant (2006). Top 10 species are bolded in red.

Species	2006			2007		
	n	%	rank	n	%	rank
<i>Neoclytus m. mucronatus</i> (Fabricius)	374	21.3	1	333	15.6	2
<i>Neoclytus scutellaris</i> (Olivier)	201	11.5	2	210	9.9	5
<i>Obrium maculatum</i> (Olivier)	195	11.1	3	356	16.7	1
<i>Elaphidion mucronatum</i> (Say)	179	10.2	4	268	12.6	3
<i>Ecyrus d. dasycerus</i> (Say)	171	9.8	5	239	11.2	4
<i>Distenia undata</i> (Fabricius)	142	8.1	6	75	3.5	7
<i>Styloleptis biustus</i> (LeConte)	113	6.4	7	133	6.3	6
<i>Neoclytus a. acuminatus</i> (Fabricius)	59	3.4	8	44	2.1	9
<i>Eburia quadrigeminata</i> (Say)	35	2	9	10	0.5	20
<i>Leptostylus transversus</i> (Gyllenhal)	29	1.7	10	37	1.7	10
<i>Parelaphidion aspersum</i> Haldeman	29	1.7	10	18	0.8	18
<i>Lepturges angulatus</i> (LeConte)	24	1.4	11	31	1.5	11
<i>Xylotrechus colonus</i> (Fabricius)	24	1.4	11	22	1	14
<i>Knulliana c. cincta</i> (Drury)	18	1	12	29	1.4	12
<i>Urographis triangulifer</i> (Haldeman)	15	0.9	13	6	0.3	23
<i>Anelaphus parallelus</i> (Newman)	13	0.7	14	6	0.3	23
<i>Liopinus alpha</i> (Say)	11	0.6	15	19	0.9	17
<i>Eupogonius pauper</i> LeConte	10	0.6	16	4	0.2	25
<i>Lepturges pictis</i> (LeConte)	9	0.5	17	4	0.2	25
<i>Clytoleptis</i> sp.	7	0.4	18	6	0.3	23
<i>Dryobius sexnotatus</i> Linsley	7	0.4	18	20	0.9	16
<i>Heterachthes pallidus</i> Haldeman	7	0.4	18	5	0.2	24
<i>Saperda</i> n. sp.	7	0.4	18	3	0.1	26
<i>Anelaphus pumilus</i> (Newman)	5	0.3	19	23	1.1	13
<i>Leptostylopsis planidorsus</i> (LeConte)	5	0.3	19	8	0.4	21
<i>Nyssodrysina haldemani</i> (LeConte)	5	0.3	19	1	0.05	28
<i>Urographis fasciatus</i> (DeGeer)	5	0.3	19	8	0.4	21
<i>Goes pulverulentus</i> (Haldeman)	4	0.2	20	2	0.1	27
<i>Obrium rufulum</i> (Gahan)	4	0.2	20	17	0.8	19
<i>Oncideres c. cingulata</i> (Say)	4	0.2	20	5	0.2	24
<i>Psyrassa pertenuis</i> (Casey)	4	0.2	20	2	0.1	27
<i>Saperda discoidea</i> Fabricius	4	0.2	20	4	0.2	25
<i>Aegomorphis quadrigibbus</i> (Say)	3	0.2	21	21	1	15
<i>Leptostylus asperatus</i> (Haldeman)	3	0.2	21	19	0.9	17
<i>Saperda tridentata</i> Olivier	3	0.2	21	6	0.3	23

Table Cont'd

Species	2006			2007		
	n	%	rank	n	%	rank
<i>Aegomorphis modestus</i> (Gyllenhal)	2	0.1	22	1	5	28
<i>Megacyllene caryae</i> (Gahan)	2	0.1	22	-	-	-
<i>Methia pusilla</i> (Newman)	2	0.1	22	17	0.8	19
<i>Micranoplium unicolor</i> (Haldeman)	2	0.1	22	1	0.05	28
<i>Orthosoma brunneum</i> (Forster)	2	0.1	22	-	-	-
<i>Plinthocoelium s. suaveolens</i> (Linnaeus)	2	0.1	22	3	0.1	26
<i>Sphenostethus taslei</i> (Buquet)	2	0.1	22	-	-	-
<i>Ancylocera bicolor</i> (Olivier)	1	0.1	23	3	0.1	26
<i>Anelaphus villosus</i> (Fabricius)	1	0.1	23	69	3.2	8
<i>Ataxia crypta</i> (Say)	1	0.1	23	3	0.1	26
<i>Curius dentatus</i> Newman	1	0.1	23	-	-	-
<i>Enaphalodes atomarius</i> (Drury)	1	0.1	23	-	-	-
<i>Enaphalodes rufulus</i> (Haldeman)	1	0.1	23	-	-	-
<i>Goes debilis</i> LeConte	1	0.1	23	-	-	-
<i>Lepturges confluens</i> (Haldeman)	1	0.1	23	-	-	-
<i>Strangalia famelica</i> Newman	1	0.1	23	2	0.1	27
<i>Urographis despectus</i> (LeConte)	1	0.1	23	1	0.05	28
<i>Euderces r. reichei</i> LeConte	-	-	-	7	0.3	22
<i>Phymatodes amoenus</i> (Say)	-	-	-	6	0.3	23
<i>Goes pulcher</i> (Haldeman)	-	-	-	5	0.2	24
<i>Urgleptes signatus</i> LeConte	-	-	-	4	0.2	25
<i>Goes tigrinis</i> (DeGeer)	-	-	-	3	0.1	26
<i>Liopinus punctatus</i> (Say)	-	-	-	2	0.1	27
<i>Strangalia bicolor</i> (Swederus)	-	-	-	2	0.1	27
<i>Strangalia luteicornis</i> (Fabricius)	-	-	-	2	0.1	27
<i>Saperda lateralis</i> Fabricius	-	-	-	1	0.05	28
<i>Euderces pini</i> (Olivier)	-	-	-	1	0.05	28
<i>Neoclytus jouteli</i> Davis	-	-	-	1	0.05	28
Total	1752			2128		

Relative Abundance of Cerambycidae

In 2006 and 2007, the same model emerged as the best model for predicting relative abundance of Cerambycidae and included Treatment (partial cut or control), the covariables Period (1, 2 or 3) and Totdead, and an interaction between Treatment and Period (Tables 2.9a, b). This model would emerge as the best model 64% of the time given many repetitions for 2006 and 71% of the time for 2007 and are therefore informative models according to AIC weights (Tables 2.9a, b).

Table 2.9. Pseudo AIC_C, Δ AIC_C, and weight (w_i) values for competing models explaining the relative abundance of cerambycid beetles (CRA) in a) 2006 and b) 2007. The highlighted model is the best model. Treat = treatment type (one-yr-old cut vs. two-yr-old cut vs. control), Period = sampling period (1, 2, or 3), Totdead = number of trees in decay classes 5-9, BA = basal area, Decadent = number of trees over 50cm dbh, and SBA = basal area of sugarberry.

a)	MODELS 2006	PSEUDO AIC _C	Δ AIC _C	w_i
	CRA = Treat Period Treat*Period Totdead	374.56	0	0.64
	CRA = Treat Period Treat*Period Totdead BA	377.06	2.5	0.18
	CRA = Treat Period Treat*Period Totdead BA Decadent	377.15	2.59	0.18
	CRA = Treat Period Treat*Period	419.78	45.22	0.00
	CRA = Treat Period Totdead	458.24	83.68	0.00
	CRA = Null	728.48	353.92	0.00

b)	MODELS 2007	PSEUDO AIC _C	Δ AIC _C	w_i
	CRA = Treat Period Treat*Period Totdead	377.38	0	0.71
	CRA = Treat Period Treat*Period Totdead BA	378.24	0.86	0.30
	CRA = Treat Period Treat*Period Totdead BA Decadent	379.28	1.9	0.27
	CRA = Treat Period Treat*Period Totdead BA Decadent SBA	384.58	7.2	0.02
	CRA = Treat Period Treat*Period	398.91	21.53	0.00
	CRA = Treat Period Totdead	451.21	73.83	0.00
	CRA = Null	658.08	280.7	0.00

During 2006, relative abundance of cerambycids was greater in CUT1 than CON ($t_{87} = 2.91$, $p = 0.005$). During 2007, relative abundance was greater in CUT2 than either CUT1 ($t_{68} = -3.64$, $p = 0.0015$) or CON ($t_{68} = -6.16$, $p < 0.0001$) (Table 2.10). However, abundance in CUT1 did not differ from CON during 2007 ($t_{68} = 2.19$, $p = 0.08$) (Table 2.10).

Relative abundance was greater during Period 2 than Period 1 ($t_{87} = -14.03$, $p < 0.0001$) and Period 3 ($t_{87} = 9.62$, $p < 0.0001$) and was greater during Period 3 than Period 1 ($t_{87} = -4.8$, $p < 0.0001$) during 2006. Similarly, during 2007, relative abundance was greater during Period 2 than Period 1 ($t_{68} = -8.81$, $p < 0.0001$) and Period 3 ($t_{68} = 9.52$, $p < 0.0001$). No difference was observed, however, between Period 1 and Period 3 during 2007 ($t_{68} = 0.81$, $p = 0.70$) (Table 2.10). While the variable Period adds information to the model, it is not biologically interesting since we expect seasonal variation in the relative abundance of saproxylic beetles.

Table 2.10. 2006 and 2007 estimates per sample unit, standard error (SE), and 95% upper and lower confidence limits (UCLM and LCLM) for class and quantitative variables predicting relative abundance of cerambycid beetles; CUT1 = one-year-old partial cuts, CUT2 = two-year-old partial cuts, CON = controls; Sampling Period = PER1, PER2, or PER3, Totdead = the total number of dead trees in decay class 5-9.

Year	Variable	Estimate	SE	UCLM	LCLM
2006	CUT1	20.50	2.50	25.51	15.49
2006	CON	16.50	1.67	19.88	13.12
2006	PER1	11.22	1.47	14.21	8.23
2006	PER2	28.59	3.77	36.28	20.91
2006	PER3	16.44	1.32	19.14	13.74
2006	Totdead	1.19	1.03	1.13	1.25
2007	CUT1	25.33	3.62	32.78	17.89
2007	CUT2	31.26	3.11	37.66	24.86
2007	CON	22.22	2.33	27.02	17.43
2007	PER1	21.93	2.18	26.41	17.44
2007	PER2	35.70	3.96	43.84	27.57
2007	PER3	21.19	2.08	25.45	16.92
2007	Totdead	1.16	1.03	1.09	1.23

The 2006 and 2007 interaction between Treatment and Period was important. While more cerambycids were caught in partial cuts, this was not consistent across periods (Fig. 2.6a, b). More cerambycids were caught in CON than CUT1 during Period 1 but more were caught in CUT1 during Period 2 and 3 in 2006. This was also the case in 2007; more cerambycids were caught in CON than either CUT1 or CUT2 in Period 1, however, Period 2 and 3 exhibited the same trend in that the most beetles were caught in CUT2 followed by CUT1 and CON in Period 2 and 3.

For each additional dead tree in a plot, there was an estimated 1.19 more beetles during 2006 and 1.16 during 2007 (Table 2.10). The dead trees variable (Totdead) consisted primarily of trees in later stages of decay (decay class 7 and 8) therefore cerambycid beetles were related to the number of dead trees in later stages of decay.

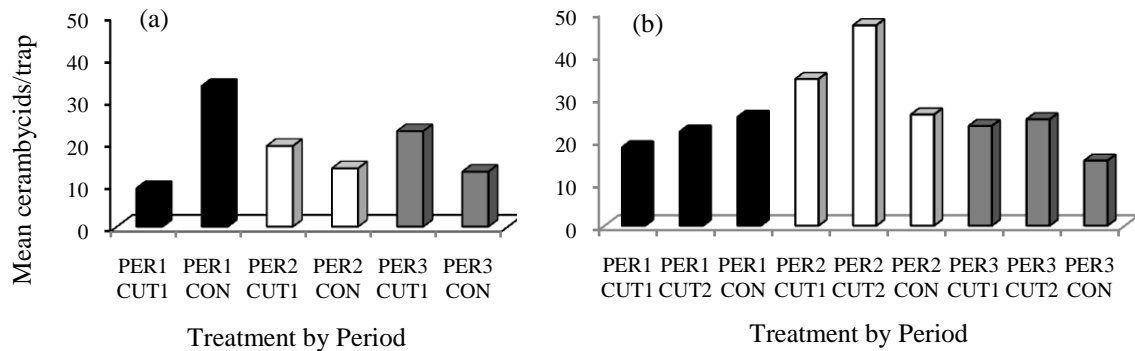


Figure 2.6. Mean number of cerambycid captures by treatment type and period in (a) 2006 and (b) 2007. CUT1 = one-year-old partial cuts, CUT2 = two-year-old partial cuts, CON = controls, and PER = Period.

Species Richness of Cerambycidae

Species richness during 2006 and 2007 was the same among partial cuts and controls but varied with Period during 2006 (Tables 2.11a, b and 2.12). 2006 Period 2 samples were more cerambycid rich than Period 1 ($t_{91} = -5.63$, $p < 0.0001$) but did not differ from Period 3 samples ($t_{91} = 2.1$, $p = 0.09$). Period 3 samples were also more species rich than Period 1 ($t_{91} = -3.61$, $p = 0.0015$) (Table 2.12). That species varied seasonally is expected and not that biologically interesting.

Table 2.11 Pseudo AIC_C, ΔAIC_C, and weight (w_i) values for competing models explaining the species richness of cerambycid beetles (CSR) in a) 2006 and b) 2007. The highlighted model is the best model. Treat = treatment type (one-yr-old cut vs. two-yr-old cut vs. control), Period = sampling period (1, 2, or 3), Totdead = number of trees in decay classes 5-9, BA = basal area, Decadent = number of trees in decay classes 3 or 4, and SBA = basal area of sugarberry.

a)	MODELS 2006	PSEUDO AIC _C	ΔAIC _C	w_i
CSR = Period		72.12	0	0.40
CSR = Treat Period		72.79	0.67	0.28
CSR = Treat Period Treat*Period		73.02	0.9	0.25
CSR = Treat Period Treat*Period Totdead		75.99	3.87	0.06
CSR = Treat Period Treat*Period Totdead BA		78.83	6.71	0.01
CSR = Treat Period Treat*Period Totdead BA Decadent		83.01	10.89	0.00
CSR = Treat		92.59	20.47	0.00
CSR = Null		93.49	21.37	0.00

b)	MODELS 2007	PSEUDO AIC _C	Δ AIC _C	w _i
CSR = Null		53.82	0	0.81
CSR = Treat		58.88	5.06	0.06
CSR = Treat Totdead		59.19	5.37	0.06
CSR = Treat Period Totdead		59.62	5.8	0.04
CSR = Treat Period Period*Treat Totdead		61.34	7.52	0.02
CSR = Treat Period Treat*Period Totdead BA		63.48	9.66	0.01
CSR = Treat Period Treat*Period Totdead BA Decadent		70.34	16.52	0.00
CSR = Treat Period Treat*Period Totdead BA Decadent SBA		70.48	16.66	0.00

Although no differences were found in sample species richness among treatments in either 2006 or 2007, rarefaction curves indicate total cerambycid species richness was higher in partial cuts than controls during 2006, but no differences were observed during 2007 (Fig. 2.7a, b). This indicates that over the course of the summer season, the number of species was greater in partial cuts than controls, but a snapshot of cerambycid species in any one sample would be about the same.

Table 2.12. 2006 and 2007 estimates per sample unit, standard error (SE), and 95% upper and lower confidence limits (UCLM and LCLM) for class and quantitative variables predicting species richness of cerambycid beetles. CUT1 = one-year-old partial cuts, CUT2 = two-year-old partial cuts, CON = controls, PER1, 2, and 3 = Period 1, 2, or 3.

Year	Variable	Estimate	SE	UCLM	LCLM
2006	CUT1	7.56	0.37	8.29	6.82
2006	CON	6.36	0.40	7.17	5.54
2006	PER1	5.03	0.36	5.77	4.29
2006	PER2	8.78	0.40	9.60	7.96
2006	PER3	7.28	0.43	8.15	6.41
2007	CUT1	9.15	0.58	10.33	7.96
2007	CUT2	9.00	0.46	9.94	8.06
2007	CON	8.07	0.60	9.3	6.85
2007	PER1	7.7	0.49	8.71	6.7
2007	PER2	9.56	0.62	10.83	8.3
2007	PER3	8.96	0.48	9.95	7.98

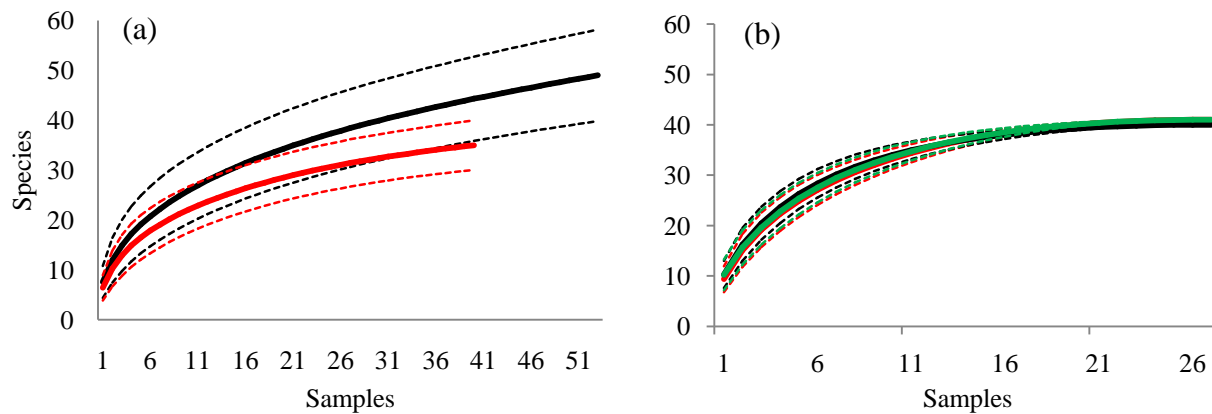


Figure 2.7. Rarefaction curves for total cerambycid species richness in (a) 2006 and (b) 2007. Species caught in successive samples are indicated by black for CUT1, red for CON, and green for CUT2. Solid lines are SOBS rarefaction and dotted lines are upper and lower 95% confidence intervals.

