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Impacts of Timber Cutting on Breeding Birds in Southern Wisconsin Woodlots

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Abstract

The impacts of timber harvest on breeding birds in southern Wisconsin woodlots have been poorly understood. The literature on this topic comes from work outside the state on large forested tracts, and the results are likely not applicable to small woodlots in southern Wisconsin. Thus, a 5-year field study was initiated in 1981 on 5 oak or ash-oak woodlots located on wildlife properties in Dane and Jefferson counties, Wisconsin, to experimentally cut timber and evaluate the avian response. Vegetation surveys for all 5 woodlots before cutting revealed that oak was not reproducing adequately to sustain itself, and was being replaced by maple, cherry, or elm in the sapling layer. Three woodlots were cut for sawtimber, and the downed treetops were removed through a firewood sale within 2 years or were left on the ground; 2 uncut woodlots were monitored as controls. Logging intensity varied over the 3 cut woodlots, but logging reduced the importance of dominant tree species (oak, ash, and hickory) and the density of total live trees, dead trees, saplings, and tree cavities in all 3 woodlots; however, logging increased the density of shrubs and downed logs.

Bird surveys indicated that logging affected each of the cut woodlots differently. Total bird abundance was not affected by logging in any woodlot. Species diversity of birds increased in the second year after logging in all 3 woodlots. Eastern wood-pewees and eastern phoebes were reduced in the first and second years, respectively, after logging in all 3 woodlots. More species were impacted positively as logging intensity and woodlot size increased. The species affected were related to their feeding guild, forest habitat utilization, and to the cleanup of downed treetops after logging. Logging effects in all 3 stands became more positive for birds as a whole from year 1 to year 2 following logging. Data suggest that the positive effects would continue at least through 4 years after logging. Notes on alternative strategies for oak management suggest that fire needs further consideration as a tool to control oak competition.

Contents

Introduction

An accelerating demand for fuelwood and a continuing need for other wood products have increased the wood harvest in southern Wisconsin (Blyth et al. 1981). From 1967 to 1981, the volume of timber cut for saw logs increased 91%, while the harvest of fuelwood increased 512%. Hardwoods made up most of these harvests, with northern red oak the primary species cut for both saw logs and fuelwood. Such demands are evident on both public and private lands. Wisconsin Department of Natural Resources (DNR) wildlife managers are considering timber sales and fuelwood cutting on public wildlife lands, while private landowners are interested in managing their land for both timber and wild birds.

The impacts of cutting on breeding birds in small (< 40 acres) southern Wisconsin woodlots have been poorly understood. Woodlots in southern Wisconsin can be viewed as islands of habitat for certain species (Ambuel and Temple 1983); continued fragmentation of these habitat islands may be contributing to the decline of certain woodland bird species (Robbins 1979, Whitcomb et al. 1981, Ambuel and Temple 1982). In 1975-76, March surveyed the vegetation and breeding birds of small upland woodlots in southeastern Wisconsin, but he did not identify the important variables associated with avian abundance indices (March 1975, 1976*a*, and 1976*b*).

Many studies have documented the habitat associations of deciduous forest birds, whose abundance is primarily related to vegetative structure and woodlot size (Bond 1957, MacArthur et al. 1962, Anderson and Shugart 1974, Galli et al. 1976, Tilghman 1977, Probst 1979, Noon et al. 1979, Whitcomb et al. 1981, Ambuel and Temple 1983, Kahl et al. 1985). However, little quantitative research has been done on the effects of timber management on deciduous forest birds (Noon et al. 1979). To date, such studies have concerned larger forested tracts or different forest types than those in southern Wisconsin and may not be applicable here (Shaw 1971, Schemnitz 1976, Hardin and Evans 1977, Evans and Conner 1979, Thomas et al. 1979, Mannan et al. 1980).

To evaluate the effects of timber management on breeding birds, many factors need to be examined. For example, elimination of a woodlot is an obvious loss of forest habitat for birds. Less obvious are the impacts of habitat changes resulting from selective cutting within woodlots. After cutting in large woodlots, forest edge bird species should increase while forest interior bird species should decrease. Less clear is the effect of cutting on birds that can utilize both the forest interior and edge; therefore, the effect of cutting on total bird abundance and species diversity (i.e., species richness) is also unclear. The effect of cutting a small woodlot is especially uncertain; small woodlots have little or no true interior habitat and probably lack the rarer forest interior bird species. Resident bird species in small woodlots are generally the more common species, and decreases in their numbers from logging would not likely decrease species diversity on a local scale. In addition, certain key woodland habitat components may be particularly affected by logging. For example, snags and blowdowns are often removed; yet the density required by woodland birds is not known (Hardin and Evans 1977, Kitts 1981, Dingledine and Haufler 1983).

In 1981, I began a 5-year study of five small oak or ash-oak woodlot stands on public wildlife properties in Dane and Jefferson counties, Wisconsin. Oak was not reproducing adequately in these areas to maintain itself. The primary objective of this study was to evaluate the response by breeding birds to selective timber cuts. The vegetation of each woodlot stand was surveyed by layer before and after logging to determine importance values based on frequency, density, and dominance, and a compositional index for each stand. In each woodlot, populations of breeding birds were surveyed before and after logging to determine density, which was used as the population index for each species or group of species. For analysis, bird species were grouped by cavity needs, feeding guild, and forest habitat utilization. Four fixed effects models were used to perform analysis of variance on densities for different bird species and species groups.

The secondary objective of this study was to collect observations on the effects of logging on the regeneration of oak and to suggest possible alternative techniques for oak management. The oak forest type is desirable for a wide variety of wildlife species. But maintaining oaks in southern Wisconsin has historically been difficult. There were few oak forests but many oak savannahs in south-central Wisconsin before settlement (Curtis 1974:325-351). Following settlement, suppression of fire caused oak savannahs to succeed into oak forests (Cottam 1949). The oak forests then succeeded into maple-linden climax forests because slower-growing oak seedlings were unable to compete with shade-tolerant maple and linden seedlings (Larsen 1953, Auclair and Cottam 1971, McCune and Cottam 1985, Crow 1988, Lorimer 1989). Guidelines for the management of logging and woodland birds in oak forests have been general and untested (Probst 1979, Temple et al. 1979). In Wisconsin, sawtimber sales are being used experimentally to open up the forest canopy and encourage oak reproduction below (Lorimer 1989, Wis. Dep. Nat. Resour. 1990).

Study Area and Methods

Woodlot Location and Management

Five woodlot stands (3 oak and 2 ash-oak) were selected for study on 2 DNR Wildlife Areas (WA): Goose Lake WA in eastern Dane County and Rome Pond WA in eastern Jefferson County (Fig. 1). Squirrels were the target management species on these woodlots, and oak reproduction was not maintaining the oak forest type. Timber was cut selectively on 3 of the woodlots to open up the canopy (sawtimber sale) and treetops were removed to clear the ground (firewood sale). Timber was removed by the public under contractual agreement with the DNR. Two woodlots, 1 on each wildlife area, were left uncut and were monitored as experimental controls to measure annual variability of bird abundance and sampling error.

At the Goose Lake WA, Stand 1 was cut for sawtimber in July-August 1981. A total of 113 mbf was cut from this 35-acre woodlot (3.2 mbf/acre), with 95% of the harvest (454 trees) being mature oak. This cutting removed 40% of the canopy in a contiguous pattern, generally on 1 side of the woodlot. The downed treetops (100+ cords) were removed during January-September 1982. Stand 2, a 70-acre drumlin, served as a control for woodlot cuttings on Goose Lake WA. Stand 3, 15 acres on a north-facing slope at Goose Lake WA, was cut for sawtimber in February 1984. A total of 44 mbf was cut (2.9 mbf/acre), with 59% of the harvest as ash and 22% as mature oak. The downed treetops (30 cords) were removed from December 1984 to June 1985.

At the Rome Pond WA, Stand 4, a 55-acre low drumlin, served as a control and Stand 5, a 7-acre woodlot located on a hilltop, was cut in January 1984. A total of 14 mbf was cut (2.0 mbf/acre); the primary species harvested were ash (61%) and oak (17%). The downed treetops (10 cords) were not removed as scheduled and remained on the ground through June 1985.

Vegetation Surveys

The vegetation of each woodlot was surveyed by layer to provide background descriptions of species composition and importance.[1] Five vegetation layers were sampled: tree, sapling, tree seedling, shrub, and ground vegetation layers. Sampling was done at a density of 1 sampling station/acre with a minimum of 10 sampling stations/stand.

Tree and sapling layers were surveyed in May for 2 years both before and after timber cutting, using the point-center quarter method (Cottam and Curtis 1956), yielding importance values (*IV*) based on frequency, density, and dominance (basal area), and a compositional index for the stand (Curtis 1974). The

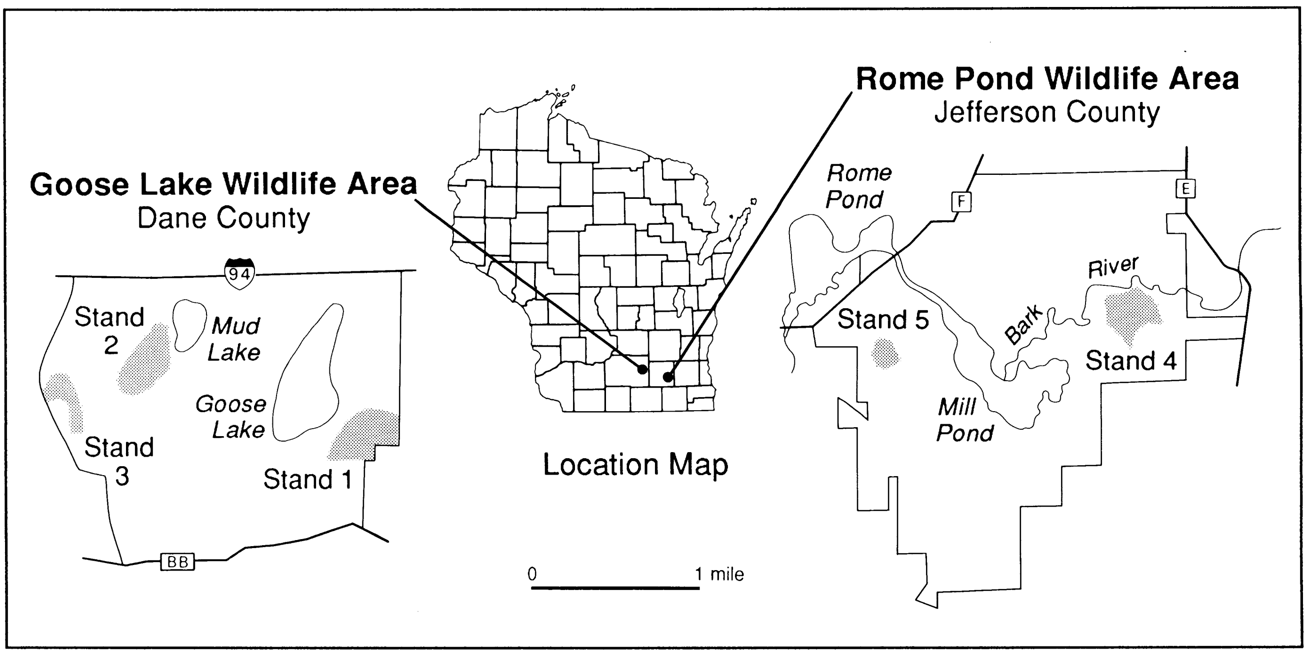


Figure 1. *Location of study woodlots.*

[1]Scientific names of plants and birds are listed in Appendix A.

occurrences of dead standing trees, tree cavities, and fallen trees were recorded within the variable radius used in point-center quarter sampling, and their abundance per sampling station was calculated.

