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Woodpecker nest site selection in oak forests of the Driftless Area in the Upper Midwest

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To my family
for fostering in me
respect for all of God's creatures

and

to my husband Troy
for offering smiling help in the field,
rescuing me from countless computer problems,
and providing boundless support, friendship, and love.

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PREFACE

This thesis is a response to an identified need for natural history information on cavity nesting birds in Minnesota. The 1994 Generic Environmental Impact Statement (GEIS) on Timber Harvesting and Forest Management in Minnesota predicted a decline in several species of cavity-nesting birds based on intensity of timber harvest. In response to GEIS predictions and recommended mitigation, the Minnesota Legislature passed the Sustainable Forest Act of 1995 calling for the creation of a Forest Resources Council to oversee conservation and management of Minnesota forests. Several technical teams developed guidelines for specific management topics including guidelines for harvesting timber that will favor wildlife. These guidelines were recently published by the Minnesota Forest Resources Council in a book titled, "Sustaining Minnesota Forest Resources: Voluntary Site-level Forest Management Guidelines" (1999).

The Forest Resources Council guidelines offer suggestions about the number of snags of certain size classes that should be left during harvest. However, they offer few recommendations on the specific characteristics or preferred distribution of leave trees. In addition, their recommendations were not based on local field research. Forest management guidelines will be most effective when they are based on regionally appropriate biological knowledge.

The goal of this thesis was to obtain natural history information on the nest sites of primary cavity-nesting birds and use this information to (1) evaluate existing snag management guidelines and (2) offer additional insight for managing oak forests of the Driftless Area to benefit cavity-nesting wildlife. During the summers of 1997 and 1998, I found active woodpecker nests in oak forests of southeastern Minnesota and western Wisconsin. I took vegetation measurements of the nest site at three levels: the circular plot around the tree, the nest tree, and the nest hole. I also took vegetation measurements of unused forest sites. To identify characteristics of nest sites used by woodpeckers, I compared nest sites to unused forest sites. I also compared the characteristics of nest sites among the woodpecker species. My thesis is divided into two chapters. Analysis at the level of the nest tree and nest hole is presented in Chapter 1, and analysis of vegetation surrounding the nest trees is presented in Chapter 2. Management implications are included in both chapters.

I hope that this study will provide the Minnesota Department of Natural Resources and other relevant agencies with information necessary to conserve cavity-nesting birds.

CHAPTER 1. WOODPECKER NEST TREE CHARACTERISTICS IN OAK FORESTS OF THE DRIFTLESS AREA IN THE UPPER MIDWEST

ABSTRACT

The characteristics of woodpecker nest trees have been widely studied in some regions of North America. However, there is little research from the Upper Midwest. Knowledge of the specific characteristics of woodpecker nest trees is needed by timber harvesters to know which trees to leave during harvest to best meet the needs of cavity-nesting birds. The purpose of this study was to identify attributes of nest trees used by primary cavity-nesting birds by comparing nest trees to unused trees and by considering differences in nest trees among the woodpecker species. I found 166 active woodpecker nests in oak forests of the Driftless Area. For each nest tree, I recorded the height, diameter, status, and several aspects of tree decay (e.g., bark cover, top condition, limb condition, and presence of old cavities, branch stubs, tree scars, or significant dead portions). I also recorded these measurements for the four potential nest trees closest to each active nest tree. In addition, I recorded these measurements for 137 randomly selected potential nest trees. Using paired t-tests and chi-square analysis, I found that each woodpecker species had a unique set of characteristics that separated their nest trees from random potential nest trees. Considered as a group, using an extension of the McNemar test for related samples, I found that woodpeckers chose trees that were larger, both in diameter and height, more often elm or aspen, more likely to have old cavities present, with more decay indicators than adjacent potential nest trees. The Yellow-bellied Sapsucker *(Sphyrapicus varius)* differed from the other species by nesting in living trembling aspens (Populus *tremuloides)* with intact tops, complete bark cover, and >3 decay indicators near the nest hole. The diameters of nest trees differed significantly among species, but height of nest hole and nest tree did not. Holes of woodpecker nest trees faced south or southeast significantly more often than by chance alone, even when excluding leaning trees. Woodpeckers create holes in trees that are used by many species of cavity dwelling wildlife. This study indicates that generic management for all woodpecker species may not be adequate because individual species have specific nest tree requirements. Management recommendations for cavitynesting birds need to be tailored to meet a diversity of species needs.

INTRODUCTION

Woodpeckers play a key role in forest communities. The unique ability of woodpeckers to excavate holes in trees for nesting and roosting creates habitat for many other species of cavity-dwelling wildlife. In addition, as predators of forest insects, woodpeckers help control insect outbreaks (Bruns 1960).

Only certain trees are suitable for woodpecker excavation. To begin, the tree must be large enough to support a nest. The required tree size depends on the body size of the woodpecker (Conner et al. 1975), but larger trees, both in diameter and height, are generally used more often than smaller trees (Welsch & Howard, Jr. 1983, Zarnowitz & Manuwal 1985). Woodpeckers also require trees with heartwood decay (Kilham 1971, Conner et al. 1976). Heartwood decay, which is due to fungal invasion of the inner wood, softens the wood and facilitates excavation. As a consequence of the need for heartwood decay, woodpeckers often choose dead or dying trees for nest hole excavation.

However, some tree species can contain suitable heartwood decay while they are still living. Living aspen (Populus spp.) trees may develop suitable heartwood decay when they mature and are widely used for nesting by woodpeckers (Kilham 1971, Runde & Capen 1987). Woodpeckers are not obligate on certain tree species for nesting. However, some tree species are preferred substrates for woodpecker nest excavation (Thomas et al. 1979).

The characteristics of nest trees used by woodpeckers have been widely studied in some regions of North America. Research on woodpecker nest site selection in the western United States is most extensive. Woodpecker nest site selection has been studied in Douglas-fir *(Pseudotsuga menziesii)* forests of western Oregon (Mannan et a1.1980, Schreiber & deCalesta 1992), ponderosa pine *(Pinus ponderosa)* forests in Arizona and Oregon (Scott 1978, Li & Martin 1991, Scott & Oldemeyer 1983, Bull & Meslow 1977), aspens in Colorado and Oregon (Winternitz & Cahn 1983, Dobkin et al. 1995, Scott et al. 1980), cottonwood (Populus *deltoides)* bottomlands in Colorado (Sedgewick & Knopf 1986, 1990), Jeffrey pine-white fir *(Pinus jeffreyi-Abies concolor)* forests in the Sierra Nevada (Raphael & White 1984), western hemlock-Douglas-fir *(Tsuga heterophyllaPseudotsuga menziesii)* forests in Washington (Zarnowitz & Manuwal 1985), western larch-Douglas-fir *(Larix occidentalis-Pseudotsuga menziesii)* forests in Montana (McClelland & Frissel 1975), and lodgepole pine-Engelmann spruce-subalpine fir *(Pinus contorta-Picea engelmannii-Abies lasiocarpa)* forests in Colorado (Scott et al. 1978).

Outside the western United States, there are fewer studies on the characteristics of nest trees used by woodpeckers. Studies have been done in northern hardwood forests of Vermont, New York, and New Hampshire (Runde & Capen 1987, Swallow et al. 1986, Kilham 1971). There have been several publications from research done in oak-hickory forests of southwestern Virginia (Conner & Adkisson 1977, Conner et al. 1975, Conner et al. 1976, Conner 1975). There are a few studies from the Upper Midwest, including oak hickory forests of east-central Illinois (Reller 1972) and riparian areas in Iowa (Stauffer & Best 1982).

Because characteristics of snag communities vary widely among biotic communities (Zeedyk 1983), information from other parts of the United States may not be applicable to oak forests of the Driftless Area. Sound information on the nest tree requirements of woodpeckers is needed to develop forest management guidelines to meet the needs of cavity-nesting birds.

Declines in the numbers of several species of cavity-nesting birds were predicted in the Generic Environmental Impact Statement (GEIS) on Timber Harvesting and Forest Management in Minnesota (1994). In response to GEIS predictions and recommended mitigation, the Minnesota Legislature passed the Sustainable Forest Act of 1995 calling for the creation of a Forest Resources Council to oversee conservation and management of Minnesota forests. Several technical teams developed guidelines for specific management topics including guidelines for harvesting timber that will favor wildlife.

The Forest Resources Council guidelines offer suggestions on number of trees of certain size classes that should be left during harvest. However, they offer few recommendations on the specific characteristics of leave trees. In addition, their recommendations were not based on local field research. The objective of my study was to identify attributes of nest trees used by primary cavity-nesting birds by comparing nest trees to unused trees and by considering differences in nest trees among the woodpecker species. I designed this study to address the following questions:

1) Do trees chosen for nesting by woodpeckers differ from unused trees in terms of tree size, tree condition, and tree species?
2) Are there differences among woodpecker species in nest tree size, tree condition, and tree species?
3) Is there non-random woodpecker cavity entrance orientation?

STUDY AREA AND METHODS

Study Area

The study area was Houston and Filmore counties of southeastern Minnesota and LaCrosse County of western Wisconsin (Figure 1). This area is included in Bailey's (1994) North Central U.S. Driftless and Escarpment Section (222L) of the Eastern Broadleaf Forest (Continental) Province. This region is more simply referred to as the Driftless Area. This area was uncovered by the Wisconsin Glaciation, which retreated 10,000 to 12,000 years ago (Tester 1995). A surface layer of loess that covers the till and bedrock characterizes much of the upland area. The deposits are deeply eroded, forming hills and valleys. The pre-settlement vegetation was oak woodland and brushland and maple-basswood forest, according U.S. General Land office survey notes as compiled by Marschner (1974). Now the land is highly fragmented, consisting primarily of patches of oak forest surrounded by agricultural lands.

I selected plots from available state-owned forests on the basis of accessibility and intensity of public use. Because I did not randomly choose the plots, the forest characteristics may not be representative of the Driftless Area. However, the level of representation is improved by the fact that the plots were widely scattered, with about 90 km between the westernmost and easternmost plots. I chose plots in the Richard J. Dorer Memorial State Hardwood Forest, Forestville State Park, and Coulee State Experimental Forest. I had a total of 12 plots; 8 plots used each year. In 1997, I used Forestville, Underbakky, Bonnieville, Brightsdale, Sand Barrens, Money Creek, Quarry, and Oak Ridge. In 1998, I used the four easternmost study plots again (Sand Barrens, Money Creek, Quarry, and Oak Ridge), but also included Reno, Hamel, Coulee North, and Coulee South (see Appendix A for topographic maps of the study areas and location descriptions based on U.S. Public-Land Survey System).

The study area has a varied history including logging, grazing, and fire. None of the plots was logged in the last ten years; however, firewood cutting was allowed at Underbakky. Only the Quarry plot, which included some private land, was grazed in the last 10 years. Some plots were within forest fragments as small as 40 ha, while others were within more extensive forest tracts.

The plot canopies were dominated by oaks *(Quercus rubra, Q. alba, Q. bicolor)* and hickories *(Carya ovata, C. cordiformis),* but also included elms *(Ulmus americana, U. rubra),* basswood *(Tilia americana),* aspen *(Populus tremuloides, P. grandidentata),* other hardwoods, and some white pine *(Pinus strobus).* Young plants of these canopy trees, hazel *(Corylus* spp.), gooseberry *(Ribes* spp.), and raspberry *(Rubus* spp.) made up the woody understory. The study area is classified as oak forest, according to the Minnesota Department of Natural Resources County Biological Survey. All plots were in mature forest, aging from 80 to 120 years, with a component of dead and dying trees. Breeding bird surveys indicated that the plots had 56 bird species, including 13 cavity nesting species (Friberg, per. comm.).

The plots ranged from 28 to 40 ha in size (mean = 36 ha). I marked the plots with flagging tape, forming a grid spaced at 50 m or 100 m intervals. I used the grids to plot locations of woodpecker activity on field maps, to mark nest locations, and to specify locations for the randomly selected sites.

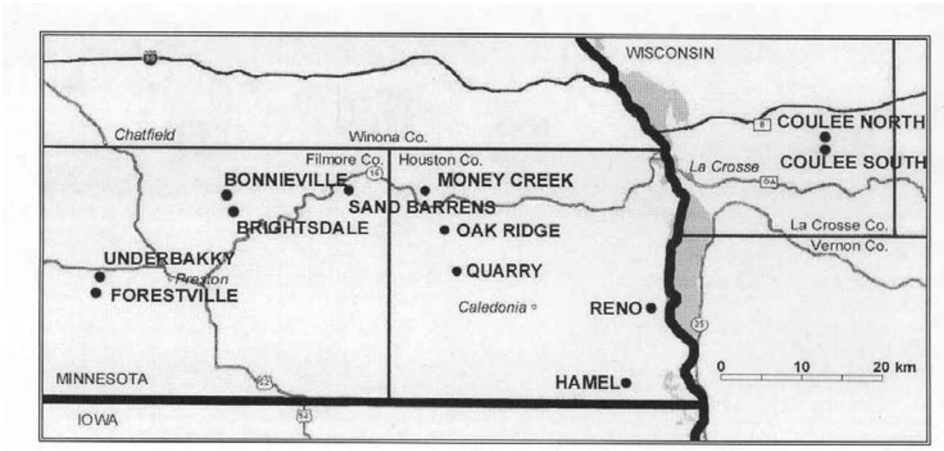

Figure 1. Houston and Filmore counties of Minnesota and La Crosse County of Wisconsin with the locations of the 12 study plots indicated.

Nest Searching

In 1997, I began nest searching 6 May and ended 23 June. In 1998, warm El Nino weather brought an early spring so I began nest searching April 20 and ended June 22. After formal nest searching ended, I serendipitously found some additional nests during vegetation surveys. There was little attempt to equalize nest searching effort among the plots, because the goal was to find as many nests as possible. I included nests found outside plots as long as they were within the study area.

I searched for active nests of all primary cavity-nesting birds on the plots, excluding the Black-capped Chickadee. The primary cavity-nesting birds included Downy, Hairy, Red-bellied, Red-headed, and Pileated woodpeckers, Yellow-bellied Sapsuckers, and Northern Flickers (for scientific names see Table 2).

I found nests by following woodpecker vocalizations, drumming, and flight paths. By systematically walking the plots and examining trees with indications of possible use such as cavities and fresh chips at the base, I found additional nests. I found nests of the Red-headed Woodpecker along roadsides, as well as on the plots (for details of the nest searching methods see Appendix B).

I confirmed nests as active if I observed any of the following: 1) adult completely entering nest hole and remaining in cavity for over 10 minutes; 2) adult flushed from nest hole; 3) adult feeding young; and 4) young calling from cavity. Because of difficulty locating

Red-headed Woodpecker nests, adult repeatedly entering the nest cavity but not remaining inside during my observation period was considered sufficient evidence of activity.

Vegetation Surveys

I recorded characteristics of all active woodpecker nest trees found in 1997 and 1998. I began vegetation surveys of the nest trees shortly after nestlings fledged. I also recorded the vegetation measurements for the four potential nest trees closest to the nests. Potential nest trees were defined as non-nest trees, within the height and diameter requirements of cavity-nesting birds, with at least two indicators of heartwood decay (Conner 1978). In accordance with the minimum nest heights and tree diameters used by woodpeckers, potential nest trees were > 15.2 cm DBH and > 1.8 m tall (Thomas et al. 1979). 1 also recorded these measurements for randomly selected potential nest trees. The potential nest trees were used for comparison to woodpecker nest trees. In addition, trees in randomly located subplots were surveyed to determine the availability of trees of different species and size classes. I modified the study methods after Runde and Capen (1987). A description of vegetation measurements is provided in Table 1.

I recorded vegetation characteristics to describe tree size, tree condition, and tree species of nest trees and potential nest trees. To describe tree size, I recorded tree height and diameter at breast height (DBH). To describe the tree condition, I recorded tree status, top condition, limb condition, percentage live wood and percentage bark cover in quartile classes, and presence of decay indicators including old cavities, tree scars, branch stubs, fungal conks, and significant dead portions.

To describe the characteristics of the nest tree at the position of the excavation, I recorded several additional measurements of nest trees. Measurements at the nest hole included nest height, hole orientation, substrate lean relative to nest hole, substrate limb type, and hole position relative to canopy. In addition, several variables describing tree condition at nest height, including substrate live or dead, top condition, presence of decay indicators, and bark cover, were recorded.