Non-Cerambycidae

Twenty-four species of Non-Cerambycidae were captured during 2006 and 31 were captured during 2007 (Table 2.13). The most abundant five species were the same in both years (Table 2.13).

Relative Abundance of Non-Cerambycidae

The best model predicting relative abundance of non-cerambycid beetles included Treatment and BA during 2006 and Treatment, Period, and an interaction between Treatment and Period during 2007 (Tables 2.14a, b). The best 2007 model was selected based on the least number of variables since weights were similar between the three top models.

During 2006, relatively more non-cerambycid beetles were caught in CUT1 than CON ($t_{91} = 2.07$, $p = 0.04$) (Table 2.15). During 2007, more beetles were caught in CUT2 than CUT1 ($t_{69} = -2.59$, $p = 0.03$) but not than CON ($t_{69} = -0.79$, $p = 0.75$). CUT1 and CON were not different ($t_{69} = -0.16$, $p = 0.12$) (Table 2.15).

The three functional groups of non-cerambycids exhibited differing trends in relative abundance among treatments and between years (Table 2.16). Only fresh wood species were consistently more abundant in partial cuts in both years (Table 2.16).

Table 2.13. Non-cerambycid wood-boring species captured during 2006 and 2007. The most abundant five species are highlighted in red.

Family	Species	2006			2007		
		n	%	rank	n	%	rank
Bostrichidae	<i>Xylobiops basilaris</i> (Say)	-	-	-	1	0.1	18
Brentidae	<i>Arrhenodes minutus</i> (Drury)	11	1.7	10	14	1.4	11
Buprestidae	<i>Agrilus</i> spp.	-	-	-	8	0.8	14
	<i>Buprestis</i> sp.	-	-	-	2	0.2	18
	<i>Chrysobothris</i> spp.	22	3.5	6	35	3.6	6
	<i>Dicerca</i> spp.	143	22.5	2	60	6.1	4
	<i>Texania</i> sp.	-	-	-	2	0.2	18
Cleridae	<i>Chariessa pilosa</i> (Forster)	26	4.1	5	39	4	5
	<i>Cregya oculatis</i> Say	-	-	-	6	0.6	16
	<i>Cymatodera</i> spp.	6	0.9	13	16	1.6	10
	<i>Enoclerus ichneumoneus</i> (F.)	5	0.8	14	16	1.6	10
	<i>Monophylla terminata</i> (Say)	3	0.5	16	2	0.2	18
	<i>Neorthopleura damicornis</i> (Say)	59	9.3	3	267	27.2	1
	<i>Priocera castanea</i> Newman	-	-	-	1	0.1	19
	<i>Pyticeroides laticornis</i> (Say)	7	1.1	12	20	2	9
Elateridae	<i>Alaus oculatus</i> (Linnaeus)	4	0.6	15	7	0.7	15
	<i>Dicrepidius</i> sp.	1	0.2	18	-	-	-
	<i>Hemirhipus fascicularis</i> (F.)	-	-	-	2	0.2	18
	<i>Melanotus</i> spp.	210	33.1	1	212	21.6	2
	<i>Orthostethus infuscatus</i> Germar	-	-	-	1	0.1	19
Eucnemidae	<i>Dromaeolus</i> spp.	11	1.7	10	27	2.7	7
	<i>Euryptychus heterocerus</i> Say	-	-	-	1	0.1	19
	<i>Fornax bicolor</i> Melsheimer	2	0.3	17	-	-	-
	<i>Nematodes</i> spp.	39	6.1	4	181	18.4	3
Lymexylidae	<i>Melittomma sericeum</i> (Harris)	5	0.8	14	3	0.3	17
Mordellidae	<i>Glipa hilaris</i> (Say)	5	0.8	14	1	0.1	19
	<i>Hoshihananomia octopunctata</i> F.	8	1.3	11	6	0.6	16
	<i>Yakuhananomia bidentata</i> (Say)	19	3	8	9	0.9	13
Passandridae	<i>Catogenus rufus</i> (Fabricius)	3	0.5	16	6	0.6	16
Staphylinidae	<i>Hersperus apicalis</i> Say	21	3.3	7	10	1	12
	<i>Pinophilus latipes</i> Gravenhorst	1	0.2	18	1	0.1	19
Synchroidae	<i>Synchroa punctata</i> Newman	6	0.9	13	6	0.6	16
Trogossitidae	<i>Temnocheila acuta</i> LeConte	18	2.8	9	26	2.6	8
Total		635			988		

Table 2.14. Pseudo AIC_C , ΔAIC_C , and weight (w_i) values for competing models explaining the relative abundance of non-cerambycid beetles (NRA) in a) 2006 and b) 2007. The highlighted model is the best model. Treat = treatment type (one-yr-old cut vs. two-yr-old vs. control), Period = sampling period (1, 2, or 3), Totdead = number of trees in decay classes 5-9, BA = basal area, SBA = basal area of sugarberry, and Decadent = number of trees in decay classes 3 to 4.

a)	MODELS 2006	PSEUDO AIC_C	ΔAIC_C	w_i
	NRA = Treat BA	257.81	0.00	0.52
	NRA = Treat Period BA	259.93	2.12	0.18
	NRA = Treat Period Period*Treat BA	261.18	3.37	0.10
	NRA = BA	261.24	3.43	0.09
	NRA = Treat Period Period*Treat Totdead BA Decadent	261.49	3.68	0.08
	NRA = Treat Period Period*Treat Totdead BA	263.9	6.09	0.02
	NRA = Treat Period Period*Treat Totdead	268.19	10.38	0.00
	NRA = Null	268.72	10.91	0.00

b)	MODELS 2007	PSEUDO AIC_C	ΔAIC_C	w_i
	NRA = Treat Period Period*Treat Totdead	259.83	-0.44	0.28
	NRA = Treat Period Period*Treat Totdead BA	260.11	-0.16	0.33
	NRA = Treat Period Period*Treat	260.27	0	0.35
	NRA = Treat Period Period*Treat Totdead BA Decadent	263.43	3.6	0.07
	NRA = Treat Period Period*Treat Totdead BA Decadent SBA	264.75	4.48	0.04
	NRA = Treat Period	290.58	30.31	0.00
	NRA = Null	299.00	39.17	0.00

Table 2.15. 2006 and 2007 estimates per sample unit, standard error (SE), and 95% upper and lower confidence limits (UCLM and LCLM) for class and quantitative variables predicting relative abundance of non-cerambycid beetles. CUT1 = one-year-old partial cuts, CUT2 = two-year-old partial cuts, CON = controls, PER1, 2, and 3 = Period 1, 2, or 3, BA = basal area.

Year	Variable	Estimate	SE	UCLM	LCLM
2006	CUT1	7.24	0.66	8.58	5.91
2006	CON	6.10	0.56	7.2	4.98
2006	PER1	6.24	0.74	7.5	4.7
2006	PER2	7.47	0.8	9.01	5.8
2006	PER3	6.53	0.8	8.15	4.9
2006	BA	1.28	1.09	1.08	1.53
2007	CUT1	11.37	1.28	14.01	8.73
2007	CUT2	13.11	1.74	15.8	10.05
2007	CON	12.93	1.4	16.7	9.5
2007	PER1	14.15	1.84	17.9	10.4
2007	PER2	11.9	1.39	14.7	9.03
2007	PER3	11.4	1.11	13.6	9.1

Table 2.16. Comparison of relative abundance of functional groups of non-cerambycids between treatments and years. # SP = the number of species in the functional group, total n = the total sample size for that functional group and Mean/trap = n/number of samples in that treatment since 2006 had varying samples for each treatment; CUT1 = 53 and CON = 40. 2007 had 27 samples for each treatment (CUT1, CUT2, and CON).

Functional Group	# Sp	2006				# Sp	2007					
		Total n		Mean/trap			Total n			Mean/trap		
		CUT1	CON	CUT1	CON		CUT1	CUT2	CON	CUT1	CUT2	CON
Rotting Wood	11	179	131	3.4	3.3	12	128	134	194	4.7	5	7.2
Fresh Wood	3	127	49	2.4	1.2	7	43	51	28	1.6	1.9	1
Predators	10	83	66	1.6	1.7	12	118	162	130	4.4	6	4.8

During 2006, differences were not found in the abundance of non-cerambycids caught in Period 1, 2, or 3. However, in 2007, more beetles were caught in Period 1 than Period 3 ($t_{69} = 2.5$, $p = 0.039$) but no differences were observed between Period 1 and Period 2 ($t_{69} = 2.01$, $p = 0.12$) and Period 2 and 3 ($t_{69} = 0.63$, $p = 0.88$). Relative abundance increased with increasing BA in 2006 (Table 2.15). In 2006, beetle abundance was higher in CUT1 than CON across periods but it was not in 2007, as indicated by the interaction between treatment and period (Fig. 2.8a, b). In 2007, the interaction was similar to the cerambycids; non-cerambycids were more abundant in CON in Period 1 but higher in CUT2 followed by CUT1 in Period 2 and 3 (Fig. 2.8a, b).

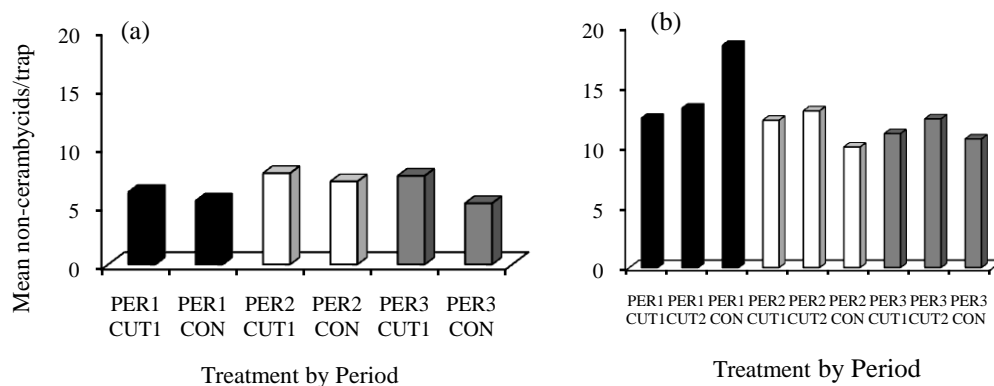


Figure 2.8. Mean number of non-cerambycid captures by treatment type and period in a) 2006 and b) 2007. CUT1 = one-year-old cuts, CUT2 = two-year-old cuts, CON = Controls, and PER1, 2, and 3 = Period 1, 2, and 3.

Species Richness of Non-Cerambycidae

In 2006 and 2007, the most informative model was the null model (Tables 2.17, 2.18).

Table 2.17. Pseudo AIC_C , ΔAIC_C , and weight (w_i) values for competing models explaining the species richness of non-cerambycid beetles (NSR) in a) 2006 and b) 2007. The highlighted model is the best model. Treat = treatment type (one-yr-old cut vs. two-yr-old cut vs. control), Period = sampling period (1, 2, or 3), Totdead = number of trees in decay classes 5-9, BA = basal area, and SBA = basal area of sugarberry.

a)	MODELS 2007	PSEUDO AIC_C	ΔAIC_C	w_i
NSR = Null		162.97	0	0.74
NSR = Treat		165.93	2.96	0.17
NSR = Period Treat		168.84	5.87	0.04
NSR = Period Treat Treat*Period Totdead		169.91	6.94	0.02
NSR = Period Treat Treat*Period		170.16	7.19	0.02
NSR = Treat Period Treat*Period Totdead BA		171.27	8.3	0.01
NSR = Treat Period Treat*Period Totdead BA Decadent		174.34	11.37	0.00

b)	MODELS 2007	PSEUDO AIC_C	ΔAIC_C	w_i
NSR = Null		83.55	0	0.88
NSR = Treat		87.8	4.25	0.11
NSR = Treat Period		92.55	9	0.01
NSR = Treat Period Treat*Period		96.06	12.51	0.00
NSR = Treat Period Treat*Period Totdead		100.28	16.73	0.00
NSR = Treat Period Treat*Period Totdead BA		101.86	18.31	0.00
NSR = Treat Period Treat*Period Totdead BA Decadent		103.43	19.88	0.00
NSR = Treat Period Treat*Period Totdead BA Decadent SBA		104.83	21.28	0.00

Table 2.18. 2006 and 2007 Estimates, SE, and 95% UCLM and LCLM for class variables considered in models for species richness of non-cerambycid beetles.

Year	Variable	Estimate	SE	UCLM	LCLM
2006	CUT1	3.44	0.25	3.94	2.94
2006	CON	3.46	0.31	4.09	2.84
2006	PER1	3.23	0.33	3.89	2.56
2006	PER2	3.78	0.37	4.53	3.03
2006	PER3	3.34	0.31	3.98	2.71
2007	CUT1	5.33	0.38	6.12	4.54
2007	CUT2	4.81	0.35	5.55	4.07
2007	CON	4.88	0.37	5.65	4.12
2007	PER1	4.9	0.31	5.53	4.25
2007	PER2	5.07	0.37	5.83	4.31
2007	PER3	5.07	0.43	5.95	4.19

Although treatment had no effect on sample species richness, total richness indicated by rarefaction curves tended to be higher in partial cuts in both years (Fig. 2.9a, b).

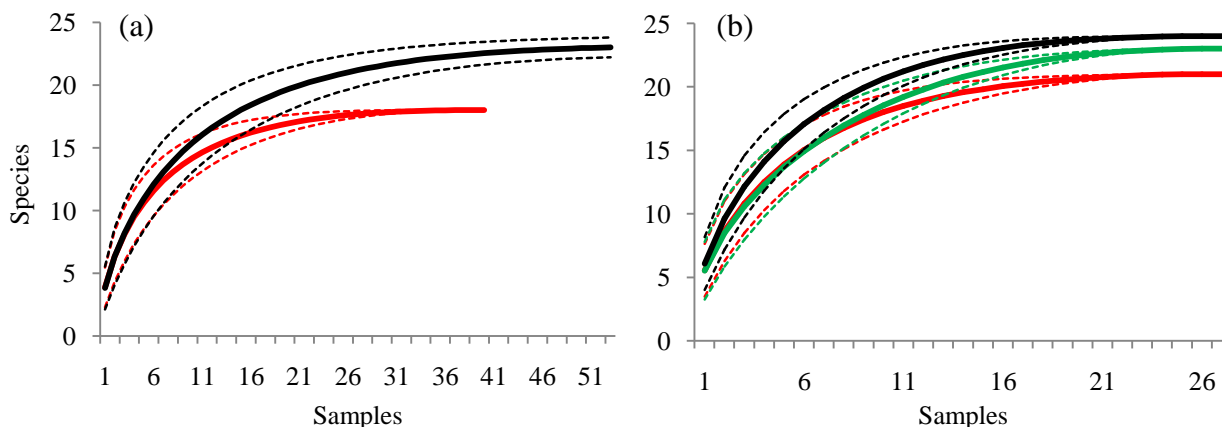


Figure 2.9. Rarefaction curves for total non-cerambycid species richness in (a) 2006 and (b) 2007. Total species collected in CUT1 are indicated by black, red for CON, and green for CUT2. Solid lines are SOBS rarefaction and dotted lines are upper and lower 95% confidence intervals.

Individual Species of Cerambycidae and Non-Cerambycidae

Species composition was similar between CUT1 and CUT2; the species caught in CUT2 were also captured in CUT1 except for two species that were unique. Some species, however, seemed to rely on conditions available in either partial cuts or uncut controls since they were exclusively or predominately captured there. Including only species with total abundance ≥ 8 (it would be difficult to discern preference with too few individuals); six species were exclusively or predominately caught in partial cuts; *Saperda tridentata* Olivier 100% (9 of 9 captures), *Catogneus rufus* (F.) 100% (9 of 9), *Melittomma sericeum* (Harris) 100% (8 of 8), *Knulliana c. cincta* (Drury) 96% (45 of 46), *Eburia quadrigeminata* (Say) 91% (41 of 45), and *Anelaphus parallelus* (Newman) 84% (16 of 19). One species was predominantly captured in controls; *Dryobius sexnotatus* Linsley 85% (23 of 27). As well, many more species were exclusively caught in partial cuts (31) than (10) controls with abundance < 8 .

Principal Components Analysis

Seventeen saproxylic species in 2006 and 16 in 2007 with abundance >1% were analyzed with PCA. The scree plot indicated five principal components (PC) to retain in 2006 and three in 2007 (Fig. 2.10a, b). The weighted and unweighted variances are shown in Table 2.19.

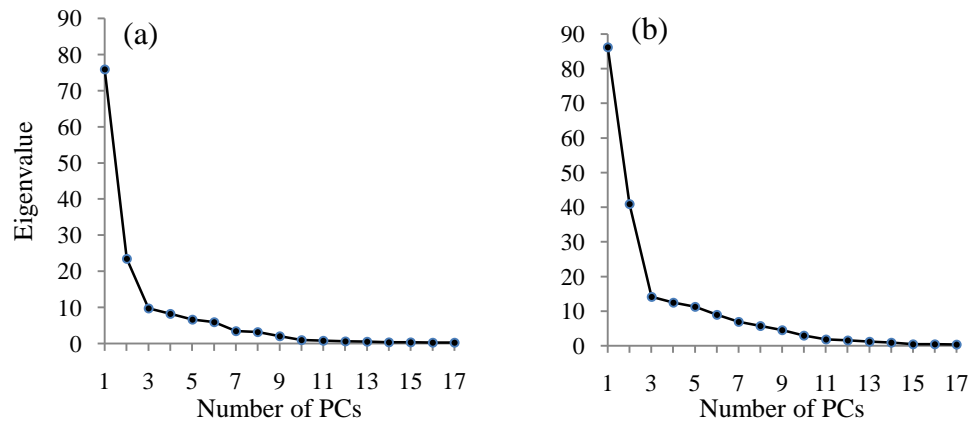


Figure 2.10. Scree plot of eigenvalues for principal components in Principal Component Analysis of species in a) 2006 and b) 2007. The elbow in the plot denotes the number of principal components to retain.