Tree seedling, shrub, and ground vegetation layers were surveyed in late May to early June 1981-85 in each stand using methods of the U. S. Forest Service (Ohmann and Ream 1971). Circular milacre plots were used for sampling tree seedlings and shrubs yielding *IV* based on frequency and density (tree seedlings), and frequency, density, and dominance (shrubs). Quadrats (1- by 2-ft) were used for ground vegetation, yielding *IV* based on frequency and dominance (ground coverage).

Similarities of vegetation among the study woodlots before logging were compared by correlating the *IV* between each possible pair of woodlots, for tree, sapling, shrub, and ground layers; each species represented 1 datum point in a Pearson Correlation Coefficient (SAS Institute, Inc. 1985), with double-zero matches excluded.

Breeding Bird Surveys

Populations of breeding birds were indexed on the study woodlots for 1-2 years before and 2-4 years after timber cutting, using fixed-strip transects. The occurrences of singing males and all calling birds within 150 ft of the transect lines were recorded. Bird surveys began at sunrise and continued up to 5 hours after sunrise, as suggested by Tilghman (1977). Each stand was surveyed 2-5 times each year during June. Control and treatment stands were surveyed on the same day and in the same order for each location, to reduce the daily variability associated with bird activity. Parallel transects were laid out 400 ft apart and flagged in each stand. Transect lengths for stands 1-5, respectively, were: 3,609, 7,415, 2,592, 5,610, and 787 ft.

The number of birds counted in each stand was divided by the acreage of the stand's transect area, and the resulting density (birds/acre) was used as the population index for each species or group of species. Similarities of bird communities among the study woodlots before logging were compared by correlating the transformed density indices (log[density+1]) between each possible pair of woodlots for each of the species groups; each species represented 1 datum point in a Pearson Correlation Coefficient (SAS Institute Inc. 1985), with double-zero matches excluded.

Removing downed oak log with skidder equipment in woodlot Stand 1.

Northern red oak saw logs removed from woodlot Stand 1.

Bird species were grouped for analysis based on: cavity needs (cavity users, cavity nesters) (Scott et al. 1977); feeding guild (ground foragers, foliage gleaners) (Maurer et al. 1981); and forest habitat utilization (forest interior, intermediate, and edge species) (Whitcomb et al. 1981).[2] The 3 forest habitat utilization groups encompassed all bird species, while the feeding guild and cavity needs groups were not comprehensive. The cavity users group included species dependent on tree cavities for feeding, perching, and nesting; the cavity nester group used cavities only for nesting.

Data Analysis

The General Linear Models (GLM) Procedure from the SAS Institute Inc. (1985) was used to perform analysis of variance (ANOVA) on densities for different bird species and species groups. Four different fixed effects models were used (GLM-1, GLM-2, GLM-3, GLM-4) to account for lack of balance and synchrony among cutting (Table 1).

GLM-1 and GLM-2 were limited to Stands 2-5 and years 1982-85, because logging in Stand 1 was not synchronized with that in Stands 3 and 5, and potential year effects may have been important (Table 2). Stands 3 and 5 were replicates of logged stand types and 2 and 4 were replicates of control stand types to test for stand type, year, and year-by-stand type interaction effects. An interaction effect ($P < 0.05$) suggested a logging impact when it coincided with the logged years.

GLM-3 and GLM-4 included Stand 1, pooled calendar years into time periods (pre- and post-logging), and considered stands individually rather than pooled as stand types. Time-by-stand interaction effects indicated differences in bird responses over time among stands, and similar linear functions of cell means were used to determine which stands had different responses. GLM-3 included all stands, but GLM-4 included only Stands 1 and 2 to test for logging impacts on birds for 4 years after logging Stand 1.

GLM-1 was a balanced ANOVA, using mean annual bird density for each stand as the dependent variable. GLM-2, GLM-3, and GLM-4 were unbalanced ANOVAs, using census dates as replicates within stand-years, and bird density on each sample date as the dependent variable. GLM-2 also tested for stand main effects and interactions with stand type and year. Linear functions of cell means were used in GLM-1 and GLM-2 to separate the overall year-by-stand type interaction into impacts from the first and second years following logging.

[2]Bird species analyzed within each group are listed in Appendix B.

Results

Vegetation

Pre-logging Profile. All 5 study woodlots were classified as dry-mesic along an ordination of forest stands (Curtis 1974). Stand 1 was dominated before logging by northern red oak and ash in the tree layer, American hophornbeam and red maple in the sapling layer, ash in the seedling layer, and Allegheny blackberry, common chokecherry, and mapleleaf viburnum in the shrub layer (Tables 3, 4). Stand 1 had the lowest sapling density of the 5 study woodlots (Table 5).

Stand 2 was the driest woodlot, dominated by northern red and white oak in the tree layer, with a diverse sapling layer dominated by red maple and black cherry, and a diverse seedling layer (Table 6). Stand 2 had the densest shrub layer of the 5 study woodlots, dominated by mapleleaf viburnum, common chokecherry, and Allegheny blackberry (Table 4, 5).

Stand 3 was dominated before logging by ash and shagbark hickory in the tree layer; it had the densest sapling layer of the 5 woodlots, dominated by elm (Tables 5, 7). The seedling layer was dominated by ash and elm (Table 7). The shrub layer was dominated by common chokecherry and gray dogwood before logging (Table 8).

Stand 4 was a diverse woodlot, with dominance spread among white oak, ash, and American hophornbeam in the tree layer, American hophornbeam and American linden in the sapling layer, and a variety of species in the seedling layer (Table 6). Stand 4 was younger than the other woodlots with the smallest trees at the highest density (Table 5). Stand 4 also had a dense shrub layer dominated by common pricklyash, common chokecherry, and rafinesque viburnum (Table 8).

Stand 5 was the wettest woodlot, dominated before logging by ash and white oak in the tree layer, American hophornbeam and elm in the sapling layer, and elm, ash, and sugar maple in the seedling layer (Table 9). Stand 5 had the lowest density of shrubs, dominated by common chokecherry and rose (Table 5, 8).

The tree layers were very similar among the 5 study woodlots. The *IV* of the tree layer were correlated ($P < 0.05$) between 6 of the 10 possible stand comparisons and at least weakly correlated ($P < 0.10$) between all pairs of woodlots except Stands 1 and 3 (Table 10). Trees of Stands 1 and 3 differed mainly in the greater importance of northern red oak and American hophornbeam in Stand 1 and the greater importance of shagbark hickory, ash, and white oak in Stand 3.

Table 1. *Experimental design used for the 5 timber stands.*

	Stand No. (Goose Lake)			Stand No. (Rome Pond)	
Year	**1**	**2**	**3**	**4**	**5**
1981	pre-cut	control	—	—	—
1982	post-cut 1 yr.	control	pre-cut	control	pre-cut
1983	post-cut 2 yr.	control	pre-cut	control	pre-cut
1984	post-cut 3 yr.	control	post-cut 1 yr.	control	post-cut 1 yr.
1985	post-cut 4 yr.	control	post-cut 2 yr.	control	post-cut 2 yr.

Table 2. *Analysis of variance models* used in evaluating logging impacts on breeding birds.*

Model	Dependent Variable	Model Factors	Data Included	Design Balance
GLM-1	Mean annual bird density	Stand type** Year Interaction	Stands 2-5 (1982-85)	Yes
GLM-2	Bird density on sample date	Stand type Stand Year Interaction	Stands 2-5 (1982-85)	No
GLM-3	Bird density on sample date	Stand Time[a] Interaction	Stands 1-5 (1982-85)	No
GLM-4	Bird density on sample date	Stand Time Interaction	Stands 1-2 (1981-85)	No

* From the General Linear Models (GLM) Procedure from the SAS Institute Inc. (1985).
** Logged or not logged during study.
[a] Before or after logging.

The sapling layers were not very similar among the 5 woodlots. The *IV* of the sapling layer were correlated ($P < 0.05$) between only 4 of 10 stand comparisons (Table 10). Saplings of Stand 3 were not similar ($P > 0.10$) to any other stand, mainly because of the great importance of elm in Stand 3.

The shrub layers also were not very similar among the 5 woodlots. The *IV* of the shrub layer were only correlated ($P < 0.05$) between Stands 1 and 2, 2 and 3, and 3 and 5 (Table 10). Shrubs of Stand 4 were not similar ($P > 0.10$) to any other stand, mainly because of the great importance of common prickly-ash in Stand 4.

The ground layers were very similar among the 5 woodlots. The *IV* of the ground layer were correlated ($P < 0.05$) between all pairs of stands except Stands 4 and 5 (Table 10). Ground layer plants of Stands 4 and 5 differed mainly in the greater importance of common mayapple in Stand 5 and the greater importance of snow trillium, black snakeroot, and viney honeysuckle in Stand 4 (Table 11).

The seedling layers were not very similar among the 5 woodlots. Ash was the dominant species in Stands 1 and 3; elm was dominant in Stand 5. Stands 2 and 4 had diverse seedling layers.

