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Wildlife Response to Whole
Tree Harvesting of Aspen

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WILDLIFE RESPONSE TO WHOLE TREE HARVESTING OF ASPEN

By

Dean Earl Beyer

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ABSTRACT

WILDLIFE RESPONSE TO WHOLE TREE HARVESTING OF ASPEN

By

Dean Earl Beyer

Increasing demand for wood chips both as a fuel and for chip products has caused an increased use of whole tree harvesting. To determine the effect of whole tree harvesting on wildlife, 6 experimental plots ($\bar{X}$ = 5.73 ha) were established. Three plots were clearcut during the first 2 weeks of August 1981, using whole tree harvesting procedures. Breeding song bird populations were censused using a spot mapping method. Small mammal populations were determined by monitoring densities of woody shrubs and sprouts <5 cm dbh, frequency of grasses and forbs and percent vertical cover of vegetation and slash. Whole tree harvesting significantly reduced all cover >30 cm. The diversity of the breeding bird community, including both numbers and species, was reduced. Analysis of the small mammal response was confounded by population flucuations which could not be attributed to the treatment.

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INTRODUCTION

The demand for wood, both as a fuel and for wood products, has been steadily increasing in recent years (Houghton and Johnson 1976, Arola and Miata 1981). Rising energy prices and unpredictable energy supplies have caused an increased interest in the use of a less expensive, renewable source of energy such as wood. Although wood fuel cannot supply a large percentage of the nation's energy requirement, it can provide an energy alternative to private industries and individuals (Houghton and Johnson 1976). Bradley et al. (1980) in a study of the potential for energy independence of several northern Michigan and Wisconsin pulp and paper mills, have shown the feasibility and cost effectiveness of wood fuel. Wood fueled electrical generating facilities in Burlington, Vermont and northern Minnesota have also proven operational.

Individuals prefer to use roundwood fuel, particularly hardwoods, to obtain the highest Btu for their money (Blyth and Wilhelm 1975). However, industries can utilize anything that burns, including pulpwood portions of trees, branches, tops, rotten trees, and small sound trees (Bradley et al. 1980). Because of the variability in the form of available wood fuel sources before burning, industries convert all forms into wood chips. Since its introduction in 1971 (Young 1974), whole tree harvesting is the most common cutting technique employed in obtaining wood for fuel. At this date, whole tree harvesting consists of utilizing the entire above ground portions of trees; utilization of the root system is not yet entirely feasible. In most cases the wood is chipped at the cutting site. Areas clearcut using whole tree harvesting techniques have less slash and residue than areas harvested with conventional clearcutting practices. By using whole tree harvesting techniques, the amount of wood obtained from an area may increase by almost 100% (Upper Great Lakes Timber Incorporated 1971).

The response of wildlife populations to conventional clearcutting has been investigated. Dimock (1974) reported that the residual slash remaining after conventional clear-cutting enhances the habitat for many small mammals and birds by providing escape cover, and food in the form of insects which are supported by the slash. Several other researchers have documented the relationship of protective cover and small mammal populations (Eadie 1953, Morris 1955, Lovejoy 1971, M'Closky and Lajoie 1975). Conner and Crawford (1974) observed 2 species of woodpeckers (Picoides pubescens and P. villosus) feeding extensively on the slash of a 1 year old mixed oak clearcut. Conner and Adkisson (1974) reported extensive use of a 1 year old clearcut by nesting bluebirds (Sialis sialis).

The only information to date on wildlife responses to whole tree harvesting was an investigation of small mammal population responses reported by Hahn and Michael (1980). Their study found that whole tree harvesting of a deciduous forest results in a decreased abundance of small mammals. This decrease in abundance persisted until the clearcuts were 6 years old. However, Hahn and Michael could not conclude that the reduction of logging residue (slash) was the inherent factor for the population decline. They suggested factors such as the amount of soil disturbance or vegetation remaining after conventional clearcutting may have produced the differing results between studies. Another possible explanation offered was that the thick vegetative regrowth may have reduced the value of slash. Information on songbird utilization of whole tree harvested areas is completely lacking.