Table 2.19. Variance explained by each Principal Component (PC) retained in the PCA analysis for the rotated factor pattern method in 2006 and 2007.

Year	Principal Component	Weighted	Unweighted
2006	PC 1	67.6	1.6
2006	PC 2	9.4	1.5
2006	PC 3	32.1	1.3
2006	PC 4	9.5	1.2
2006	PC 5	7.2	1.2
2007	PC 1	40.3	1.9
2007	PC 2	84.7	1.9
2007	PC 3	16.2	1.2

The variables and covariables found to be correlated with the 2006 PCs by the MANOVA were Treatment (CUT1 or CON) (Wilkes-Lambda $F_{5,80} = 4.56$, $p = 0.0010$), Period (1, 2, or 3) (Wilkes-Lambda $F_{10,160} = 6.15$, $p < 0.0001$), Treatment*Period (Wilkes-Lambda $F_{10,160} = 2.68$, $p = 0.0046$), and Totdead (Wilkes-Lambda $F_{5,80} = 4.36$, $p = 0.0015$).

In 2006, PC1 was most highly positively correlated with *Neoclytus mucronatus* (F.) and *Neoclytus scutellaris* (Olivier), (Table 2.20). PC1(2006) was explained by the covariable Period ($F_{2,85} = 14.23$, $p < 0.0001$). PC1(2006) was more abundant in Period 2 (0.61 ± 0.26) than Period 1 (-0.58 ± 0.05) ($t_{95} = -5.4$, $p < 0.0001$) and Period 3 (-0.06 ± 0.05) ($t_{95} = -3.02$, $p = 0.0093$), and PC1(2006) was more abundant in Period 3 than Period 1 ($t_{95} = -2.5$, $p = 0.0387$).

PC2(2006) was most highly positively correlated with the cerambycids *Ecyrus d. dacycerus* (Say), and *Elaphidion mucronatum* (Say) and was explained by Treatment ($F_{1,85} = 20.93$, $p < 0.0001$) and Period ($F_{2,85} = 4.34$, $p = 0.0161$). The estimate for PC2(2006) was higher in CUT1 than CON ($t_{95} = 4.44$, $p < 0.0001$). PC2(2006) was greater in Period 3 (0.20 ± 0.14) than Period 1 (-0.38 ± 0.13) ($t_{95} = -2.8$, $p = 0.0183$) but not than Period 2 (0.16 ± 0.23) ($t_{95} = 0.30$, $p = 0.95$). PC2(2006) was greater in Period 2 than Period 1 ($t_{95} = -2.5$, $p = 0.04$).

PC3(2006) was most highly positively correlated with the cerambycid *Obrium maculatum* (Olivier). A Period*Treatment interaction was observed ($F_{2,85} = 6.05$, $p = 0.0035$) and PC3(2006) increased by 1.57 with each additional dead tree ($F_{1,85} = 11.2$, $p = 0.0012$).

PC4 was principally composed of *Distenia undata* (F.). This PC was not different among the treatment types and was not correlated with any of the covariables ($F_{8,85} = 1.16$, $p = 0.33$).

PC5 was most highly positively correlated with *Dicerca* spp. and most highly negatively correlated with *Melanotus* spp. (Table 2.20). PC5 was explained by Period ($F_{2,85} = 4.18$, $p = 0.019$). PC5 was higher in Period 3 (0.43 ± 0.23) than Period 2 (-0.27 ± 0.13) ($t_{95} = -2.69$, $p = 0.023$) but not than Period 1 (-0.17 ± 0.13) ($t_{95} = -2.24$, $p = 0.07$). Period 1 and 2 were not different ($t_{95} = -0.39$, $p = 0.91$).

In 2007, the variables found to be correlated with the principal components by the MANOVA were Treatment (CUT1, CUT2, or CON) (Wilkes-Lambda $F_{6,134} = 2.79$, $p = 0.0138$) and Period (1, 2, or 3) (Wilkes-Lambda $F_{6,134} = 8.07$, $p < 0.0001$).

Table 2.20. Rotated factor pattern for species with abundance >1% of total for either 2006 or 2007. Species with values >0.5 were selected as being important for that Principal Component. Species highlighted in red were important in either 2006 or 2007 whereas species highlighted in blue were important in both years. Dashes indicate species that were not >1% in that year.

Species	2006					2007		
	PC1	PC2	PC3	PC4	PC5	PC1	PC2	PC3
<i>Anelaphus villosus</i> (F.)	-	-	-	-	-	53	-15	-4
<i>Chariessa pilosa</i> (Forster)	9	-1	25	8	7	1	39	15
<i>Chrysobothris</i> spp.	-6	2	-5	-9	-4	27	2	1
<i>Dicerca</i> spp.	-1	8	-14	0	85	4	8	24
<i>Distenia undata</i> (F.)	17	29	-10	93	-3	-8	-4	17
<i>Eburia quadrigeminata</i> (Say)	-3	35	-13	12	16	-	-	-
<i>Ecyrus d. dasycerus</i> (Say)	6	53	14	-15	1	11	22	-12
<i>Elaphidion mucronatum</i> (Say)	10	86	3	-13	-7	-3	34	29
<i>Leptostylus transversus</i> (Gyllenhal)	6	0	3	-14	5	0	16	3
<i>Melanotus</i> spp.	-5	-3	2	-4	-57	-10	19	36
<i>Nematodes</i> spp.	4	-3	29	-15	-9	56	-4	-1
<i>Neoclytus a. acuminatus</i> (F.)	10	13	0	-1	-19	-2	-3	12
<i>Neoclytus m. mucronatus</i> (F.)	96	-13	23	-4	-5	-12	99	-2
<i>Neoclytus scutellaris</i> (Olivier)	75	32	28	-25	-6	16	47	64
<i>Neorthoppleura damicornis</i> (Say)	1	12	-10	-23	-9	54	-1	57
<i>Obrium maculatum</i> (Olivier)	10	-4	99	2	-1	93	1	-31
<i>Parelapheidion aspersum</i> Haldeman	-2	24	-7	32	-2	-	-	-
<i>Styloleptis biustus</i> (LeConte)	18	11	-2	-29	-3	-16	50	-4

PC1(2007) was principally composed of the cerambycids; *Obrium maculatum* (Olivier) and *Anelaphus villosus* (F.) and the predators; *Nematodes* spp. and *Neorthoppleura damicornis* (Say) (Table 2.20) and could be explained by Period ($F_{2,69} = 10.22$, $p = 0.0001$). PC1(2007) was higher in Period 1 (0.59 ± 0.26) than Period 2 (-0.21 ± 0.12) ($t_{74} = 3.46$, $p = 0.0026$) and Period 3 (-0.39 ± 0.1) ($t_{74} = -4.25$, $p = 0.0002$) but Period 2 and 3 were not different ($t_{74} = 0.78$, $p = 0.71$).

PC2(2007) was composed of *Neoclytus mucronatus* (F.) and *Styloleptis biustus* (LeConte) and could be explained by Period ($F_{2,69} = 13.47$, $p < 0.0001$). PC2 was higher in Period 2 (0.68 ± 0.29) than Period 1 (-0.42 ± 0.03) ($t_{74} = 4.81$, $p < 0.0001$) and Period 3 (-0.26 ± 0.06) ($t_{74} = -3.98$, $p = 0.0005$). Period 1 and 3 were not significantly different ($t_{74} = 0.82$, $p = 0.69$).

PC3(2007) was composed of *Neoclytus scutellaris* (Olivier) and *Neorthoppleura damicornis* (Say), a predator (Table 2.20). MANOVA results indicated none of the variables or covariables were related to PC3 even though both *N. scutellaris* (Olivier) and *N. damicornis* (Say) were almost double their abundance in CUT2 than CUT1 or CON.

Harvest Wounds

Twenty-four of 110 (22%) plot trees in 2005 partial cuts and 18 of 89 (20%) trees in 2006 partial cuts had residual trees with harvest wounds. Seven percent of wounds were broken tops, the rest were to the lower bole or roots. Thirteen percent were extra-large wounds, 35% large wounds, 28% medium, and 17% small. Wounded trees were from 10-108 cm dbh ($32.8 \text{ cm} \pm 8.12 \text{ cm}$). Because few harvest wounded trees were dead ($n = 2$), I only included vigorous and decadent trees for analysis. No difference in decay class of trees with small harvest wounds and large wounds was found ($F_{1,51} = 0.03$, $p = 0.86$) indicating harvest wounds did not affect the decay class of trees two years following harvest in this study.

Discussion

The results of this study indicate partial cutting can be used as a tool to increase the abundance of saproxylic beetles and seasonal species richness and these effects continue for at least two years post-harvest. However, abundance among treatments fluctuates greatly throughout the summer season and between years. Uncut forest starts off the season with more saproxylic beetles than partial cuts from mid-April to mid-May. This time frame features the highest mean/trap of non-cerambycids and the second highest mean/trap of cerambycids. However, by mid-May through to the end of July, saproxylic beetles are in most cases more abundant in partial cuts than controls with two-year-old cuts having the highest abundance followed by one-year-old cuts. This seasonal fluctuation could be responsible for the lack of consistency in relative abundance among treatments but illustrates the importance of maintaining

both uncut forest and partial cut forest. No other studies have examined relative abundance and species richness over season to my knowledge.

Relative abundance also varied greatly by year, most notably in the non-cerambycids which were about twice as abundant in 2007 as in 2006. This annual variation causes more differences in means than do treatments; however, yearly variation, which is likely due to natural climatic variability, cannot be manipulated. In this case, the spring season was warmer in 2007 compared to 2006 (National Weather Service data 2008) and probably accounted for the higher abundance and richness of beetles in 2007.

Species richness of saproxylic beetles for the entire season was greater in partial cuts than controls but no seasonal fluctuations were observed. As well, species richness varied greatly between years with more species during 2007 than 2006. This yearly variation was not due to the addition of Bayou Cocodrie as a site in 2007 since only one new species (*Buprestis* sp.) was collected there. Furthermore, it was not due to the addition of two-year-old-cuts since there was not a succession of species from one-year-old cuts to two-year-old cuts; only two species (both unique) were exclusive to two-year-old cuts. This is in contrast to Hammond et al. (2001) that documented a conspicuous succession of species from one-year-old cuts to two-year old cuts.

The effect of partial cutting on abundance is most pronounced for Cerambycidae and Buprestidae, both families associated with fresh dead wood. Cerambycids and buprestids likely responded to the input of fresh, sun-exposed, dead wood in the form of logging slash (Warriner et al. 2002; Ulyshen et al. 2004) that was present one and two years post-harvest. Saproxylic beetles in general tend to occur in greater abundance in more sun-exposed conditions (Jonsell et al. 1998; Sverdrup-Thygeson and Ims 2002; Lindhe and Lindelow 2004; Bouget 2005a; Lindhe et al. 2005) such as those that occur after forest fire, windfall, or tree-fall (Kaila et al. 1997; Jonsell et al. 1998; Jonsson et al. 2005). Species preferring sun-exposed substrates are more common during the early stages of log decay especially in hardwood systems (Jonsell et al. 1998;

Jonsson et al. 2005). Similar to this study, relative abundance of saproxylic beetles was also found to be greater in recently thinned stands (one or two years post-harvest) than unthinned stands in Mississippi and South Carolina BLH (Warriner et al. 2002; Ulyshen et al. 2004). However, beetle abundance may begin decreasing shortly after harvest relative to the maximum age of the stand. As little as five to six years later, beetle abundance can begin to decline to levels lower than the original uncut stand once CWD decomposes (Ulyshen et al. 2004; Gutowski et al. 1985). This outlines the importance of a continuous supply of standing dead wood which enhances the local abundance of cerambycids as found in this study.

The fact that cerambycid abundance is correlated with the number of snags seems to contradict their preference for fresh CWD in partial cuts. However, some species may be adapted to sun-exposed fresh dead wood that would arise from a major disturbance (such as the six species found in this study that predominately or exclusively were found in partial cuts) while others [such as *D. sexnotatus* (Linsley) and *O. maculatum* (Olivier)] to standing dead trees created by the natural process of tree mortality.

As well, species may be adapted to different substrates. Other studies have found different assemblages, species richness, and relative abundance of saproxylic beetles in snags versus logs (Shiegg 2001; Sverdrup-Thygeson and Ims 2002; Jonsell and Weslien 2003; Gibb et al. 2006; Hjalten et al. 2007). Association with different substrates may be particularly evident in bottomlands where logs are frequently inundated creating a difference in moisture content between standing dead trees and logs (Braccia and Batzer 2001; Jonsell and Weslien 2003).

In this study, large harvest wounds did not alter the decay class of trees one or two years post-harvest and should not be expected to contribute to tree mortality in the short term. Lombardero et al. (2006) found mechanically wounding *Pinus resinosa* trees by removing two horizontal strips of bark from 40% of the circumference of the tree, had no effect on bark beetles and that six years later, all but two of the experimental trees were still vigorous and were

indistinguishable in crown quality and stem volume from control trees. Other methods have more utility in killing trees for wildlife purposes (Conner et al 1982; Aulen 1991; Farris et al., 2002). Girdling trees has been investigated for creating snags but injecting trees with 2, 4-D kills trees faster than girdling trees (Conner et al. 1983). Further, injecting trees may be more cost effective than girdling (Conner et al. 1983).

The results of this study, and other studies conducted in bottomland hardwoods (Warriner et al. 2002; Ulyshen et al. 2004; Ulyshen and Hanula 2007) indicate wood-borers like cerambycid and buprestid beetles are much more abundant in BLH than in coniferous ecosystems (Jonsell et al. 2004; Lindhe and Lindelow 2004; Jonsell et al. 2005; Abrahamsson and Lindbladh 2006; Schroeder et al. 2006; Saint-Germaine et al. 2007) and bark-beetles such as Scolytinae are less abundant in BLH. Hardwood species generally host higher abundances and richness of wood-borers than softwood species (Jonsell et al. 2005; Saint-Germaine et al. 2007; Jonsell et al. 2007). Although this may be a real characteristic of these systems, it may also be due to differences in sampling techniques or flying strategies of beetles. Scolytinae are often small and since beetles were sorted through a 6 mm filter, it could be argued that Scolytines were filtered, however, Scolytinae of any size were not abundant in samples (*personal observation*). The comparison among regions is difficult since entomologists in other parts of the world have not used Sante traps to capture saproxylic beetles while Sante trapping is the only method used and documented in the Southern U.S.

Contrary to expected, beetles were six times more abundant in top vessels than bottom vessels (nine times more cerambycids and three times more non-cerambycids). This was probably due to decreased effectiveness of bottom vessels after precipitation that both diluted the attractant (ethanol) with rainwater and cluttered vessels with leaves. Sante traps with mesh walls may greatly facilitate capture of cerambycid beetles compared to plastic surfaces used in trunk window traps where they may escape before falling into collection vessels.

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Chapter 3: Nest and Roost Tree and Site Selection of Pileated Woodpeckers (*Dryocopus pileatus*) in Partial Cut and Uncut Bottomland Hardwood Forests

Introduction

Management of bottomland hardwoods (BLH) on private and public lands in the Mississippi Alluvial Valley is shifting to partial cut harvesting to meet wildlife objectives (Guilfoyle et al. 2005; LMVJV 2007). Both group and single tree partial cutting are considered favorable methods of harvesting from a silvicultural and wildlife perspective (Meadows and Stanturf 1999; Moorman and Guynn 2001; Graves 2002; Somershoe et al. 2003) since these methods can increase vertical structure for resident and migrant songbirds, wild turkey (*Meleagris gallopavo*), and white-tailed deer (*Odocoileus virginianus*), as well as release advanced regeneration in a stand (*LDWF forest prescriptions 1999-2002*; Hamilton et al. 2005). Partial cutting may not however, benefit cavity nesting birds like pileated woodpeckers that depend on dead wood for nesting and roosting, since partial cutting often targets large-diameter, poor quality trees for removal (Meadows and Goeltz 2005).

Pileated woodpeckers (*Dryocopus pileatus*) are common residents BLH forests of Louisiana that excavate nest and roost cavities. These cavities are subsequently used by secondary cavity nesters such as prothonotary warblers (*Protonotaria citrea*), eastern bluebirds (*Sialia sialis*), Great crested flycatchers (*Myiarchus crinitus*), Carolina chickadees (*Parus carolinensis*), tree swallows (*Tachycineta bicolor*), and wood ducks (*Aix sponsa*) and also by cavity-dependent saproxylic beetles, southern flying squirrels (*Glaucomys volans*), bats, and red wasps (*Polistes* spp.) (Conner and Saenz 1996; McClelland and McClelland 1999; Adkins Giese and Cuthbert 2003; Bull et al. 2007). No studies have been conducted on the effects of partial cutting on nesting and roosting ecology of the pileated woodpecker. In fact, basic information on the characteristics of nest and roost trees used by pileated woodpeckers is limited in the south regardless of forest type or management strategy. Numerous studies have evaluated nest and

roost tree characteristics in the northwest (Bull et al. 1992; McClelland and McClelland 1999; Aubry and Raley 2002); however, extrapolating information from one locality to another is not advisable since a large degree of geographic variation exists in pileated woodpecker behavior (McClelland and McClelland 1999). My objectives were to: (1) identify differences in characteristics of nest and roost trees of pileated woodpeckers between partial cuts and uncut controls in Louisiana; (2) identify differences in preference of tree characteristics indicated by a difference in use versus availability between partial cuts and uncut forest; and (3) determine differences in pileated woodpecker selection of nest and roost sites between partial cuts and controls. I predicted pileated woodpeckers would select tree species with lower wood density, trees in larger dbh classes, and in more advanced stages of decay for nesting and roosting. I predicted preferred cavity trees would be more limiting in partial cuts since specific species, dbh classes, and decay classes are selected for removal in partial cuts which would no longer be available for nesting or roosting. I expected woodpeckers to select sites with higher basal area in partial cuts whereas in controls, I expected them to use sites with basal area in proportion to what was available since basal area is more uniform in uncut forest.