Logging Effects. Logging Stand 1 sharply decreased the importance of northern red oak so that it became a co-dominant tree with ash (Table 3). Logging decreased the density of tree basal area by 38%, total live trees by 29%, tree cavities by 55%, and dead standing trees by 57% (Table 5). The number of logs per sampling station increased over 4-fold after timber cutting and remained at a 3-fold increase after the firewood sale. Lower vegetation layers were also affected by the logging. Sapling density decreased 47%, with American hophornbeam saplings showing the largest relative decrease in importance. Shrub density initially decreased following logging and during treetop removal, then sharply increased to 360% of the pre-cutting density. Logging increased shrub diversity and the dominance of Allegheny blackberry at the expense of pagoda dogwood and common poison ivy (Table 4).

Table 3. *Summary of tree species importance values* of 3 layers in Stand 1, before (1981) and after (1982-83 mean) logging.*

Species**	Tree Layer Before	Tree Layer After	Sapling Layer Before	Sapling Layer After	Seedling Layer Before	Seedling Layer After[a]
Northern red oak	38	20	1	<1[b]	6	4
Ash	20	22	12	16	57	41
American hophornbeam	14	11	35	27	12	7
Black/pin cherry	9	11	8	8	13	10
Red maple	8	12	20	23	6	9
Shagbark hickory	5	7	6	4	3	8
American linden	2	5	6	5	3	5
White oak	1	6	2	1	0	0
Serviceberry	1	1	5	2	0	0
American/slippery elm	0	2	4	13	0	10
Others[c]	2	3	2	1	0	6
Compositional index[d]	1,776	1,806	–	–	–	–

* Importance values of tree and sapling layers include frequency, density, and dominance; importance values of seedling layer include only frequency and density. Some values are rounded.

** See Appendix A for scientific names.

[a] Mean of 1982-85.

[b] Present but less than 1.

[c] Individual species numbering less than 5 include: boxelder maple, sugar maple, bitternut hickory, common hackberry, bigtooth aspen.

[d] Method from Curtis (1974:94-99).

Table 4. *Summary of shrub species importance values* in Stands 1 and 2, 1981-85.*

Species**	Stand 1 Before Logging	Stand 1 After Logging	Stand 2 Control
Allegheny blackberry	22	29	17
Common chokecherry	19	16	21
Mapleleaf viburnum	14	11	23
Pagoda dogwood	10	4	1
Common poison ivy	10	3	6
Red raspberry	7	6	<1[a]
Blackcap raspberry	5	5	1
Gray dogwood	4	8	14
American filbert	2	6	8
Rafinesque viburnum	1	1	5
Others[b]	7	12	5

* Importance values include frequency, density, and dominance.

** See Appendix A for scientific names.

[a] Present but less than 1.

[b] Individual species numbering less than 5 include: American bittersweet, roundleaf dogwood, winterberry holly, gooseberry, rose, European red elder, nannyberry viburnum, common pricklyash.

Table 5. *Comparison of vegetation parameters among the 5 study woodlots before and after logging.*

	Stand 1		Stand 2	Stand 3		Stand 4	Stand 5	
Parameter*	**Before**	**After****	**Control**	**Before**	**After[a]**	**Control**	**Before**	**After[a]**
Trees/acre	192	136	151	215	188	230	224	222
Saplings/acre	188	100	332	458	315	344	386	340
Tree basal area (ft^2)/acre	136	84	132	144	109	117	146	116
Sapling basal area (ft^2)/acre	6	4	8	12	8	9	10	8
Dead trees/sampling station	0.7	0.3	0.6	0.3	0.2	0.3	0.2	0.2
Cavities/sampling station	0.3	0.1	0.1	0.0	0.0	0.1	0.5	0.0
Logs/sampling station	1.1	4.4	0.8	0.9	2.1	1.6	0.9	1.2
1,000 shrub stems/acre	6.7	13.8	9.6	5.2	5.4	7.4	4.5	5.2

* Estimates derived from systematic sampling.
** Mean of first 4 years after logging.
[a] Mean of first 2 years after logging.

Table 6. *Summary of tree species importance values* of 3 layers in Stand 2 (1981-82 mean) and Stand 4 (1982-83 mean), the control woodlots.*

	Tree Layer		Sapling Layer		Seedling Layer	
Species**	**Stand 2**	**Stand 4**	**Stand 2**	**Stand 4**	**Stand 2[a]**	**Stand 4[b]**
Northern red oak	35	10	8	3	10	7
White oak	20	20	1	0	3	5
Shagbark hickory	14	12	3	0	22	7
Red maple	8	3	21	2	14	1
Black cherry	6	5	14	5	18	12
Ash	6	17	9	12	13	19
Bitternut hickory	3	1	9	0	<1[c]	0
American hophornbeam	1	17	8	42	2	13
American/slippery elm	1	4	6	10	9	13
Common hackberry	1	0	6	0	2	0
Hawthorn	<1[c]	0	8	2	2	<1[c]
Serviceberry	<1[c]	0	7	2	4	2
American linden	0	10	<1[c]	15	<1[c]	11
Sugar maple	0	2	0	7	0	10
Others[d]	5	<1[c]	1	<1[c]	<1[c]	<1[c]
Compositional index[e]	1,540	1,782	–	–	–	–

*Importance values calculated as in Table 3.
**See Appendix A for scientific names.
[a]Mean of 1981-85.
[b]Mean of 1982-85
[c]Present but less than 1.
[d]Individual species numbering less than 5 include: boxelder maple, juniper, apple, bigtooth aspen, quaking aspen, willow.
[e]Method from Curtis (1974:94-99).

Table 7. *Summary of tree species importance values* of 3 layers in Stand 3, before (1982-83 mean) and after (1984-85 mean) logging.*

Species**	Tree Layer		Sapling Layer		Seedling Layer	
	Before	After	Before	After	Before	After
Ash	31	22	13	12	40	25
Shagbark hickory	23	19	0	0	6	13
White oak	12	16	0	0	2	2
American/slippery elm	10	10	54	53	33	29
Northern red oak	10	8	0	0	1	8
Black/pin cherry	6	6	15	6	10	19
Red maple	4	5	5	6	6	2
American hophornbeam	1	5	5	17	1	0
Bitternut hickory	1	5	0	0	0	0
Serviceberry	0	0	5	2	0	0
Others[a]	2	4	3	4	2	2
Compositional index[b]	1,681	1,692	–	–	–	–

* Importance values calculated as in Table 3.
** See Appendix A for scientific names.
[a] Individual species numbering less than 5 include: boxelder maple, sugar maple, common hackberry, hawthorn, bigtooth aspen, American linden.
[b] Method from Curtis (1974:94-99).

Table 8. *Summary of shrub species importance values* in Stands 3, 4, and 5, 1982-85.*

Species**	Stand 3		Stand 4	Stand 5	
	Before	After	Control	Before	After
Common chokecherry	36	28	20	42	35
Gray dogwood	18	34	8	10	26
Rafinesque viburnum	16	16	20	9	9
Mapleleaf viburnum	8	17	<1[a]	0	0
Common poison ivy	6	0	3	2	0
Gooseberry	0	4	10	8	2
Common pricklyash	0	0	23	0	0
Allegheny blackberry	0	0	6	0	0
Blackcap raspberry	0	0	1	0	7
Rose	0	0	0	14	12
Sumac	0	0	0	10	0
Honeysuckle	0	0	0	4	8
Others[b]	16	2	9	2	2

* Importance values calculated as in Table 4.
** See Appendix A for scientific names.
[a] Present but less than 1.
[b] Individual species numbering less than 5 include: pagoda dogwood, silky dogwood, American filbert, cathartic buckthorn, red raspberry, greenbrier, nannyberry viburnum.

Table 9. *Summary of tree species importance values* of 3 layers in Stand 5 before (1982-83 mean) and after (1984-85 mean) logging.*

	Tree Layer		Sapling Layer		Seedling Layer	
Species**	**Before**	**After**	**Before**	**After**	**Before**	**After**
Ash	34	32	12	13	18	14
White oak	17	12	0	0	0	0
Northern red oak	13	15	0	0	8	1
American/slippery elm	11	15	23	20	35	35
American hophornbeam	8	3	30	30	4	8
Shagbark hickory	6	7	0	2	3	1
American linden	4	11	6	4	4	10
Sugar maple	3	4	17	19	18	22
Black cherry	1	0	3	2	6	7
Others[a]	3	0	8	10	6	2
Compositional index[b]	1,852	1,750	–	–	–	–

* Importance values calculated as in Table 3.
** See Appendix A for scientific names.
[a] Individual species numbering less than 5 include: boxelder maple, red maple, serviceberry, American hophornbeam, common hackberry, bigtooth aspen, juniper.
[b] Method from Curtis (1974:94-99).

Table 10. *Summary of Pearson Correlation Coefficients between the importance values for vegetation layers of each pair of woodlots before logging.*

	Stand No.			
Stand No.	**2**	**3**	**4**	**5**
Tree layer				
1	.713**	.427	.456*	.547**
2		.446*	.519**	.421*
3			.566**	.790**
4				.736**
Sapling layer				
1	.501**	.009	.798**	.628**
2		.146	.115	.056
3			.018	.222
4				.846**
Shrub layer				
1	.755**	.265	.013	.251
2		.523**	.189	.342
3			.417	.740**
4				.384
Ground layer				
1	.641**	.558**	.473**	.494**
2		.517**	.493**	.659**
3			.302**	.635**
4				.206

* Weak correlation between the pair of woodlots ($P < 0.10$).
** Correlation between the pair of woodlots ($P < 0.05$)

Logging impacted Stand 3 similarly to Stand 1, but the effect was not as severe. Logging decreased the density of tree basal area 24%, live trees 12%, dead standing trees 33%, and saplings 31%; the density of logs doubled and shrubs increased slightly (4%) following logging and during the treetop removal (Table 5). After logging, tree layer dominance was more equitably spread among ash, shagbark hickory, and white oak (Table 7). Gray dogwood and mapleleaf viburnum increased in shrub importance following logging (Table 8).