To determine the availability of trees of various sizes and species for nesting and to get a sample of randomly selected potential nest trees, I sampled trees in circular subplots (11.3 m radius) randomly distributed across the study sites. I located these random subplots 15 m from randomly selected grid-points in randomly selected azimuths. I surveyed 9 subplots on the 8 study sites during each field season, for a total of 144 random sites. This resulted in a survey of approximately one percent of the total study area. For all the trees within the subplots, I recorded species, status, and size class (see Appendix C for copies of data forms). For potential nest trees within the circular subplots, I took the same vegetation measurements that were taken on nest trees. Out of each of the subplots that contained potential nest trees, one potential nest tree was randomly chosen for comparison to nest trees. This resulted in a sample of 137 randomly selected potential nest trees.

Table 1. Descriptions of vegetation measurements taken for nest trees and potential nest trees in oak forests of the Driftless Area, 1997-98.

Variable	Categories	Description
Heartwood Fungal Conks	Presence, Absence	Fomes igniarius, the shelf fungus of trembling aspen, and other large shelf fungi
Sapwood Fungus	Presence, Absence	Small, superficial tree fungi
Old cavities	Presence, Absence	Holes that looked like they were completely excavated by a woodpecker
Trees scars	Presence, Absence	Any old wounds to the tree with exposed heartwood, including natural cavities, deserted excavation attempts of woodpeckers, and deep woodpecker foraging holes
Significant dead portions	Presence, Absence	Dead portions of a tree that were big enough to serve as nesting substrate for the Downy Woodpecker >15 cm diameter and >30 cm long)
Branch stubs	Presence, Absence	A tree with an unhealed broken branch or stem >15 cm in diameter and >30 cm long or an unhealed broken branch <1 m and connected to a stem >15 cm in diameter
Percentage Live Wood	0-25, >25-50, >50-75, >75	A subjective estimate of percentage live wood in quartile classes
Percentage Bark Cover	0-25, >25-50, >50-75, >75	A subjective estimate of percentage bark cover in quartile classes
Tree Status	Alive, Dead, Partly Dead	A partly dead tree was a tree that forked with one fork dead or a tree that had only a few small remain in living branches >75 /o dead).
Top Condition	Top Intact, Top Broken, Broken Fork	A top broken tree had a top that ended abruptly and did not taper. In a broken fork tree, the trunk slit with one fork intact and other broken.
Limb Condition	Trunk, Main Branches, 2° Branches, Foliage Twigs	Type of branches remaining, regardless of whether the branches were dead or alive.
Nest hole position relative to canopy	Above, Within, Below	Nest holes above the average height of top of high canopy were considered above, while nest holes below the average height of bottom of high canopy were considered below.
Nest substrate limb type	Trunk, Main Branch, 2° Branch, 3° plus	Nest substrate refers to the wood in which the nest hole was excavated. Limb type refers to whether the hole is located in the main trunk or in a limb that branches from the trunk.
Substrate Lean Relative to Nest	Acute, Vertical, Obtuse	An acute nest hole refers to a hole on the underside of a leaning tree, while an obtuse hole refers to a hole on the to side of the lean.

Data Analysis

I compared nest trees to potential nest trees to evaluate woodpecker nest tree selection. Comparisons of nest trees among the woodpecker species were also made to determine interspecific similarities and differences in nest tree characteristics. The :DBH data had a long right tail so it was transformed using the reciprocal square root. The transformation was chosen using a Box-Cox plot (Box & Cox 1964). Because of the low variance of Yellow-bellied Sapsucker nest tree DBH and height, I used unpooled variance for t-tests involving this species. Alpha levels <0.05 were used to indicate significance.

I statistically compared size, condition, and species of nest trees to potential nest trees. I used paired t-tests to compare DBH and height of nest trees to the mean of four adjacent potential nest trees. An extension of the McNemar test for related samples (Miettinen 1968) was used to compare the condition and species of all woodpecker nest trees to the sample of adjacent potential nest trees. Using the McNemar extension, I established comparisons using 2 or 3 categories for each independent variable. The independent variables with three categories included tree status (alive, dead, or partly dead), top condition (intact, broken fork, broken top), limb condition (trunk, main branches or secondary branches, foliage-bearing twigs). Independent variables with two categories included tree species (elm or aspen, other), number of decay indicators (<3, 3+), percentage live wood (0-25%, >25%), percentage bark cover low (0-25%, >25%), percentage bark cover high (0-75%, >75%), and presence and absence of branch stubs, heartwood fungal conks, tree scars, old cavities, and significant dead portions.

Because the adjacent potential nest trees were near the nest site selected by each woodpecker, comparing nest trees to adjacent potential nest trees provided a more controlled comparison than comparing nest trees to randomly selected potential nest trees. However, because of high skew and small sample size, the extension of the McNemar test could not be used when comparing the nest trees to potential nest trees for each individual species. Instead, I used chi-square tests of homogeneity to compare nest trees to a randomly selected sample of potential nest trees. The independent variables tested included tree species elm or aspen (elm/aspen, other), tree species aspen (aspen, other), percentage bark cover low (0-25%, >25%), percentage bark cover high (0-75%, >75%), tree status (alive, dead or partly dead), tree top condition (top intact, broken fork, broken top), number of decay indicators (<3, 3+), and presence and absence of branch stubs, heartwood fungal conks, sapwood fungus, tree scars, old cavities, and significant dead portions. If I found a significant difference within a 2 X C chi-square contingency table, I broke the table down into non-independent 2 X 2 tables for examination of where nonhomogeneity occurred (Brunden 1972).

I also made comparisons among the woodpecker species for tree size, condition, and species. I used Kruskal-Wallis ANOVA to compare the DBH and height among the seven species of woodpeckers. When I found a significant difference among species, I used a multiple comparison procedure using rank sums to determine which species differed significantly from each other (Dunn 1964). To compare the condition and species of the nest tree among the species of woodpecker, I used chi-square tests of homogeneity. Condition of the tree at the nest hole was also compared among species using chi-square tests. Chi-square tables that showed non-homogeneity were broken down into non-independent 2 X 2 tables for an examination of where the nonhomogeneity occurred (Brunden 1972). The Northern Flicker and the Pileated Woodpecker were not included because of low sample size.

I used chi-square tests to test for randomness in nest hole orientation for all nest trees and separately for nest trees with a vertical bole.

RESULTS

I found 166 nests, including 76 in 1997 and 90 in 1998 (Table 2).

Comparison of Nest Trees and Unused Trees

I was interested in whether woodpecker nest trees differed in size from potential nest trees. Woodpecker nest trees had significantly greater diameters and heights than adjacent potential nest trees (Table 3). Over 50% of nest trees were between 23 and 38 cm DBH (Figure 2). This diameter class was used out of proportion to its availability (X2=893, p,0.000, d.£=1).

The decay condition of woodpecker active nest trees also differed from potential nest trees. In comparison to adjacent potential nest trees, nest trees of all woodpeckers combined had fewer broken tops ($p<0.05$), foliage-bearing twigs present more often ($p<0.01$), heartwood fungus present more often ($p<0.01$), significant dead portions present less often ($p<0.05$), more total decay indicators present ($p<0.001$), and were more often elm or trembling aspen ($p<0.001$). Nest trees also were more likely to have old cavities present (55% of nest trees and 4% of potential nest trees), but the high skew invalidated the McNemar extension. These results were highly influenced by the large sample of Yellow-bellied Sapsuckers. When the Yellow-bellied Sapsucker was excluded, number of decay indicators ($p<0.01$) and tree species elm or aspen ($p<0.001$) remained significant. The percentage of nest trees with old cavities still remained high (51 % of nest trees and 8% of potential nest trees). There was no difference found between nest trees and potential nest trees in tree status, percentage live wood or bark cover, or in the presence of branch stubs or tree scars.

Each woodpecker species had its own set of characteristics that differentiated its nest trees from randomly selected potential nest trees (Table 4).

Certain tree species were extensively used for nesting by woodpeckers. Woodpeckers chose American elms *(Ulmus americana)* and trembling aspens (Populus *tremuloides)* for nesting much more often than expected based on availability (X2=391, p,0.000, d.f.=1). American elm and trembling aspen provided 70% of all nest sites but constituted only 10% and 5% of all trees in random plots, respectively. Dead American elms made up < 1 % of available trees and dead slippery elms made up approximately 1 of available trees.

Comparison Among Woodpecker Species

I wanted to determine if nest tree selection differed among species of woodpeckers. I found a significant difference in nest tree DBH, but not nest tree height or nest height (Table 5). Differences in nest tree condition among the woodpecker species were found using chi-square tests (Table 6). There was no difference found in limb condition, number of decay indicators, and presence of branch stubs, tree scars, and old cavities.

Vegetation characteristics at the nest hole for the seven species of woodpecker are summarized in Table 7. Chi-square tests of the nest cavity data showed some differences among the woodpecker species (Table 8). There was no difference found in substrate limb type and presence of branch stubs, tree scars, and old cavities within 1 m of the nest hole.

Entrance Orientation

The orientation of woodpecker nest holes was distributed non-randomly (Figure 3). Holes of all woodpecker nest trees combined faced south or southeast significantly more often than by chance alone (d.f.=1, $p<0.01$). The frequency of nest trees with holes facing south or southeast was still significant after removing all trees with a lean (d.£=1, $p<0.01$). Eighty-two percent of all nest trees had no lean, 17% of nest holes were on the underside of a lean, and 1 % were on the topside of a lean.

Table 2. Percentage of nest trees with each characteristic for seven species of woodpecker in oak forests of the Driftless Area, 1997-98.

	DOWO[a]	HAWO[b]	RBWO[c]	RHWO[d]	YBSA[e]	PIWO[f]	NOFL[g]	ALL[h]
Sample Size	44	22	29	20	42	4	5	166
Tree Used (%)							4	
American Elm	48	36	34	70	7	50	80	37
Quaking Aspen	11	27	17	10	88	25	0	34
Oak	23	14	14	5	5	0	0	12
Paper Birch	2	9	10	0	0	0	0	4
Basswood	2	0	21	0	0	0	0	4
Big-toothed Aspen	0	0	3	10	0	25	0	2
Black Cherry	5	5	0	0	0	0	0	2
Other	9	9	0	5	0	0	20	5
Presence of Decay Indicators (%)								
Branch Stubs	100	100	100	100	100	100	100	100
Heartwood Fungus	16	45	24	10	95	25	0	40
Sapwood Fungus	32	14	28	5	2	0	20	17
Tree Scars	23	36	38	10	19	50	75	27
Old Cavities	41	45	55	70	67	75	50	55
Sig. Dead Portion	95	64	100	90	14	75	80	70
% Live Wood (%)								
0-25	82	55	66	90	10	75	80	58
25-50	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
50-75	*0*	5	3	0	2	0	0	2
75-100	18	41	31	10	88	25	20	40
% Bark (%)								
0-25	39	23	31	70	5	50	25	30
25-50	7	14	3	0	0	0	25	5
50-75	2	0	0	0	0	25	25	2
75-100	52	64	66	30	95	25	25	63
Tree Status (%)								
Live	16	36	24	10	88	25	20	38
Dead	80	55	66	90	10	75	80	57
Partly Dead	5	9	10	0	2	0	0	5
Tree Top (%)								
Intact	48	55	24	50	98	50	80	58
Broken Top	27	27	48	20	2	25	0	23
Broken Fork	25	18	28	30	0	25	20	19
Limb Condition (%)								
Trunk	14	9	7	5	0	25	0	7
Main Branches	14	9	14	10	0	0	0	8
20 Branches	11	5	7	10	0	0	0	6
Foliage Twigs	61	77	72	75	100	75	100	78
# of Decay Indicators (%)								
1-2	39	32	34	30	26	25	25	32
3	50	45	24	55	55	25	50	46
4	11	18	41	15	17	50	25	20
5	*0*	5	0	0	2	0	0	1

a Downy Woodpecker *(Picoides pubescens)*
b Hairy Woodpecker *(Picoides villosus)*
c Red-bellied Woodpecker *(Melanerpes carolinus)*
d Red-headed Woodpecker *(Melanerpes erythrocephalus)*
e Yellow-bellied Sapsucker *(Sphyrapicus varius)*
f Pileated Woodpecker *(Drycopus pileatus)*
g Northern Flicker *(Colaptes auratus)*
h Includes nests of all woodpecker species found

Table 3. Paired comparison of nest trees with the mean of the four adjacent potential nest trees for seven species of woodpecker in oak forests of the Driftless Area, 1997-98.

	Tree Diameter (cm)					Tree Height (m)				
	Diff.[a]	SE	t	df		Diff.	SE	t	df	
Downy Woodpecker	-0.7	2.4	-0.8	43	NS	2.6	1.1	2.4	43	*
Hairy Woodpecker	-0.8	2.8	-1.0	21	NS	2.8	1.3	2.1	21	*
Red-bellied Woodpecker	10.2	5.4	2.1	28	*	4.3	1.4	3.1	28	**
Red-headed Woodpecker	17.0	4.7	4.5	19	***	6.5	1.3	5.1	19	***
Yellow-bellied Sapsucker	0.1	1.2	0.5	41	NS	5.2	0.8	6.2	41	***
Pileated Woodpecker	39.9	19.7	3.4	3	*	9.4	6.2	1.5	3	NS
Northern Flicker	31.4	20.6	1.6	3	NS	4.7	1.4	3.4	3	*
All Species	5.3	1.6	2.3	164	***	4.3	0.5	8.2	164	***

* P<0.05,** P<0.01,*** P<0.001, and NS P>0.05

[a]The difference of the means (Diff.) and the standard error of the difference of the means (SE) are presented here from the untransformed data.

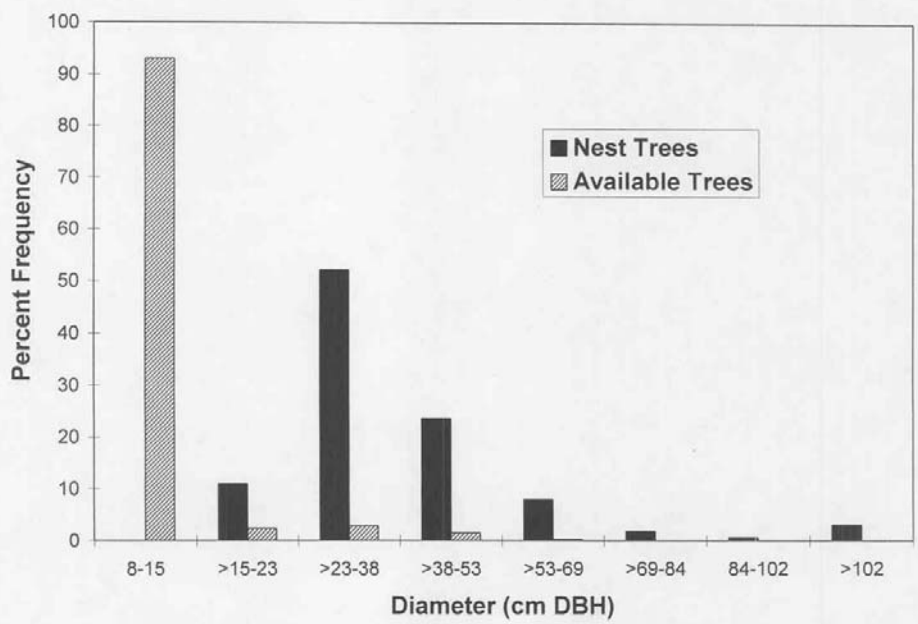

Figure 2. Diameter (cm DBH) in size classes for all woodpecker nest trees and available trees in oak forests of the Driftless Area, 1997-98.

Table 4. Characteristics that significantly differed (chi square tests of homogeneity) for seven species of woodpecker in oak forests of the Driftless Area, 1997-98.

	% of trees with characteristic	
	Nest trees	**Random Potential Nest Tree**
Downy Woodpecker		
Dead or partly dead*	84	66
Broken forked top** (df=2)	25	6
Tree elm or quaking aspen***	59	18
Old cavities present***	41	4
Sapwood fungus present*	32	11
3 or more decay indicators***	61	28
0-25% bark cover***	39	9
Hairy Woodpecker		
Tree elm or quaking aspen'	64	18
Old cavities present***	45	4
Heartwood decay fungus present***	45	13
Without significant dead portion***	36	9
3 or more decay indicators"	68	28
Red-bellied Woodpecker		
Tree elm or quaking aspen'	52	18
Broken forked top*** (df=2)	28	6
Old cavities present***	55	4
3 or more decay indicators***	66	28
0-25% bark cover"	31	9
Red-headed Woodpecker		
Tree elm or quaking aspen***	80	18
Dead or partly dead*	90	66
Broken fork" (df=2)	30	6
Old cavities present***	70	4
3 or more decay indicators***	70	28
0-25% bark cover***	70	9
Yellow-bellied Sapsucker		
Tree alive***	88	34
Top intact*** (df=2)	98	62
Tree quaking aspen***	88	8
Old cavities present'	67	4
Heartwood decay fungus present***	95	13
No significant dead portion***	86	9
3 or more decay indicators***	74	28
75-100% bark cover*	95	81
Pileated woodpecker		
Tree elm or quaking aspen'	75	18
Old cavities present***	75	4
3 or more decay indicators'	75	28
0-25% bark cover"	50	9
Northern flicker		
Tree elm or quaking aspen**	80	18
Old cavities present***	50	4
3 or more decay indicators***	75	28

*** p<0.05, ** p<0.01, *** p<0.001, df=1 unless otherwise indicated**

Table 5. DBH and height of nest trees of seven species of woodpecker in oak forests of the Driftless Area, 1997-98.