Study Area

Pileated woodpeckers were studied in the Three Rivers and Red River WMAs in east central Louisiana in 2006 and 2007. The area of the two WMAs comprised 22,781 ha of BLH that were historically flooded by the Mississippi River to the East. Since the construction of levees on the Mississippi River, the system is now predominately ponded only by precipitation and periodically by the Red River to the West. The main soil on both study sites was Sharkey clay that is of poor drainage and high fertility (*LDWF forest prescriptions 1999 to 2002*). Partial cuts consisted of the overcup oak-bitter pecan (*Quercus lyrata-Carya aquatica*) association before and after harvest. One control site in Red River WMA was composed of the sugarberry

(*Celtis laevigata*)-overcup oak association and the other of the overcup oak-bitter pecan association. Three Rivers WMA controls were composed of the sugarberry-overcup oak association.

Pileated woodpecker territories were located in group and single tree partial cuts and uncut controls. The selection of cut sites was only a result of what was available on public lands and was not designed to compare different types of partial cuts; group or single tree. The study was not designed to compare different types of partial cuts. Partial cuts consisted of one 85 ha group cut and one 145 ha single tree cut harvested in 2005 and two group cuts harvested in 2006 (25 ha and 85 ha). All partial cuts were harvested in either the summer or fall. Approximately 30% of the basal area (BA) was removed in each treatment according to a prescription to “promote advanced regeneration, create white tailed deer (*Odocoileus virginianus*) browse and cover, and maintain and provide vertical structure for Neotropical migratory birds and wild turkey (*Meleagris gallopavo*)” (*LDWF forest prescriptions 1999 to 2002*). Gaps created by single tree cuts were 0.02-0.08 ha while group cutting created 0.4-2 ha openings (Meadows and Stanturf 1997). Baldcypress (*Taxodium distichum*), cavity trees, and large overcup oak (>70cm dbh) were avoided for harvest. As well, 50% of declining trees were left for addition to the standing dead wood component (*LDWF forest prescriptions 1999 to 2002*).

Methods

Study Design

Nests of birds in this study were initially located for the purpose of capturing birds for radio-transmitter application as part of the foraging ecology study (*Chapter 4*). In 2006, nest searching began in mid-March and continued until mid-May. Nest searching consisted of using audio and visual cues to follow birds to nests. In 2007, nest searching began in early February while birds were still excavating cavities. Nests were found opportunistically until the end of

April during foraging observations. Once nests were found, they were revisited once or twice before capture attempts to confirm activity. I recorded nests as being active if incubation, mate switching, or presence of young was confirmed (Fig 3.1). All nest cavities that were excavated were used in analyses, regardless of activity status. Presumably, a cavity excavated but not used by a pileated woodpecker would still be a potential nest site for secondary cavity nesters or habitat for other animals that use cavities. Also, cavities excavated but not used for nesting may have been used for roosting or may be used in subsequent years for nesting (Jackson and Jackson 2004). Nest success was determined during foraging observations after capture attempts were concluded. A nest was determined as being successful if fledglings were observed in the territory.

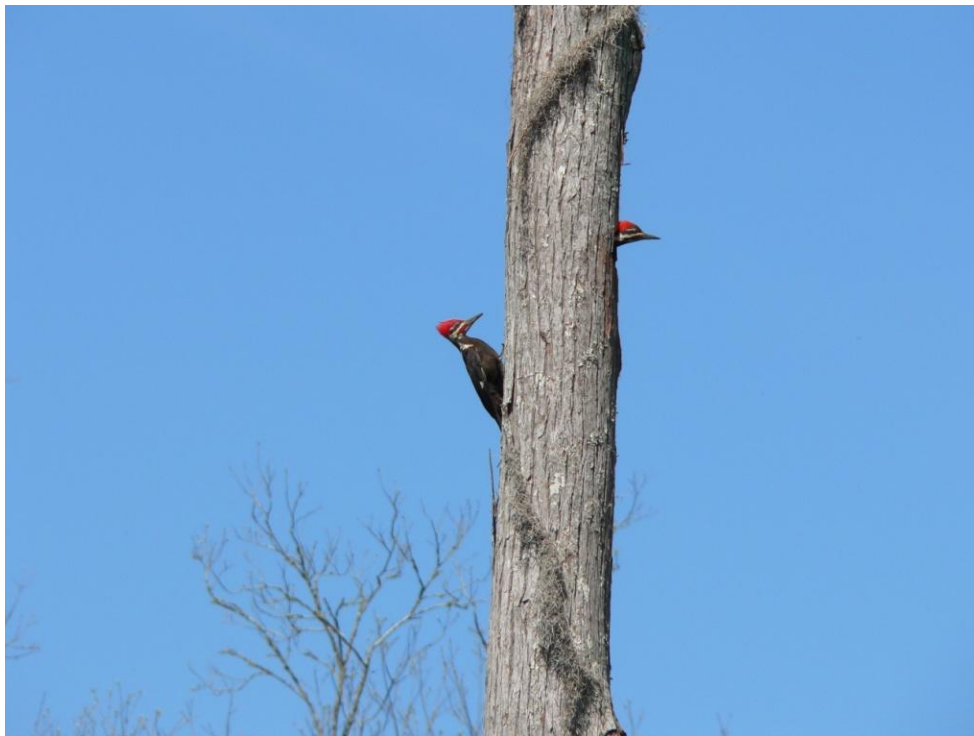


Figure 3.1. Confirmation of active nest site by mate switching.

Once birds were captured and fitted with radio-transmitters, they could also be located at roosts during the morning and evening. Roost locations were found from March to July in both years by following radio-marked birds in partial cuts and uncut controls. Roosts were located

sporadically; consequently, the information on the number of roost cavities used by individuals could not be determined with this data.

Vegetation Plots

For each nest and roost tree, I established a 0.04 ha plot using the cavity tree as the center. I recorded species, dbh, decay class, and vine class of each tree ≥ 10 cm dbh, including the cavity tree. I used decay classes developed by Foti et al. (2005) (Table 4.1).

Table 3.1. Tree condition and description of decay classes (Foti et al. 2005).

Decay Class	Tree Condition	Description
1	Vigorous	Live tree, live crown
2		<1/3 crown dieback
3		1/3-2/3 crown dieback
4	Decadent	>2/3 crown dieback
5		Recently dead
6	Early Stage of Decay	Retains only large limbs
7		Only bole ≥ 8 m
8	Late Stage of Decay	Only bole <8 m
9		Only stump
10	Downed	Log

Vine density on trees was assessed by classifying the number of vines on the tree into one of five vine classes (Table 3.2). Tree species and frequency of vegetation <10 cm dbh was also measured in the northeast quadrant of each plot.

Table 3.2. Vine classes of trees.

Vine Class	Number of Vines
0	0
1	1-2
2	3-5
3	6-9
4	10+

In addition to cavity tree plots, I established 0.04 ha random plots to collect data on trees available to woodpeckers. Plots were sampled within the territory of a nesting or roosting

woodpecker between 50 and 200 m from the cavity tree in a random direction and within the same treatment type (partial cut or control) as the cavity tree. I recorded tree characteristics as explained above on all trees.

Selection of Tree Characteristics

To determine if tree characteristics (species, dbh class, decay class, and vine class) were used more than they were available, I compared the proportion of use of nest and roost tree characteristics to the proportion of tree characteristics available in random plots with logistic regression (PROC LOGISTIC in SAS 9.1). Trees from cavity tree plots that were not used for nesting or roosting were not included as available trees in analyses to avoid any bias that may have existed with trees in close proximity to nest trees. In essence, only the cavity tree was used from cavity tree plots, while all trees were used from availability plots to compare tree characteristics. The tree data were divided into two data sets that consisted of: (1) partial cut; and (2) uncut control. Cavity trees from one-year-old and two-year-old partial cuts were pooled since structurally, partial cuts were similar. Data from 2006 and 2007 were pooled for analyses and nest and roost trees were pooled since they were not mutually exclusive; nests were used as roosts and also by males during nesting in this study. Accordingly, two separate logistic regressions were done to determine differences in preference among treatments. Since woodpeckers did not use trees <40 cm dbh for nesting or roosting, all trees <40 cm dbh were removed from analyses.

To avoid quasi-separation of data, which occurs when there are not records in every category, broader categories were formed in the tree data. Species occurring less frequently than 1% of the total available and used trees were combined into an “other” category and included honey locust (*Gleditsia triacanthos*), green ash (*Fraxinus pennsylvanica*), persimmon (*Diospyros virginiana*), swamp privet (*Forestiera acuminata*), and cedar elm (*Ulmus crassifolia*). In partial cuts, woodpeckers used ten baldcypress trees for nests and roosts but none were sampled in

random plots. Therefore, the data were quasi-complete since baldcypress had no observations in the “available” category. It was clear baldcypress was being selected without statistical evidence. To solve this conundrum, baldcypress was not considered statistically for the partial cut analysis. Trees ≥ 90 cm dbh were combined into one dbh class. Decay classes were reduced to three classes; vigorous trees (decay class 1-2), decadent trees (decay class 3-4), and snags (decay class 5-7). Decay classes 8 and 9 were not considered available since woodpeckers did not use trees for nesting that were less than 8 meters tall.

Vine classes were also reduced to three classes; 0 = no vines; 1 = 1-5 vines; and 2 = >5 vines). The dataset for the uncut control cavity trees had incomplete representation of dbh classes across species; therefore, separate nested logistic regressions were used to analyze each of these variables. Site and cut-type were included as random variables.

Selection of Site Characteristics

Calculations were made from the plot data to use as site characteristic variables to determine their influence on nest and roost site selection. Basal area (BA), the number of trees ≥ 10 cm dbh in the plot (TOTREE), decadent trees ≥ 10 cm dbh (DECADENT), dead trees in the plot ≥ 10 cm dbh (TOTDEAD), trees ≥ 50 cm dbh (DBH50), the number of different tree species (NUMSP), stems in regeneration < 10 cm (REGEN), and trees in vine class 3 and 4 (VINES) were calculated from the nest and roost and random plot data.

Pearson Correlation Coefficients in (PROC CORR in SAS 9.1) were used to identify highly correlated variables before conducting logistic analyses. In parametric tests, it is important that variables are not correlated with each other to prevent multicollinearity since this causes large fluctuations in regression coefficients and variance estimates can be inflated (Geaghan *pers. comm.*). Therefore, variables with high correlation (≥ 0.4) with other variables were considered for removal from the analyses.

Results

A total of 20 nest and roost trees were found in uncut controls and 17 were found in partial cuts. Nests were most difficult to find during incubation, more easily found during the nestling stage, and most easily found during excavation. Six cavities that were fully excavated were not used for nesting and were all in controls. Nestlings were observed in six of eight (75%) active nests in 2006 and 9 of 10 (90%) active nests in 2007. All nests that were last observed having nestlings probably fledged young based on conservative field observations of fledglings. Of the three failed nests, one was in a partial cut and two were in controls, although one failed nest in a control was likely due to abandonment following capture.

Selection of Tree Characteristics

Pileated woodpeckers used a variety of tree species for nesting and roosting (Fig 3.2). Of the 24 nest cavity trees, 8 (33%) were in bitter pecan, 7 (29%) in baldcypress, 5 (20%) in sugarberry, 2 (8%) in black willow, 1 (4%) in overcup oak, and 1 unidentified (Table 3.3). Three of seven nest trees that were in baldcypress broke off at the nest cavity in the same year either during or after nesting. No other nest trees broke off during or after nesting. Of the 15 roost trees, 7 (47%) were in baldcypress, 4 (27%) in overcup oak, 2 (13%) in bitter pecan, 1 (6.5%) in sugarberry, and 6.5% unidentified.

Twenty-four nests were found in trees between 42 and 95 cm dbh (60.5 ± 3.02 ; mean and SE) and 15 roosts were found of which dbh was between 42 and 150 cm (70.3 ± 7.03). Twenty-two of 24 (92%) nest cavities and 12 of 15 (80%) roost cavities were in live trees. Only two nest cavities were in dead trees (decay class 6 and 7) and both of these nest trees were also used as roosts. On one occasion, the female and male roosted in the same nest tree. All seven roosts in baldcypress were hollow with multiple cavities even though trees were still technically alive. Characteristics of 20 cavity trees were compared to characteristics of 84 random trees in controls

and 17 cavity trees were compared to 69 random trees in partial cuts. Tree variables that were retained by logistic regression were tree species, dbh class, and decay class.



Figure 3.2. Nest and roost trees; a) pileated woodpecker beside a typical roost tree in a baldcypress tree; b) observer attaching a leg noose trap below the roost cavity in a multi-cavity overcup oak roost tree; c) pileated woodpecker about to enter a nest cavity in a bitter pecan tree; d) early morning capture at a baldcypress nest tree.

Table 3.3. Characteristics of 2006 and 2007 nests and roosts in partial cuts (CUT) and controls (CON); Cav = nest (N) or roost (R); Year = year the nest or roost was found; Terr = Red River (RR) or Three Rivers (TR) WMA; Status = active (A) or abandoned (N); Species = unidentified (UN), sugarberry (SB), black willow (BW), bitter pecan (BP), overcup oak (OO), or baldcypress (BC); DBH = diameter at breast height, DC = decay class, 1 = vigorous, 2 = decadent, and 3 = dead; Sub = substrate, DB = dead branch; Vines = number of trees with vine class 4/0.04 ha; BA = basal area (m²/0.04 ha); and #Trees = number of trees/0.04 ha plot.

Treat	Cav	Year	Terr	Status	Species	DBH	DC	Sub	Vines	BA	#Trees
CON	N	2006	RR11	A	SB	95	1	BOLE	1	33	19
CON	N	2006	RR13	A	BW	57	4	DB	4	8.8	6
CON	N	2006	RR15	A	BP	52	2	BOLE	0	21	14
CON	N	2006	TR14	A	BC	72	1	BOLE	0	16	1
CON	N	2007	RR13	A	BP	88	3	BOLE	1	35.3	20
CON	N	2007	RR15	N	BP	59	2	BOLE	4	37.3	11
CON	N	2007	RR17	N	SB	54	1	BOLE	0	23	15
CON	N	2007	RR17	A	SB	43	2	DB	0	25	20
CON	N	2007	TR03	A	BW	57	4	BOLE	4	27.3	19
CON	N	2007	TR16	N	SB	60	1	BOLE	1	36	12
CON	N	2007	TR25	N	BP	59	2	BOLE	1	24	15
CON	N	2007	TR27	N	SB	47	2	BOLE	4	22	13
CON	N	2007	TR31	N	BC	86	3	BOLE	1	30	14
CON	N/R	2006	RR12	A	UN	62	6	BOLE	0	36	14
CON	N/R	2007	TR24	A	BP	42	7	BOLE	4	39.3	13
CON	R	2006	TR14	A	BC	150	2	BOLE	4	21.3	9
CON	R	2007	RR17	A	BC	91	2	BOLE	0	48	19
CON	R	2007	RR18	A	OO	66	3	BOLE	1	36	10
CON	R	2007	TR24	A	BC	76	1	BOLE	0	25	32
CON	R	2007	TR24	A	SB	54	1	BOLE	1	28	19
CUT	N	2006	RR01	A	BP	42	4	BOLE	0	22.8	11
CUT	N	2006	RR02	A	OO	59	4	DB	4	29.5	12
CUT	N	2006	TR10	A	BP	81	4	BOLE	0	60.5	15
CUT	N	2007	RR02	A	BC	74	1	BOLE	3	30	16
CUT	N	2007	RR18	A	BC	59	4	BOLE	1	36.5	16
CUT	N	2007	RR32	A	BC	51	4	BOLE	2	52.8	17
CUT	N	2007	RR22	A	BC	50	4	BOLE	0	20	13
CUT	N	2007	RR23	A	BC	54	1	BOLE	1	37	9
CUT	N	2007	TR14	A	BP	48	3	BOLE	0	23	18
CUT	R	2006	TR03	A	OO	46	3	BOLE	0	33.3	4
CUT	R	2006	TR10	A	BC	102	2	BOLE	0	60.5	15
CUT	R	2007	RR21	A	BP	62	2	BOLE	0	31.3	15
CUT	R	2007	RR32	A	OO	55	5	BOLE	4	21.4	7
CUT	R	2007	TR10	A	OO	74	3	BOLE	0	20	11
CUT	R	2007	TR14	A	BC	62	3	BOLE	0	35	10
CUT	R	2007	TR14	A	BC	62	2	BOLE	0	40.6	14
CUT	R	2007	TR14	A	BC	51	3	BOLE	2	40	17

Pileated woodpeckers used baldcypress more than expected in controls ($X^2_1 = 7.25$, $p = 0.0071$) and partial cuts. This selection was even more apparent in partial cuts where the availability stayed approximately the same but use approximately doubled (53% versus 26%) (Fig. 3.3). In partial cuts and controls, bitter pecan and sugarberry were used in proportion to availability; however, woodpecker use of sugarberry was greatly reduced in partial cuts since sugarberry was not as available in partial cuts. Woodpeckers used overcup oak less than it was available in both controls ($X^2_1 = 7.75$, $p = 0.0054$) and partial cuts ($X^2_1 = 8.35$, $p = 0.0039$). Woodpeckers were selective of dbh classes in controls ($X^2_5 = 23.28$, $p = 0.0003$) but not in partial cuts. In controls, the 40 cm dbh class was used less than expected ($X^2_1 = 10.04$, $p = 0.0015$), whereas the 90+ cm dbh class was used more than expected ($X^2_1 = 4.92$, $p = 0.0265$) (Fig. 3.4). In controls, decay classes were used in proportion to availability, although in partial cuts, vigorous trees were used less than expected ($X^2_1 = 6.68$, $p = 0.0098$) and decadent trees were used more than expected ($X^2_1 = 5.58$, $p = 0.0101$) (Fig. 3.5).