Small mammals and birds were selected for study because of their ecological importance and public interest. Small mammals are usually present in sufficient populations that can be readily sampled and they are often strict habitat selectors. Therefore, changes in species and/or numbers will be indicative of habitat changes. The small mammal community also contains a range of trophic groups (West et al. 1981).

Public interest in songbirds has been steadily increasing in recent years (Zagata 1978). Peterson (1980) has identified 3 roles of birds in western communities. These roles are economical, aesthetic, and ecological. Bruns (1960) and Jackson (1979) have shown the important role of insectivorous birds in pest management. The importance of the aesthetic role of birds is difficult to identify because conclusions are often hampered by intangible and variable results. Because birds have evolved with vegetation they are an integral part of a community (Thomas et al. 1975). Therefore, birds can be important indicators of environmental quality (Graber and Graber 1976).

Because whole tree harvesting is a relatively new technique, little research has been done to determine its effect on wildlife populations. Increasing use of whole tree harvesting to meet energy demands and the increasing importance of wildlife resources makes it important to determine what effect whole tree harvesting has on wildlife populations.

OBJECTIVES

The objective of this study was to examine and evaluate the response of wildlife populations to clearcutting using whole tree harvesting procedures. Specifically, this study investigated potential changes in absolute population densities of breeding birds, relative population densities of small mammals, and species composition and diversity of the small mammal and breeding bird communities. A second objective was to describe changes in vegetative composition and structure which influenced the small mammal and breeding bird communities.

STUDY AREA DESCRIPTION

The study area was a 129.5 ha aspen (Populus spp.) stand owned by Dow Corning Corporation, located in the S ½ of Section 13, T16N, R2E, Mills Township, Midland County, Michigan. The area is approximately 7 km north of Midland (Fig. 1).

The site is in the east-central portion of the lower peninsula and lies within the Saginaw Lake-Border Plain physiographic region (Sommers 1977). The area is drained by the Tittabawassee watershed, which empties into Saginaw Bay.

Soils on the study site are of Lenawee, Ingersoll, Pipestone, Wixom, and Kingsville series. The Lenawee series consist of poorly drained silty clay soils. Soils of the Ingersoll series are poorly drained silty loams. Pipestone, Wixom, and Kingsville series are poorly drained sandy soils. Thus, all but the highest areas are wet for most of the year. These soils are best suited for aspen which have grown 17-20m in 50 years on the site. Topography is gently rolling with slopes ranging from 0-6% (Hutchinson 1979).

The continental-type climate at Midland (43°37'N latitude, 84°15'W longitude) characteristically has larger daily,