		Nest Tree DBH (cm)					Nest Tree Height (m)					Nest Height (m)			
	n		Mean	SE	Min.	Max.		Mean	SE	Min.	Max.		Mean	SE	Min.	Max.
Downy Woodpecker	44	ab*	35	1.9	16	63	a	17.1	0.9	6.0	29	a	12.2	0.6	4.0	22
Hairy Woodpecker	22	a	33	3.0	20	76	a	16.5	1.1	7.5	24	a	9.5	0.8	4.5	17
Red-bellied Woodpecker	29	c	47	5.0	23	137	a	18.2	1.1	8.0	29	a	13.2	0.6	6.0	20
Red-headed Woodpecker	20	c	54	7.0	28	168	a	18.6	1.2	6.5	27	a	11.8	0.7	6.3	21
Yellow-bellied Sapsucker	42	a	30	0.8	19	42	a	19.5	0.6	8.0	34	a	7.9	0.4	4.0	13
Pileated Woodpecker	4	be	69	23.1	42	127	a	21.1	5.0	9.0	29	a	7.0	1.1	5.0	9
Northern Flicker	4	be	69	21.8	38	121	a	17.8	2.6	14.0	23	a	10.4	3.3	2.5	15
All woodpeckers	165		39	1.7	16	168		18.1	0.4	6	34		10.7	0.3	2.5	22

*Means preceded by the same letter are not significantly different (Dunn (1964) multiple comparison procedure based on ranks)

Table 6. Significant differences (chi-square) among nest tree characteristics of five species of woodpecker in oak forests of the Driftless Area, 1997-98.

	Percentage of nests							
	Tree species quaking aspen	Heartwood fungus present	Sapwood fungus present	Significant dead portion present	Livewood 75-100%	Bark cover 75-100%	Tree alive	Top intact
Downy Woodpecker	11 a*	16 a	32 a	95 a	18 a	52 a	16 a	48 a
Red-bellied Woodpecker	11 a	24 ac	28 ab	100 a	31 a	66 a	24 a	24 a
Red-headed Woodpecker	27 a	10 ac	5 ab	90 ab	10 a	30 a	10 a	50 a
Hairy Woodpecker	17 a	45 c	14 ab	64 b	41 a	64 a	36 a	55 a
Yellow-bellied Sapsucker	88 b	95 b	2 b	14 c	88 b	95 b	88 b	98 b

*Percentages followed by the same letter are not significantly different (Brunden (1972) multiple comparison procedure)

Table 7. Percentages of nest holes with a given characteristic for seven species of woodpecker in oak forests of the Driftless Area, 1997-98.

	DOWO	HAWO	RBWO	RHWO	YBSA	PIWO	NOFL	ALL
Sample Size	44	22	29	20	42	4	5	166
Decay Indicators within 1 m of Nest Hole								
Branch Stubs	84	71	97	90	90	75	60	86
Heartwood Fungus	2	38	17	5	83	25	0	31
Tree Scars	9	14	10	10	17	0	50	13
Old Cavities	32	32	38	35	33	50	20	34
Nest Hole Position Relative to Canopy								
Above	2	5	14	10	0	0	0	5
Within	79	64	83	80	38	0	80	64
Below	24	32	3	10	62	100	20	31
% Bark within 1 m of Nest Hole								
0-25	36	14	14	50	5	25	25	22
25-50	5	14	14	10	0	25	50	8
50-75	7	5	14	5	0	25	25	7
75-100	52	68	59	35	95	25	25	63
Substrate Status								
Live	2	32	0	5	88	25	20	29
Dead	98	68	100	95	12	75	80	71
Substrate Top Condition								
Intact	30	55	10	25	93	25	40	45
Broken Top	64	36	83	70	7	50	40	49
Broken Fork	7	9	7	5	0	25	20	6
Substrate Limb Type								
Trunk	66	73	66	50	98	100	80	74
Main Branches	30	27	31	40	2	0	20	23
Secondary Branches	5	0	3	10	0	0	0	3
# of Decay Indicators within 1 m of Nest Hole								
0	5	14	3	5	0	25	20	5
1	64	32	45	55	5	0	40	38
2	32	45	45	35	67	75	40	46
3+	0	9	7	5	29	0	0	10

Table 8. Significant differences (chi-square) found among the nest holes of five species of woodpecker in oak forests of the Driftless Area, 1997-98.

	Heartwood fungus within 1 m of nest hole	Nest hole placed below canopy	Bark cover within 1 m of nest hole 75. 100%	Nest hole substrate alive	Nest hole substrate top intact	3+ decay indicators within 1 m of nest hole
Downy Woodpecker	2 a*	24 a	52 a	2 a	30 ac	0 a
Red-bellied Woodpecker	17 ab	3 a	59 a	0 a	10 ac	7 a
Red-headed Woodpecker	5 ab	10 a	35 a	5 ab	25 ac	5 a
Hairy Woodpecker	38 b	32 ab	68 ab	32 b	55 c	9 a
Yellow-bellied Sapsucker	83 c	62 b	95 b	88 c	93 b	29 b

*Percentages followed by the same letter are not significantly different (p>0.0025 by Brunden (1972) multiple comparison procedure)

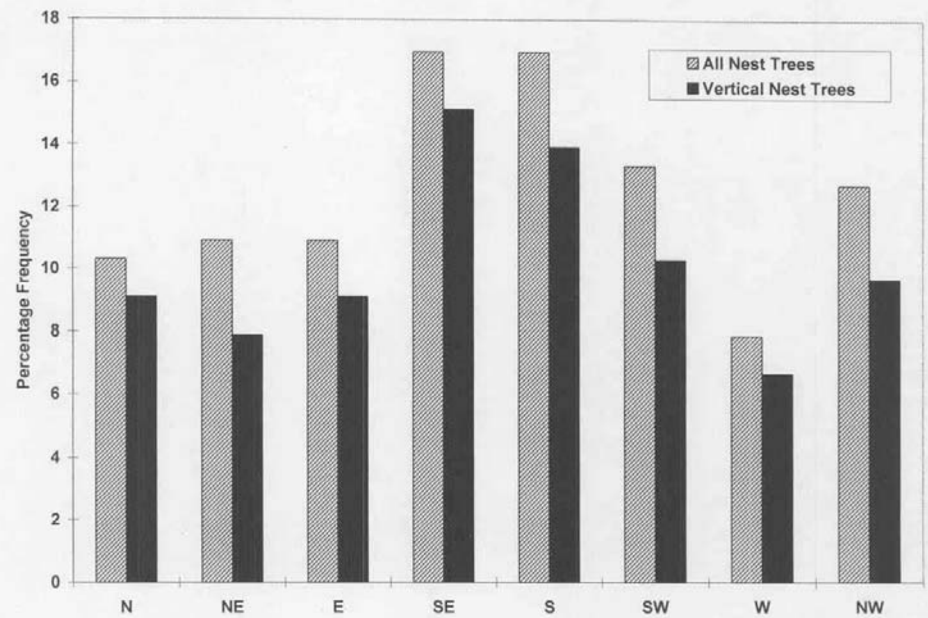

Figure 3. Percentage of nest holes by orientation for seven species of woodpeckers in oak forests of the Driftless Area, 1997-98.

DISCUSSION

Tree Size

Many investigators have found woodpecker nest trees to be larger than unused snags (Zarnowitz & Manuwal 1985, Shreiber & deCalesta 1992, Welsch & Howard, Jr. 1983, Bull & Meslow 1977). By comparing nest trees to unused trees that met minimum size requirements, rather than to random unused trees, I established a more rigorous comparison.

Nevertheless, I found that woodpeckers chose trees that were larger in diameter than adjacent potential nest trees. There are many possible advantages to nesting in larger trees. To begin, larger trees may have more places to excavate. They are likely to be older and therefore more decayed. Finally, larger trees allow for thicker walls, which provide thermal insulation, protection from predators, and lower probability of breaking at cavity height (Miller & Miller 1980, Kilham 1971).

If trees are too small in diameter, overcrowding may reduce the number of young to fledge (Kilham 1968, Conner 1979, Evans & Conner 1979, Miller & Miller 1980). The range of tree diameters used by Downy and Hairy woodpeckers and Yellow-bellied Sapsuckers in my study are comparable to those ranges found in the literature (Thomas et al. 1979, Conner et al.

1975, Evan & Conner 1979). However, in my study, 55% of trees used by Red-bellied Woodpeckers and 20% of trees used by Red-headed Woodpeckers were below the optimum range of nest tree diameters given for these species (Evans & Conner 1979). Selection may be different for these species in my study area or my sample may not be representative. However, it could also mean that there is a shortage in the study area of larger diameter trees required by the Red-bellied and Red-headed woodpeckers.

Generally, woodpeckers with larger body sizes require larger diameter nest trees (Conner et al. 1975). In accordance with the findings of other investigators (Conner et al. 1975, Brawn et al. 1984, Li & Martin 1991, Raphael & White 1984), I found a significant difference among woodpecker species in nest tree diameter.

Woodpeckers chose nest trees that were taller than adjacent potential nest trees. When taller trees are available, nest heights tend to be higher (Miller & Miller 1980). Miller and Miller (1980) argued that taller nest heights make nest cavities less easily detected and reached by predators. A nest located high in the tree gives the woodpecker more time to dislodge or discourage a predator climbing the trunk (Kilham 1971). Other investigators have also found that woodpeckers chose taller trees (Sedgewick & Knopf 1990, Welsch & Howard, Jr. 1983, Zarnowitz & Manuwal 1985).

There were no significant differences among woodpecker species in nest tree height or nest hole height in my study. However, other researchers have found differences in nest tree height or nest hole height (Conner et al. 1975, Brawn et al. 1984, Raphael & White 1984, Stauffer & Best 1982). Harestad and Keisker (1989) explained difference in nest tree height among woodpeckers as a consequence of different preferences for snag condition. They argued that dead snags had broken tops more often, resulting in an association with shorter trees for those woodpecker species that preferred dead trees. Indeed, in this study, the mean nest tree height of the Yellow-bellied Sapsucker, which mostly used living trees, was slightly higher than that of the Downy, Hairy, Red-bellied, and Red-headed woodpeckers, which mostly used dead trees. It is reasonable that I did not detect a difference in nest hole height, because I did not detect a difference in nest tree height among species. Other investigators have found that differences in nest hole height were not significant after the effects of tree height were removed (Raphael & White 1984, Stauffer & Best 1982).

Tree Condition

Trees used by woodpeckers had several indicators of heartwood decay. Soft heartwood is a necessity for excavation, while sound sapwood surrounds the nest and protects it from predators (Kilham 1971, Conner et al. 1976). Tree wounds provide access to the heartwood of a tree and serve as entry points for fungus. Conner (1976) and others offered the following tree characteristics as indicators of possible heartwood decay: conks of heartwood fungus, branch stubs, tree scars, old cavities, and dead portions. I found that trees with extensive sapwood decay were not used for nesting, as these trees probably did not offer adequate protection of the nest cavity. The number of decay indicators present depended in part on the tree species. Tree species with especially hard wood, like oaks and cherries, required more decay for the wood to become suitably softened for excavation.

Woodpeckers often chose trees with old cavities. Old cavities are clear indicators of past suitability and also serve as entry points for additional heartwood fungus. One active Yellow-bellied Sapsucker nest tree contained 16 old cavities.

Woodpecker species vary in their excavation abilities (Spring 1965). These differences in ability lead to differences in condition of snags chosen for nesting. Downy Woodpeckers are weak excavators, and they often chose trees with some sapwood fungus (Harestad & Keisker 1989, this study). Presence of sapwood fungus indicates that the outer wood is soft, making the wood easier to excavate. Yellow-bellied Sapsuckers most often nested in living trees with sound sapwood and with several indicators of heartwood decay. *Fomes igniarius is* a heartwood fungus that attacks live wood, especially of trembling aspen, softening the heartwood but leaving the sapwood sound (Harestad & Keisker 1989). Nearly all Yellow-bellied Sapsucker nest trees had conks of *Fomes* igniarius present.

Tree Species

American elms and trembling aspens were extensively used for nesting. It is interesting that there was a complete avoidance of slippery elm for nesting, even though there were more dead slippery elms available than American elms. This suggests that American elm has decay characteristics that suit woodpeckers. Accounts of nest tree species used by woodpeckers in the Upper Midwest are minimal (Reller 1972). Swallow (1986) and others found that the probability of elm snags having cavities was high in hardwood forests of central New York.

The propensity for Yellow-bellied Sapsuckers to nest in aspens has been well documented (Kilham 1971, Runde & Capen 1987, Thomas et al. 1979, Harestad & Keisker 1989). Yellow-bellied Sapsuckers are weak excavators (Jackman 1974), so the extensive decay characteristics of mature aspen are suitable.

Red-headed woodpeckers mostly nested in American elms, especially large, barkless elms with many broken branches. Dutch elm disease may have benefited Redheaded woodpeckers by creating highly suitable snags; however the disease eliminated American elm as a major forest species. In the future, Red-headed and other woodpeckers will not have as many dead elms for nesting. Elms that died from Dutch elm disease are losing suitability for nesting as tree decay becomes extensive. Additional dead elms are lost from blow down and human removal. Red-headed woodpeckers will need to rely more heavily on other tree species for nesting or face continued decline. According to Breeding Bird Survey data, abundance of Red-headed woodpeckers in Minnesota has been significantly declining since 1966 (Green 1995).

The Downy, Hairy, and Red-bellied woodpeckers showed more variation in the tree species chosen. Because tree species selected for nesting vary by the locality, availability, and tree condition (Bull et al. 1980), one should be cautious before applying these tree species results to other areas.

Entrance Orientation

There are many probable explanations for non-random orientation of woodpecker nest hole entrances. Holes may be oriented to maximize sun exposure, easing incubation duties (Reller 1972, Lawrence 1966, Dennis 1969, Baker 1971, Inouye 1974). The tendency for nests to be oriented in a certain direction might result from nest tree lean due to phototrophic influences (Conner 1975). Nests on the underside of a lean may receive some protection from rain entering the cavity. They may be easier to defend because climbing predators would be at a relative disadvantage (Kilham 1971). The underside of a lean is a moister environment, which may promote fungal growth, softening the wood and making it more suitable for excavation (Dennis 1969). Nest holes may point away from prevailing winds to offer protection from cold air (Conner 1975), while some investigators believe nest entrances may orient toward the wind to provide ventilation (Reller 1972).

In my study, when the nest tree leaned, the nest hole was placed on the underside of the lean in all but one case. However, the propensity to orient south or southeast remained significant even after excluding trees with a lean. Sun exposure is probably an important factor contributing to the non-random hole orientation. Indeed, the Hairy Woodpecker, which began nesting earliest in the spring, had a southerly orientation most frequently. Avoidance of prevailing westerly winds may explain why fewer nests faced southwest than southeast.

MANAGEMENT IMPLICATIONS

It is important that suitable cavity trees are left during timber harvest. The value of such trees extends beyond their importance to woodpeckers. In oak forests of the Driftless Area, secondary cavity-nesting birds like the Great-Crested Flycatcher *(Myiarchus crinitus),* Tufted Titmouse *(Parus bicolor),* House Wren *(Troglodytes aedon),* White-breasted Nuthatch *(Sitta carolinensis),* and Barred Owl *(Strix varia)* all use old woodpecker holes for nesting. Studies have shown that lack of suitable nest sites is a limiting factor for many species of cavity-nesting birds (Dobkin et al. 1995, Zarnowitz and Manuwal 1985, Cunningham et al. 1980).

The Minnesota Forest Resources Council recently released voluntary site-level management guidelines for Minnesota forests. They recommended retaining all snags during harvest. For living trees, the guidebook contained prescriptions for the number of trees by size class that should be left during harvest. It also contained some recommendation on the condition and species of leave trees (Minnesota Forest Resources Council 1999).

My study did not address the number of trees that should be left during harvest, however it offers insight into the characteristics of trees used for nesting. The Forest Resources Council guidelines emphasized retaining living trees as well as snags, and my study confirmed this need. The guidelines suggested that living trees that are left should have a range of conditions including some with heartwood decay, as well as larger and smaller healthy trees. While woodpeckers did not nest in trees without some decay in my study, retention of some healthy trees on long rotation will provide future snags. However, emphasis should be placed on retaining trees with sound sapwood that also show signs of heartwood decay, such as broken tops. I found that trees with old woodpecker nest cavities are especially important for nesting, so trees with old cavities should be retained.