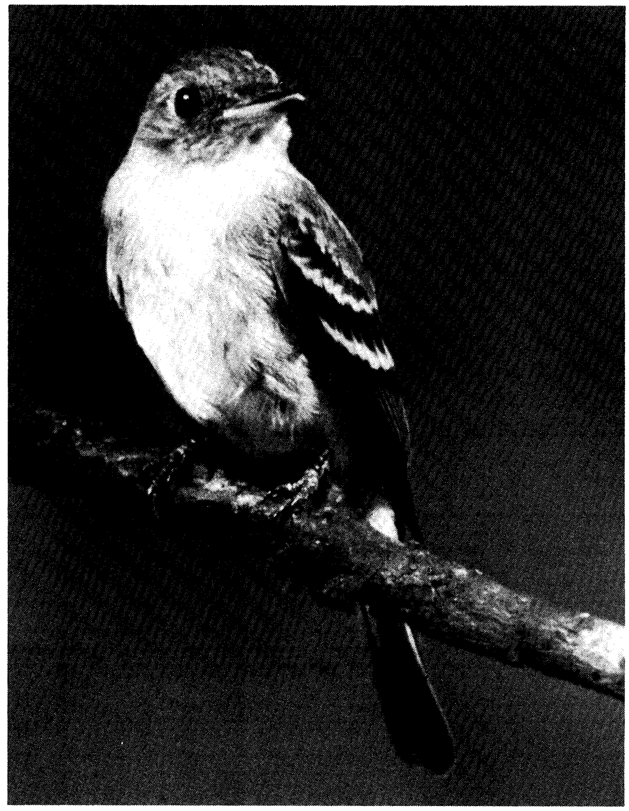
Logging in Stand 5 had the least impact of the 3 cut woodlots, changing the density of live and dead standing trees very little and decreasing tree basal area 21% and sapling density 12%. Without treetop removal, the density of shrub stems/acre increased 16% and logs/sampling station increased 33% (Table 5).

All woodlots had diverse ground layer vegetation. However, the impact of logging on the ground layers was not clear due to high sampling variability, as demonstrated for Stands 2 and 4, the control plots, which received no management. Species diversity of the ground layer after logging went up slightly in Stand 1 but went down in Stands 3 and 5 (Tables 11, 12). Changes in species importance were not well replicated on the 3 cut woodlots. For example, bedstraw decreased all 4 years after logging in Stand 1, dramatically increased after logging Stand 5, yet showed little change in Stand 3. The sampling intensity of 1 station/acre was probably not enough to document real changes in the ground layer vegetation.

The effect of logging on the seedling layer varied in the 3 logged woodlots. The only consistent impact was a decrease in ash seedlings, which was significant in Stands 1 and 3.

Breeding Birds

Pre-logging Profile. Blue jay was the most abundant species counted in all of the woodlots before logging except Stand 4, where red-eyed vireo was the most abundant and blue jay was second in abundance (Tables 13-17). Similarity in bird species among the 5 woodlots before logging was positively related to woodlot size. Lists of the 10 most abundant species in the 3 largest stands (1, 2, and 4) had 8 species in common to all (blue jay, red-eyed vireo, eastern wood-pewee, scarlet tanager, northern cardinal, white-breasted nuthatch, black-capped chickadee, and great crested flycatcher). The 10 most abundant species in the 2 smallest stands (3 and 5) had only 4-7 species in common with the top 10 species of the largest woodlots.



Eastern wood-pewees were negatively impacted in all 3 woodlots. Photo by Mike Hopiak for the Cornell Lab of Ornithology.

Total bird species densities were similar among all 5 woodlots. Correlation coefficients of bird densities calculated between all possible pairs of woodlots ranged from 0.697 to 0.950 (all $P < 0.01$, Table 18). Similarity in densities was again related to woodlot size. Correlation coefficients among Stands 1, 2, and 4 averaged 0.922, while coefficients among Stand 3 and all other woodlots and Stand 5 and all other woodlots averaged lower (0.847 and 0.739, respectively).

All woodlots had similar proportions of their individuals as cavity users (10-20% range) and cavity nesters (28-35% range) before logging. Ground foragers made up similar proportions of the bird community in Stands 1-4 (3-12% range) but a higher proportion in Stand 5 (21%). Foliage gleaner and forest interior habitat birds made up similar proportions of the bird community in Stands 1-4 (15-30% range and 10-18% range, respectively) but a lower proportion in Stand 5 (4% and 6%, respectively). Intermediate forest habitat birds made up similar proportions in Stands 3-5 (69-73% range) but a lower proportion in Stand 1 (63%) and a higher proportion in Stand 2 (79%). Forest edge birds made up similar proportions in Stands 1, 3, and 5 (19-22% range), but lower proportions in Stands 2 and 4 (8% and 11%, respectively).

Table 11. *Summary of ground layer importance values* in Stands 3, 4, and 5, 1982-85.*

	Stand 3		Stand 4	Stand 5	
Species**	**Before**	**After**	**Control**	**Before**	**After**
Common mayapple	18	12	4	25	26
Wild cranesbill	13	20	6	4	5
Virginia creeper	8	10	4	0	0
Early meadowrue	8	5	0	6	8
Enchanter's nightshade	6	10	2	4	4
Common anemonella	6	6	<1[a]	0	0
Feather solomonplume	6	4	6	4	4
Honeysuckle	5	2	6	0	0
Wood anemone	4	3	2	5	2
Bedstraw	3	7	10	7	22
Solomon's seal	2	7	4	0	4
Ash	2	1	<1[a]	3	6
Elm	2	<1[a]	<1[a]	5	0
Common poison ivy	<1[a]	2	2	5	0
Black snakeroot	<1[a]	0	10	1	0
Snow trillium	0	0	11	0	0
Sweet cicely	0	0	6	4	1
Wild sarsasparilla	0	0	<1[a]	7	0
Others[b]	17(7)	11(6)	27(26)	19(6)	18(5)
Species encountered/sample	1.5	1.3	1.0	1.9	1.5

* Importance values include frequency and dominance only.
** See Appendix A for scientific names.
[a] Present but less than 1.
[b] Number of species shown in parentheses.

Table 12. *Summary of ground layer importance values* in Stand 1 before (1981) and after logging (1982-85 mean) and in Stand 2 (1981-85 mean).*

	Stand 1		Stand 2
Species**	**Before**	**After**	**Control**
Bedstraw	19	9	10
Common mayapple	11	13	13
Enchanter's nightshade	10	10	2
Virginia creeper	7	7	2
Common anemonella	7	4	1
Wild cranesbill	6	8	10
Feather solomonplume	6	3	6
Blackberry	5	4	3
Black snakeroot	3	6	1
Sweet cicely	3	5	13
Tickclover	3	3	5
Wild sarsasparilla	0	<1[a]	6
Others[b]	20(21)	28(26)	29(21)
Species encountered/sample	0.9	1.1	0.9

* Importance values include frequency and dominance only.
** See Appendix A for scientific names.
[a] Present but less than 1.
[b] Number of species shown in parentheses.

Table 13. *Average number of birds encountered per census* in Stand 1 prior to (1981) and after (1982-85) logging.*

Species or Group	1981	1982	1983	1984	1985
Species**					
Blue jay	4.6	4.8	3.7	2.8	2.0
Eastern wood-pewee	3.2	3.8	4.7	4.0	5.5
Scarlet tanager	2.6	3.6	4.7	3.0	1.0
Red-eyed vireo	2.6	2.4	3.0	2.5	1.5
Northern cardinal	2.6	2.4	1.0	1.5	2.0
Common grackle	2.6	0.6	0.7	0.3	0.0
White-breasted nuthatch	2.4	3.6	1.7	3.0	2.0
Great crested flycatcher	2.4	1.8	1.7	2.8	1.0
Black-capped chickadee	2.0	2.8	1.0	0.5	4.5
Wood thrush	1.8	0.8	2.0	1.5	2.0
Red-headed woodpecker	1.8	0.2	0.7	0.5	1.0
Downy/hairy woodpecker	1.6	1.0	0.3	0.5	0.5
Cedar waxwing	1.4	0.0	3.3	2.3	1.5
Rose-breasted grosbeak	1.2	0.4	0.7	0.0	0.5
Red-winged blackbird	1.2	0.0	0.0	0.3	1.0
Ovenbird	1.2	0.0	0.0	0.3	0.0
Indigo bunting	0.8	1.4	2.0	4.3	3.0
American robin	0.6	0.0	0.7	1.3	2.0
Veery	0.4	0.2	1.0	0.3	0.5
Red-bellied woodpecker	0.2	1.2	2.3	1.3	2.5
Gray catbird	0.0	1.0	2.7	1.8	3.5
Northern flicker	0.0	0.8	1.3	0.5	0.5
Brown-headed cowbird	0.0	0.2	0.7	1.3	0.0
Common yellowthroat	0.0	0.0	1.3	2.0	0.5
Chestnut-sided warbler	0.0	0.0	1.0	1.5	4.5
Rufous-sided towhee	0.0	0.0	1.0	0.0	0.0
Others[a]	0.4	1.2	1.2	1.9	1.5
Total individuals	37.6	34.2	44.4	42.0	44.5
Total no. species	22	24	28	28	25
Groups[b]					
Cavity users	3.6	3.2	4.6	2.8	4.5
Cavity nesters	10.4	11.4	9.0	9.1	12.0
Ground foragers	4.2	3.8	10.6	10.7	10.5
Foliage gleaners	7.2	9.2	13.7	9.8	13.5
Forest interior species	6.8	7.4	7.4	6.6	3.5
Intermediate species	23.6	23.2	31.6	26.9	32.5
Forest edge species	7.2	3.6	5.4	8.5	8.5

* Five censuses in 1981-82, 3 in 1983, 4 in 1984, 2 in 1985.
** See Appendix A for scientific names.
[a] Includes individual species that averaged less than 1.0 individual/census in all years.
[b] See Methods section in text and Appendix B for definition of groups.

Table 14. *Average number of birds encountered per census* in Stand 2, a control woodlot, 1981-85.*

Species or Group	1981	1982	1983	1984	1985
Species**					
Blue jay	8.0	7.0	4.3	7.5	7.0
Eastern wood-pewee	4.6	1.6	2.0	4.3	3.0
Red-eyed vireo	3.8	4.0	2.0	3.8	1.5
Northern cardinal	3.6	0.8	1.0	0.8	0.0
Black-capped chickadee	3.4	1.8	1.0	1.0	2.5
Great crested flycatcher	3.2	3.0	0.7	1.5	1.0
Downy/hairy woodpecker	3.0	1.4	2.7	0.8	0.0
Scarlet tanager	2.0	3.0	1.7	2.3	2.5
White-breasted nuthatch	2.0	0.8	0.7	2.3	1.5
Indigo bunting	1.8	0.0	0.0	0.0	0.0
Rose-breasted grosbeak	1.4	0.2	0.0	0.0	0.0
Cedar waxwing	1.0	0.6	4.7	2.3	3.0
Wood thrush	1.0	0.6	1.7	0.8	1.0
Red-headed woodpecker	1.0	0.4	0.3	1.0	0.0
Northern flicker	0.6	0.8	0.3	1.0	1.0
Ovenbird	0.2	1.2	1.3	0.0	0.0
Red-bellied woodpecker	0.2	1.0	1.0	1.0	0.0
Common grackle	0.2	0.2	1.7	0.8	0.0
Yellow-billed cuckoo	0.0	0.2	0.0	1.0	0.0
American robin	0.0	0.0	0.3	1.8	0.5
Others[a]	1.8	2.4	1.3	3.4	1.0
Total individuals	42.8	31.0	28.7	37.4	25.5
Total no. species	22	24	20	23	13
Groups[b]					
Cavity users	4.8	3.6	4.3	3.8	1.0
Cavity nesters	13.4	9.2	6.7	8.6	6.0
Ground foragers	3.4	2.8	4.0	3.1	1.0
Foliage gleaners	11.6	9.6	9.4	9.4	9.5
Forest interior species	4.2	5.2	3.7	5.1	4.0
Intermediate species	34.4	24.0	22.4	27.1	20.5
Forest edge species	4.2	1.8	2.6	4.7	1.0

* Five censuses in 1981-82, 3 in 1983, 4 in 1984, 2 in 1985.
** See Appendix A for scientific names.
[a] Includes individual species that averaged less than 1.0 individual/census in all years.
[b] See Methods section in text and Appendix B for definition of groups.