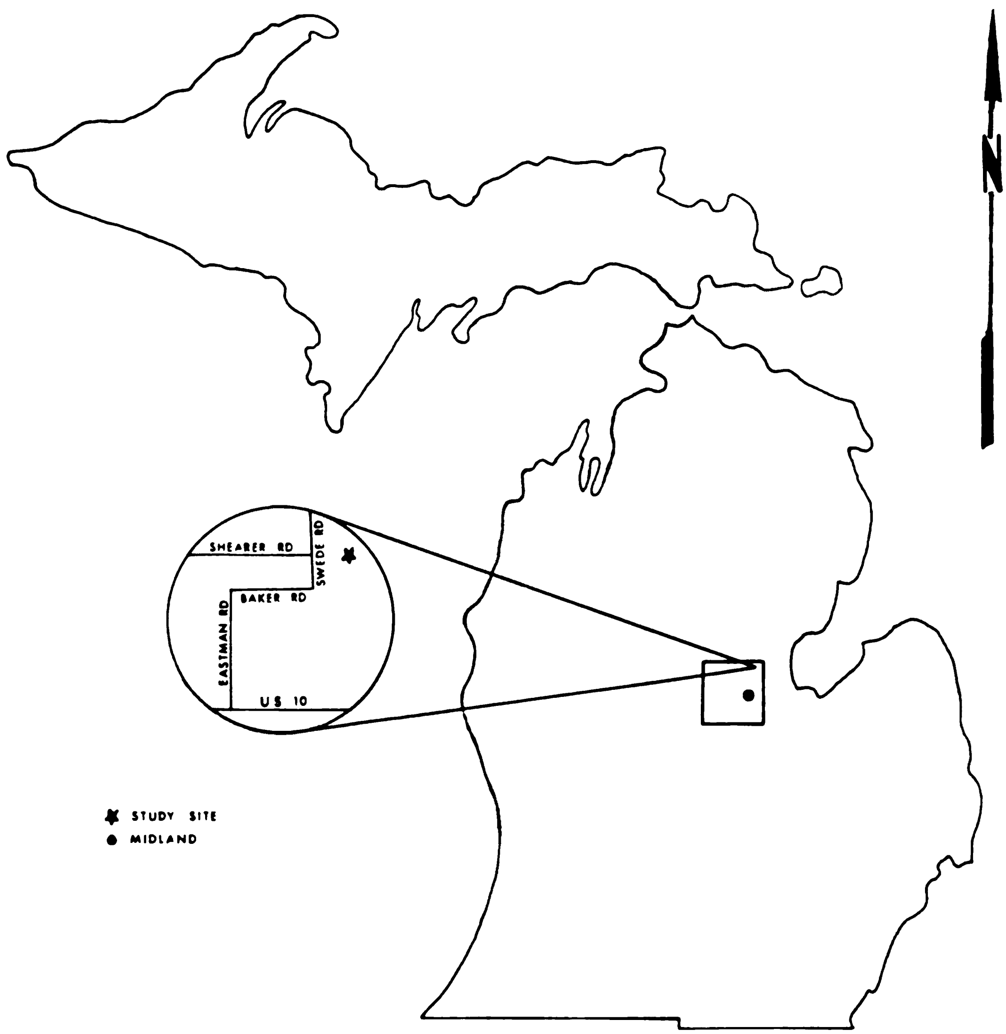


Figure 1. Location of the study area relative to Midland, Midland County, and Michigan.

monthly, and annual temperature flucuations than areas which are at the same latitude, but closer to the Great Lakes. The higher plateau region to the northwest shelters the area from the effect of Lake Michigan. Mean annual temperature for the area is 8.8°C, ranging from a monthly low in January (-4.9°C) to the monthly high in July (22°C). The mean annual precipitation is 75.2cm with 58% of the total received during the crop season of May-October. Mean annual snowfall is 92.2cm, which is approximately half of what is received in the Lake Michigan snowbelt (Michigan Weather Service 1974). Mean monthly temperatures throughout the study period were similar to the long term average, except for lower than normal temperatures in January and February 1982 and higher than normal temperatures in May 1982. Total precipitation received throughout the period was similar to the long term average, although amounts of precipitation received in individual months varied considerably (Figure 2).

Overstory vegetation consisted primarily of bigtooth aspen (*Populus grandidentata*) and quaking aspen (*P. tremuloides*), with fewer numbers of white birch (*Betula papyrifera*), swamp white oak (*Quercus bicolor*), red maple (*Acer rubrum*), basswood (*Tilia americana*), and green ash (*Fraxinus pennsylvanica*). The major understory species were bracken fern (*Peteridium aquilinum*), red raspberry (*Rubus strigosa*), blackberry (*R. alleghaniensis*), dogwood (*Cornus* spp.), speckled alder (*Alnus rugosa*), and black cherry (*Prunus serotina*). Lesser amounts of viburnum (*Viburnum* spp.), juneberry (*Amelanchier*