The Minnesota Forest Resources Council guidelines suggested that 50% of all leave trees be >30 cm DBH, with 1-2 trees >45 cm DBH per clump or per acre. Considering the diameters of trees used for nesting in this study, this recommendation seems adequate. It is important that diameters near the mean for each species are provided to encourage excavation of normal-sized cavities and reduce death of nestlings due to overcrowding. The guidelines did not address height of trees retained, probably because they recommended leaving all snags. Tree height is more important when choosing among snags than among living trees. If choices need to be made about which snags to retain, the larger diameter and taller snags should be retained.

The Minnesota Forest Resources Council guidelines listed different tree species as excellent, good, or fair to retain based on longevity, windfirmness, and cavity potential. Elms were listed as one of the excellent leave tree species. My study confirmed that the American elm is an excellent leave tree, but slippery elm has very limited cavity potential and should not be considered a replacement for American elm. Aspens were very important cavity trees in my study but were only listed as good leave trees in the guidelines. Aspens are not ideal in terms of longevity or windfirmness. Aspen trees usually fall about five years after death (Hunter 1990). However, unlike other tree species, trembling aspen trees were highly utilized as living trees. Limited windfirmness can be countered in part by retaining clumps of aspen rather than scattered trees. However, undue emphasis should not be placed on importance of tree species. Woodpeckers are not obligate on certain tree species for nesting. However, woodpeckers do require certain levels of decay, which vary by tree species.

Living trees left for cavity-dwelling wildlife during harvest need to be maintained on long rotations to develop suitable decay characteristics for nesting. Old growth conditions may take > 100 years to develop in both oak-hickory forests and aspen forests (Hardin & Evans 1977, Wintemitz & Cahn 1983). Harvesting reserve clumps before they have matured will severely limit their wildlife value.

The proliferation of forest management research and guidelines across the United States demonstrates a commitment to meeting needs of multiple forest users. More research is needed on longevity of reserve trees and long-term impacts of existing forest management practices on wildlife. However, by following recommendations made in this study and made by the Minnesota Forest Resources Council, timber harvesters should be able to enhance conditions for cavity-dwelling wildlife.

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CHAPTER 2. INFLUENCE OF SURROUNDING VEGETATION ON WOODPECKER NEST TREE SELECTION IN OAK FORESTS OF THE DRIFTLESS AREA IN THE UPPER MIDWEST

ABSTRACT

The purpose of this study was to obtain information on the habitat surrounding woodpecker nest trees in oak forests of the Driftless Area to determine if surrounding vegetation influences nest tree selection. The influence of surrounding vegetation has ramifications for the distribution of leave trees for cavity-nesting birds. It can also dictate whether management should be focused on nest trees or on broader habitat requirements. I designed the study to determine 1) if vegetation surrounding woodpecker nest trees differs from random sites and 2) if vegetation surrounding nest trees differs among woodpecker species. I surveyed vegetation in 11.3 m radius circles centered on 165 active woodpecker nest trees in oak forests of southeastern Minnesota and western Wisconsin. I recorded species, status, and size class of all trees within the circular plot. I also recorded presence and condition of potential nest trees. Additional vegetation measurements included tree canopy height, tree canopy cover, shrub cover, downed wood cover, and plot slope. I also took these same measurements in 144 randomly selected circular plots. Using Bonferronized F-tests, I found many significant differences between nest sites and random sites. Forward stepwise sequential F-tests indicated that the number of potential nest trees and the basal area of dead elms were the most important variables in distinguishing nest sites and random sites. Discriminant function analysis correctly classified 71% of the observations. However, when I compared nest sites only to those random sites containing a tree likely suitable for nesting, I found no differences. This suggests that the nest tree had a greater influence in nest site selection than did the surrounding vegetation. Yellow-bellied Sapsucker nest trees were surrounded by a significantly higher basal area of trembling aspen (Populus *tremuloides)* and density of mast-producing trees than the nest trees of the Downy, Hairy, Red-bellied, Red-headed, and Pileated woodpeckers, and the Northern Flicker. However, I found no interspecific differences among Downy, Hairy, Red-bellied, and Red-headed woodpeckers. My study is significant because it indicates forest management for cavity-nesting birds focused on providing suitable nest trees may be more important than management focused on broader habitat requirements.

INTRODUCTION

As primary cavity-nesting birds, woodpeckers excavate holes in trees for nesting and roosting. Secondary cavity-nesting birds later use these holes. In Minnesota, 23 species of birds use old woodpecker nest holes for nesting (Green 1995). In addition, mammals such as squirrels and bats use tree cavities as dens or cover.

Woodpecker excavation of nest holes requires that trees contain some heartwood decay (Kilham 1971, Conner et al. 1976). Consequently, most woodpeckers are dependent on dead and dying trees. Many studies have shown a relationship between snag density and abundance of cavity-nesting birds (Raphael & White 1984, Dickson & Conner 1983, Scott & Oldemeyer 1983, Stribling et al. 1990, Zarnowitz 1983).

Intensive management of forests for timber may detrimentally impact populations of cavity-nesting birds. For example, Scott and Oldemeyer (1983) found that densities of cavity-nesting birds decreased by 53% when conifer snags were removed during harvest of ponderosa pine *(Pinus ponderosa)* forests in Arizona. In an unharvested control plot, they found densities of cavity-nesting birds increased by 32%. Careful management for wildlife during harvest can reduce the impact on cavity-nesting birds. On an adjacent plot where snags were left standing during timber harvest, the same investigators found that densities of cavity-nesting birds increased by 25%.

Federal laws, such as the Multiple Use Act of 1960 and the National Forest Management Act of 1976, require that national forests be managed for multiple uses, including timber and wildlife. Many states have also enacted laws and policies regarding management of state forests. The Minnesota Legislature passed the Sustainable Forest Act of 1995 calling for the creation of a Forest Resources Council to oversee conservation and management of Minnesota forests. Several technical teams developed guidelines for harvesting timber that will favor wildlife. Guidelines that serve to coordinate timber harvest and wildlife conservation will be most effective if they are based on solid knowledge of wildlife habitat requirements.

While there have been numerous studies on the characteristics of woodpecker nest trees (for a few examples see McClelland & Frissell 1975, Scott 1978, Welsch & Howard, Jr. 1983, Runde & Capen 1987), research on the habitat surrounding woodpecker nest trees is not as extensive (Conner et al. 1975, Conner & Adkisson 1976, Conner & Adkisson 1977, Raphael & White 1984, Brawn et al. 1984, Petit et al. 1985, Swallow et al. 1986, Li & Martin 1991). Several of these investigations were done in oak-hickory forests (Conner et al. 1975, Conner & Adkisson 1976, Conner & Adkisson 1977, Brawn et al. 1984, Petit et al. 1985).

Minimal research concerning the habitat of cavity-nesting birds in Minnesota has been done. Niemi and Hanowski (1984) studied relationships of birds to habitat characteristics in logged areas of northern Minnesota. They found little evidence to support any relationship between number of dead trees and abundance of most species of cavity-nesting birds. Howe (1995) and others found that 6 out of 9 species that showed no significant relationships with overall forest characteristics were cavity-nesting birds. They speculated that overall forest characteristics were less important to species with specific nest tree requirements. However, Schulte and Niemi (1998) found that the House Wren *(Troglodytes aedon)* and Eastern Bluebird *(Sialia sialis)* were associated with higher densities of dead trees and more variation in dead trees in early-successional forests of northern Minnesota. There has been no previous research specifically targeting the characteristics of vegetation surrounding active nests of cavity-nesting birds in Minnesota.

Without knowledge of the specific habitat requirements of cavity-nesting birds, development of timber management guidelines to favor these species can be difficult. The Minnesota Forest Resources Council (1999) recently released voluntary site-level forest management guidelines. These guidelines addressed the number of trees of different size classes that timber harvesters should reserve for cavity-nesting birds during harvest. The guidelines did not suggest whether trees left during harvest should be distributed in clumps or scattered across the harvest area. In addition, it is unclear whether one set of guidelines can address the needs of all the woodpecker species in Minnesota. If habitat requirements vary widely among species, guidelines may need to address each species individually.

The purpose of this study was to obtain information on the habitat surrounding woodpecker nest trees in oak forests of the Driftless Area to determine if surrounding vegetation influences nest site selection. The influence of surrounding vegetation has ramifications for the distribution of leave trees for cavity-nesting birds. It can also dictate whether management should be focused on nest trees or on broader habitat requirements. To address the question of whether guidelines must target individual species, I also examined if characteristics of surrounding vegetation differed among woodpecker species.

I located active woodpecker nests and surveyed vegetation of nest sites and random sites. I tested the following null hypotheses:

1) There is no difference in habitat selection between woodpecker nest sites and random sites.

2) There is no difference in habitat selection between woodpecker nest sites and random sites that include a tree likely suitable for nesting.

3) There is no difference in habitat selection among woodpecker species.

I designed this study to compare nest sites to random forest sites to determine if woodpeckers choose among habitats when selecting nest sites. However, in this comparison, I could not separate the influence of the nest tree from the influence of surrounding vegetation. To minimize the influence of the nest tree, I also compared nest sites to random sites containing a tree suitable for nesting.

STUDY AREA AND METHODS

Study Area

The study area was Houston and Filmore counties of southeastern Minnesota and LaCrosse County of western Wisconsin (Figure 4). This area is included in Bailey's (1994) North Central U.S. Driftless and Escarpment Section (222L) of the Eastern Broadleaf Forest (Continental) Province. This region is more simply referred to as the Driftless Area. This area was uncovered by the Wisconsin Glaciation, which retreated 10,000 to 12,000 years ago (Tester 1995). A surface layer of loess that covers the till and bedrock characterizes much of the upland area. The deposits are deeply eroded, forming hills and valleys. The pre-settlement vegetation was oak woodland and brushland and maple-basswood forest, according U.S. General Land office survey notes as compiled by Marschner (1974). Now the land is highly fragmented, consisting primarily of patches of oak forest surrounded by agricultural lands. I selected plots from available state-owned forests on the basis of accessibility and intensity of public use. Because I did not randomly choose the plots, the forest characteristics may not be representative of the Driftless Area. I chose plots in the Richard J. Dorer Memorial State Hardwood Forest, Forestville State Park, and Coulee State Experimental Forest. I had a total of 12 plots; 8 plots used each year.

In 1997, I used Forestville, Underbakky, Bonnieville, Brightsdale, Sand Barrens, Money Creek, Quarry, and Oak Ridge. In 1998, I used the four easternmost study plots again (Sand Barrens, Money Creek, Quarry, and Oak Ridge), but also included Reno, Hamel, Coulee North, and Coulee South (see Appendix A for topographic maps of the study areas and location descriptions based on U.S. Public-Land Survey System).

The study area has a varied history including logging, grazing, and fire. None of the plots was logged in the last ten years; however, firewood cutting was allowed at Underbakky. Only the Quarry plot, which included some private land, was grazed in the last 10 years. Some plots were within forest fragments as small as 40 ha, while others were within more extensive forest tracts.

The plot canopies were dominated by oaks *(Quercus rubra, Q. alba, Q. bicolor)* and hickories *(Carya ovata, C. cordiformis),* but also included elms *(Ulmus americana, U. rubra),* basswood *(Tilia americana),* aspen *(Populus tremuloides, P. grandidentata),* other hardwoods, and some white pine *(Pinus strobus).* Young plants of these canopy trees, hazel *(Corylus* spp.), gooseberry *(Ribes* spp.), and raspberry *(Rubus spp.)* made up the woody understory. The study area is classified as oak forest, according to the Minnesota Department of Natural Resources County Biological Survey. All plots were in mature forest, aging from 80 to 120 years, with a component of dead and dying trees. Breeding bird surveys indicated that the plots had 56 bird species, including 13 cavitynesting species (Friberg, per. comm.).

The plots ranged from 28 to 40 ha in size (mean = 36 ha). I marked the plots with flagging tape, forming a grid spaced at 50 m or 100 m intervals. I used the grids to plot locations of woodpecker activity on field maps, to mark nest locations, and to specify locations for the randomly selected sites.

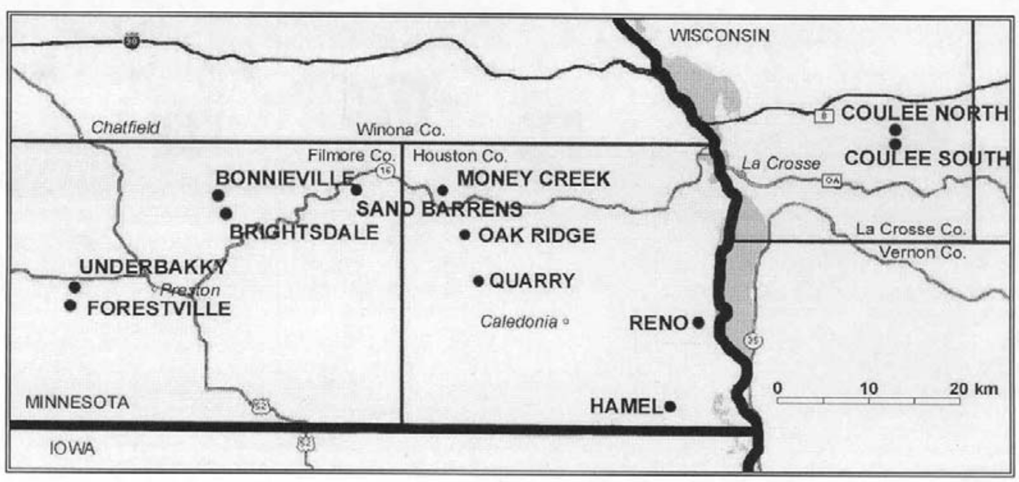

Figure 4. Houston and Filmore counties of Minnesota and La Crosse County of Wisconsin with the locations of the 12 study plots indicated.

Nest Searching

In 1997, I began nest searching 6 May and ended 23 June. In 1998, warm El Nino weather brought an early spring so I began nest searching April 20 and ended June 22. After formal nest searching ended, I serendipitously found some additional nests during vegetation surveys. There was little attempt to equalize nest searching effort among the plots, because the goal was to find as many nests as possible. I included nests found outside plots as long as they were within the study area.

I searched for active nests of all primary cavity-nesting birds on the plots, excluding the Black-capped Chickadee. The primary cavity-nesting birds included Downy, Hairy, Red-bellied, Red-headed, and Pileated woodpeckers, Yellow-bellied Sapsuckers, and Northern Flickers (for scientific names see Table 10).

I found nests by following woodpecker vocalizations, drumming, and flight paths. By systematically walking the plots and examining trees with indications of possible use such as cavities and fresh chips at the base, I found additional nests. I found nests of the Red-headed Woodpecker along roadsides, as well as on the plots (for details of the nest searching methods see Appendix B).

I confirmed nests as active if I observed any of the following: 1) adult completely entering nest hole and remaining in cavity for over 10 minutes; 2) adult flushed from nest hole; 3) adult feeding young; and 4) young calling from cavity. Because of difficulty locating Red-headed Woodpecker nests, adult repeatedly entering the nest cavity but not remaining inside was considered sufficient evidence of activity.

Vegetation Surveys

I surveyed vegetation of woodpecker nest sites and random sites during the summers of 1997 and 1998 (see Appendix C for copies of data forms). The vegetation surveys of random sites began after formal nest searching ended, while surveys of nest sites began shortly after the nestlings fledged. I completed these surveys within one month to minimize the impact of changing forest conditions with time. I modified the survey methods after Martin and Conway (1994). A description of the equipment and methods used for each vegetation measurement is provided in Table 9. Habitat as defined in this study concerns only the conditions immediately surrounding the nest trees (11.3 m radius).

I centered nest sites on every active woodpecker nest I found. I located random sites 15 m from randomly selected grid-points in randomly selected azimuths. I surveyed 9 sites on the 8 study plots during each field season, giving a total of 144 random sites. This resulted in a survey of approximately one percent of the total study area. I used these random sites for statistical comparison to nest sites on the plots.