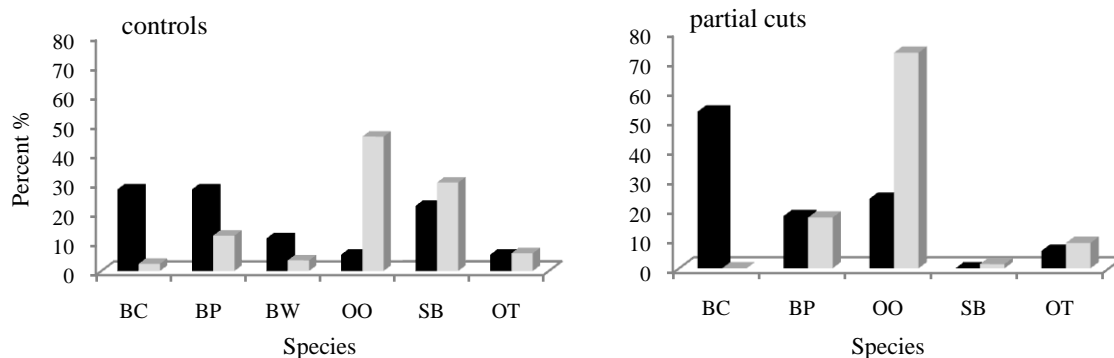


Figure 3.3. Comparison in percent of use (black) versus availability (grey) of tree species of nest and roost trees in uncut controls and partial cuts including trees ≥ 40 cm dbh. BC = baldcypress, BP = bitter pecan, BW = black willow, OO = overcup oak, SB = sugarberry, and OT = green ash and unidentified.

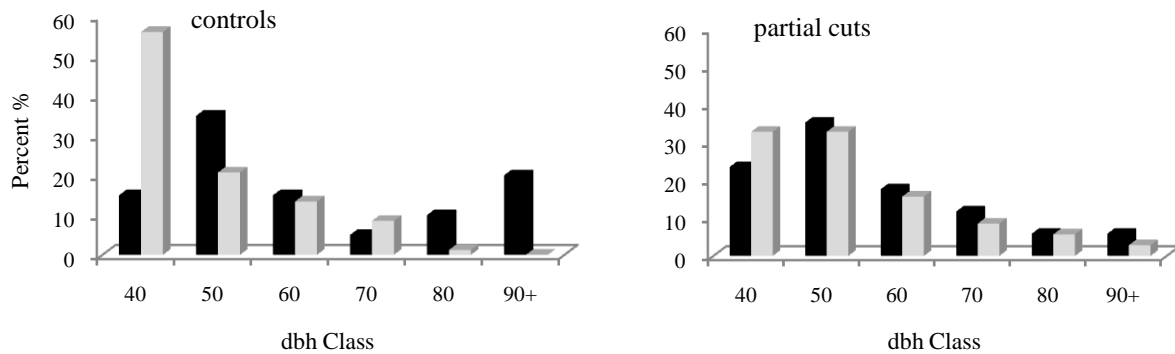


Figure 3.4. Comparison in percent of diameter class use (black) versus availability (grey) of nest and roost trees in uncut controls and partial cuts including only trees ≥ 40 cm dbh.

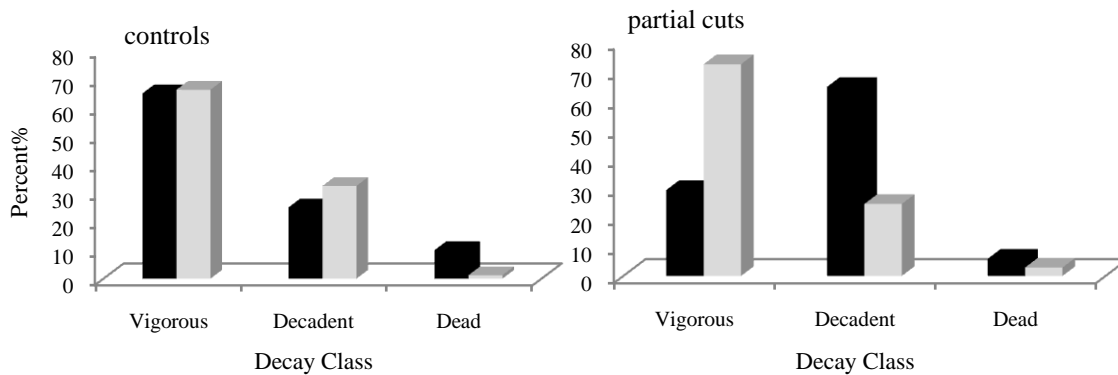


Figure 3.5. Comparison in percent of decay class use (black) versus availability (grey) of nest and roost trees in uncut controls and partial cuts including only trees ≥ 40 cm dbh. Vigorous = trees in decay class 1-2, Decadent = weakened trees in decay class 3-4, and Dead = trees in decay class 5-7.

Selection of Site Characteristics

Forty-eight plots were compared in partial cuts of which 16 were cavity sites and 32 were random sites. In controls, 46 plots were compared including 20 cavity tree sites and 26 random sites. Basal area of nest and roost plots was between 8.8 and 60.5 m²/ha (29 ± 1.6). One nest with a low basal area value had a large basal area in trees < 10 cm dbh and another was in the middle of a baldcypress swale with no surrounding vegetation except for baldcypress knees.

Results of Pearson Correlation tests indicated BA and DBH50 were highly correlated. I performed simple linear regression analyses to determine the nature of the correlation. In controls, BA was correlated to the number of trees <50 cm dbh ($F_{1,21} = 4.84$, $p = 0.0392$) but was not correlated to the number of trees ≥ 50 cm dbh in a plot (DBH50) ($F_{1,21} = 3.39$, $p = 0.08$). In partial cuts, the opposite was true; basal area was not correlated to the number of trees <50 cm dbh ($F_{1,46} = 0.05$, $p = 0.83$) but was correlated to DBH50 ($F_{1,46} = 48.39$, $p < 0.0001$). DBH50 was retained since it more accurately reflected large trees and was consistent. Variables used in the logistic regression were: the number of different species in a 0.04 ha plot (NUMSP), the number of trees ≥ 50 cm dbh (DBH50), and the amount of regeneration in a plot (REGEN). Logistic regression of used and unused sites indicated woodpeckers were more likely to use a plot if there were more trees ≥ 50 cm dbh in control sites ($X^2_1 = 4.76$, $p = 0.0292$) as well as in partial cut sites ($X^2_1 = 12.74$, $p = 0.0004$).

Discussion

Others have stated that pileated woodpeckers are dependent on old-growth forest and may use cutover areas only because they have strong site fidelity (McClelland and McClelland 1999; Bull et al. 2007). In Louisiana, however, I found radio- and non-radio-tagged woodpeckers used partial cuts to nest and roost even when uncut mature forest was available only meters away. I found no evidence in the data to indicate partial cuts provide substantially different or worse conditions for nesting or roosting. Woodpeckers were able to find trees in partial cuts of sufficient species, dbh, and decay class for nesting and roosting that were comparable to uncut forest. Interestingly, pileated woodpeckers were also found nesting in a baldcypress swale devoid of other trees and in an agricultural hedgerow. Conner et al. (1975) also found pileated woodpeckers sometimes successfully nested in field hedgerows, meadows, and clearcuts in Virginia. In Louisiana, nest success in partial cuts (7/9) was similar to that in

controls (8/9). This contrasts a study in Oregon that found nest success was negatively related to the amount of harvested area (predominately fuel reductions) (Bull et al. 2007). In contrast to pileateds of the north, pileated woodpeckers in Louisiana do not depend on old-growth or even uncut forest for nesting or roosting.

Contrary to my predictions, woodpeckers used predominately live trees for nesting and roosting in both partial cuts and uncut forest. Live trees, both vigorous and decadent, were abundant in both types of treatments in this study; therefore, woodpeckers had many substrates available for nesting and roosting. Interestingly, woodpeckers preferred decadent trees in partial cuts even though just as many decadent trees were available in both partial cuts and controls. The reasons for this are unclear. Similarly, nests in Washington coniferous forest were also more likely to occur in decadent trees than snags; however, roosts were in trees in later stages of decay than those used for nesting (Aubry and Raley 2002). Conversely, pileated woodpeckers preferred to nest and roost in snags in early stages of decay in mature coniferous forest in Oregon and Montana as well as in Virginia oak forest (Conner et al. 1975; Bull et al. 1992; McClelland and McClelland 1999).

Both partial cuts and controls provide trees large enough for pileated woodpeckers to nest and roost in although woodpeckers prefer very large trees (≥ 90 cm dbh) and avoid trees in the 40 cm dbh class in uncut forest. Nest and roost tree dbh in partial cuts (42-81 cm, mean = 60) and controls (42-150 cm, mean = 68.5) were well within the ranges recorded by others; 33-208 cm (Conner et al. 1975; Brawn et al. 1984; Bull et al. 1992; Mellen et al. 1992; McClelland and McClelland 1999; Aubry and Raley 2002). Pileated woodpeckers are selective in the size of tree for nesting and roosting because they need a tree of sufficient size to contain their large bodies (Brawn et al. 1984; Aubry and Raley 2002).

I predicted pileated woodpeckers would prefer the least demanding tree species to excavate since excavating is so energetically demanding (Jackson and Jackson 2004). This was

the case in Louisiana. Although woodpeckers used two of the most dense species for nests and roosts (bitter pecan and overcup oak), they preferred baldcypress (less dense), and avoided overcup oak (more dense) (Table 3.4). This preference was especially marked in partial cuts where the proportional use of baldcypress was almost double of that in partial cuts even though the proportional availability was about the same. The sugarberry component in partial cuts was greatly reduced from uncut forest, probably from harvesting and in the absence of sugarberry in partial cuts; woodpeckers used more baldcypress instead of choosing other species more

Table 3.4. Specific gravity of tree species available to pileated woodpeckers. Specific gravity is based on weight when oven-dry and volume when green. From Green et al. (1999).

Species	Specific gravity
black willow	0.36
baldcypress	0.42
sugarberry	0.49
green ash	0.53
overcup oak	0.57
bitter pecan	0.61

available such as overcup oak. While baldcypress may provide an energy efficient tree to excavate, three of the seven nests in baldcypress broke off at the cavity, rendering the cavity unsuitable for wildlife that require a covered cavity. This was not observed in any other species. Therefore, I recommend leaving large-sized sugarberry (≥ 40 cm dbh) in partial cuts since these trees are more durable and could be valuable to other wildlife that use pileated cavities.

Woodpeckers excavated single nest cavities in sound baldcypress and excavated multiple openings in hollow baldcypress for roosting. All baldcypress cavity trees had broken tops or broken large limbs but were still classified as living even though they were hollowed by heart rot. This is because baldcypress can seal off fungal infections (Jackson and Jackson 2004). Pileateds favored broken top snags for nests and roosts in other regions of the U.S. (Conner et al.

1975; Bull et al. 1992; McClelland and McClelland 1999; Aubry and Raley 2002) whereas in Louisiana, no nests were considered broken topped snags because baldcypress was still living. The structure is probably similar between broken-topped snags and broken-topped living baldcypress.

Pileated woodpeckers excavate more cavities than they use in a season. In this study, I found that 38% (6 of 16) nests were excavated but not used for nesting. This and the fact that baldcypress trees pileateds use for nesting break off indicate pileateds influence the structure of bottomland hardwoods to a large degree and are likely a keystone species in the south.

Nest and roost tree sites selected by pileated woodpeckers had more trees ≥ 50 cm dbh in the immediate vicinity of the nest in both controls and partial cuts. This indicates that clusters of large trees should continue to be left when harvesting. Others have also found that nest sites include large trees in the vicinity of the nest tree. They assert that woodpeckers are choosing nest sites with other potential nest trees available to reduce predator efficiency since predators would have to search more trees (Adkins Giese and Cuthbert 2003). Still others have suggested that these large trees may provide local foraging trees (Aubry and Raley 2002; Adkins Giese and Cuthbert 2003); however, this seems unlikely in my study sites since pileateds rarely spent time by the nest foraging. It seems more likely that nest trees occurred in clusters since vegetation is often patchy and woodpeckers were selecting cavity trees with certain characteristics independently of the surrounding vegetation (Howe et al. 1995; Adkins Giese and Cuthbert 2003). Regardless of whether woodpeckers are selecting sites with more large trees or large trees occurred in clusters, woodpeckers found clusters for nesting and roosting in both partial cuts and controls. This adds support to my conclusion that partial cuts provide sufficient habitat for nesting and roosting.

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Chapter 4: Foraging Ecology of Pileated Woodpeckers (*Dryocopus pileatus*) in Partial Cut and Uncut Bottomland Hardwood Forests

Introduction

During the 1920s and 1930s, widespread clearcutting or high-grading of bottomland hardwood (BLH) forests occurred (Tanner 1942; King et al. 2005) with little regard for future volume or ecological impacts. Since the 1930s, the value paradigm has changed and within the last 10-15 years, BLH forest management on both public (10% of lands) and private lands (90%) may include wildlife objectives for both game and nongame animals (LMVJV 2007). In Louisiana, this paradigm shift resulted in changes in harvesting techniques. Harvesting now includes tools such as group and single tree partial cutting that can create habitat for species requiring vertical structure in the understory (*LDWF forest prescriptions 1999-2002*).

Although partial cutting is beneficial to some animals, large diameter and poor quality trees (deformed, moribund, or dead) are normally targeted for removal (Meadows and Goelz 2005). This could negatively impact species that depend on large, dead trees for foraging. On the other hand, partial cutting often leaves an abundant source of dead wood in the form of logging slash (CWD) and stumps and invariably results in wounds to residual standing trees that may eventually lead to tree death (Meadows and Stanturf 1997; Nebeker et al. 2005). Thus, it is unknown whether the combined effects of partial cutting would have negative, positive, or negligible effects on species depending on dead wood.

Pileated woodpeckers (*Dryocopus pileatus*) are known to depend on large diameter snags (Flemming et al. 1999; LeMaitre and Villard 2005; Raley and Aubry 2006); however, they are also known to forage extensively on downed structures such as logs and stumps (Bull and Holthausen 1993; Hartwig et al. 2006; Raley and Aubry 2005). Pileated woodpeckers prey on a variety of organisms including wood-boring adult and larval beetles (i.e. Cerambycidae,

Buprestidae, and Elateridae), *Pheidole* ants, carpenter ants (*Camponotus* spp.), and poison ivy (*Rhus radicans*) (Bull and Jackson 1995). In BLH, partial cutting creates habitat for wood-boring beetles in the few years following harvest (Warriner et al. 2002; Ulyshen 2004; *Chapter 2*). Pileated woodpeckers have plastic foraging behavior exemplified by variation in use of foraging tactics, substrates, and prey (Conner 1980; Conner 1981; Bull and Holthausen 1993; Conner et al. 1994; Flemming et al. 1999; Raley and Aubry 2004; LeMaitre and Villard 2005; Hartwig et al. 2006; Raley and Aubry 2006). Because of their plasticity, pileateds may be able to take advantage of an increased beetle resource in partial cuts.

No studies that I am aware of have compared the foraging ecology of pileated woodpeckers in stands that have been harvested to those that have not. In this study, I compare differences in foraging behavior between partial cut stands and uncut stands. Studies indicate pileated woodpeckers change foraging tactics and substrates with variation in availability of prey types (Conner 1981; Raley and Aubry 2004). For example, Conner (1981) found pileated woodpeckers glean on an abundant arthropod community on the surface of live trees and excavate at the base of dead trees to access carpenter ant galleries. Partial cut harvesting could alter the availability of species composition, dbh class, and decay class of substrates in the remaining stand, stimulating the use of different foraging tactics. Numerous studies have characterized pileated woodpecker use and selection of tree characteristics for excavation foraging (Flemming et al. 1999; Raley and Aubry 2004; LeMaitre and Villard 2005; Hartwig et al. 2006; Raley and Aubry 2006). In this study, I include substrates used for all types of foraging tactics (i.e. excavating, pecking, gleaning, scaling, probing, and berry-eating).

The second part of this study involved determining variation in prey use among partial cuts and uncut forest through forage sign and scat. Woodpeckers create unique sign when excavation foraging that can usually be associated with specific prey (Raley and Aubry 2004).

For instance, large, deep, rectangular sign usually indicates foraging on carpenter ant colonies (Raley and Aubry 2004). In this way, arthropods likely consumed by excavation foraging can be compared among treatments. Another method to quantify major arthropod groups in the diet of woodpeckers is the examination of scat (Beckwith and Bull 1985; Rosenburg and Cooper 1990; Bull et al. 1992; Pechacek and Kristin 2004). Contents of scat have a close correspondence with stomach contents since clues exist for virtually every type of solid food a bird may eat (Rosenburg and Cooper 1990).

My objectives were to (1) determine differences in foraging tactics, forage substrate type and diameter, and forage height in recent partial cuts versus uncut forest; (2) assess woodpecker selection of tree characteristics (species, dbh, decay class, wound class, and vine class) by comparing trees used by pileated woodpeckers to random trees available in recent partial cuts and controls; and (3) compare forage sign and scat contents between partial cut versus uncut control forest in BLH of Louisiana.

Study Area

The foraging ecology study took place concurrently with the nest and roost study in 2006 and 2007 in Three Rivers and Red River WMAs in east central Louisiana. See *Chapters 2 and 3* for additional site information.

Methods

Capture

Pileateds were located in both partial cuts and controls by surveying for woodpeckers using audio and visual cues starting in March, 2006 or February, 2007. Subsequently, nests were found primarily to capture birds for radio-transmitter application. In 2006, males were captured from the nest with hoop nets made of mosquito netting attached with duct tape to an extendable pole (Rochelle Renken *pers. comm.*; Eric Baca *pers. comm.*) or by target mist-netting (Fig. 4.1).