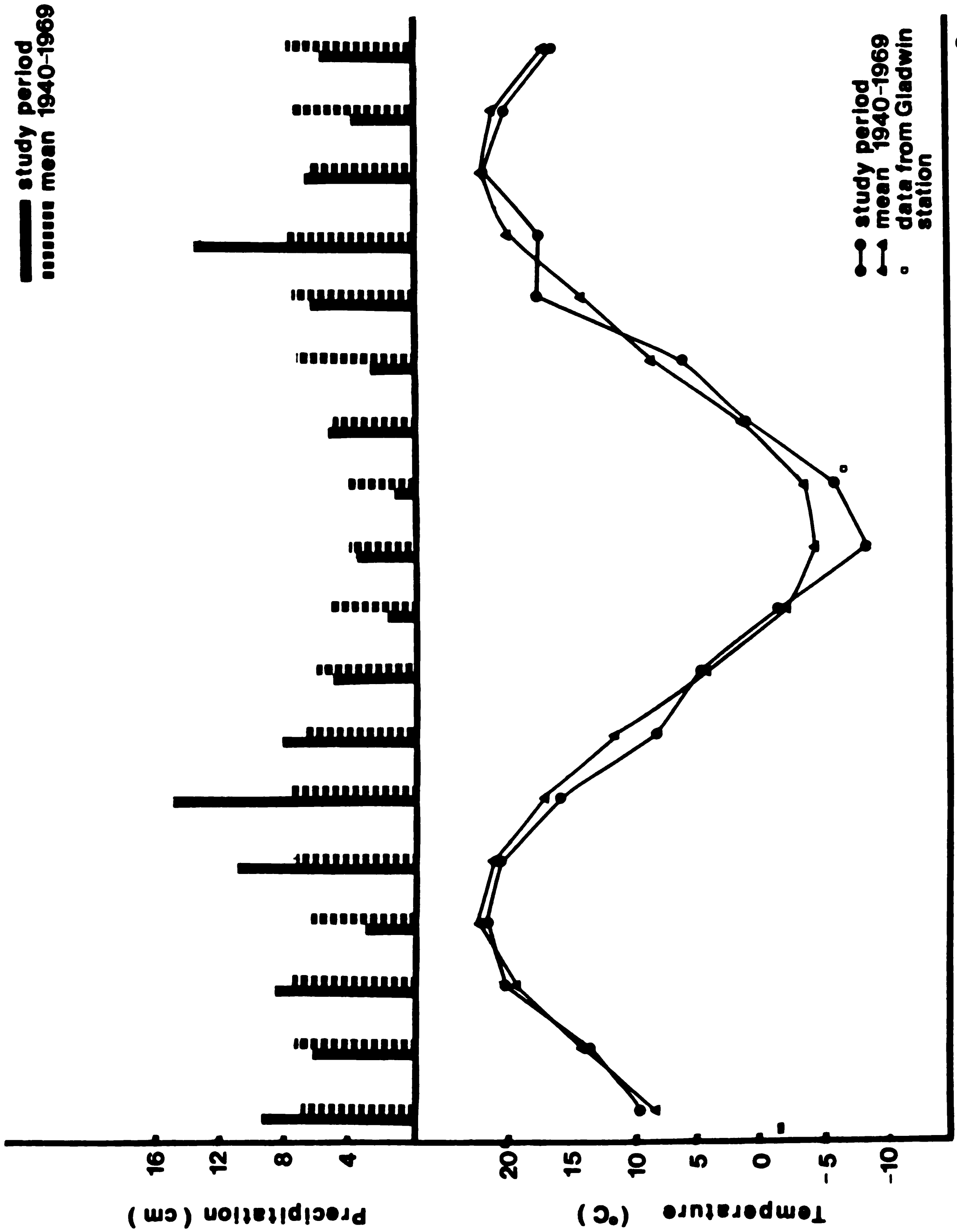


Figure 2. Mean monthly temperatures and total monthly precipitation during April 1981 through September 1982 in Midland County, Michigan.

spp.) and witchhazel (*Hamamelis virginiana*) occurred in a patchy distribution.