I measured vegetation in 11.3 m radius circles (0.04 ha). Within these circular plots, I collected data to describe the canopy, the forest floor, and the trees. To characterize the canopy, I recorded canopy height, total canopy cover, and high canopy cover. To describe the forest floor, I recorded plot slope, shrub cover, and downed wood cover. Cover of shrubs and downed wood, along with canopy cover, were recorded four times for each circular plot, one in each of the principle directions, 5 m from the nest tree. To obtain data on the density and basal area of various tree species, I recorded the size, status, and species of all trees within the sites. I described in detail potential nest trees within each circular plot, as these trees are likely important to woodpeckers for nesting and foraging. Potential nest trees were defined as trees unused for nesting, within the height and diameter requirements of cavity-nesting birds, with at least two indicators of heartwood decay (Conner 1978). In accordance with minimum nest height and tree diameter requirements for woodpeckers, potential nest trees were >15.2 cm DBH and >1.8 m tall (Thomas et al. 1979). To describe potential nest tree size, I recorded tree height and diameter at breast height (DBH). To describe the tree condition, I recorded tree status, top condition, limb condition, percentage live wood and percentage bark cover in quartile classes, and presence of decay indicators including old cavities, tree scars, branch stubs, fungal conks, and significant dead portions. I also recorded the tree species.

I defined a portion of the random sites as suitable sites. Suitable sites were random sites that contained a tree suitable for nesting. Trees suitable for nesting were defined as elm or trembling aspen trees with more than two decay indicators or potential nest trees with old cavities. I used these tree characteristics as defining criteria because they accounted for a significant difference found between active woodpecker nest trees and adjacent unused potential nest trees in this study area (see Chapter 1). Twenty-three random sites contained at least one suitable tree and were used for comparison to nest sites on the plots.

Table 9. Descriptions of vegetation measurements taken in woodpecker nest sites and unused sites in oak forests of the Driftless Area, 1997-98.

Variable	Equipment	Description
Size class of trees	Biltmore stick	Classified all trees >2 m tall into 8 DBH classes as defined by James & Shugart 1970 .
Status of trees	None	Partly dead tree: forks with one fork dead or a mostly dead with a few small remaining living branches. Dead: must be completely dead to be considered dead. Alive: may have significant dead portions.
High canopy cover	Densiometer	Cover of all foliage >5 m high, excluded low sub-canopies (Martin & Conway 1994).
Total canopy cover	Densiometer	Cover of all foliage >1.5 m high Martin & Conway 1994).
Tree canopy height	Clinometer	Measured average height of top of canopy (Martin & Conway 1994 .
Plot slope	Clinometer	Average slope of land across subplot.
Shrub cover	1 m^2 PVC frame	Cover in classes of all woody plants <1.5 m tall, excluding Parthenocissus *spp.* and *Rhus radicans.* Classes defined according to Kuchler 1967. Four 1 m2 samples taken.
Downed wood cover	1 m^2 PVC frame	Cover in classes of all downed wood >5 cm diameter, excluding wood completely covered in moss or litter. Classes defined according to Kuchler (1967). Four 1 m2 samples taken.

Data Analysis

I did four separate statistical analyses. First, I compared nest sites to random sites.. Second, to minimize the influence of the nest tree, I compared nest sites to suitable sites. I used both comparisons to evaluate influence of surrounding vegetation in woodpecker nest tree selection. The third and fourth analyses were done to determine if any similarities or differences in habitat existed among woodpecker species.

Wilks' lambda test was used to test for multivariate differences between groups (Johnson & Wichern 1992). Wilks' lambda corresponds to the equivalent form of the Ftest of Ho: no treatment effects in the univariate case. The model used in the MANOVA included blocks on plot and year. If a significant difference among groups was found using Wilks' lambda (a=0.05), Bonferronized univariate F-tests were used to see which variables accounted for the differences (Kuehl 1994). I used forward stepwise sequential F-tests (Bingham, pers. comm.) to select variables for discriminant function analysis. I started by selecting the variable with the most significant univariate F, then I included the variable with the largest univariate F when the first variable was used as a covariate. The selection process continued until no variable had a high enough sequential F to be included (a.=0.15). I used Bonferronized F-statistics at each stage, using the number of "out" variables as the number of tests. The discriminant function analysis combined the selected habitat variables into the one function that most effectively separated the groups. I used the discriminant function to classify the observations (Johnson & Wichern 1992). The number of observations correctly classified indicated the strength of the separation.

To determine if any similarities or differences in habitat existed among woodpecker species, I did two analyses. Upon initial examination of the habitat data, it was clear that the habitat of the Yellow-bellied Sapsucker differed greatly from the habitat of other species of woodpeckers. While a multivariate comparison among all woodpecker species at once may seem logical, this approach would fail to detect subtle differences in habitat among the Downy, Hairy, Red-bellied, and Red-headed woodpeckers. This is because the large difference in habitat between the Yellow-bellied Sapsucker and the other woodpeckers would mask the finer differences among the other woodpecker species. Consequently, I separated the analysis among the woodpecker species into two separate multivariate analyses. I compared the Yellow-bellied Sapsucker to the other woodpeckers to determine which habitat variables were most important in separating the Yellow-bellied Sapsucker from the other woodpecker species. Then, I compared habitat among the Downy, Hairy, Red-bellied, and Red-headed woodpeckers to see if a multivariate technique could detect any differences in habitat. I excluded Pileated Woodpeckers and Northern Flickers from this analysis because of low sample size.

The 24 habitat variables used in the analyses included: percentage total canopy cover, percentage high canopy cover, canopy height, plot slope, genus-level richness, genus-level diversity, percentage shrub cover, percentage downed wood cover, and number and basal area of total trees, trembling aspen, dead trees, dead or partly dead trees, dead or partly dead trees >38 cm DBH, dead elms, potential nest trees, and mastproducing trees per ha. Mast-producing trees included all living oak trees *(Quercus rubra, Q. alba, Q. bicolor),* hickory trees *(Carya ovata, C cordiformis),* and black walnut *(Juglans niger). I* transformed the data as necessary to meet the assumptions of normality and equal variance (Box & Cox 1964). All computations were done using Macanova, an interactive program for statistical analysis (Oehlert & Bingham 1998).

RESULTS

I found 165 active woodpecker nest sites (Table 10).

A Comparison of Nest Sites and Random Sites

I found significant differences between nest sites and random sites when I considered all habitat variables simultaneously (Wilk's lambda=104.1, p-0.000). Ten of 24 habitat variables showed significant differences between nest sites and random sites when I considered each variable separately using F-tests (Table 11). Using a forward stepwise procedure, density of potential nest trees and the basal area of dead elms were selected for discriminant function analysis (p<0.15). The separation of the habitat based on the discriminant function was significant (F=68.6; d.f.=2,286; p~0.000). When I used the discriminant function to classify each observation as either a nest site or random site, 71 % of observations were classified correctly.

A Comparison of Nest Sites and Suitable Sites

To minimize the influence of the nest tree, I compared nest sites to random sites containing a tree suitable for nesting. I was unable to detect any differences between nest sites and suitable sites using multivariate or univariate tests (Wilk's lamdba=14.0, p=0.946). Forward stepwise variable selection did not select any variables for discriminant function analysis (p>0.15), which indicated the similarity between nest sites and suitable sites.

A Comparison of Yellow-bellied Sapsucker to the Other Woodpeckers

I combined habitat data for Downy, Hairy, Red-bellied, Red-headed, and Pileated woodpeckers, and the Northern Flicker and compared it to the habitat of the Yellowbellied Sapsucker. When I considered all the habitat variables simultaneously, I detected a strong difference in habitat (Wilk's lambda=73.2, p,0.000). When I considered each habitat variable separately using F-tests, 7 of the 24 habitat variables showed a significant difference between the two groups (Table 12). Basal area of trembling aspen and density of mast-producing trees were selected for creation of a discriminant function. The separation of habitat based on the discriminant function was also significant (F=38.9; d.f.=2,162; p-0.000). I used the discriminant function to classify each observation as either a Yellow-bellied Sapsucker nest site or a nest site of the other woodpecker species. Eighty-two percent of observations were classified correctly.

A Comparison Among the Other Woodpecker Species

To detect subtle differences in habitat among the Downy Hairy, Red-bellied, and Red-bellied woodpeckers, I simultaneously compared all habitat variables for these four species. Habitat was marginally significantly different among these woodpecker species (Wilk's lambda=93.2, p=0.047). No significant differences were found when each habitat variable was considered separately using Bonferronized F-tests. No variables had a strong enough effect in distinguishing the groups to be selected for discriminant function analysis (p>0.15).

Table 10. Mean values and standard errors for vegetation characteristics of nest sites and unused sites in oak forests of the Driftless Area, 1997-98.

	DOW0[a]		**HAWO[b]**		**RBWO[c]**		**RHWO[d]**		**PIWO[e]**		**NOFL[f]**		**YBSA[g]**		**ALL BUT YBSA[h]**		**ALL[i]**		**Random**		**Suitable**	
Sample Size	44		22		29		20		4		4		42		123		165		144		23	
	x	SE	x	SE	x	SE	x	SE	x	SE	x	SE	x	SE	x	SE	x	SE	x	SE	x	SE
Total trees/ha	583	31	584	47	601	34	514	75	786	247	231	33	743	21	571	22	614	19	613	16	721	32
Trembling aspen/ha	24	8	35	17	14	5	24	15	94	94	0	0	131	17	25	6	52	7	33	9	78	22
Dead trees/ha	103	11	93	12	84	12	123	15	106	41	62	24	110	8	99	6	102	5	73	5	111	16
Dead or partly dead (PD) trees/ha	112	12	105	12	90	12	126	15	112	47	62	24	120	9	106	6	110	5	83	5	120	16
Dead or PD >38 cm DBH/ha	16	3	18	5	21	4	32	6	19	6	19	6	8	3	21	2	18	2	10	1	11	5
Dead elms/ha	44	9	40	10	31	10	61	14	44	21	62	24	20	5	43	5	37	4	12	2	17	6
Mast-producing trees/ha	199	21	202	31	203	28	204	45	237	212	19	12	312	23	197	15	226	13	270	14	282	40
Potential Nest Trees/ha	4	0.3	4	0.4	3	0.3	5	0.5	3	1.2	3	0.9	6	0.5	4	0.2	5	0.2	3	0.2	5	0.6
Percentage total canopy cover	95	1	91	4	94	3	68	8	93	5	69	9	98	0.3	89	2	91	2	97	0.3	97	0.5
Percentage high canopy cover	94	2	90	4	93	3	67	8	92	4	65	13	96	1	87	2	89	2	95	0.3	96	0.7
Canopy height (m)	20	0.5	18	0.6	20	0.8	20	1.0	19	2.9	19	2.1	20	0.4	19	0.3	19	0.3	21	0.3	20	1.0
Plot slope (degrees)	11	1.0	12	1.6	11	1.7	7	2.0	4	2.3	8	4.4	9	1.1	10	0.7	10	0.6	13	0.6	10	1.5
Basal area (BA) of trees (m2/ha)	32	1.6	29	1.8	34	2.2	35	3.7	43	4.6	31	4.7	38	1.4	33	1.0	34	0.9	30	0.8	33	2.1
BA trembling aspen (m2/ha)	1.8	0.7	2.0	0.9	1.2	0.5	1.5	1.0	4.4	4.4	0.0	0.0	9.3	1.2	1.7	0.4	3.6	0.5	1.6	0.4	4.5	1.5
BA dead trees (m2/ha)	5.9	0.7	6.2	1.2	7.9	1.6	11.2	1.2	14.3	7.7	12.8	6.1	4.8	0.6	7.8	0.6	7.0	0.5	3.2	0.3	5.4	1.0
BA dead or PD trees (M2 /ha)	6.5	0.8	7.3	1.3	8.5	1.5	11.3	1.2	14.3	7.7	12.8	6.1	5.3	0.7	8.3	0.6	7.6	0.5	4.1	0.3	5.9	1.1
BA dead or PD >38 cm DBH	2.9	0.6	4.2	1.2	5.9	1.7	7.0	1.4	12.0	8.4	11.9	6.1	1.4	0.5	5.1	0.6	4.1	0.5	1.9	0.3	2.0	1.1
BA dead elms (m2/ha)	3.2	0.7	3.3	0.9	4.4	1.7	6.6	1.4	12.2	8.7	12.8	6.1	1.1	0.4	4.7	0.7	3.7	0.5	0.4	0.1	0.9	0.3
BA mast trees (m2/ha)	15	1.7	12	1.7	16	2.2	14	3.1	6	6.1	5	4.0	19	1.7	14	1.0	15	0.9	19	0.9	17	2.0
BA potential nest trees (m1/ha)	10	0.9	10	1.6	12	1.5	16	2.3	14	6.2	23	6.2	12	1.0	12	0.8	12	0.6	7	0.6	9	1.4
Genus-level richness	5	0.3	5	0.4	5	0.3	5	0.6	4	0.3	3	0.5	6	0.2	5	0.2	5	0.1	5	0.1	6	0.3
Genus-level diversity	1.8	0.1	2.0	0.1	2.0	0.1	1.6	0.2	1.3	0.2	1.4	0.2	2.1	0.1	1.8	0.1	1.9	0.0	2	0.0	2.0	0.1
Percentage shrub cover	25	3	27	5	31	4	14	2	18	7	22	12	27	3	24	2	25	2	27	1	31	4
Percentage downed wood	6.5	1.2	4.9	1.2	4.6	1.0	6.0	1.3	7.5	3.3	2.8	2.8	5.7	0.7	5.6	0.6	5.6	0.5	4	0.4	4.4	1.1

a Downy Woodpecker *(Picoides pubescens)*
b Hairy Woodpecker *(Picoides villosus)*
c Red-bellied Woodpecker *(Melanerpes carolinus)*
d Red-headed Woodpecker *(Melanerpes erythrocephalus)*
e Yellow-bellied Sapsucker *(Sphyrapicus varius)*
f Pileated Woodpecker *(Drycopuspileatus)*
g Northern Flicker *(Colaptes auratus)*
h Downy, Hairy, Red-bellied, Red-headed, and Pileated woodpeckers, and the Northern Flicker
i Includes nests of all woodpecker species

Table 11. Mean values, F-statistics, and Bonferronized p-values for variables that differed significantly between nest sites and random sites in oak forests of the Driftless Area, 1997-98. The percentages of points corrected classified using the discrimination function is also included.

	Nest Sites		Random Sites			
	SE	Mean	Mean	SE	F statistics	Bonfer-ronized p-values
*Potential nest trees/ha	0.2	5	3	0.2	41.9	0.000
*Basal area (BA) of dead elms (M2 /ha)	0.5	3.7	0.4	0.1	32.7	0.000
Basal area dead trees (m2/ha)	0.5	7	3	0.3	23.0	0.000
BA potential nest trees (M2 /ha)	0.6	11.8	7.3	0.6	22.2	0.000
Dead elms/ha	4.0	37	12	1.9	21.0	0.000
BA dead or partly dead trees (m2/ha)	0.5	8	4	0.3	16.6	0.001
BA trembling aspen (M2 /ha)	0.5	4	2	0.4	15.4	0.003
BA trees (M2 /ha)	1	34	30	1	9.9	0.043
Dead trees/ha	5	102	73	5	9.8	0.045
Canopy height (m)	0.3	19	21	0.3	9.7	0.048
correctly classified		64			83	

*Selected by stepwise analysis and used in classification

Table 12. Mean values, F-statistics, and Bonferronized p-values for variables that differed significantly between Yellow-bellied Sapsuckers and six other species of woodpecker in oak forests of the Driftless Area, 1997-98. The percentages of nests corrected classified using the discrimination function is also included.

	Yellow-bellied Sapsucker		Other woodpeckers			
	SE	Mean	Mean	SE	F statistics	Bonfer ronized p-values
*Basal area of trembling aspen (M2 /ha)	1.2	9	2	0.4	44.6	0.000
Trembling aspen/ha	17	131	25	6	38.9	0.000
Potential nest trees/ha	0.5	6	4	0.2	24.0	0.000
Genus-level richness	0.2	6.4	5.0	0.2	13.6	0.007
BA dead or PD >38 cm DBH (M2 /ha)	0.5	1.1	4.7	0.6	12.1	0.015
*Mast-producing trees/ha	23	312	197	15	11.9	0.017
correctly classified		74			85	

*Selected by stepwise analysis and used in classification

DISCUSSION

A Comparison of Nest Sites and Unused Sites

The vegetation of woodpecker nest sites differed from the vegetation of random sites in this study. Density of potential nest trees and basal area of dead elms were the most important variables in distinguishing between nest sites and random sites. Potential nest trees are trees within the height and diameter requirements for nesting with at least two decay indicators, which makes them likely candidates for nesting. Dead elms were also very important nest trees for excavators in this study area (Chapter 1). The importance of these variables could indicate that woodpeckers are choosing nest trees surrounded by other trees probably suitable for nesting. Li and Martin (1991) suggested that woodpeckers may choose nest trees surrounded by potential nest trees to reduce predator efficiency because the predators would be forced to search more sites. The trees surrounding the nest trees may also be important for foraging. I observed woodpeckers foraging on dead elms and other trees with decay indicators.