In 2007, woodpecker nest cavities were sometimes higher than the 60 ft pole could extend or were obstructed by branches, preventing use of the extendable pole from the ground.

Consequently, we attempted capture at the nest from a ladder or a deer stand, climbed trees with ascenders and attached leg noose traps constructed of fishing line to the outside of cavities (Cooper et al. 1995), or attempted target mist-netting (Fig 4.1). Target mist-netting consisted of setting up a mist-net in an area of high woodpecker activity (usually a nest tree) and playing recordings of drums to attract woodpeckers to the mist-net. The mist-net set up consisted of three stacked, 12 m, 100 mm gauge mist-nets from AVINET that were strung on a pulley between two high branches of dominant trees. The pulley system was guided over branches by throwing a 3 g sinker attached to fishing line and a fishing rod. The fishing rod was used to manage the fishing line to prevent tangling.

Following capture, pileated woodpeckers were weighed, banded, and fitted with 8 g radio-transmitters from AVM Instrument Company, Ltd. (2006) or 6.95 g transmitters from Holohil Systems Ltd. (2007) mounted on a backpack harness made of 5 mm Teflon ribbon (1.0 g) (Fig 4.2). The pack was centered on the back of the bird and attached over the breast with sewing thread using the design of Catherine Raley (*USFS Pacific Northwest Research Station*) (Fig 4.2). Transmitter package weight was less than 3% of the bird's total weight except for one that was 3.4%. Three percent is the untested recommended maximum weight for transmitter packages for pileated woodpeckers (Mellen et al. 1992; Bull and Jackson 1995).

Foraging Observations

Radio-telemetry was used to assist in locating birds for foraging observations since pileated woodpeckers were difficult to relocate. Since not all territories had radio-tagged woodpeckers, actual territory delineations of all birds were unknown; therefore, territory delineation was used for spatial reference rather than for a specific pair or group of birds.

a)



b)



c)



d)

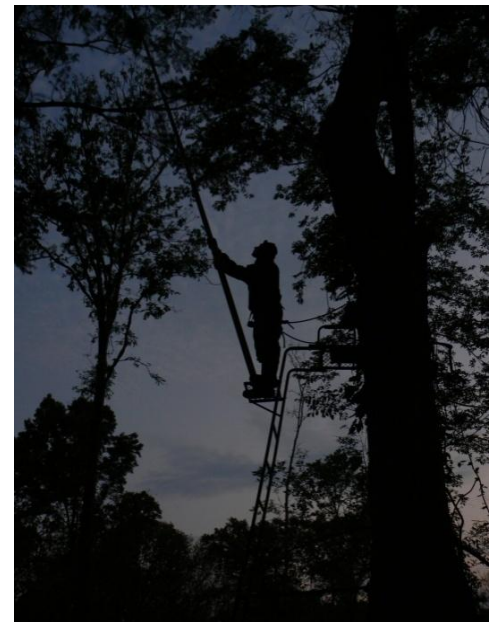


Figure 4.1. Pileated woodpecker capture methodology; a) ascending into a nest tree on a climbing rope with ascenders; b) hoop net on extendable pole over cavity; c) canopy net for target mist-netting; d) capture attempt with hoop net and extendable pole from a deer stand.



Figure 4.2. Transmitter application and bird handling techniques; a) transmitter in hand showing the size of the Holohil unit; b) bird in hand with Holohil transmitter attached and antenna visible on the back of the bird; c) front of transmitter harness showing Teflon ribbon across the breast; d) release of bird.

Woodpeckers were observed for as long as possible up to a maximum of ten observations. An observation consisted of the duration a bird used the same tactic upon the same substrate and was considered a new observation when the bird changed tactics or substrates. Six foraging tactics used by pileated woodpeckers were defined: a) excavating - digging holes of various depths in the wood; b) pecking - striking the bill against the substrate to remove some of the exterior of the substrate; c) gleaning - securing food items from the surface of the substrate; d) probing - foraging in cracks or holes with bill or tongue; e) scaling - chiseling perpendicularly into the substrate; and f) berry-eating - grasping and pulling berries with the bill. Forage substrate (live or dead limb, live or dead bole, and vine), forage height, tree height, and substrate diameter were also recorded. Forage and tree height were measured with a clinometer and substrate diameter was estimated based on a relative comparison with the length of the folded wing of a pileated woodpecker, which is around 21 cm (Martjan Lammertink *pers. comm.*).

An observation ended when a woodpecker either changed tactics or substrates or flew from view. Behavior was recorded continuously for the time the bird was in view or after it changed trees up to five times, after which all trees the bird had used for foraging were measured. The maximum of five trees was due to the logistic constraint of human memory (i.e. it was difficult to remember the positions and directions from the original observation location of more than five different trees to measure).

Foraging tree data (use data) were collected and compared to random tree data (availability data) to quantify woodpecker selection of tree species, dbh, decay class, wound class, and vine class. Foraging tree data were collected once the woodpecker flew away from a foraging tree.

Random tree data were collected in 0.04 ha circular plots in the same territory and treatment type to assess tree attributes available to woodpeckers. Three to five random plots

were measured in each woodpecker territory to obtain information on available tree characteristics. I used decay classes developed by Foti et al. (2005) (Table 4.1).

Table 4.1. Tree condition and description of decay classes (Foti et al. 2005).

Decay Class	Tree Condition	Description
1	Vigorous	Live tree, live crown
2		<1/3 crown dieback
3		1/3-2/3 crown dieback
4	Decadent	>2/3 crown dieback
5		Recently dead
6	Early Stage of Decay	Retains only large limbs
7		Only bole ≥ 8 m
8	Late Stage of Decay	Only bole <8 m
9		Only stump
10	Downed	Log

Vine density on trees was assessed by classifying the number of vines on the tree into one of five vine classes (Table 4.2).

Table 4.2. Vine classes of trees.

Vine Class	Number of Vines
0	0
1	1-2
2	3-5
3	6-9
4	10+

In 2006, I estimated the percent surface area covered by forage sign on structures used for foraging by pileateds to evaluate use of structural characteristics such as dbh and decay class. Sign persists as the tree decays and may give misleading results about the quality of a structure in its present state; therefore, in 2007, I documented forage sign I witnessed the woodpecker create. Sign was then linked to a specific prey source as per Table 4.3. This technique has been found to be accurate for identifying food items about 80% of the time in areas of the northwest (Raley and Aubry 2004).

Table 4.3. Foraging tactic, sign, and associated prey.

Tactic	Sign	Prey	Source
Excavate	Large, deep, rectangular hole	Carpenter ants	Connor 1981; Bull and Holthausen 1993; Raley and Aubry 2004
Excavate	Large excavation to heartwood	<i>Pheidole</i> ants	<i>Personal observation</i>
Excavate	Shallow over large surface area	Wood-boring beetle larvae aggregations	Raley and Aubry 2004
Excavate	Small, deep, isolated hole	Large, solitary wood-boring beetle larvae (cerambycids)	Kilham 1976; Raley and Aubry 2004
Scale	Removal of bark over large area	Bark-beetle larvae and termites	Kilham 1976; Raley and Aubry 2004

Scat Analysis

To compare food items consumed by birds that had partial cuts available to them versus those that did not, I collected scat from pileated woodpeckers during their capture and also opportunistically during foraging observations by searching the area below a bird that defecated. Scat samples were stored in 100% ethanol until they were analyzed in the lab. Before dissecting samples, I made a reference collection based on specimens I collected during fieldwork to compare contents of scat. Specimens were collected from substrates where I saw woodpeckers foraging.

Scats were sampled by emptying the contents of a sample into a Petri-dish and randomly placing a 2 cm diameter plastic ring in the Petri-dish. To determine the number of ant individuals, I searched for head capsules or mandibles when the sample was extremely digested. Based on field observations that woodpeckers decapitate adult beetles of the families Eucnemidae and Passalidae, I based my determination of the number of beetle individuals on other evidence such as legs and elytra if mandibles were not present. All items removed from the 2 cm diameter ring were glued to stock card and tallied after the sample had been dissected. For each sample, the proportion of individuals of each prey group (wood-boring beetle, carpenter ant, *Pheidole* ant, vegetative, or other) was calculated. Scat samples were pooled between years since I had small sample sizes.

Statistical Analyses

Pearson Correlation Coefficients with $r \geq 4$ (PROC CORR in SAS 9.1) were used to identify variables with multicollinearity problems before conducting parametric analyses. If variables were correlated, one of the variables was removed from the analysis.

Foraging Behavior

A Generalized Linear Mixed Model (GLMM) (PROC MIXED in SAS 9.1) was used to determine the variables that influenced the duration of a foraging observation. Nominal categorical predictor variables were forage tactic, forage substrate, species, and treatment type. Ordinal predictor variables were decay class, substrate diameter class (1 = 1-4 cm, 5 = 5-9 cm, and the rest follow dbh classes as described above), and the quantitative variable forage height. The variables site, season, territory, and sex were included as random variables in the models.

GLMM was also used to compare forage height and substrate diameter among treatments. Quantitative responses were log transformed if residuals failed to meet tests of normality (Shapiro-Wilke <0.05). Years were analyzed separately because of varying study designs. When variables were significant, the Tukey-Kramer adjustment for the p-value was used to test for differences in levels of a variable.

To test for differences in proportions of use of foraging tactics and foraging substrates between partial cuts and controls, I built a contingency table and conducted a chi-square test of independence (PROC FREQ in SAS 9.1). I also used a test of independence to find differences in proportions of prey among treatments in a subset of 2007 data where sign was observed, as well as to test for differences in proportions of scat contents among treatments.

Tree Characteristics

Stepwise logistic regression (PROC LOGISTIC in SAS 9.1) was used to determine whether levels of tree characteristic variables; species (SP), diameter class (DBHC),

decay class (DC), vine class (VC), and wound class (WC) were used more than they were available and if this differed in one- and two-year old partial cuts and uncut controls. Data were therefore partitioned into 2006 one-year-old partial cuts and controls and 2007 one- and two-year-old partial cuts and controls resulting in five logistic regression analyses. Species with frequency <5% of the total trees in the study that were either used for foraging or available were collapsed into an “other” group. The variable DBHC consisted of trees ≥ 10 cm in 10 cm classes up to 90+ cm. Decay classes were collapsed into vigorous trees (decay classes 1 and 2), decadent trees (decay classes 3 and 4), trees in early stages of decay (decay classes 5 and 6), and trees in late stages of decay (decay classes 7 and 8).

The Hosmer-Lemeshow test of model lack of fit was used to determine if the logistic model fit the data adequately (James Geaghan *pers. comm*). Likelihood ratios from tests of global significance were used to test for model significance and for significant variables (<0.05), Wald Chi-Square statistics were used to determine levels of variables that were used out of proportion to their availability. All analyses were conducted with SAS version 9.1 (SAS Institute Inc 2003).

Results

Capture

Eleven woodpecker territories were located in 2006; six in one-year-old cuts and five in controls. Seven males were captured from May 1 to May 26, 2006. Six males were caught upon first exit from nest cavities between 0545 and 0701 and one was captured with a target mist net. All males were captured during the nestling stage except for one that was caught during the incubation stage. This pair subsequently abandoned the nest. One male captured in a control territory was depredated by an avian predator around 27 days after capture. Since birds were not followed every day it was difficult to ascertain the exact mortality date.

In 2007, 20 territories were located, seven in the 2006 one-year-old partial cuts, seven in 2005 two-year-old partial cuts (the same territories from 2006 except one additional), and six in controls (four the same from the previous year and two new). Seven birds were captured. Two females were captured with target mist nets on February 27 and March 13, 2007 at 0630 and 0650. From April 26 to May 1, 2007, three males were caught from nest cavities with hoop nets between 0613 and 0635 and a male and female were captured with a leg noose trap at the nest on April 25 and 27, 2007. Both of these birds were likely depredated by an avian predator; one sometime around 12 days after capture, the other sometime around 43 days after capture. Both were found dead in control areas and the remains consisted of the transmitter, flight feathers, and tail. Woodpeckers weighed between 231 and 336 g (293.43 ± 7.29 , mean \pm SE, $n = 14$).

Foraging Observations

Foraging observations were conducted on radio- and non-radio-transmitted male and female woodpeckers from April 8 to August 4, 2006 and February 4 to July 19, 2007 in partial cuts and uncut controls. Since partial cuts were small relative to a pileated woodpecker territory, pileateds that foraged in partial cuts also had access to uncut controls and were frequently relocated in controls; the reverse was not true of birds in controls. Therefore, birds in partial cuts should have had both habitat types available whereas birds in controls only had one type available.

On average, it took about one hour to locate pileated woodpeckers. Birds were observed from 50-100 m away on most occasions in the winter when foliage was absent and from shorter distances (25-50 m) during the summer. In 2006, I collected 457 foraging observations that amounted to 600 minutes or 10 hours of forage time that excluded time the bird spent doing non-foraging activities. The average foraging observation was 77.4 seconds (SE = 6.7, min = 1, max = 900). In 2007, I collected 759 foraging observations that amounted to 1434 minutes or close to 24 hours. The average foraging observation was 107 seconds (SE = 10, min = 1, max = 3000).

None of the variables exhibited multicollinearity so all were retained for further analyses. Vine class analyses, however, were confounded because vine class 4 occurred more frequently on very large trees (i.e. trees ≥ 60 cm dbh); therefore, the vine class variable was removed.

Foraging Tactics and Substrates

Pileated woodpeckers spent the highest proportion of their foraging time in 2006 and 2007 excavating (58%), followed by pecking (14%), gleaning (14%), scaling (7%), berry-eating (4%), and probing (3%). They foraged on live boles (41%), dead branches (27%), live branches (13%), dead boles (10%), and vines (9%) (Figs. 4.3 and 4.4).

The amount of time a pileated woodpecker spent on a particular substrate was related to the tactic it used in 2006 ($F_{5,435} = 10.56$, $p < 0.0001$) and 2007 ($F_{5,757} = 92.44$, $p < 0.0001$) as well as the decay class of the tree in 2006 ($F_{3,435} = 5.53$, $p = 0.001$) and 2007 ($F_{5,757} = 2.69$, $p < 0.0044$). Observations were longest when woodpeckers were foraging for poison ivy berries or excavating in trees in the later stages of decay (decay classes 7 and 8) (Table 4.5). Treatment did not affect the length of time a pileated woodpecker spent foraging on a particular substrate in either year.

Pileated woodpeckers foraged higher in controls than one-year-old cuts in 2006 ($F_{1,454} = 8.44$, $p = 0.0039$) but there was no difference in forage height in 2007 ($F_{2,755} = 0.50$, $p = 0.61$). Forage substrate diameter among treatments did not differ during 2006 ($F_{1,454} = 0.13$, $p = 0.72$) but did in 2007 ($F_{2,755} = 4.14$, $p = 0.0163$). In 2007, substrate diameter was larger in CUT 1 than CUT2 ($F_{2,755} = 2.44$, $p = 0.0148$) and CON ($F_{2,755} = -2.58$, $p = 0.0101$) but CON and CUT2 forage diameter were the same ($F_{2,755} = -0.37$, $p = 0.8$).

Foraging tactics were used in different proportions in partial cuts versus controls in 2006 ($X^2 = 2417$, $p < 0.0001$) and 2007 ($X^2 = 2394$, $p < 0.0001$). In both years, more excavating was observed in controls than partial cuts and more gleaning in partial cuts. However, more variation

was observed between years than among treatments. Pileated woodpeckers excavated more in 2007 than 2006 and pecked more in 2006 than 2007 (Fig. 4.3). This illustrates that there were probably large fluctuations in availability of prey between years, and that yearly fluctuations drive tactic use more than fluctuations among treatments.

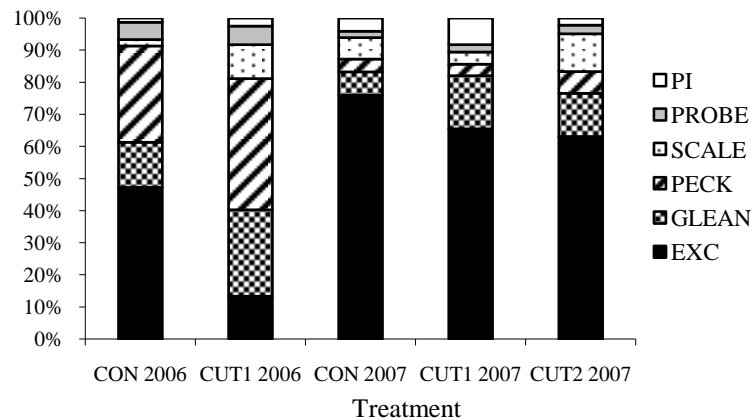


Figure 4.3. Proportion of forage time each forage tactic was observed being used by pileated woodpeckers in 2006 and 2007 treatments. Note: the units are in total time, not number of observations; PI = poison ivy, EXC = excavate, CON = control, CUT1 = one-year-old cut, and CUT2 = two-year-old cut.

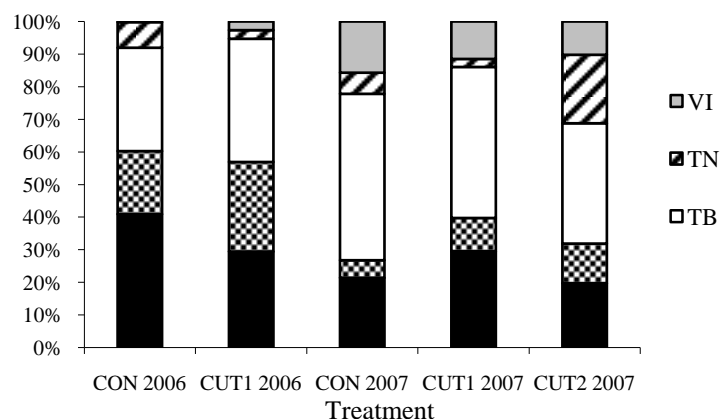


Figure 4.4. Proportion of forage time each forage substrate was observed being used by pileated woodpeckers in 2006 and 2007 treatments; DB = dead branch, LB = live branch, TB = live bole, TN = dead bole, VI = vine, CON = control, CUT1 = one-year-old cut, and CUT2 = two-year-old cut.