METHODS

Six experimental plots were established on the study area (Fig. 3). To insure homogeneity of vegetation among study plots, plot locations and shape were based on the species composition and density of the overstory vegetation. Four rectangular plots, 5.65 ha (201m x 281m) and 2 square plots, 5.81 ha (241m x 241m) were selected under this constraint. Baseline data on these plots were collected from May through July 1981. Plots 2, 4, and 6 were selected for treatment and were clearcut during the first 2 weeks of August 1981, utilizing whole tree harvesting procedures. These plots were selected because of their accessibility by harvesting equipment and tractor trailers. All vegetation 5cm dbh and greater was cut down and chipped, while a majority of the vegetation smaller than 5cm dbh was knocked down by harvesting equipment.

Vegetative Sampling

Vertical cover was measured by the line intercept method (Gysel and Lyon 1980), on randomly located transects within each study plot. Percent cover of vegetation was measured in 4 strata for small mammals: 0-10cm, 10-30cm, 30-100cm, and greater than 1m. These strata were within the ranges

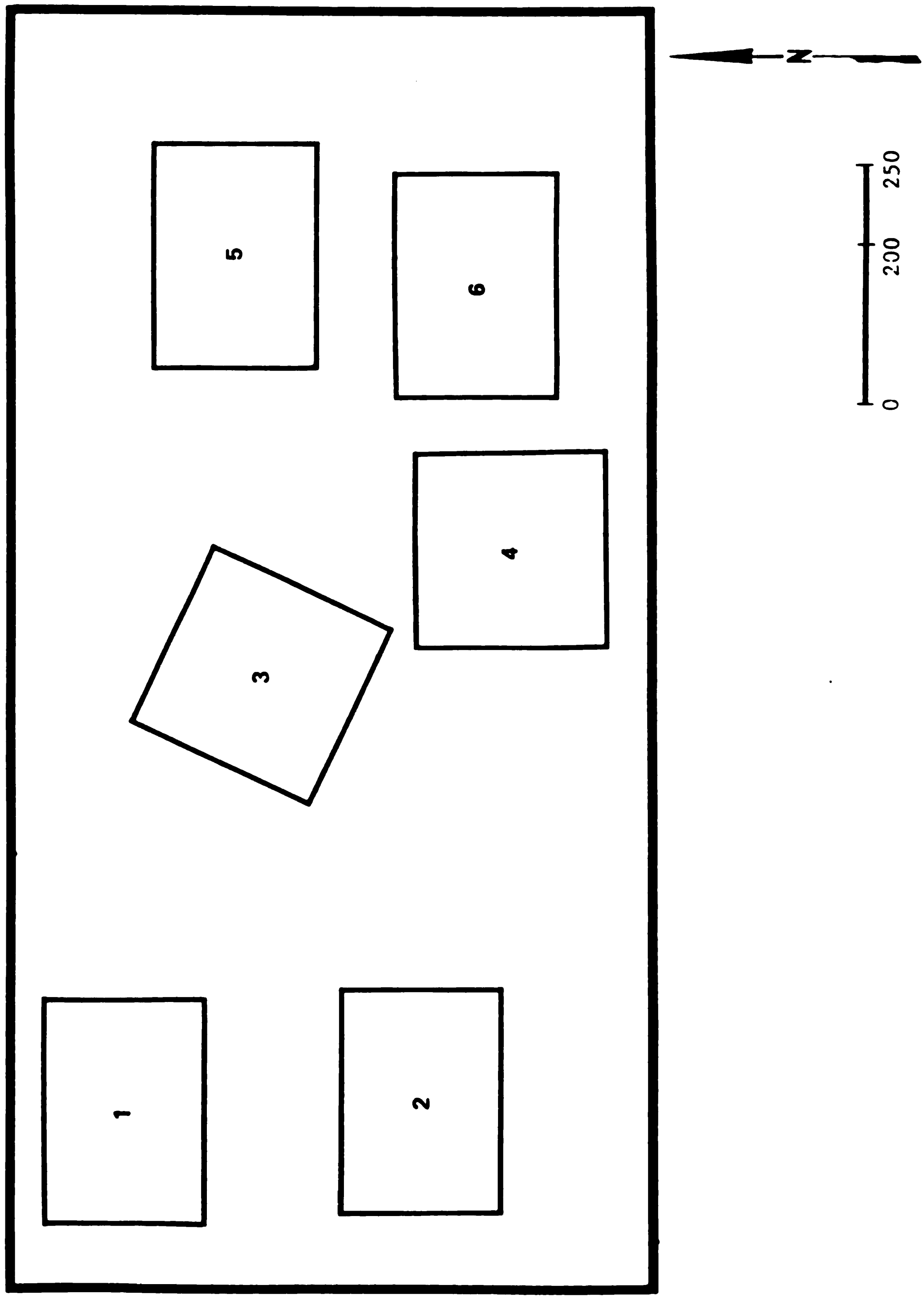


Figure 3. Location of study plots within the study area in Midland County, Michigan.

proposed in the literature (Rosenzweig and Winakur 1969) and corresponded to the plant life forms found on the study site. Three strata were used to measure percent cover for birds: 0-1m, 1-7m, and greater than 7m. Percent cover of slash was measured in a 0-30cm stratum. Using 1 edge of a measuring tape for the line, vegetation contacts were recorded down to 1cm with gaps less than 5cm ignored. Slash contacts 3cm and greater were recorded. Numbers and lengths of transects were varied to meet sample size requirements. In addition to sampling the cover of the study plots, a 40m buffer zone around each plot was also sampled using the line intercept method.

Nested plots were used to determine density of woody shrubs and sprouts, and frequency of grasses and forbs. Grasses were recorded by genera, while forbs and woody vegetation were recorded by species. Frequency of grasses and forbs were recorded in 2m x 25m quadrats and woody shrubs and sprouts 5cm dbh and less were counted in 2m x 30m quadrats. Each study plot and its buffer zone were sampled by randomly locating points which represented a corner of the quadrat.