Other investigators have also found differences between woodpecker nest sites and random sites (Raphael & White 1974, Conner & Adkisson 1976). However, it is unclear whether the differences actually influenced nest site selection. Even though a significant difference in habitat between nest sites and random sites was found, one cannot assume that vegetation surrounding the nest tree actually influenced nest site selection. Characteristics of adjacent trees are not independent. Disease can spread among nearby trees, a strong wind may break the branches of a group of trees, or a clump of trees may grow larger because of ideal growing conditions at their location. I observed clumps of dead and dying .trees in the study area. Land (1989) and others found that snags are often found in clumps in Florida slash pine plantations. Therefore, it is difficult to separate the influence of the nest tree from the influence of surrounding trees in nest site selection.

Other investigators have compared nest sites to random sites centered on snags (Li & Martin 1991, Swallow et al. 1986, Brawn et al. 1984). In this approach, the influence of the nest tree is less than if the random plots were just representative of available habitat. However, the influence of surrounding habitat is still confounded by the influence of the nest tree. For example, the snags chosen for plot centers may be smaller on average than snags chosen for nesting and likewise be surrounded by smaller snags, giving the questionable result that the larger snags surrounding the nest trees influenced selection.

An ideal research design would compare nest sites and random sites centered on identical nest trees. Petit (1985) and others achieved this design in a study done in oakhickory forests of Ohio. They compared the habitat surrounding used and unused randomly located polystyrene snags. They found that the artificial snags selected for nesting were surrounded by lower percentage canopy cover, fewer small trees, and fewer total trees.

Within the constraints of my research design, I developed a comparison that did not confound the influence of the nest tree with the influence of surrounding vegetation. I compared nest sites to suitable sites, which were random sites that contained a tree suitable for nesting. Given that each suitable site contained an unused tree suitable for nesting, it can be concluded that any difference in habitat between nest sites and suitable sites contributed to the difference in selection. The crucial result was that no habitat variables distinguished nest sites and suitable random sites. This is important because it suggests that surrounding vegetation may have minimal influence on nest tree selection. However, differences in surrounding vegetation may exist for characteristics that I did not measure, and it is possible that selection is so variable that I did not have adequate statistical power to detect differences in surrounding vegetation. My results support the findings of Howe (1995) and others who found no significant habitat associations for the Downy, Hairy, and Pileated woodpeckers and the Northern Flicker in Nicolet National Forest in the western Great Lakes region. The investigators asserted that these cavity nesting birds select specific nest trees so overall forest characteristics may be less important.

A Comparison Among Woodpecker Species

I was also interested in whether the characteristics of habitat surrounding nest trees differed among woodpecker species. In this study, basal area of trembling aspen was an important variable in separating the habitat of the Yellow-bellied Sapsucker from all other woodpecker species combined. The habitat association between Yellow-bellied Sapsuckers and aspens has been well documented (Evan & Conner 1979, Thomas et al. 1979, Westworth & Telfer 1993). Many studies have shown that Yellow-bellied Sapsuckers often use aspen trees for nesting (Runde & Capen 1987, McClellan 1977, Kilham 1971, Scott et al. 1980, Chapter 1). Given that aspens grow in clumps, the high basal area of aspens surrounding the nest trees is likely a result of sapsuckers selecting aspens for nest trees. It is less clear why density of mast-producing trees is an important variable separating nest sites of Yellow-bellied Sapsuckers from the other woodpeckers. In my study, Yellow-bellied Sapsuckers rarely used mast-producing trees for nesting (Chapter 1).

The habitat surrounding the nest trees was quite similar for the Downy, Hairy, Red-bellied, and Red-headed woodpeckers in my study. However, other investigators have found differences in basal area, density of stems, and canopy height among Downy Woodpeckers, Hairy Woodpeckers, Pileated Woodpeckers, and Northern Flickers in oak hickory forests (Brawn et al. 1984, Conner & Adkisson 1977). Difference in basal area and canopy height could be explained by varying preference for nest tree size by woodpecker species. For example, the Pileated Woodpecker had the largest average nest tree diameter (Conner et al. 1975) and was also surrounded by the greatest average basal area and the highest crown canopy height (Conner & Adkisson 1977). This lends support to the argument that apparent woodpecker selection for vegetation surrounding the nest tree may actually be explained by selection for the nest tree.

The finding that the habitat of the Red-headed Woodpecker could not be distinguished from the habitat of the Downy, Hairy, or Red-bellied woodpeckers is unusual. The propensity for Red-headed Woodpeckers to choose nest trees in open areas is well established (Scott et al. 1977, Robbins et al. 1983). However, more than half the Red-headed Woodpecker nests in this study were found in closed canopy forests. It is possible that continued removal of snags in agricultural areas, blow-downs, and competition from European Starlings (Harrison 1975, pers. obs.) may have forced Redheaded Woodpeckers into closed canopy forests. In this study area, nesting in closed canopy forests may put Red-headed Woodpeckers in competition for nest trees with Redbellied Woodpeckers and southern flying squirrels (Glaucomys volans). Aggressive interaction between Red-headed and Red-bellied woodpeckers at the nest tree was observed. In addition, several Red-headed Woodpecker nests were taken over by southern flying squirrels during the breeding season.

MANAGEMENT IMPLICATIONS

I found a difference in habitat between nest sites and random sites, but this difference may be explained by the influence of the nest tree. Woodpeckers may be selecting for nest trees with certain characteristics independent of the surrounding vegetation, but because trees with these characteristics tend to occur in patches, it appears that surrounding vegetation influenced nest site selection. The important result of this study is that no habitat variables could distinguish between nest sites and random sites that contained a tree suitable for nesting. This suggests that management should be focused on nest trees rather than broader habitat requirements. Many investigators have argued that vegetation surrounding woodpecker nest trees influences nest site selection (Conner et al. 1975, Swallow et al. 1986, Raphael & White 1974), but none of these studies separated the influence of the nest tree from the influence of surrounding vegetation.

Whether or not surrounding vegetation actually influenced nest site selection, woodpeckers clearly chose nest trees in patches containing high densities of potential nest trees and high basal area of dead elms. While I did not design my study to address the question of whether leave trees should be scattered or clumped, the fact that nest trees were surrounded by snags suggests that clumps of snags should be left for cavity-nesting birds during harvest. However, the literature includes disagreement as to whether leave trees should be scattered or clumped.

Some investigators recommend that individual leave trees be evenly distributed across the harvest area because woodpecker territoriality limits the use within each clump (Evans & Conner 1979). Ryan (1995) found that birds used isolated snags much more than clumped snags in northern Wisconsin clearcuts. In addition, secondary cavity-nesting birds like American Kestrels *(Falco spaverius),* Eastern Bluebirds, and Tree Swallows *(Tachycineta bicolor)* respond best to tree cavities in open areas (Green 1995).

However, other investigators argue that a clumped distribution is best (McClelland 1977, Raphael & White 1984). Lawrence (1966) found no interspecific territorial behavior when woodpeckers in northern hardwoods of Ontario nested in close proximity. Raphael and White (1984) argued that clumping of reserve trees increases foraging efficiency by reducing intertree flight time. In addition, Gibbons (1994) argued that trees immediately surrounded by other living trees persist longer. Clusters of snags provide trees in close proximity for future nesting and roosting (Bull & Meslow 1977). From a timber management perspective, a clumped distribution may be a practical necessity. A clumped distribution can reduce the spread of genetically inferior trees from snags and reduce widespread retardation of growth around reserve trees (Styskel 1983). Modeling studies are needed to weigh the effects of increased snag longevity in clumps and increased woodpecker use of isolated trees.

Management for the Yellow-bellied Sapsucker is less ambiguous. Yellow-bellied Sapsuckers chose nest trees within clumps of mature aspens. Because aspens are highly susceptible to blow-downs and because Yellow-bellied Sapsuckers tolerated nesting in close proximity in this study, clumps of mature aspens should be left for the Yellowbellied Sapsucker. Aspens are popular nesting substrates for other woodpecker species as well, so clumps of mature aspen are likely to be widely used. It is important that reserve clumps of aspen are not harvested before they have matured to the point where they become suitable for woodpeckers. Old growth conditions may take > 100 years in aspen forests (Winternitz & Cahn 1983).

Habitat did not differ among Downy, Hairy, Red-bellied, or Red-headed woodpeckers. This suggests that management guidelines need not address the habitat needs of each species individually. During harvest, managers should leave clumps of dead and dying trees, especially dead elms, for these woodpeckers. In this study, the plot with the highest density of dead trees contained by far the most nests found. While more research is needed to determine the best distribution of leave trees, snags are clearly an important component of forest structure and should be retained during harvest.

Research is needed that compares woodpecker use of nest trees before and after logging of surrounding vegetation to see if a nest tree becomes unsuitable when the surrounding vegetation is altered. However, the results from this study suggest that management should focus on individual nest trees rather than broader habitat requirements.

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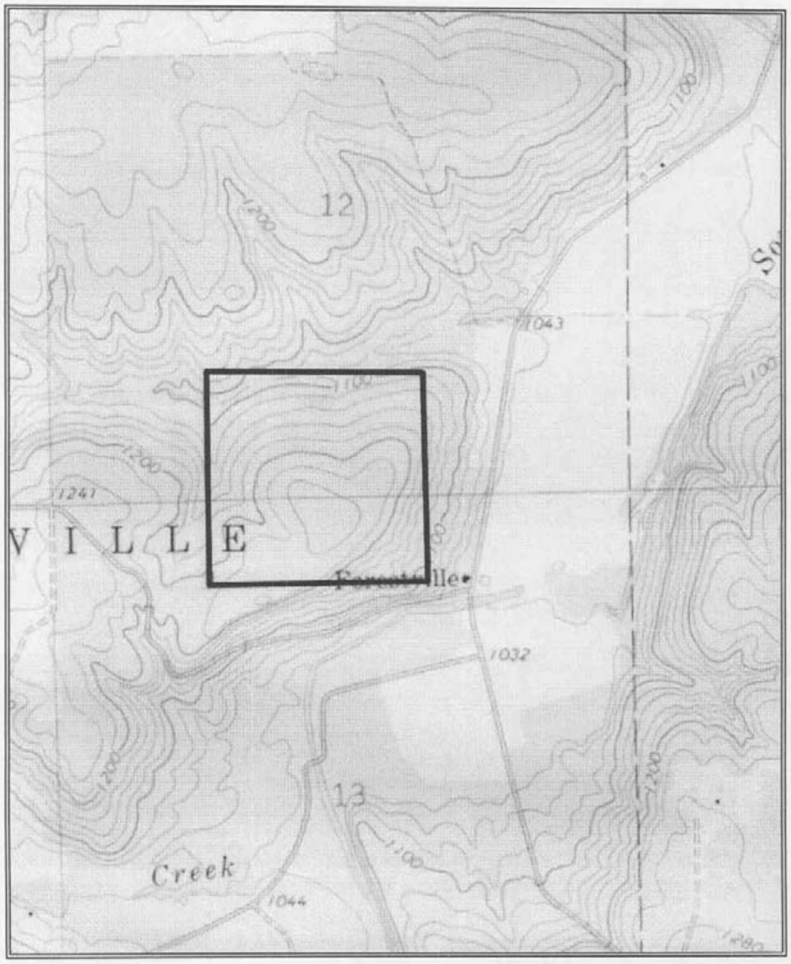
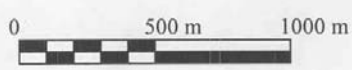
APPENDIX A. TOPOGRAPHIC PLOT MAPS

FORESTVILLE (≈ 36 ha)

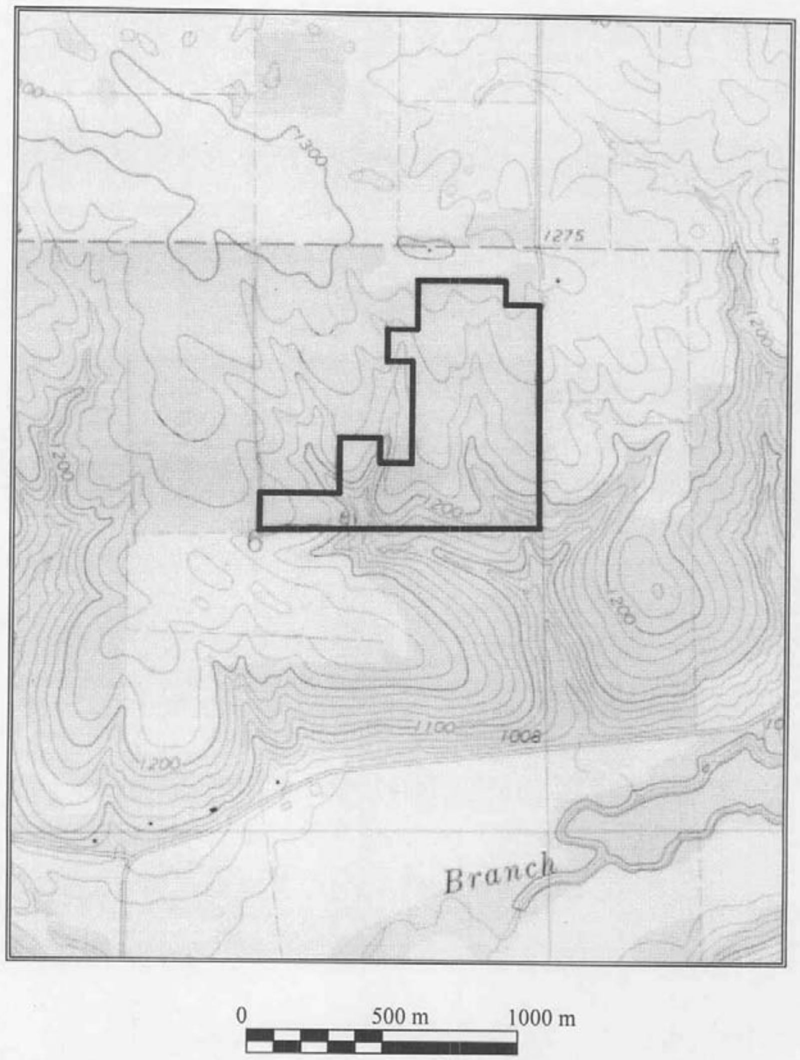




SE ¼ SW ¼ sec. 12, T. 102 N, R. 12 W, Filmore Co., Minnesota (Forestville State Park)

APPENDIX A (CONTINUED). TOPOGRAPHIC PLOT MAPS

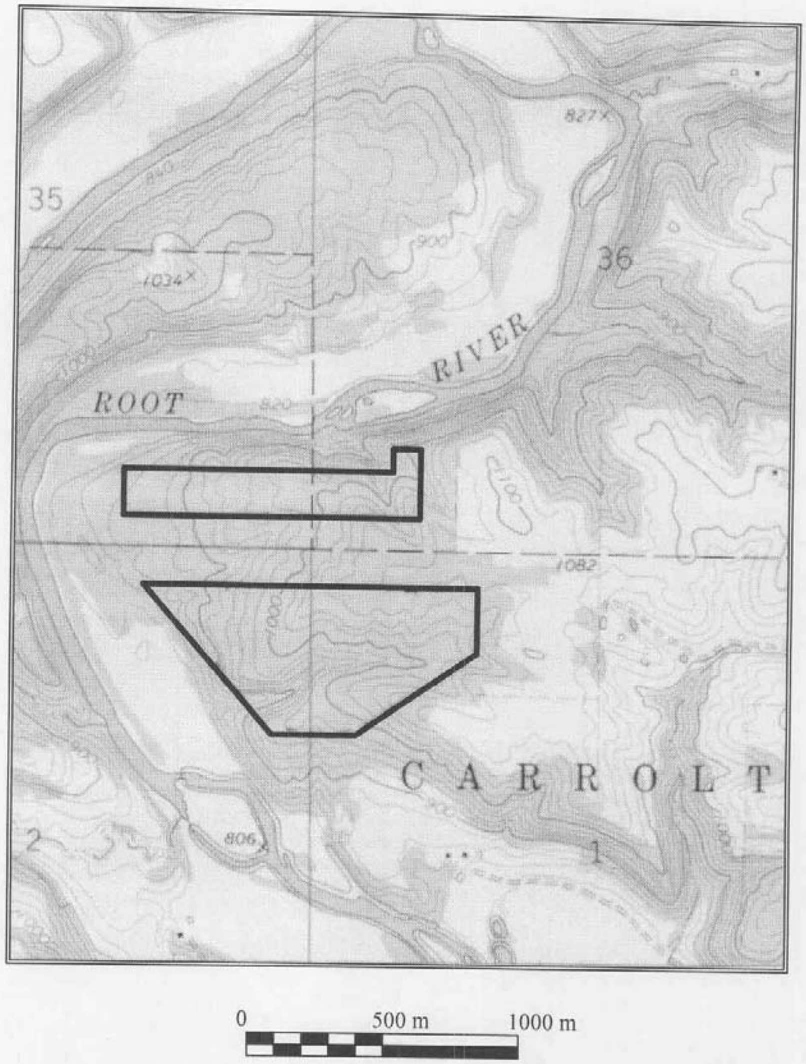
UNDERBAKKY (≈ 28 ha)