Table 15. *Average number of birds encountered per census* in Stand 3, prior to (1982-83) and after (1984-85) logging.*

Species or Group	1982	1983	1984	1985
Species**				
Blue jay	2.6	1.0	2.0	1.0
Red-eyed vireo	1.4	1.7	1.5	0.5
Gray catbird	1.2	1.3	0.8	1.0
Great crested flycatcher	1.2	0.7	0.8	1.0
White-breasted nuthatch	1.2	0.7	0.5	1.0
Red-bellied woodpecker	1.2	0.7	0.0	0.0
Common grackle	1.0	1.3	0.0	0.0
Eastern wood-pewee	1.0	0.7	1.5	2.0
Northern cardinal	0.8	0.3	0.0	1.0
Downy/hairy woodpecker	0.6	0.7	1.5	1.0
Scarlet tanager	0.6	0.0	1.0	0.5
Red-headed woodpecker	0.4	1.0	0.0	0.0
Northern flicker	0.2	0.7	1.0	0.5
Cedar waxwing	0.2	0.0	0.0	1.5
Ovenbird	0.2	0.0	0.0	1.5
Black-capped chickadee	0.0	0.3	0.3	3.0
Wood thrush	0.0	0.0	1.0	1.0
Rufous-sided towhee	0.0	0.0	1.0	0.0
Others[a]	0.2	2.6	0.6	1.5
Total individuals	14.0	13.7	13.5	18.0
Total no. species	16	19	14	17
Groups[b]				
Cavity users	2.4	3.1	2.5	1.5
Cavity nesters	4.8	4.8	4.1	6.5
Ground foragers	1.4	1.9	3.1	4.0
Foliage gleaners	2.2	2.0	2.8	5.5
Forest interior species	2.0	0.7	1.5	3.0
Intermediate species	10.4	8.7	11.4	14.0
Forest edge species	1.6	4.3	0.6	1.0

* Five censuses in 1982, 3 in 1983, 4 in 1984, 2 in 1985.
** See Appendix A for scientific names.
[a] Includes individual species that averaged less than 1.0 individual/census in all years.
[b] See Methods section in text and Appendix B for definition of groups.

Table 16. *Average number of birds encountered per census* in Stand 4, a control woodlot, 1982-85.*

Species or Group	1982	1983	1984	1985
Species**				
Red-eyed vireo	8.0	9.0	8.5	11.0
White-breasted nuthatch	4.6	3.0	5.3	7.5
Scarlet tanager	4.6	1.0	6.0	2.0
Blue jay	4.4	7.0	2.3	0.5
Black-capped chickadee	4.4	2.0	5.5	3.0
Eastern wood-pewee	3.8	6.5	11.0	7.0
Red-headed woodpecker	2.8	3.0	1.3	1.0
Downy/hairy woodpecker	2.8	2.0	2.0	2.0
Northern cardinal	2.6	1.5	4.5	1.0
Great crested flycatcher	2.4	5.5	5.5	4.0
Northern flicker	2.2	1.0	1.5	1.5
Brown-headed cowbird	2.0	0.0	0.3	0.0
Red-bellied woodpecker	1.6	0.5	0.0	1.0
Ovenbird	1.2	0.0	0.3	0.5
Acadian flycatcher	0.6	3.0	0.3	0.0
Gray catbird	0.6	1.0	2.3	1.5
Cedar waxwing	0.4	2.0	0.3	3.5
Eastern phoebe	0.4	0.0	0.0	3.0
American robin	0.2	0.0	2.8	2.5
Yellow-billed cuckoo	0.2	0.0	1.0	0.0
Blue-gray gnatcatcher	0.0	4.0	3.3	2.5
Cerulean warbler	0.0	2.5	2.3	5.0
Common yellowthroat	0.0	1.5	0.0	0.5
Unknown woodpecker	0.0	0.0	0.0	1.0
Others[a]	3.8	1.0	2.0	2.0
Total individuals	53.6	57.0	68.8	63.5
Total no. species	31	20	26	25
Groups[b]				
Cavity users	9.4	6.6	5.8	6.5
Cavity nesters	20.8	17.1	22.1	21.0
Ground foragers	2.4	1.0	4.3	5.5
Foliage gleaners	17.6	14.0	20.3	20.0
Forest interior species	11.0	9.5	14.5	15.5
Intermediate species	35.4	42.5	48.8	42.5
Forest edge species	7.6	5.0	5.0	5.5

* Five censuses in 1982, 2 in 1983, 4 in 1984, 2 in 1985.
** See Appendix A for scientific names.
[a] Includes individual species that averaged less than 1.0 individual/census in all years.
[b] See Methods section in text and Appendix B for definition of groups.

Table 17. *Average number of birds encountered per census* in Stand 5, prior to (1982-83) and after (1984-85) logging.*

Species or Group	1982	1983	1984	1985
Species**				
Northern flicker	1.6	0.0	0.0	1.0
Wood thrush	1.4	1.0	0.8	0.5
Downy/hairy woodpecker	1.0	1.0	0.8	1.0
Gray catbird	0.8	1.5	1.3	0.0
Great crested flycatcher	0.8	1.0	0.5	1.0
Northern cardinal	0.8	0.5	1.0	0.5
Eastern wood-pewee	0.6	1.0	0.8	2.0
Blue jay	0.4	2.0	0.8	1.0
Red-bellied woodpecker	0.4	0.5	0.0	1.0
House wren	0.0	2.0	0.0	0.0
European starling	0.0	1.5	0.5	0.0
American robin	0.0	1.0	1.0	0.5
Others[a]	1.6	1.0	2.7	1.5
Total individuals	9.4	14.0	10.2	10.0
Total no. species	12	13	16	12
Groups[b]				
Cavity users	3.0	1.5	0.8	3.0
Cavity nesters	4.6	2.5	2.1	4.5
Ground foragers	2.4	2.5	2.7	0.5
Foliage gleaners	0.0	1.0	1.5	0.5
Forest interior species	0.8	0.5	0.8	0.5
Intermediate species	8.0	9.0	7.1	8.5
Forest edge species	0.6	4.5	2.3	1.0

* Five censuses in 1982, 2 in 1983, 4 in 1984, 2 in 1985.
** See Appendix A for scientific names.
[a] Includes individual species that averaged less than 1.0 individual/census in all years.
[b] See Methods section in text and Appendix B for definition of groups.

Abundance of most bird species groups was not very similar among the 5 woodlots before logging. Densities of cavity users or ground foragers were not correlated ($P > 0.05$) between any of the woodlots. Densities of cavity nesters were only correlated between Stands 1 and 4, while densities of forest edge habitat species were only correlated between Stands 1 and 3. Densities of foliage gleaners were correlated among Stands 2, 3, and 4 (Table 18). Densities of forest interior habitat species were correlated among Stands 1, 3, and 5 and between Stands 1 and 2 (Table 18); this group in Stand 4 was not similar to any other woodlot, mainly because of the abundance of acadian flycatcher and cerulean warbler in Stand 4. Densities of intermediate forest habitat species were correlated among all woodlots except between Stands 1 and 5, and Stands 4 and 5 (Table 18); these exceptions were mainly due to the greater abundance of northern flicker, gray catbird, and wood thrush in Stand 5 and were probably related to the small woodlot size.

Logging Effects. Forty-five bird species and 9 species groups were analyzed in GLM-1, and no year effects were found ($P > 0.05$). Only 1 species showed a year-by-stand type interaction effect ($P < 0.05$) related to the logging years: rufous-sided towhee was positively impacted but only in the first year after logging in Stands 3 and 5. This species has been associated with dense shrubby cutover areas or grassy openings in Wisconsin (Mossman and Lange 1982), conditions similar to the 2 logged stands. The few effects found with GLM-1 were probably the result of the extremely low sample sizes when the data were analyzed in a balanced ANOVA.

The same species and species groups were analyzed in GLM-2. Only eastern wood-pewee showed a year effect ($P < 0.05$), increasing during 1982-85. Only 2 species showed year-by-stand type interaction effects ($P < 0.05$) related to the logging years: eastern phoebe and ovenbird. Eastern phoebe increased dramatically on the control woodlots in the second year after logging, but was never encountered

Table 18. *Summary of Pearson Correlation Coefficients of bird species densities calculated between each pair of woodlots before logging.*

	Stand No.			
Stand No.	**2**	**3**	**4**	**5**
Total species densities				
1	.950**	.890**	.899**	.697**
2		.919**	.916**	.758**
3			.877**	.801**
4				.701**
Foliage gleaner species densities				
1	.844	.844	.830	.876
2		.921*	.930*	.713
3			.965**	.833
4				.698
Forest interior habitat species densities				
1	.945**	.938**	.495	.878*
2		.806	.413	.752
3			.692	.972**
4				.715
Intermediate forest habitat species densities				
1	.916**	.547*	.717**	.427
2		.705**	.756**	.478*
3			.668**	.608**
4				.386

* Correlation between the pair of woodlots ($P < 0.05$).
** Strong correlation between the pair of woodlots ($P < 0.01$)

on logged woodlots, suggesting that the logged habitat was unsuitable for this species. The availability of nest sites, including human-associated sites, is generally more important to this species than vegetation features (Mossman and Lange 1982), so this result is unexplained. Ovenbird was positively impacted in the second year after logging, but the impact only occurred in Stand 3 and was unexpected.