Sampling of percent cover, frequency of forbs and grasses, and density of woody shrubs and sprouts were conducted on all plots including their buffer zones during June and July 1981, prior to treatment. In 1982, percent cover was estimated during June and July on both treatment and control plots and their buffer zones. Frequency of grasses and forbs, and density of woody shrubs and sprouts were sampled only on the treatment plots in 1982.

Density of trees greater than 5cm dbh was sampled in 10m x 20m quadrats in each of the 3 control plots during May 1982. Species, height, and dbh were recorded for all trees within each quadrat. Relative frequency, relative density, relative dominance, and importance values were calculated for each species (Cox 1976).

Breeding Bird Censusing

Breeding bird populations were censused using a spot-mapping method (International Bird Census Committee 1980). In 1981, censusing began on 27 May and continued through 15 June. Censusing in 1982 began on 11 May and was completed on 16 June. Each plot, including a 40m buffer zone, was flagged at 20m intervals to form a grid which served as a reference for mapping bird territories. The same 2 observers censused the plots in both years. Several trial runs were made together by both observers in order to standardize techniques as much as possible. Censusing began ½ hour after sunrise and continued for approximately 3 hours. Each observer censused 2 plots each morning. The sequence of plots to be sampled was alternated to eliminate biases caused by changes in bird activity throughout the 3 hour period. The starting point within each plot and the observer were also alternated each census. Censuses were not taken on days when it was raining, foggy, or when winds exceeded 32 km/hr. Each plot was censused 8 times in 1981, and 12 times in 1982. Following censusing each morning, individual birds were followed to locate nests and further delineate territories. International Bird Censusing Committee (IBCC) (1970) guidelines were used for data recording, summarization, evaluation, and presentation. One exception to the IBCC guidelines was the size of the study plots, which were less than the recommended 10 ha size for closed habitats.