SE ¼ NE ¼ sec. 6, T. 102 N, R. 11 W, Filmore Co., Minnesota (Richard J. Dorer Memorial State Forest)

APPENDIX A (CONTINUED). TOPOGRAPHIC PLOT MAPS

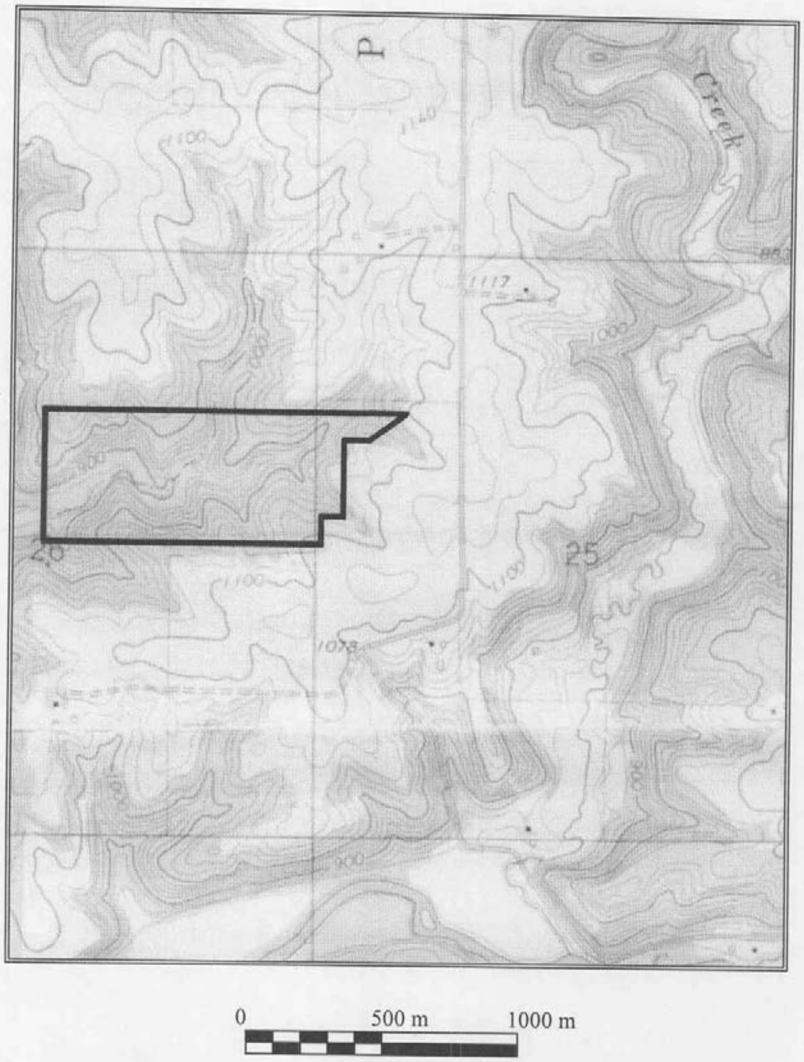
BRIGHTSDALE (≈ 32 ha)



NW ¼ NW ¼ sec. 1, T. 103 N, R. 10 W, Filmore Co., Minnesota (Brightsdale Management Unit, Richard J. Dorer Memorial State Forest)

APPENDIX A (CONTINUED). TOPOGRAPHIC PLOT MAPS

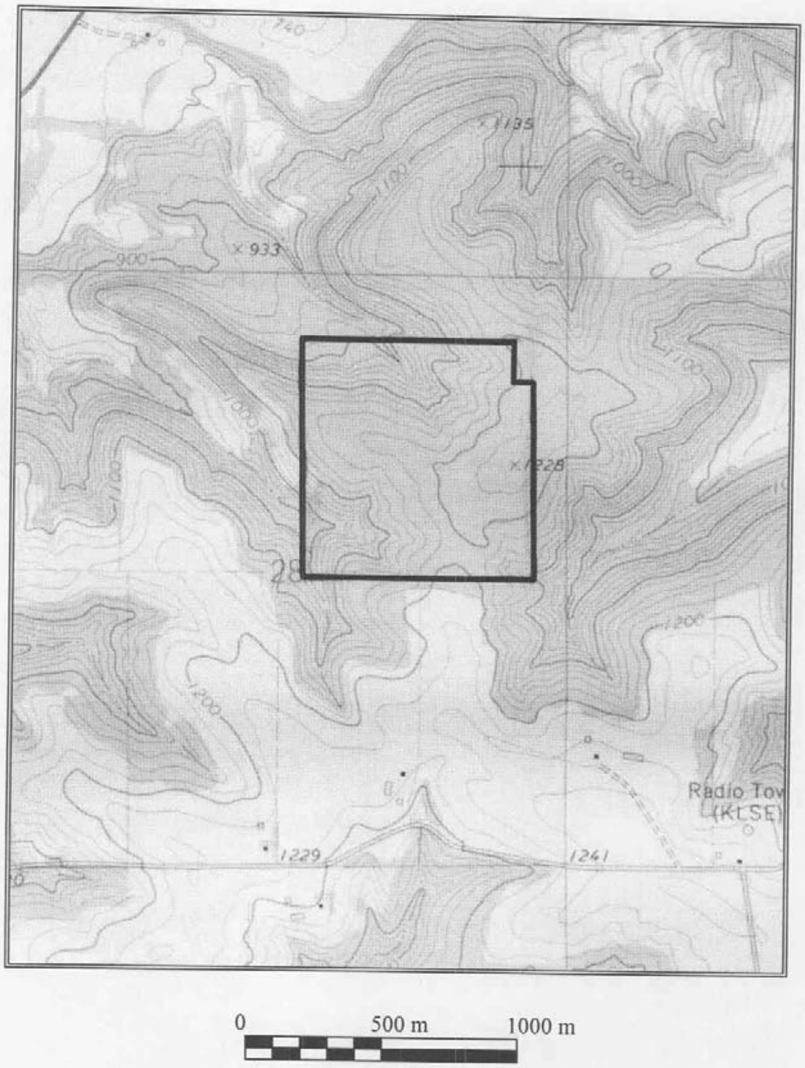
BONNIEVILLE (≈ 39 ha)



S½ NE ¼ sec. 26, T. 104 N, R. 10 W, Filmore Co., Minnesota (Richard J. Dorer Memorial State Forest)

APPENDIX A (CONTINUED). TOPOGRAPHIC PLOT MAPS

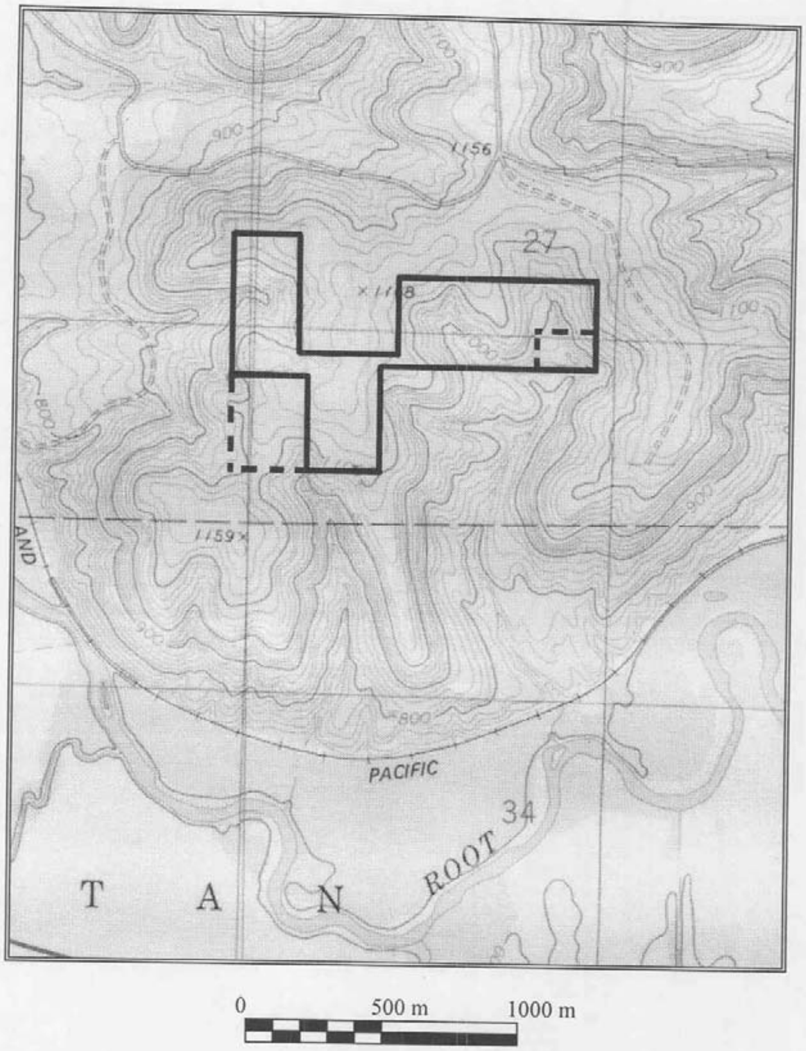
SAND BARRENS (≈ 35 ha)



NE ¼ sec. 28, T. 103 N, R. 8 W, Filmore Co., Minnesota (just south of Rushford Sand Barrens Scientific and Natural Area, Richard J. Dorer Memorial State Forest)

APPENDIX A (CONTINUED). TOPOGRAPHIC PLOT MAPS

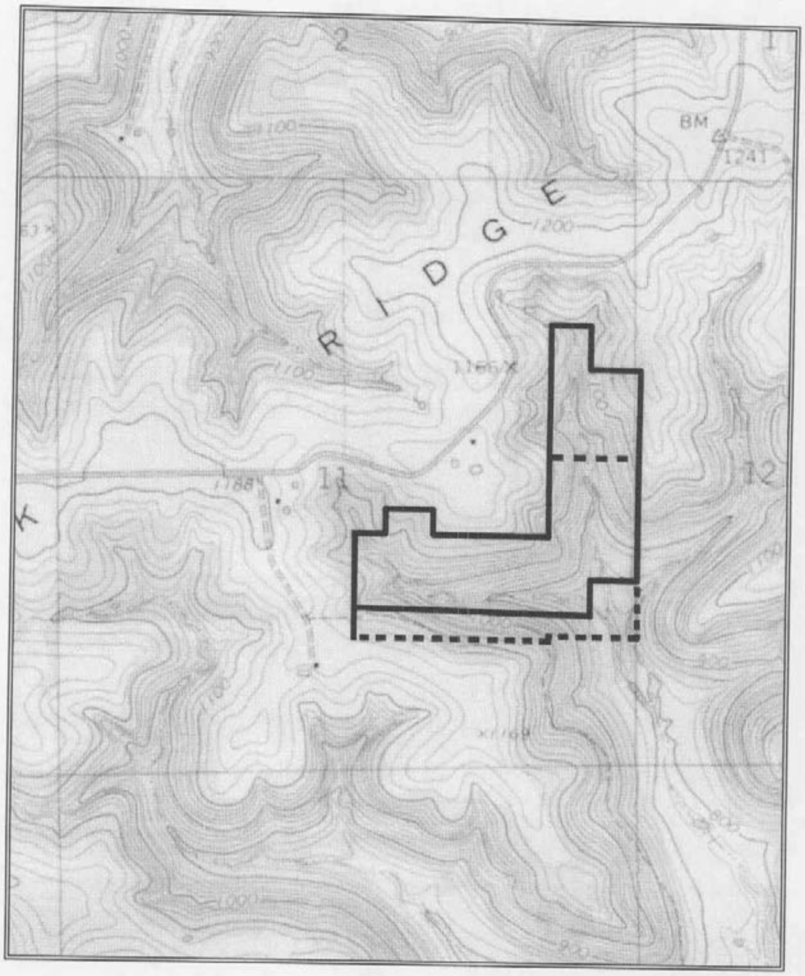
MONEY CREEK (≈ 37 ha)

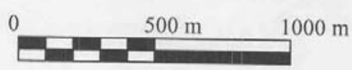


SW ¼ sec. 27, T. 104 N, R. 7 W, Houston Co., Minnesota (Vinegar Ridge Recreational Area, Money Creek Forest Management Unit, Richard J. Dorer Memorial State Forest)

APPENDIX A (CONTINUED). TOPOGRAPHIC PLOT MAPS

OAK RIDGE (≈ 39 ha)

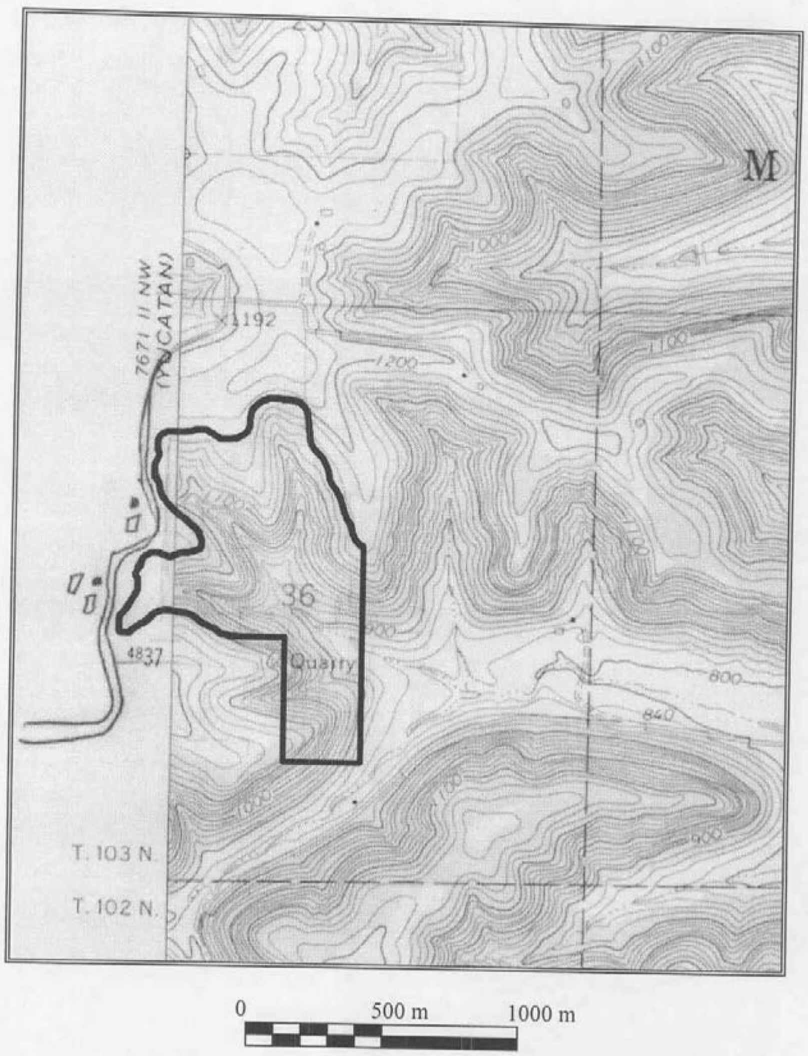




N ½ SE ¼ sec. 11, T. 103 N, R. 7 W, Houston Co., Minnesota (Wet Bark Recreation Area, Oak Ridge Management Unit, Richard J. Dorer Memorial State Forest)