Because there were few year effects, I analyzed 47 species and 9 species groups in GLM-3, which included Stand 1 and ignored calendar year. There was little agreement among results from the 3 cut woodlots in the first 2 years after logging. Eleven species and 3 species groups showed time-by-stand interaction effects ($P < 0.05$) related to logging years. Only 2 species and the factor of species diversity showed consistent results for all 3 logged woodlots (Table 19). Eastern wood-pewee was negatively impacted in all 3 logged woodlots in the first year, and eastern phoebe was negatively impacted in the second year after logging. The negative impact on wood-pewee follows their known preference to forage under the canopy of mature deciduous forests in Wisconsin (Mossman and Lange 1982). Red-bellied woodpecker was positively impacted in the second year after logging in Stands 1 and 5 but not in Stand 3. This species occurs in habitats with a semi-open canopy and high oak *IV* in Wisconsin (Mossman and Lange 1982); logging increased the former but reduced the latter. Species diversity for all 3 logged woodlots was positively impacted in the second year after logging.

Logging in Stand 1 affected 5 bird species and 1 species group differently than in Stands 3 and 5 (Table 19). Ovenbird and veery were negatively impacted in the first year after logging in Stand 1. Ovenbird is associated with larger and more mature forests in Wisconsin (Bond 1957), which corresponds to the findings in this report. Chestnut-sided warbler, veery, American goldfinch, common yellowthroat, and the ground forager group were positively impacted in the second year after logging in Stand 1. Veery prefers dense shrubs or understory (Mossman and Lange 1982), which were initially reduced, then increased following logging. The other 3 species have all been associated with shrubby forest edges or openings in Wisconsin, which would increase with logging.

Logging in Stand 3 affected 4 bird species differently than in Stands 1 and 5 (Table 19). Common yellowthroat was negatively impacted unexpectedly in the first year after logging in Stand 3. Black-capped chickadee, ovenbird, and song sparrow were positively impacted in the second year after logging in Stand 3. Song sparrow is associated with shrubby edges (Mossman and Lange 1982), which increased with logging. Black-capped chickadee, however, is a generalist species and would not be expected to increase on logged areas.

Logging in Stand 5 affected 2 bird species and 2 species groups differently than in Stands 1 and 3 (Table 19). Cavity users were negatively impacted in the first year after logging, ground foragers were negatively impacted in the second year after logging, and wood thrush was negatively impacted in both of the first 2 years after logging in Stand 5. Wood thrush has been associated with small openings within woodlots having high percentages of canopy coverage (Mossman and Lange 1982); thrush would decline, therefore, after logging opens up the canopy. Eastern wood-pewee was positively impacted in the second year after logging in Stand 5, which was unexpected.

By listing characteristics of the bird species that were impacted (Table 20), some additional relationships of their feeding guild and forest habitat utilization with timber cutting can be seen. Ground foragers showed a negative response when treetops were left on the ground after logging (year 1 in all stands, year 2 in stand 5), but a more positive response after removal of downed treetops (year 2, stands 1 and 3). The few "forest edge" and foliage gleaner species that were impacted were always positively impacted and only in year 2. Aerial feeders were generally negatively impacted, whereas intermediate habitat species showed a mixed response to cutting.

Forty-two species and 9 species groups were analyzed in GLM-4, which included only Stands 1 and 2 for which I had data for 4 years after logging. Twelve species and 2 species groups showed time-by-stand interaction effects ($P < 0.05$), and the effect for all but 1 species was related to logging. The only negative bird response was by ovenbird in the first 2 years after logging (Table 21). Indigo bunting showed a positive response in all 4 years after logging. Gray catbird, chestnut-sided warbler, ground foragers, and species diversity all showed a positive response in years 2 through 4 after logging. Common yellowthroat showed a positive response in years 2 and 3 after logging. The latter 4 species all have been associated with dense shrub openings or cutover areas in Wisconsin (Mossman and Lange 1982). Rufous-sided towhee, mourning warbler, brown-headed cowbird, black-capped chickadee, song sparrow, and sedge wren all showed a positive response only in individual years after logging, indicating spurious results for these species. Most of these species have been associated with forest edges or openings. Ground foragers showed a negative response when treetops were left on the ground after logging, but a more positive response after removal of downed treetops (Table 21).

Discussion

Interpretation of Study Results

The few consistent results among the 3 cut woodlots suggest that logging applied at different levels in each of the 3 woodlots had a different effect on the birds of each woodlot. Other explanations for the inconsistent results among woodlots seem unlikely. Controls were used to correct natural factors outside the logged woodlots, and no management took place in woodlands surrounding the study woodlots. Small sample sizes and high sampling variability of individual bird species could mask true changes, and the erratic findings seem to fit the idea of chance occurrences. However, sampling variability would be less of a problem when dealing with species groups, which have larger sample sizes.

Logging intensity was highest in Stand 1, lowest in Stand 5, and was intermediate in Stand 3. Surveys of logging impacts on the vegetation verified this pattern, while the overall response by birds in the first 2 years after logging did not.

Total bird abundance was not affected by logging in any of the woodlots. Abundance according to foraging guild and forest habitat utilization was also not affected by logging except for ground foragers, which increased in the second year after logging Stand 1 and decreased in the second year after logging Stand 5. The only effect on abundance according to intensity of cavity needs was the decrease of cavity users in the first year after logging Stand 5.

Bird species diversity increased similarly in all 3 logged woodlots and was not related to logging intensity. There were changes in species composition of the bird communities due to logging that corresponded to logging intensity. More species were impacted in Stand 1 (8 species) than in Stands 3 (6 species) and Stand 5 (4 species). About the same number of species increased as decreased in abundance in each woodlot, although the response appeared more positive as logging intensity increased. Five species increased and 4 species decreased in Stand 1 during the first 2 years after logging. Three species increased and 3 species decreased in Stand 3 during the first 2 years after logging. Two species increased and 3 species decreased in Stand 5 during the first 2 years after logging (Table 19).

Complicating the interpretation of impacts due to logging intensity was the removal of downed treetops in Stand 1 (completed during year 1) and Stand 3 (completed during years 1 and 2) but not in Stand 5. If birds responded to the overall level of habitat changes, bird community changes should have taken place fastest in Stand 1 and slowest in Stand 5. The data did not support this idea, however.

The cutting intensity and vegetation surveys indicated that Stands 3 and 5 were most similar, Stands 1 and 5 were least similar, and similarity between Stands 1 and 3 was intermediate. Bird responses did not parallel these vegetational similarities among stands. There was no greater similarity in bird responses between any pairs of woodlots. Unfortunately, forest vegetation structure was not measured, yet it has been shown to be more important than plant species composition to breeding birds (MacArthur et al. 1962); comparisons of the *IV* of the woodlots' vegetation may not adequately compare their vegetation structure and may therefore confuse interpretation.

Two species showed opposite responses between Stands 1 and 3. Ovenbird decreased in Stand 1 in the first year after logging but unexpectedly increased

Table 19. *Bird species* and species groups** that were impacted[a] in the first 2 years after logging.*

Years After Logging	Stand No. 1		Stand No. 3		Stand No. 5	
	Positive Response	Negative Response	Positive Response	Negative Response	Positive Response	Negative Response
1		eastern wood-pewee veery ovenbird		eastern wood-pewee common yellowthroat		eastern wood-pewee wood thrush cavity users
2	no. species red-bellied woodpecker chestnut-sided warbler veery American goldfinch common yellowthroat ground foragers	eastern phoebe	no. species black-capped chickadee ovenbird song sparrow	eastern phoebe	no. species red-bellied woodpecker eastern wood-pewee	eastern phoebe wood thrush ground foragers

* See Appendix A for scientific names.
** See Methods section in text and Appendix B for definition of groups.
[a] Time-by-stand interaction effect from GLM-3 ($P < 0.05$).

Table 20. *Characteristics of bird species that were impacted* in the first 2 years after logging.*

Stand No. and Year After Logging**	Positive Impact		Stand No. and Year After Logging	Negative Impact	
	Feeding Guild[a]	Forest Habitat		Feeding Guild[a]	Forest Habitat
1-2	GRFOR	Interior	1-1	GRFOR	Interior
3-2	GRFOR	Interior	1-1	GRFOR	Interior
1-2	GRFOR	Intermediate	3-1	GRFOR	Intermediate
1-2	GRFOR	Edge	5-1 and 2	GRFOR	Intermediate
3-2	GRFOR	Edge	All-1	Aerial	Intermediate
1-2	FOLGL	Intermediate	All-2	Aerial	Intermediate
3-2	FOLGL	Intermediate			
5-2	Aerial	Intermediate			
1 and 5-2	Driller	Intermediate			

* Time-by-stand interaction effect from GLM-3 ($P < 0.05$).
** Example: 1-2 means stand no. 1, 2 years after logging.
[a] GRFOR = ground forager; FOLGL = foliage gleaner.

Table 21. *Bird species* and species groups** that were impacted[a] in the first 4 years after logging in Stand 1.*

Years After Logging	Positive Response	Negative Response
1	indigo bunting	ovenbird
2	no. species indigo bunting gray catbird chestnut-sided warbler ground foragers common yellowthroat rufous-sided towhee	ovenbird
3	no. species indigo bunting gray catbird chestnut-sided warbler ground foragers common yellowthroat mourning warbler brown-headed cowbird	
4	no. species indigo bunting gray catbird chestnut-sided warbler ground foragers black-capped chickadee song sparrow sedge wren	

* See Appendix A for scientific names.

** See procedures section in text and Appendix B for definition of groups.

[a] Time-by-stand interaction effect from GLM-4 ($P < 0.05$).

in Stand 3 in the second year after logging. Common yellowthroat unexpectedly decreased in Stand 3 in the first year after logging but increased in Stand 1 in the second year after logging. Differences in the intensity of logging between the 2 stands may have been responsible for these opposite responses; however, neither of these species' responses are consistent for both years of study within each of the 2 woodlots. One or both of the conflicting responses are probably due to sampling variation. The opposite response by eastern wood-pewee in the first 2 years after logging Stand 5 is probably due to a change over time. The negative response by pewee in year 1 occurred in all 3 woodlots but was not present in any woodlot in year 2.

Pooling all 3 logged stands in each year showed a more negative response to logging in year 1 than in year 2. All of the impacts documented in year 1 were negative, affecting 5 species and the cavity user group in the woodlots. Nine species, the ground forager group, and species diversity were positively impacted, and 2 species and the ground forager group were negatively impacted in year 2 in the woodlots. Logging appeared to disrupt the bird community for the first year, with logging benefits showing up the second year. Data from Stand 1 indicate that this general positive bird response in year 2 would continue through years 3 and 4. No negative responses were found in years 3 or 4. Only 1 species showed a positive response in year 1, but 5, 6, and 6 species showed a positive response in years 2, 3, and 4, respectively.