Small Mammal Trapping

Live trapping was used to estimate small mammal populations for each of the 6 study plots. Live trapping of small mammals began in May of both 1981 and 1982, and continued monthly through September. A 6 x 6 grid with trap station spacing of 25m was located in the center of each plot. Two Sherman live-traps (H. B. Sherman, Co., Tallahassee, FL) (8 cm x 9 cm x 23 cm) were placed at each station and covered with plant material. The traps were placed by logs and other small mammal travel lanes in order to maximize captures. Both treatment and control plots were trapped concurrently for 5 consecutive nights.

Traps were set and baited on the first day of each trapping period and remained open during the 5 day sampling period. The bait mixture used in 1981 consisted of oats, peanut butter, beef fat, raisins, and anise extract. In 1982 peanut butter was deleted and packaged dog food was added to the mixture.

Traps were checked early each morning of the trapping period. All newly captured individuals were ear tagged or toe clipped. Species, identification number, and location on the grid were recorded for each capture.

Data Analysis

This study employed a completely randomized design. The linear model for the design was:

$$Y_{ij} = \mu + \tau_i + \varepsilon_{ij}$$

μ = mean of all observations

τ = variability due to treatments

ε = variability due to errors

Statistically adequate sample sizes for all vegetation sampling were determined with Freese's (1978) required sample size formula:

$$n = \frac{t^2 s^2}{E^2}$$

t = tabulated t value at the 90% confidence limit

s^2 = sample variance

E = allowable error (mean multiplied by a maximum of 20%)

One-way analysis of variance ($p < 0.10$) was used to test density of woody shrubs and sprouts, foliage height diversity, frequency of forbs and grasses, breeding bird abundance, number of species of breeding birds, breeding bird species diversity, small mammal abundance, number of species of small mammals, and small mammal diversity with respect to baseline data and treatment effects (Steel and Torrie 1980). All data were subjected to Snedecor and Cochran's (1967) test for the equality of 2 variances. Data with heterogenous variances were transformed by Log (Y+1) (Steel and Torrie 1980).

Foliage height diversity, bird species diversity, and small mammal diversity were determined by the Shannon-Weiner diversity index (Ricklefs 1979):

$$H = - \Sigma p_i \log p_i$$

p_i = decimal fraction of total individuals or total cover of the ith category

Because of a substantial decrease in total numbers of small mammals from 1981 and 1982, standard capture-recapture population estimators could not be used. Consequently, Kreb's (1966) enumeration technique was the best alternative:

$$N = A + P$$

N = minimum number of individuals of a species alive at time t.

A = actual number of individuals of a species caught at time t.

P = the number of previously marked individuals of a species caught after time t, but not at time t.

The minimum number of individuals of each species alive was determined for each study plot during every trapping period. Absolute population estimates were not essential since the emphasis of this study was determining relative differences between control and treatment plots.

Product moment correlation (Steel and Torrie 1980) ($P < 0.10$) was used to describe associations between vegetation responses and bird and small mammal responses.

RESULTS

Vegetation Characteristics

Analysis of baseline vegetation sampling from 1981 indicated that vegetation in all study plots was similar in composition and structure. A list of all species of vegetation found on the study plots is presented in the appendix (Table A-7). Prior to harvesting in August 1981, there were no significant ($p > 0.10$) differences in the amount of vertical vegetative cover between control and designated treatment plots in any bird height stratum (Fig. 4). Designated treatment plots, however, had significantly ($p < 0.05$) more cover in the 30cm - 1m small mammal height stratum than control plots (Fig. 5). There were no significant ($p > 0.10$) differences between control and designated treatment plots in any other height stratum.

The amount of cover on control plots significantly increased by 53% in the 1m - 7m stratum ($p < 0.10$), and 28% in the 30cm - 1m stratum ($p < 0.05$) from 1981 to 1932. There were no other significant differences ($p > 0.10$) in cover on control plots between years for any strata.