APPENDIX A (CONTINUED). TOPOGRAPHIC PLOT MAPS

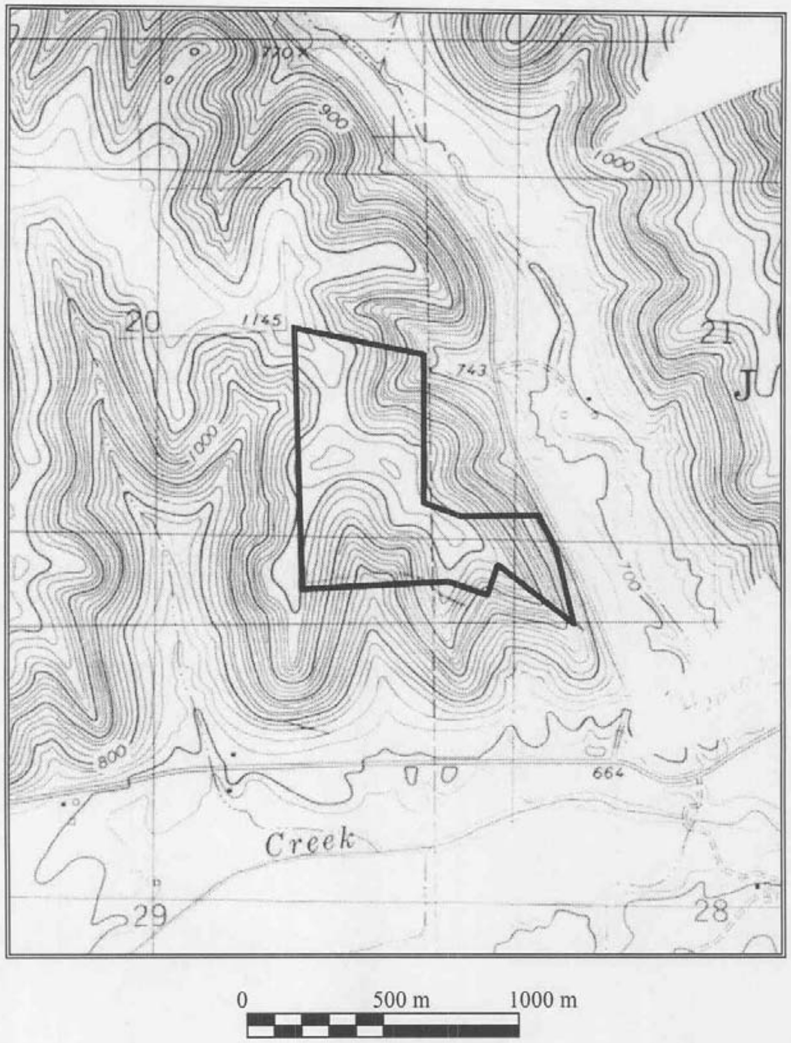
QUARRY (≈ 40 ha)



NW ¼ sec. 36, T 103 N, R. 7 W, Houston Co., Minnesota (Richard J. Dorer Memorial State Forest)

APPENDIX A (CONTINUED). TOPOGRAPHIC PLOT MAPS

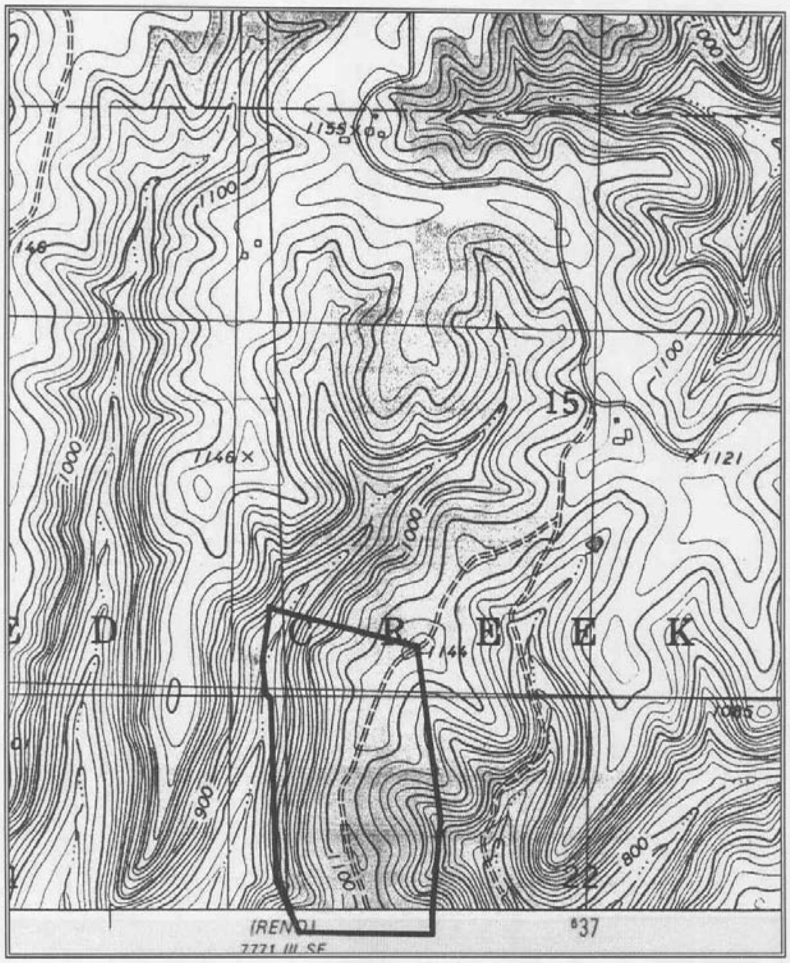
HAMEL (≈ 30 ha)



E ½ SE ¼ sec. 20, T. 101 N, R. 4 W, Houston Co., Minnesota (Richard J. Dorer Memorial State Forest)

APPENDIX A (CONTINUED). TOPOGRAPHIC PLOT MAPS

RENO (≈ 44 ha)

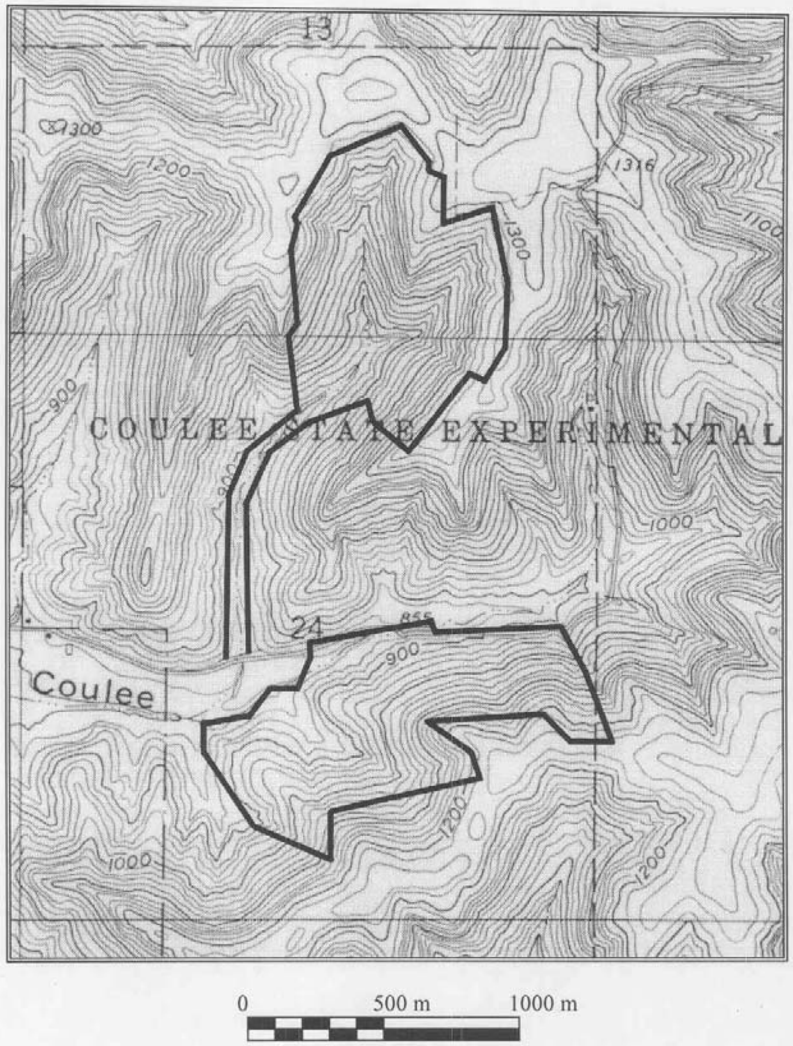


0 500 m 1000 m

NW ¼ sec. 22, T. 102 N, R. 4 W, Houston Co., Minnesota (Reno Management Unit, Richard J. Dorer Memorial State Forest)

APPENDIX A (CONTINUED). TOPOGRAPHIC PLOT MAPS

COULEE NORTH (≈ 33 ha) AND COULEE SOUTH (≈ 36 ha)



COULEE NORTH
SW ¼ SE ¼ sec. 13, T. 16 N, R. 6 W., LaCrosse Co., Wisconsin (Coulee State Experimental Forest)

COULEE SOUTH
N ½ SE ¼ sec. 24, T. 16 N, R. 6 W., LaCrosse Co., Wisconsin (Coulee State Experimental Forest)

APPENDIX B. NEST SEARCHING DETAILS

In 1997, I searched for nests with the help of nest searchers from a different project. While they focused on searching for open cup nesting birds, they let me know of any woodpecker nests they found. In 1998,1 hired a field assistant and we both searched for woodpecker nests. I searched one plot a day, arriving about half an hour after sunrise and staying until mid-afternoon. If the woodpeckers were unusually active, I would stay into the late afternoon or come back in the evening.

The nest searching methods varied depending on the species of woodpecker and the stage of the breeding cycle. Hairy Woodpeckers excavate nest holes very early in the spring, so I missed their excavation period both field seasons. For the other woodpeckers, the excavation period can be a relatively easy time to find nests. I walked quietly through the forest listening for the sound of woodpeckers excavating. Early spring of 1998, I found a personal daily record of 13 woodpecker nests at Oak Ridge by following excavation noises.

During the incubation period, the woodpeckers are not very active. Because woodpeckers were in different stages of the breeding cycle at one time, it was possible to find nests throughout the breeding season. For example, some Yellow-bellied Sapsuckers were just beginning excavation even after the Downy Woodpeckers were well into incubation. Hairy Woodpeckers had nestlings in mid-May when Yellow-bellied Sapsuckers were still copulating and excavating.

On days with low woodpecker activity, I searched the plots systematically by walking the length of the plot and searching in 50 to 100 m wide sections. I looked for trees with indications of possible use such as fresh cavities or chips at the base. These trees were loudly scraped upwards with a stick. If the scrape did not flush a woodpecker, but the hole looked new or there was woodpecker activity in the vicinity, I would wait nearby for half an hour for the occupant to return. As I gained nest searching experience, I developed search images for the types of nest trees chosen by the various woodpecker species. It did not take long to see that the hard, dead elms with broken branches were favorites of the Downy Woodpecker and live aspens with old cavities and fungal conks were used by the Yellow-bellied Sapsucker. Because I certainly did not find all the woodpecker nests on the plots, my data is probably biased toward woodpecker nests fitting the characteristics of my search images. However, this bias would not exist for the many nests (>75%) that I found by hearing excavations and nestlings and by following vocalizations and flight paths.

Territorial drumming and vocalizations provided clues to nest location. While walking the plots, I recorded sightings, drumming, and vocalizations on plot maps. After a few visits to the plots, I was able to delineate possible territories and I systematically searched these areas for nest trees. However, woodpecker territories are large and several woodpecker pairs alluded me the entire breeding season until I finally gave up, upon hearing fledglings on the territory. I also found nests by following vocalizations and flight paths. Often, the Red-bellied Woodpeckers would call directly from the nest trees. Sometimes I could invoke vocalization or drumming by imitating the drum of the Yellow-bellied Sapsucker by pounding a stick against a tree, or even by striking my pen against my metal clipboard.

I found many nests during the nestling period because woodpecker nestlings can be very loud. Sometimes nestlings of Hairy Woodpeckers and Yellow-bellied Sapsuckers could be heard more than 100 m away. I could often tell the species of woodpecker by the sound of the nestlings. The young Downy woodpeckers made a rapid, high pitched "wee-wee-wee," while Hairy nestlings had a louder deeper rougher version of the same. The young sapsuckers made a sound that reminded me of a plastic straw being quickly scraped up and down in the slot of a fast-food soft drink lid. Red-bellied and Red-headed Woodpecker young had a much softer, deeper, almost growling or purring sound. The adult woodpeckers often got very upset as I neared the nest tree and I could narrow in on the location by judging their reaction tome. Hairy Woodpeckers were especially vocal when I neared their nest trees. Very upset, they would fly from tree to tree, refusing to go to the hole to feed the nestlings. On more than one occasion I remained near a nest tree for more than an hour, convinced that I could hear nestlings between calls of upset parents, but with no nest hole in sight. By backing off and repeating my approach, I could sometimes find the hole as the parents quickly dived to it to slip the young an insect.

The Red-headed Woodpecker often chooses to nest in open areas and nests were found in isolated snags in pastures, along roadsides, and near agricultural fields, as well as on the plots. When driving to and from the plots if I saw a large snag with old cavities or a Red-headed Woodpecker, I would pull-over and do some quick nest searching. In 1998, I spent an entire day driving around Houston and Fillmore counties looking for Redheaded Woodpecker nests, but I was only able to locate one nest on that rainy day. Out of 19 Red-headed Woodpecker nests, 10 were found off the plots. Nests found off the plots were not used in the comparative analysis of nest sites to random sites.

APPENDIX C. DATA FORMS

MACROHABITAT VEGETATION MEASUREMENTS OF 0.04 HA PLOTS

Sample Plot ID Code	Date

Low Woody Downed WoodCover Class Codes			Low Woody Cover < 1.5 m tall		Downed Wood Cover
C	Continuous	> 75%			
I	Interrupted	50 - 75%	(assessed in 1 m^2 subplots)		
P	Park Like	25 - 50%	NE		
R	Rare	5 - 25%	SE		
B	Barely Present	1 - 5%	SW		
A	Almost Absent	< 1%	NW		

Total Canopy Cover		High Canopy Cover (> 5 m tall)	
(# of dots covered in densiometer)			
North:		North:	
East:		East:	
South:		South:	
West:		West:	

Dominant (> 40%) Species in High Canopy	
Species	%

Canopy Height	Plot Slope

APPENDIX C (CONTINUED). DATA FORMS

ALL TREES > 8 CM DBH WITHIN 0.04 HA PLOTS

Sample Plot ID Code [ ] Date [ ]

Size Classes (cm DBH using Biltmore Stick)							
1	2	3	4	5	6	7	8
8 - 15 cm	> 15 -23 cm	> 23 - 38 cm	> 38 - 53 cm	> 53 - 69 cm	> 69 - 84 cm	> 84 - 102 cm	> 102 cm

Tree Status	
A	Alive
D	Dead
PD	Partly Dead

Tree Species	Tree Status	DBH class

Tree Species	Tree Status	DBH class

APPENDIX C (CONTINUED). DATA FORMS

POTENTIAL NEST TREES WITHIN 0.04 HA PLOTS

(>15.2 CM DBH, > 1.8 M TALL, 2 DECAY INDICATORS)

Sample Plot ID Code [ ] Date [ ]

Decay Indicator Codes	
BS	Branch or Stem Stub
FC	Fungal Conk
OC	Old Cavities
TS	Tree Scar
DP	Significant dead portions

Tree Status	
A	Alive
D	Dead
PD	Partly Dead

Top Condition	
TI	Top Intact
BT	Top Completely Broken off
BF	Top forked with a fork broken off

% Bark Cover	
1	0 - 25%
2	> 25 - 50%
3	> 50 - 75%
4	> 75 - 100%

Species	Presence Of Decay Indicators					Tree Status	Top Cond.	% Bark	DBH (cm)	Height (m)
	BS	FC	OC	TS	DP					

APPENDIX C (CONTINUED). DATA FORMS

NEST TREE AND POTENTIAL NEST TREE COMPARISON

Woodpecker Id Code	Tag #	Date

Decay Indicator Codes	
BS	Branch or Stem Stubs
FC	Fungal Conks
TS	Wounds with Exposed Heartwood
DP	Dead Portion
OC	# of Old Cavities

Tree Status	
A	Alive
D	Dead
PD	Partly Dead

Tree Top Condition	
TI	Top Intact
BT	Top Fully Broken Off
BF	Top Forked With a Fork Broken Off

Quartile Classes	
1	0 - 25%
2	> 25 - 50%
3	> 50 - 75%
4	> 75 - 100%

Limb Condition	
T	Trunk
M	Main Branches
2	2° Branches
F	Foliage-Bearing Twigs

	Tree Species	Presence of Decay Indicators					Tree Status	Top Cond.	% Bark	% Live Wood	Limb Condition				DBH (cm)	Height (m)
		BS	FC	TS	DP	# OC					T	M	2	F		
NEST TREE																
1																
2																
3																
4																

APPENDIX C (CONTINUED). DATA FORMS

NEST

Nests Relation to Canopy
Above
Within
Below

Substrate	
	Trunk
	1° branch
	2° branch
	3° + branch

Substrate Status	
	Dead
	Alive

Substrate Condition	
	Top Intact
	Top Broken
	Top Broken With a Broken Fork

Substrate Position Relative To Nest Cavity		
		Acute
		Vertical
		Obtuse

Decay Indicators Within 1m of Nest	
	Branch or Stem Stub
	Fungal Conk
	Old Cavities
	Tree Scar

Bark Cover in Quartile Class Within 1m of Nest Hole

Nest Height (m)

Orientation of Hole

N
NW NE
W E
SW SE
S