Table 4.5. Mean and SE of time spent foraging for each of the levels of the variables; tactic and decay class. Letters indicate a difference in the time spent per tactic or substrate in each year.

	2006		2007	
	Mean	SE	Mean	SE
<u>Tactic</u>				
Probe	47.6 ^a	8.2	31.1 ^{a,b}	5.2
Scale	73.6 ^a	38.2	82.6 ^c	15.2
Glean	56.4 ^a	6.9	41.3 ^{a, c}	3.2
Peck	61.2 ^a	6.05	27.5 ^b	3.2
Poison Ivy	134 ^b	25.8	199.5 ^d	43.5
Excavate	168.2 ^b	19.1	255.4 ^d	24.8
<u>Decay Class</u>				
Vigorous	74 ^a	6.1	82.2 ^a	8.2
Decadent	70.1 ^a	7.6	107.4 ^a	15.4
Early decay stage	69.1 ^a	20.7	108.4 ^a	19.6
Late decay stage	193.5 ^b	78.8	194.6 ^b	40.9

Foraging substrates were used in different proportions in partial cuts versus controls in 2006 ($X^2 = 7518$, $p < 0.0001$) and 2007 ($X^2 = 1494$, $p < 0.0001$). During both years, live branches were used more in partial cuts than controls. During 2007, woodpeckers spent more time foraging on dead boles in CUT2 than in the other treatments. Similar to foraging tactics, more variation in substrate use was observed between years than among treatments. Pileated woodpeckers spent more time using live branches during 2006 and spent more time using vines in 2007. Large fluctuations in availability of prey between years may also influence substrate use and prey fluctuations among treatments are probably insignificant.

Foraging Sign

I obtained 204 observations where sign was identified; 81% ($n = 165$) excavating and 19% ($n = 39$) scaling. In total, 47% ($n = 96$) were of wood-boring beetles, 45% ($n = 92$) *Pheidole* ants, 4% ($n = 9$) carpenter ants, and 3% ($n = 7$) bark-beetles. The proportion of sign did not vary among treatments in 2007 ($X^2 = 8.25$, $p = 0.08$).

Tree Characteristics

In total, I collected data from 1722 substrates that were either used for foraging (657) or available in random plots (1065). The substrate availability data were derived from 25 random plots in 2006 and 52 random plots in 2007. Of the foraging structures, 545 (83%) were on live trees [302 (46%) vigorous and 243(37%) decadent], 91 (14%) on dead trees [52 (8%) early decay, 39 (6%) late decay), 14 (2%) on downed logs, and 7 (1%) on stumps. Because of the low number of observations of pileated woodpeckers foraging on downed structures and stumps, these observations were removed from the datasets and subsequent analyses were conducted only on standing structures (decay classes 1 through 8).

Woodpeckers used four species groups for foraging with frequency >5%; overcup oak (*Quercus lyrata*) (56%), bitter pecan (*Carya aquatica*) (16%), sugarberry (*Celtis laevigata*) (10%), and the other group (18%). The “other” group included baldcypress (*Taxodium distichum*) (4.8%), Nuttall oak (*Quercus nuttallii*) (2.7%), green ash (*Fraxinus pennsylvanica*) (2.2%), black willow (*Salix nigra*) (1.7%), swamp privet (*Forestiera acuminata*) (1.7%), cottonwood (*Populus heterophylla*) (1.4%), American elm (*Ulmus americana*) (0.08%), honeylocust (*Gleditsia triacanthos*) (0.04%), and unidentified (3.4%). The dbh range of foraging trees was from 3-205 cm with a mean dbh of 56 ± 1 (mean \pm SE). Fifteen percent of foraging observations were on trees in the 10-20 cm dbh class, 30% on the 30-40 dbh class, 30% on the 50-60 dbh class, 17% on the 70- 80 dbh class, and 8% on trees >90 cm dbh. Eleven foraging observations were on trees <10 cm dbh and were deleted from the dataset since there were too few to analyze.

According to logistic regression, pileated woodpeckers used species, dbh class, and decay class out of proportion to their availability indicating either preference or avoidance (Table 4.6). Trees with harvest wounds were not important.

Table 4.6. Type 3 tests of fixed effects for substrates used by pileated woodpecker for foraging in 2006 and 2007 in controls and partial cuts. All models were significant with $p < 0.0001$ using Likelihood Ratios.

Treatment	Year	Effect	DF	Wald Chi-Square	P-value
Control	2006	species	3	13.51	0.0037
Control	2006	dbh class	8	7.63	<0.0001
Control	2006	decay class	3	45.44	0.0543
Control	2007	species	3	16.05	0.0011
Control	2007	dbh class	8	61.56	<0.0001
Control	2007	decay class	3	13.97	0.0030
1-yr-old cut	2006	dbh class	8	65.2	<0.0001
1-yr-old cut	2006	decay class	3	15.6	0.0013
1-yr-old cut	2007	species	3	9.4	0.0242
1-yr-old cut	2007	dbh class	8	53.2	<0.0001
1-yr-old cut	2007	decay class	3	21.7	<0.0001
2-yr-old cut	2007	dbh class	8	136.8	<0.0001
2-yr-old cut	2007	decay class	3	12.14	0.0069

In general, woodpeckers used a higher proportion of overcup oak than other species but in most treatments, they used it in proportion to availability (Table 4.7, Fig. 4.5). In most treatments pileated woodpeckers used sugarberry less than expected and bitter pecan more than expected (Table 4.7, Fig. 4.5). In all treatments in both years, woodpeckers were observed using small dbh classes (10-20) less than expected and were observed using larger dbh class (50-70) more than expected (Table 4.7, Fig. 4.6). Dbh classes 30 and 40 were used in proportion to their availability in most treatments. Extremely large trees (dbh classes 80 and 90+) were selected in partial cuts but used in proportion to availability in controls (Table 4.7, Fig. 4.6). Because of this, trees used for foraging in one-year-old (58.19 ± 1.9) and two-year-old partial cuts (53.2 ± 1.7) averaged larger than controls (49.9 ± 1). Pileateds either used vigorous and decadent trees less than expected for foraging or in proportion to their availability (Table 4.7, Fig. 4.7). In controls and one-year-old partial cuts, woodpeckers preferred trees in early stages of decay but in two-year-old partial cuts they preferred trees in late stages of decay (Table 4.7, Fig. 4.7).

Table 4.7. 2006 and 2007 estimates and standard errors for all classes of the variables; species, dbh class, and decay class in controls, 1-year-old cuts, and 2-year-old cuts. Significant and positive estimates indicate the class was used more than expected or preferred, significant and negative estimates mean that class was used less than expected or avoided, and non-significant classes mean that class was used in proportion to availability.

Variables	Estimate and SE				
	2006 Controls	2007 Controls	2006 1-yr-old cuts	2007 1-yr-old cuts	2007 2-yr-old cuts
Species					
BP	0.82, 0.35*	0.10, 0.31	n/s	0.86, 0.43*	n/s
OO	-0.40, 0.25	0.56, 0.23*	n/s	0.10, 0.31	n/s
SB	-0.99, 0.32**	-0.76, 0.23***	n/s	-1.61, 0.89**	n/s
OT	0.57, 0.36	0.09, 0.29	n/s	0.65, 0.38	n/s
Dbh Class					
10	-3.41, 0.62****	-2.24, 0.36****	-2.69, 0.44****	-2.62, 0.54****	-2.87, 0.34****
20	-1.75, 0.48****	-1.65, 0.36****	-2.203, 0.4****	-4.63, 1.2****	-2.29, 0.37****
30	-0.29, 0.36	-0.74, 0.34*	-0.72, 0.42	-0.44, 0.45	-0.69, 0.41
40	-2.1, 0.38	-0.44, 0.35	-0.63, 0.38	-0.59, 0.44	0.076, 0.37
50	0.54, 0.46	0.86, 0.41*	-0.03, 0.38	1.34, 0.47**	0.22, 0.39
60	0.89, 0.56	0.31, 0.52	1.71, 0.58**	0.49, 0.5	0.95, 0.49*
70	1.5, 0.76*	0.82, 0.66	1.13, 0.6	1.65, 0.58**	2.43, 0.93**
80	1.46, 1.02	1.25, 1.07	0.98, 0.72	14.66, 0.75****	0.24, 0.66
90+	1.26, 1.09	1.84, 0.98	2.27, 0.93*	1.90, 0.64**	1.92, 0.95*
Decay Class					
Vigorous	-0.14, 0.41	-0.81, 0.28**	-1.26, 0.35***	-2.34, 0.51****	-0.88, 0.29**
Decadent	0.35, 0.39	-0.79, 0.26**	-0.9, 0.38*	-1.51, 0.45***	-0.28, 0.26
Early Stages	1.49, 0.63*	1.19, 0.46*	1.66, 0.59**	3.35, 1.05**	0.33, 0.53
Late Stages	-1.69, 0.91	0.41, 0.45	0.51, 0.62	0.5, 0.6	0.83, 0.39*

Significance determined with Wald Chi Square statistic. **** p<0.0001, *** p<0.001, ** p<0.01, * p<0.05

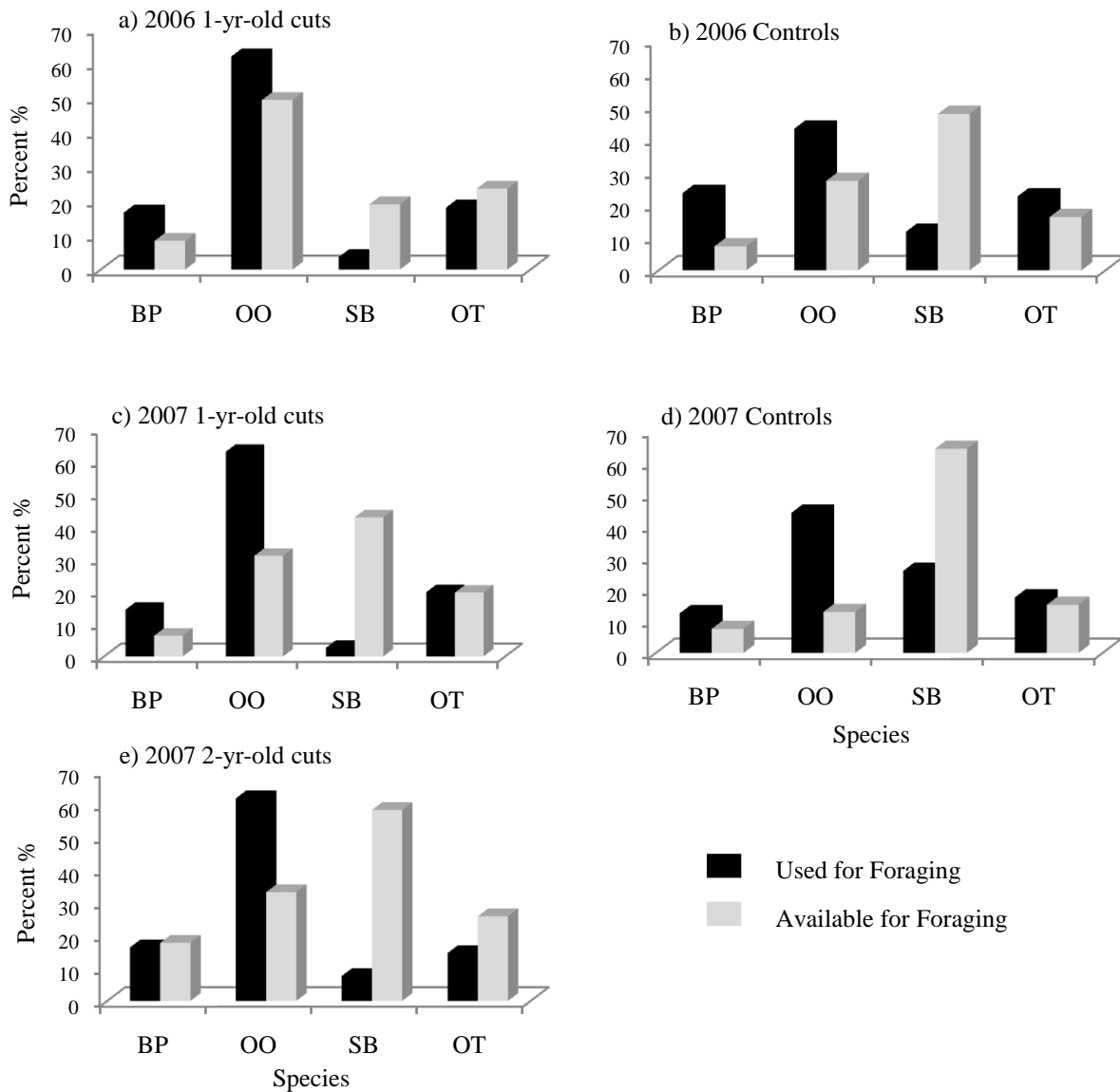


Figure 4.5. Percent use versus availability of tree species in; a) 2006 1-yr-old partial cuts; b) 2006 Controls; c) 2007 1-yr-old partial cuts; d) 2007 Controls; e) 2007 2-yr-old partial cuts. BP = bitter pecan, OO = overcup oak, SB = sugarberry, and OT = American elm, baldcypress, black willow, cottonwood, green ash, honey locust, Nuttall oak, persimmon, swamp privet, and unidentified.

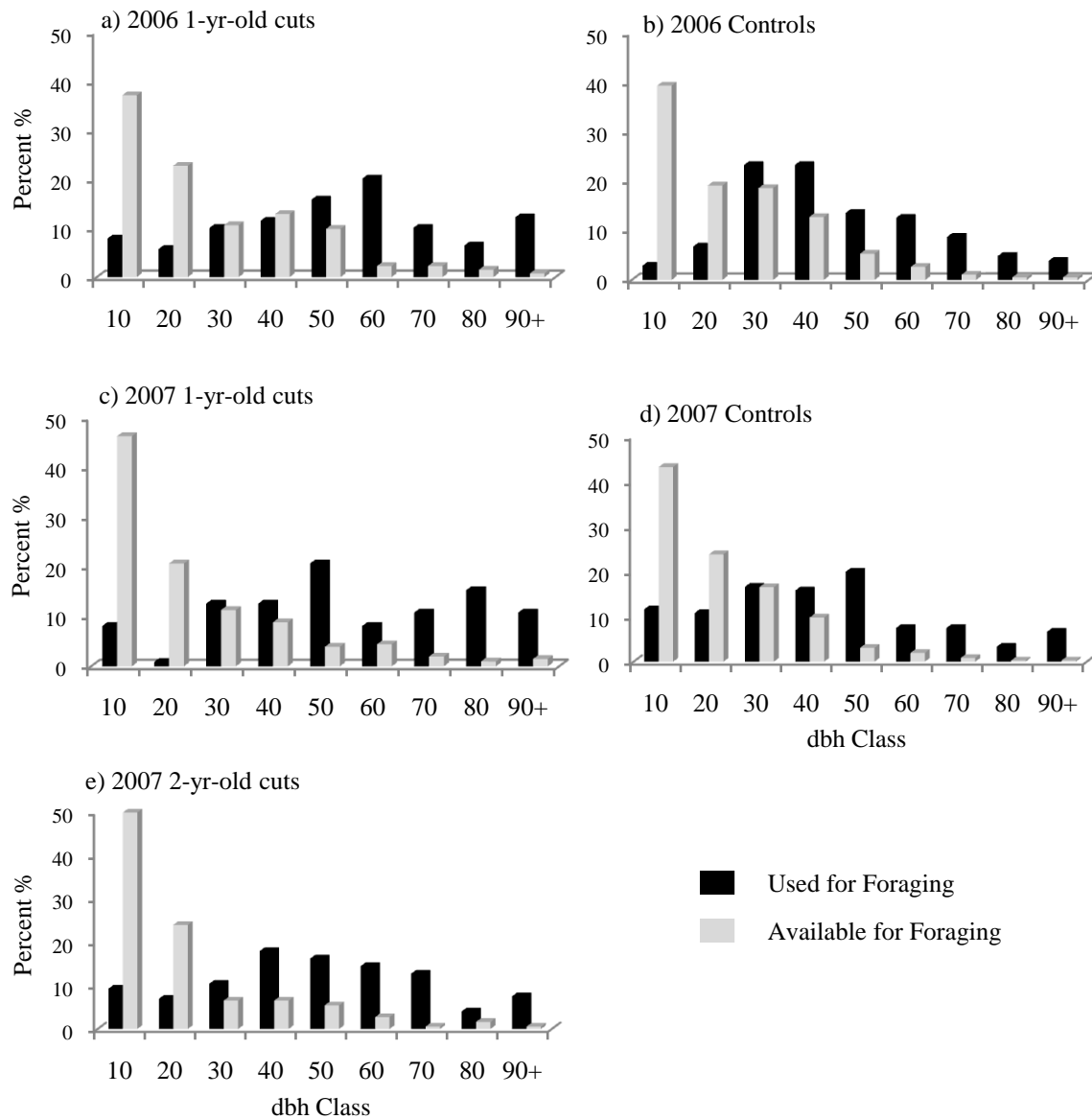


Figure 4.6. Percent use versus availability of dbh classes in uncut controls in; a) 2006 1-yr-old cuts; b) 2006 controls; c) 2007 1-yr-old cuts; d) 2007 controls; and e) 2007 2-yr-old partial cuts.