There were several differences between results of GLM-3 and GLM-4 for Stand 1 in years 1 and 2. This is due to the exclusion of 1 of the 2 control woodlots in GLM-4 and indicates instability of some results. However, Stand 2 is geographically closer to and more similar in plant and bird communities to Stand 1 than Stand 4; Stand 2 may therefore function more accurately as a control for annual variability in bird abundance.

Comparison With Other Studies

No other studies have reported evaluating similar timber cutting on small oak woodlots. Most studies in this subject area have involved the logging of non-oak forest types or the use of different cutting schemes, usually clear-cutting deciduous forests.

The most comparable study was by Webb et al. (1977), who worked in a northern hardwood forest in New York; their 25% and 50% logging intensities are comparable to the range of cutting in my study, although they worked in a large forest (1,500 acres). Eleven species were present in both studies for comparison, and there was general agreement between results. Chestnut-sided warbler increased in their study and in Stand 1 of my study. Ovenbird was reduced in their 50% logged stand but was unaffected by less intensive logging. In my study heavy logging (Stand 1) also reduced ovenbird, while light logging (Stand 3) increased ovenbird in 1 of 2 years. Wood thrush in the New York study was reduced by light logging but was only slightly reduced by 50% logging. Lighter logging also reduced wood thrush abundance in my study, while heavy logging showed no effects. Five species showed no responses to logging in either my study or the New York study (blue jay, scarlet tanager, rose-breasted grosbeak, red-eyed vireo, and white-breasted nuthatch). Two species (black-capped chickadee and veery) showed no responses in the New York study and weak or mixed responses to logging in my study. Eastern wood-pewee showed no significant response and only minor negative trends in the New York study. In my study, this species showed a negative response in all 3 woodlots in the first year but no response in the second year after logging. The different results may be because Webb et al. studied woods 1-8 years after logging, and a negative response in year 1 would be masked in an average of 1-8 years of post-logging data. Logging increased bird species diversity both in my study and the New York study.

Whitcomb et al. (1977) compared bird abundance 4-5 years after logging a 53-acre North American tulip tree – oak woodlot in southern Maryland with that of a nearby undisturbed woodlot of similar vegetation and size, although they did not quantify the logging intensity. They concluded that logging increased bird species diversity, abundance of edge species (rufous-sided towhee, indigo bunting, white-eyed vireo, mourning dove, and northern flicker) and abundance of some forest interior species (hooded warbler, Kentucky warbler, and northern cardinal), but decreased abundance of red-eyed vireo, ovenbird, and wood thrush. These results generally agree with my findings for comparable species, except that I did not find the negative response by red-eyed vireo.

Robbins (1949) compared the bird abundance of 4 stands of northern red oak – red maple at different stages after selective logging in western Maryland. He concluded that the blue-throated green warbler, red-eyed vireo, and ovenbird were negatively impacted by logging with ovenbird being least affected. Species diversity and total bird abundance increased just after logging, especially benefitting the chestnut-sided warbler, rufous-sided towhee, Canada warbler, hooded warbler, and common yellowthroat. These results agree with mine for comparable species except, again, for red-eyed vireo. Robbins documented continual increases in species diversity and total bird abundance through 12 years after logging, when the canopy species had mostly returned and the young growth species were still present.

Other researchers have predicted logging impacts on species or species groups, but these are often in reference to cutting larger forests. The cutting scheme used in all 3 stands of my study was even-age management. Stand 1 was clearcut in patches, while stands 3 and 5 were shelterwood harvests. Temple et al. (1979) and Maurer et al. (1981) predicted that these management approaches should increase bird species diversity, and Tilghman (1977) and Probst (1979) predicted greater diversity from increases in shrubs. My data support these predictions. Tilghman (1977) predicted greater diversity from lighter cutting, and my data support this. Johnston (1970), Anderson (1979), and Probst (1979) predicted total bird abundance to increase after logging, while Maurer et al. (1981) and Dingledine and Haufler (1983) predicted decreases. My data show no support for either prediction, as total bird abundance was unchanged by logging.

Cavity users and nesters can increase or decrease depending on cutting intensity and density of remaining cavity trees (Anderson 1979, Noon et al. 1979, Dingledine and Haufler 1983, Maurer et al. 1981). My quantification of cavities was poor and adds little explanation to the lack of differences I found.

There is disagreement about whether aerial feeders should increase (Anderson 1979, Probst 1979) or decrease after logging (Noon et al. 1979). The negative responses by 2 aerial feeders (eastern wood-pewee in year 1 and eastern phoebe in year 2) were the clearest results in my study.

The literature predicted that ground foragers will increase after logging unless ground cover becomes too dense (Probst 1979, Maurer et al. 1981, Tilghman 1977). My data support this, showing a negative response when treetops were left on the ground after logging but a more positive response after removal of downed treetops. Five of the 9 species that showed positive responses were ground foragers, and these were all in Stands 1 and 3 in year 2 when treetops were removed. Four of the 6 species that showed negative responses also were ground foragers, but these were all in Stand 5 or in Stands 1 and 3 in year 1, when treetops were still on the ground. Ground foragers as a group responded positively to logging in Stand 1 in year 2, and negatively to logging in Stand 5.

Noon et al. (1979) and Maurer et al. (1981) predicted that foliage gleaners would increase after logging. My data weakly supported this idea. The only response by foliage gleaners was positive for 2 species.

Forest interior species should decrease, while forest edge species should increase with the conversion of interior habitat to new edge (Robbins 1979). My data weakly support these ideas for forest edge species but not for forest interior species. The only response by forest edge species was positive for 2 species. Only 2 forest interior species showed responses (ovenbird and veery) and these were conflicting, as discussed earlier. However, neither forest edge or interior species responded as a group to logging.

Summary

1. The impacts of timber sales and firewood cutting on breeding birds in southern Wisconsin woodlots were studied from 1981-85 on 5 oak or ash-oak woodlots located on 2 wildlife areas in Dane and Jefferson counties, Wisconsin. Squirrels were the target management species on these woodlots, and oak was reproducing inadequately to sustain itself. Selective timber cutting took place on 3 of the woodlots to open up the canopy. Treetops were removed through firewood sales within 2 years (Stands 1 and 3) or were left on the ground (Stand 5). Two stands (Stands 2 and 4) were left uncut and monitored as controls. Logging intensity was highest in Stand 1 (3.2 mbf/acre, 38% removed), lowest in Stand 5 (2.0 mbf/acre, 21% removed), and was intermediate in Stand 3 (2.9 mbf/acre, 24% removed).
2. Vegetation surveys for all 5 woodlots before cutting revealed that oak was not reproducing adequately and was being replaced by maple, cherry, or elm in the sapling layer. Logging Stand 1 reduced northern red oak importance and the density of total live trees, dead trees, saplings, and tree cavities but increased the density of shrubs and logs. Logging Stand 3 reduced ash tree importance and impacted the woodlot similarly but half as much as Stand 1. Logging Stand 5 had even less impact on the forest.
3. Bird surveys before logging revealed that similarity in bird species among the 5 woodlots was positively related to woodlot size. Logging applied at different levels in each of the 3 woodlots was actually 3 treatments without replication and had different effects on the birds of each woodlot.
4. Total bird abundance was not affected by logging in any woodlot. Bird species diversity increased in the second year after logging in all 3 woodlots.
5. Eastern wood-pewee and eastern phoebe were reduced in the first and second years, respectively, after logging in all 3 woodlots. Red-bellied woodpecker was positively impacted in the second year after logging in Stands 1 and 5 but not in Stand 3.
6. Ovenbird and veery were negatively impacted in the first year after logging in Stand 1. Chestnut-sided warbler, veery, American goldfinch, common yellowthroat, and the ground forager group were positively impacted in the second year after logging Stand 1.
7. Common yellowthroat was negatively impacted in the first year after logging in Stand 3. Black-capped chickadee, ovenbird, and song sparrow were positively impacted in the second year after logging in Stand 3.
8. The cavity user group was negatively impacted in the first year after logging in Stand 5. The ground forager group was negatively impacted in the second year after logging, and wood thrush was negatively impacted in the first 2 years after logging in Stand 5. Eastern wood-pewee was positively impacted in the second year after logging in Stand 5.
9. Cavity nesters were not affected as a group by logging in any of the 3 woodlots. Logging may decrease the rarer forest interior species, although their presence in woodlots less than 50 acres may not represent viable breeding populations.
10. Logging intensity treatment and woodlot size increased together, confusing interpretation of these 2 factors. More species were impacted more positively as logging intensity and woodlot size increased. The species affected appeared to be related to their foraging guild, forest habitat preferences, and the removal of downed treetops after logging. Logging very small woodlots less intensively impacted fewer species and more negatively, although the birds impacted were more common species.
11. Logging effects in all 3 stands became more positive to birds as a whole from year 1 to 2, related to the removal of downed treetops. Data from the only stand followed for 4 years after logging indicated that the positive responses would continue.
12. My results generally agreed with the most comparable study, located in a large northern hardwood forest in New York. Other predictions in the literature about logging impacts on breeding birds showed mixed agreement with my data.

Conclusions and Management Implications

My study evaluated the impacts on breeding birds of logging small oak and ash-oak woodlots in southern Wisconsin. Unfortunately, the logging intensity and woodlot size increased together, confounding these 2 factors. Additional study of many more woodlots would be required to fully address this topic, given the potential for different responses in woodlots with different sizes, structures, and forest types, under different logging intensities. Also, my study only followed bird responses for 1-4 years after logging. These stands could be monitored periodically in the future, to determine longer-term bird responses to logging.

Several generalities emerge from my study and a review of the literature, however. Intensively logging a medium to large-sized woodlot (15+ acres) impacted more bird species positively than less intensive logging of very small woodlots. For the former, increases occurred in ground foragers, foliage gleaners, and forest edge species. Logging very small woodlots less intensively impacted fewer species and more negatively, disrupting birds without adding critical habitat components for new species. However, the birds impacted in logging small woodlots are generally the more common species and reduction in their numbers may be more acceptable.

There is a time lag after logging for overall positive effects to show, related to the removal of downed treetops. This is contrary to the time lag for negative effects to show after fire: species return to burned habitat for a period before finally abandoning it (Emlen 1970, MacClintock et al. 1977). Ground foragers can be hurt by leaving downed treetops on the ground, especially in very small woodlots. Cavity nesters, and woodpecker in particular, can tolerate the logging if snags are not extensively removed. Logging may decrease the rarer forest interior species, although their presence in woodlots less than 50 acres may not represent viable breeding populations (Noon et al. 1979, Butcher et al. 1981).

If the goal of forest management is maximum species diversity and abundance within a woodlot, logging is a compatible management tool. However, if the goal is to maintain maximum species diversity within a larger area (landscape scale), logging may be counter-productive because it may eliminate rarer forest types and hence rarer species; Temple et al. (1979) recommended preservation in these cases.

Notes on Oak Management

The secondary objective of this study was to collect observations on the effects of logging on the regeneration of oak and to suggest possible alternative techniques for oak management. For this study, the short-term impact of logging on birds was generally positive; however, without additional management, the timber cutting used in this study will probably not regenerate oak and may promote non-oak species (Sander 1977, Nyland et al. 1982, Lorimer 1989). Whether or not this will benefit birds in the long term is unknown.

On the cut stands, the forest floor after logging was not open enough for oak seedlings to grow. Dense shrubs dominated the cut areas and will shade out oak reproduction like the original forest canopy did before timber harvest. This understory interference with oak seedling growth is positively related to site quality and needs to be controlled on good sites for successful oak regeneration (Gottschalk 1983, Crow 1988, Lorimer 1989). Mechanical control of understory competitors is labor intensive and may need to be repeated frequently to prevent reinvasion of competitors. Chemical control of understory competitors is also labor intensive and has been used with mixed results (Johnson and Jacobs 1981, Nyland et al. 1982, Gottschalk 1983, Lorimer 1989). The non-selective nature of herbicides makes effective spray application difficult, while sapling and pole-sized competitors require stem injection. Some success has come from using herbicides preceding timber cutting and a year of high acorn production. Artificial regeneration of oak by planting seedlings in conjunction with mechanical and/or chemical treatment is also labor intensive and has met with mixed success (Lorimer 1989).

Fire control of oak competitors is an emerging area in oak management (Rouse 1986). Oak is well adapted to fire, which maintained several original oak-dominated plant communities (Rouse 1986, Crow 1988). Fire reduces shade-tolerant competitors of existing oak seedlings (Lorimer 1985, Rouse 1986, Crow 1988). The frequency and intensity of fires required for management is critical. Low intensity fires may not benefit oak, and a single fire may not be adequate to eliminate competition to oak reproduction. Wydeven (1989) increased oak seedling density and decreased red maple seedling density by burning a northern red oak stand 3 years after a shelterwood harvest of 30% in northeastern Wisconsin; the shelterwood cutting was considered an important part of the treatment, because an uncut stand did not respond as well to burning.

Site differences can greatly affect the success rate in using fire control for management. The liability of damage to adjacent property from an escaped fire, as well as the potential for scarring of merchantable timber, must be considered when using fire for management. Despite the unknowns in using fire for oak management, careful use of fire may hold the most promise for the future of oak woods in south-central Wisconsin.

Appendix A. *Scientific names of plants* and birds** cited in this report.*

Trees

American elm (*Ulmus americana*)
American hophornbeam (*Ostrya virginiana*)
American linden (*Tilia americana*)
Apple (*Malus* spp.)
Ash (*Fraxinus* spp.)
Bigtooth aspen (*Populus grandidentata*)
Bitternut hickory (*Carya cordiformis*)
Black cherry (*Prunus serotina*)
Boxelder maple (*Acer negundo*)
Common hackberry (*Celtis occidentalis*)
Hawthorn (*Crataegus* spp.)
Juniper (*Juniperus* spp.)
North American tulip tree (*Liriodendron tulipifera*)
Northern red oak (*Quercus rubra*)
Pin cherry (*Prunus pensylvanica*)
Quaking aspen (*Populus tremuloides*)
Red maple (*Acer rubrum*)
Serviceberry (*Amelanchier* spp.)
Shagbark hickory (*Carya ovata*)
Slippery elm (*Ulmus rubra*)
Sugar maple (*Acer saccharum*)
White oak (*Quercus alba*)
Willow (*Salix* spp.)

Shrubs

Allegheny blackberry (*Rubus allegheniensis*)
American bittersweet (*Celastrus scandens*)
American filbert (*Corylus americana*)
Blackcap raspberry (*Rubus occidentalis*)
Cathartic buckthorn (*Rhamnus cathartica*)
Common chokecherry (*Prunus virginiana*)
Common poison ivy (*Toxicodendron radicans*)
Common pricklyash (*Zanthoxylum americanum*)
European red elder (*Sambucus racemosa*)
Gooseberry (*Ribes* spp.)
Gray dogwood (*Cornus racemosa*)
Greenbrier (*Smilax* spp.)
Honeysuckle (*Lonicera* spp.)
Mapleleaf viburnum (*Viburnum acerifolium*)
Nannyberry viburnum (*Viburnum lentago*)
Pagoda dogwood (*Cornus alternifolium*)
Rafinesque viburnum (*Viburnum rafinesquianum*)
Red raspberry (*Rubus idaeus*)
Rose (*Rosa* spp.)
Roundleaf dogwood (*Cornus rugosa*)
Silky dogwood (*Cornus amomum*)
Sumac (*Rhus* spp.)
Winterberry holly (*Ilex verticillata*)

Ground Layer

Bedstraw (*Galium* spp.)
Blackberry (*Rubus* spp.)
Black snakeroot (*Sanicula* spp.)
Common anemonella (*Anemonella thalictroides*)
Common mayapple (*Podophyllum peltatum*)
Early meadowrue (*Thalictrum dioicum*)
Elm (*Ulmus* spp.)
Enchanter's nightshade (*Circaea quadrisulcata*)
Feather solomonplume (*Smilacina racemosa*)
Snow trillium (*Trillium grandiflorum*)
Solomon's seal (*Polygonatum canliculatum*)
Sweet cicely (*Osmorhiza claytonii*)
Tickclover (*Desmodium* spp.)
Viney honeysuckle (*Lonicera dioica*)
Virginia creeper (*Parthenocissus quinquefolia*)
Wild cranesbill (*Geranium malculatum*)
Wild sarsasparilla (*Aralia nudicaulis*)
Wood anemone (*Anemone quinquefolia*)

Birds[b]

Acadian flycatcher (*Empidonax virescens*)
American goldfinch (*Carduelis tristis*)
American robin (*Turdus migratorius*)
Black-capped chickadee (*Parus atricapillus*)
Blue-throated green warbler (*Dendroica virens*)
Blue jay (*Cyanocitta cristata*)
Blue-gray gnatcatcher (*Polioptila caerulea*)
Brown-headed cowbird (*Molothrus ater*)
Canada warbler (*Wilsonia canadensis*)
Cedar waxwing (*Bombycilla cedrorum*)
Cerulean warbler (*Dendroica cerulea*)
Chestnut-sided warbler (*Dendroica pensylvanica*)
Common grackle (*Quiscalus quiscula*)
Common yellowthroat (*Geothlypis trichas*)
Downy woodpecker (*Picoides pubescens*)
Eastern phoebe (*Sayornis phoebe*)
Eastern wood-pewee (*Contopus virens*)
European starling (*Sturnus vulgaris*)
Gray catbird (*Dumetella carolinensis*)
Great crested flycatcher (*Myiarchus crinitus*)
Hairy woodpecker (*Picoides villosus*)
Hooded warbler (*Wilsonia citrina*)
House wren (*Troglodytes aedon*)
Indigo bunting (*Passerina cyanea*)
Kentucky warbler (*Oporornis formosus*)
Mourning dove (*Zenaida macroura*)
Mourning warbler (*Oporornis philadelphia*)
Northern cardinal (*Cardinalis cardinalis*)
Northern flicker (*Colaptes auratus*)
Ovenbird (*Seiurus aurocapillus*)
Red-bellied woodpecker (*Melanerpes carolinus*)
Red-eyed vireo (*Vireo olivaceus*)
Red-headed woodpecker (*Melanerpes erthrocephalus*)
Red-winged blackbird (*Agelaius phoeniceus*)
Rose-breasted grosbeak (*Pheucticus ludovicianus*)
Rufous-sided towhee (*Pipilo erythrophthalmus*)
Scarlet tanager (*Piranga olivacea*)
Sedge wren (*Cistothorus platensis*)
Song sparrow (*Melospiza melodia*)
Veery (*Catharus fuscescens*)
White-breasted nuthatch (*Sitta carolinensis*)
White-eyed vireo (*Vireo griseus*)
Wood thrush (*Hylocichla mustelina*)
Yellow-billed cuckoo (*Coccyzus americanus*)

* Names after Scott and Wasser (1980).
** Names after A.O.U. (1983).

Appendix B. *Listing of bird species analyzed within each group.*

Cavity Nesters

- Black-capped chickadee
- Downy/hairy woodpecker
- Great crested flycatcher
- Northern flicker
- Red-bellied woodpecker
- Red-headed woodpecker
- Unknown woodpecker
- White-breasted nuthatch

Cavity Users

- Downy/hairy woodpecker
- Northern flicker
- Red-bellied woodpecker
- Red-headed woodpecker
- Unknown woodpecker

Ground Foragers

- American goldfinch
- Common yellowthroat
- Gray catbird
- Indigo bunting
- Ovenbird
- Rufous-sided towhee
- Song sparrow
- Veery
- Wood thrush

Foliage Gleaners

- Black-capped chickadee
- Cedar waxwing
- Chestnut-sided warbler
- Red-eyed vireo
- Rose-breasted grosbeak
- Scarlet tanager

Interior Forest

- Acadian flycatcher
- Cerulean warbler
- Ovenbird
- Scarlet tanager
- White-breasted nuthatch
- Veery

Intermediate Habitat

- Black-capped chickadee
- Blue jay
- Blue-gray gnatcatcher
- Cedar waxwing
- Chestnut-sided warbler
- Common yellowthroat
- Downy/hairy woodpecker
- Eastern phoebe
- Eastern wood-pewee
- Gray catbird
- Great crested flycatcher
- Mourning warbler
- Northern cardinal
- Northern flicker
- Red-bellied woodpecker
- Red-eyed vireo
- Rose-breasted grosbeak
- Rufous-sided towhee
- Wood thrush
- Yellow-billed cuckoo

Forest Edge

- American goldfinch
- American robin
- Brown-headed cowbird
- Common grackle
- European starling
- House wren
- Indigo bunting
- Red-headed woodpecker
- Red-winged blackbird
- Sedge wren
- Song sparrow
- Unknown sparrow

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