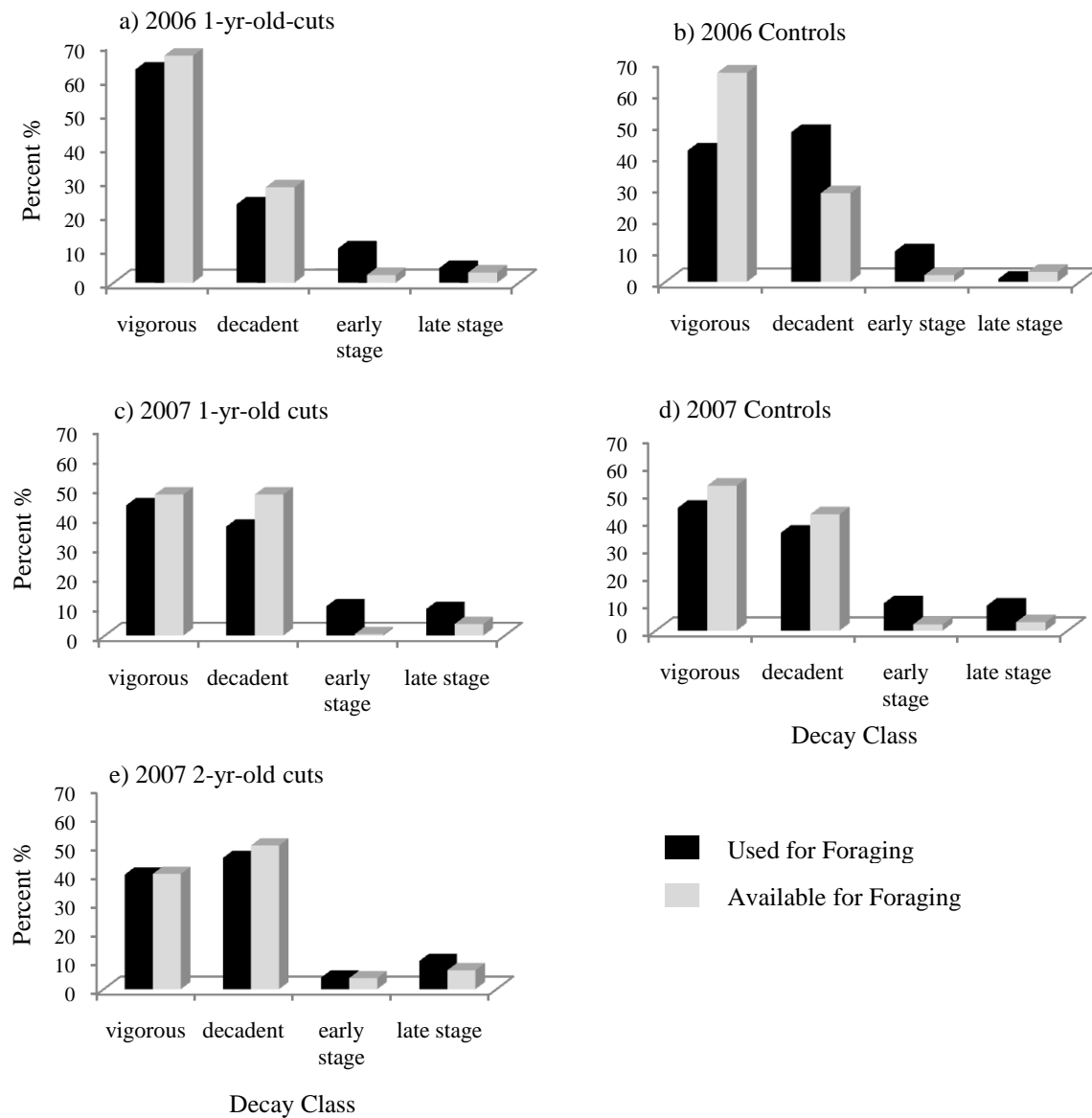


Figure 4.7. Percent pileated woodpecker foraging by decay class in controls in; a) 2006 1-yr-old cuts; b) 2006 controls; c) 2007 1-yr-old cuts; d) 2007 controls; and e) 2007 2-yr-old partial cuts. Vigorous = decay classes 1 and 2; decadent = decay classes 3 and 4; early = decay classes 5 and 6; and late stage = decay classes 7 and 8.

Scat Analysis

Scat samples were difficult to obtain once trapping concluded and ground vegetation (poison ivy) leafed out in May; nonetheless, I collected 4 scats between May 1 and June 20, 2006 and 20 between Feb 16 and June 7, 2007 (Table 4.8). Forty-four percent of individuals in scat samples were *Pheidole* ants followed by 27% unidentified seeds, 15% poison ivy seeds, 11% carpenter ants, and 5% beetles. The proportion of food items in scat varied among treatment types ($X^2 = 3195$, $p < 0.0001$). A higher proportion of *Pheidole* ants and a lower proportion

Table 4.8. Proportion of prey items in scat of pileated woodpeckers in 2006 and 2007. Proportion is the number of prey items per total items. Collection Type = Opportunistic (Opp) or Capture (Cap); Treat = treatment type, one-year-old cut (CUT1), two-year-old cut (CUT2), and control (CON); Total Items = the number of items in a 2 cm diameter plastic ring.

Date	Collection Type	Treat	Total Items	Proportion (%)				
				<i>Pheidole</i> Ants	Carpenter Ants	Beetles	Poison Ivy Seed	Unk Seed
2/16/2007	Opp	CON	36	0	0	0	19	81
3/23/2007	Opp	CON	12	8	0	25	25	42
3/30/2007	Opp	CON	23	26	9	4	30	30
4/27/2007	Opp	CON	55	47	0	4	31	18
6/7/2007	Opp	CON	17	88	0	12	0	0
2/17/2007	Opp	CUT1	126	88	12	0	0	0
2/17/2007	Opp	CUT1	47	34	0	6	17	43
2/27/2007	Cap	CUT1	25	4	0	20	36	40
2/28/2007	Opp	CUT1	40	5	3	5	30	58
3/12/2007	Opp	CUT1	24	17	21	8	29	25
3/12/2007	Opp	CUT1	45	36	0	2	18	44
4/11/2007	Opp	CUT1	28	0	0	14	43	43
4/17/2007	Opp	CUT1	20	70	30	0	0	0
5/1/2006	Cap	CUT1	33	45	9	0	12	33
5/13/2006	Cap	CUT1	28	71	0	0	29	0
6/15/2006	Opp	CUT1	57	18	70	0	12	0
6/20/2006	Opp	CUT1	47	28	64	0	9	0
2/21/2007	Opp	CUT2	60	38	0	2	10	50
3/15/2007	Opp	CUT2	65	65	20	2	8	6
3/30/2007	Opp	CUT2	45	0	4	2	9	84
4/24/2007	Opp	CUT2	77	90	0	1	3	6
4/26/2007	Cap	CUT2	20	90	5	5	0	0
4/30/2007	Cap	CUT2	27	93	4	4	0	0
5/24/2007	Opp	CUT2	25	96	4	0	0	0

of poison ivy was found in scat in CUT2. A higher proportion of carpenter ants was found in scat in CUT1 compared to CUT2 and CON.

Discussion

Foraging Behavior

My results suggest the effects of partial cutting on pileated woodpecker foraging are negligible in the few years post-harvest in Louisiana. This was indicated by few consistent differences in foraging tactics and substrate use, forage height and diameter, and tree characteristics selected such as species, dbh class, decay class, and harvest wounds between partial cuts and uncut mature forest. Although differences were negligible among treatments, forage tactic and substrate use varied between years. This indicates that more variation in prey availability occurs between years than among treatments. Although their tactic and substrate use varied between years, pileated woodpeckers used and selected similar tree characteristics in both years. This indicates that although prey may change between years, pileateds still use and select similar tree characteristics to obtain prey.

Pileated woodpeckers did not prefer to forage on increased (*see chapter 2*) CWD and stumps in partial cuts or harvest wounded residual trees. Pileated woodpeckers may not forage on CWD or stumps in BLH since potential prey such as wood-boring beetles are not available two years post-harvest. Large wood-boring beetles typically take two to three years to develop (Stehr 1991) so perhaps enough time had not elapsed to make them worthwhile prey. Pileateds also did not prefer harvest wounded trees, which is not surprising in light of the fact that harvest wounds did not alter the decay class of trees (*see chapter 2*) and would have been selected based on the same criteria as any other tree.

While pileated woodpeckers preferred large dbh snags in early stages of decay, avoided small dbh live trees, and used middle dbh classes in proportion to availability across all

treatments, they did prefer to forage on extremely large diameter trees (90+ cm dbh) in partial cuts and trees in later stages of decay in two-year-old partial cuts. This indicates these substrates may provide supplemental resources not available in uncut forest and/or that 90+ dbh trees were limiting in partial cuts. It is also possible that very large trees provide better cover from predators since pileateds are large and may be more visible foraging in more open partial cuts.

Although I found no support for my hypothesis that woodpeckers would use increased beetle resources in partial cuts by foraging on logging slash, I have contributed to the knowledge of foraging pileated woodpeckers where they have some of the largest populations in North America; Louisiana (Bull and Jackson 1995). In this context, I can compare my results to previous research on pileated woodpeckers. Woodpeckers in my study foraged on dead portions of live trees and on dead trees 37% of the time. The finding that pileateds spent a low percentage of their time using dead substrates in the present study, yet they showed a preference for dead trees, indicates that perhaps dead wood may be in short supply in the study area. In this study, snag occurrence (decay classes 5-8) was on the lower end of dead wood ranges in both controls (6.27%) and partial cut forest (7.17%) compared to old-growth dead-wood ranges in the Singer Tract, Louisiana (7.2-11%) (Shoch et al. *in proc.*) and Arkansas (7-12%) (Spetich et al. 1999). On the other hand, pileateds may have foraged more on live trees because they were taking advantage of an abundant arthropod community on the surface of live trees in the relatively warm southern BLH forests (Conner et al. 1994). In Texas, Conner et al. (1994) showed pileated woodpeckers used live trees 68% of the time even when snag availability was comparatively high (10.2%). Live trees are obviously an important foraging resource to pileated woodpeckers even though they prefer dead substrates.

I found pileated woodpeckers pecked (14%) and gleaned (14%) often. Other studies that conducted foraging observations (only four) have found pileated woodpeckers peck and

glean often which results in no visual sign. In Oregon, woodpeckers pecked (32%) and gleaned (10%) (Bull and Holthausen 1993), in Virginia during breeding and post-breeding woodpeckers mainly pecked (38%) and also gleaned (20%) (Conner 1981), and in Texas birds mainly gleaned (48%) and pecked (30%) (Conner et al. 1994). In most pileated woodpecker studies, researchers use only sign to determine woodpecker use of trees for excavation foraging. Research of other woodpecker species typically involves behavioral observations when studying foraging ecology (Villard 1994; Engstrom and Sanders 1997; Pasinelli and Hegelbach 1997; Murphy and Lenhausen 1998; Gunn and Hagan 2000; Rolstad and Rolstad 2000; Imbeau and Desrochers 2002; Melletti and Penteriani 2003). Studies that do not observe the bird directly may be missing important structural components for foraging.

Arthropod Diet

Scat and forage sign indicate few differences in woodpecker foraging in BLH where they had access to partial cuts and BLH with no access to partial cuts. In this study, *Pheidole* ants and wood-boring beetles were the primary arthropod prey as indicated by forage sign. In scat samples, the primary arthropods were probably also *Pheidole* ants and wood-boring beetles if mass is considered instead of number of individuals. The length of *Pheidole* ants was 2-3 mm, carpenter ants 4-6 mm, and beetles 30-55 mm. A woodpecker would have to consume many times more *Pheidole* ants to equal the mass of a large wood-boring beetle. Nonetheless, *Pheidole* ants comprised a large proportion of pileated woodpecker diet in both partial cuts and controls. *Pheidole* ants are probably an abundant arthropod in both partial cuts and uncut forest. Thompson and General (*pers. comm.*) found that ant species were about the same abundance in partial cuts and controls in a Mississippi BLH. As well, *Pheidole* ants are not specific about the diameter of dead substrates they use for nesting (Torgerson and Bull 1995) and in this study were

frequently foraged for in dead branches. Large trees have proportionately more dead limbs of all sizes which could be another explanation for pileated preference for large diameter trees.

Carpenter ants were rarely consumed in Louisiana which was indicated by the low percentage of remains in scat and by lack of forage sign for them. Of three previous studies that analyzed pileated scat, carpenter ants comprised 90% (n = 48) of the diet in Oregon, 68% (n = 333) in a different study in Oregon, and 54% (n = 86) in Washington (Beckwith and Bull 1985; Bull et al 1992; Raley and Aubry 2006). Carpenter ants may be less abundant in BLH since they prefer dry conditions (Furniss and Carolyn 1977; Raley and Aubry 2006) and BLH are wet or humid year-round. This would be supported by the finding that eight of nine sign for carpenter ants were in partial cuts which are more sun-exposed.

In considerable contrast to other studies, a large percentage of woodpecker diet consisted of berries. In fact, one sample was entirely vegetative. In comparison to other areas, only 4 of 86 samples (5%) contained seeds in Washington (Raley and Aubry 2006) and 1 of 48 (2%) in Oregon (Beckwith and Bull 1985). Berries are an important component of woodpecker diet in the south in contrast to pileateds of the north. That woodpeckers have access to and consume poison ivy berries in the south could explain why populations are much higher in the south than in the north. It would be interesting to learn whether pileateds have access to berries with high caloric value in the north.

Capture Success

Capturing woodpeckers at the nest with a hoop net on an extendable pole was the most reliable means of capturing birds and is recommended over other methods. Capture success was far greater with the pole/hoop net setup at active nests (90% or 9/10 attempts) than with target mist-netting (17% or 3/17 attempts). It took significantly more effort to find nests than to set up a target mist-net. Finding nests was much easier in February than April when birds were loudly

excavating nest cavities as opposed to quietly incubating eggs. The target canopy mist-net took 45 minutes to 1 hour to set up and another hour to lure the birds in with drums.

AVM transmitters either failed or began giving very weak signals between three and five weeks after attachment. Holohil transmitters worked consistently for the entire duration of the study (up to six months) and are recommended over AVM transmitters.

In general, woodpeckers were very difficult to relocate even with telemetry since they were extremely wary; raising binoculars with haste would often flush them. While radio-telemetry was supposed to help locate birds, waving an antenna around created too much movement and counteracted the benefit of knowing the bird's location. In general, it was not worthwhile to transmitter birds for foraging observations in Louisiana.

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Chapter 5: Conclusion and Recommendations

The LMVJV (2007) advocates silvicultural techniques that provide habitat for a diversity of species. Partial cutting, both group and single-tree, is an option that can be used to attain many of the desired forest conditions (DFCs) (Hamilton et al. 2005). It is well known that partial cutting can improve habitat for many species that require vertical structure (*LDWF forest prescriptions 1999-2002*; Hamilton et al. 2005). We now know, through the research in this study, that saproxylic beetles are also benefitted and pileated woodpecker nesting, roosting, and foraging are largely unaffected in the first two years after partial cutting. The partial cutting techniques used in this study incorporated recommendations for wildlife requiring large diameter trees such as Louisiana black bear (*Ursus americanus luteolus*), ivory-billed woodpecker (*Campephilus principalis*), and Rafinesque's big-eared bat (*Corynorhinus rafinesquii*) (*LDWF forest prescriptions 1999-2002*; LMVJV 2007). Therefore, management on WMAs includes objectives for large, stressed, and standing dead, and CWD; results of this study must be considered within this context.

Partial cutting can be used as a tool to increase the abundance and species richness of saproxylic beetles for at least two years post-harvest. In addition, partial cutting creates habitat for six species that occur in very low abundances in uncut forest. Logging slash should be left on-site for this benefit to be realized. Although saproxylic beetles increased in partial cuts, pileated woodpeckers did not forage on them any more than in controls. A third season of beetle trapping may yield more large-sized beetles since they take two to three years to develop.

In this study, large harvest wounds did not alter the decay class of trees one or two years post-harvest and should not be expected to contribute to tree mortality in the short term. Not surprisingly, pileateds did not prefer harvest wounded trees to others. Girdling trees also has negligible effects on killing trees but injecting trees with 2, 4-D kills trees fast (Conner et al.

1983). Creation of standing dead wood would likely increase cerambycid abundance which was found to be related to the number of standing dead trees in stands.

Woodpeckers found trees in partial cuts of sufficient species, dbh, and decay class for nesting, roosting, and foraging. Woodpeckers used mostly live, large diameter trees for nesting, roosting, and foraging, which were abundant in partial cuts; therefore woodpeckers had many substrates available. While woodpeckers *used* resources that were common, they *selected* rare resources (i.e. large diameter snags trees for foraging and baldcypress for nesting). Since partial cutting did not remove the largest trees in this study, woodpecker foraging was largely unaffected. Accordingly, pileateds benefit from the objective of leaving large diameter trees in partial cuts.

While baldcypress may provide an energy-efficient tree to excavate, three of the seven nests in baldcypress broke off at the cavity, rendering the cavity unsuitable for wildlife that would subsequently use the cavity tree and require a covered cavity. Consequently, I recommend more large sized (≥ 40 cm dbh) sugarberry be left in partial cuts since woodpeckers selected baldcypress with a reduction in the proportion of sugarberry. As well, clusters of large trees should continue to be left when partial cut harvesting to provide nest and roost sites.

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Vita

Patti Newell was born in Hamilton, Ontario, where she grew up wanting to be an artist. After a year of art school, she decided her real place in the world was studying ecology although she did not know it was called ecology at the time. A young, misguided environmentalist, she enrolled in the forestry program at the University of New Brunswick in Fredericton. She quickly realized forestry was not about saving trees, but in fact it was about cutting them down. After five years of indoctrination, she finally came to accept that responsible management is not just setting forests aside, but that in today's highly disturbed ecosystems, human manipulation is required to manage ecosystems. After working various field jobs with birds including eastern bluebird, brown-headed nuthatch, wild turkey, wood thrush, northern bobwhite, and willow flycatcher, she decided to pursue a master's degree. So after 10 years of traveling in the United States and Canada, Patti found her way to the bottomland swamps of Louisiana where she currently resides with her boyfriend Sean.