Harvesting completely removed the >7m stratum, and significantly ($P < 0.05$) reduced cover in the 1m-7m stratum

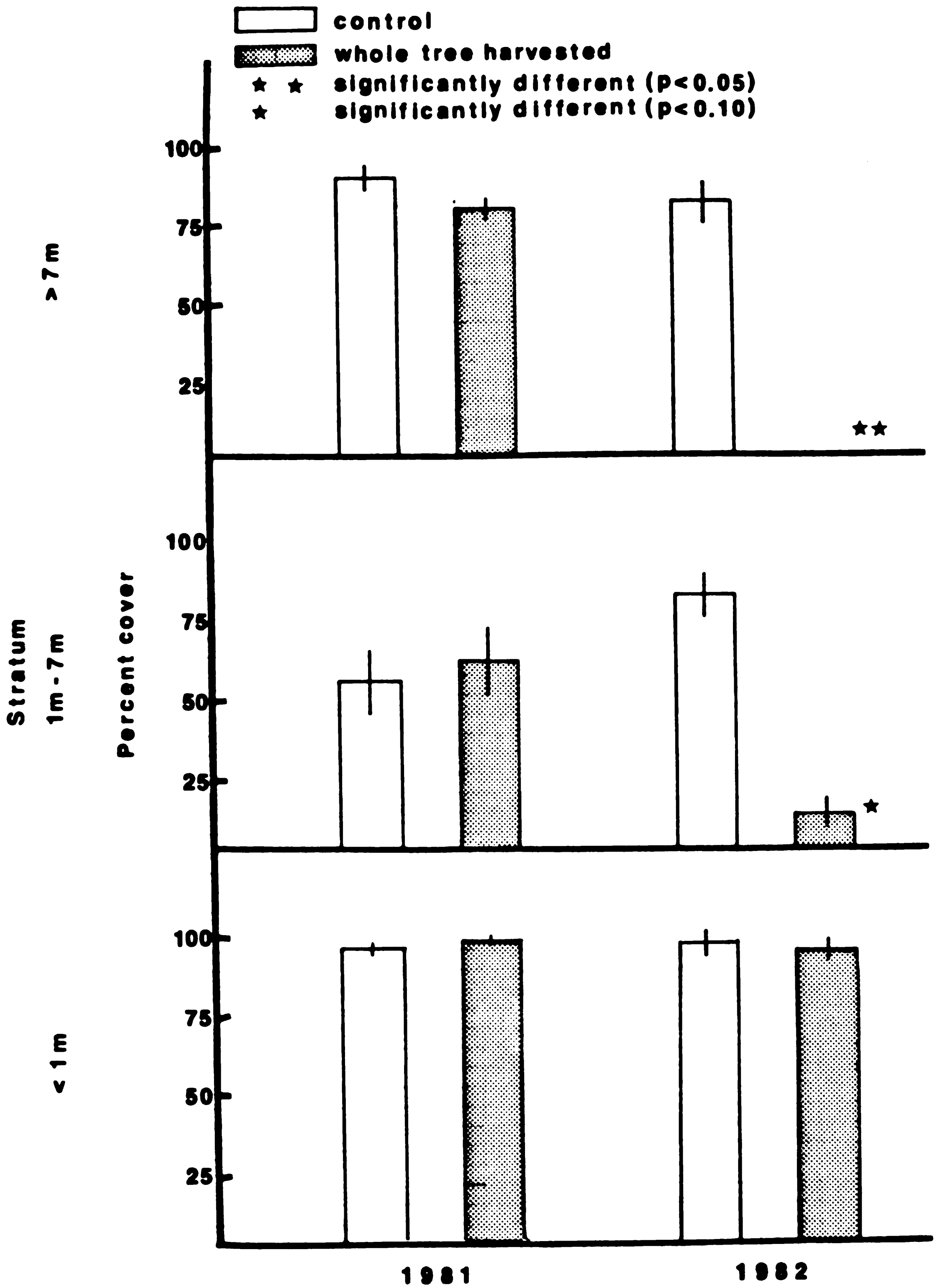


Figure 4. Mean vegetative cover and S.E. for bird height strata on control and whole tree harvested plots in Midland County, Michigan during 1931 and 1982.

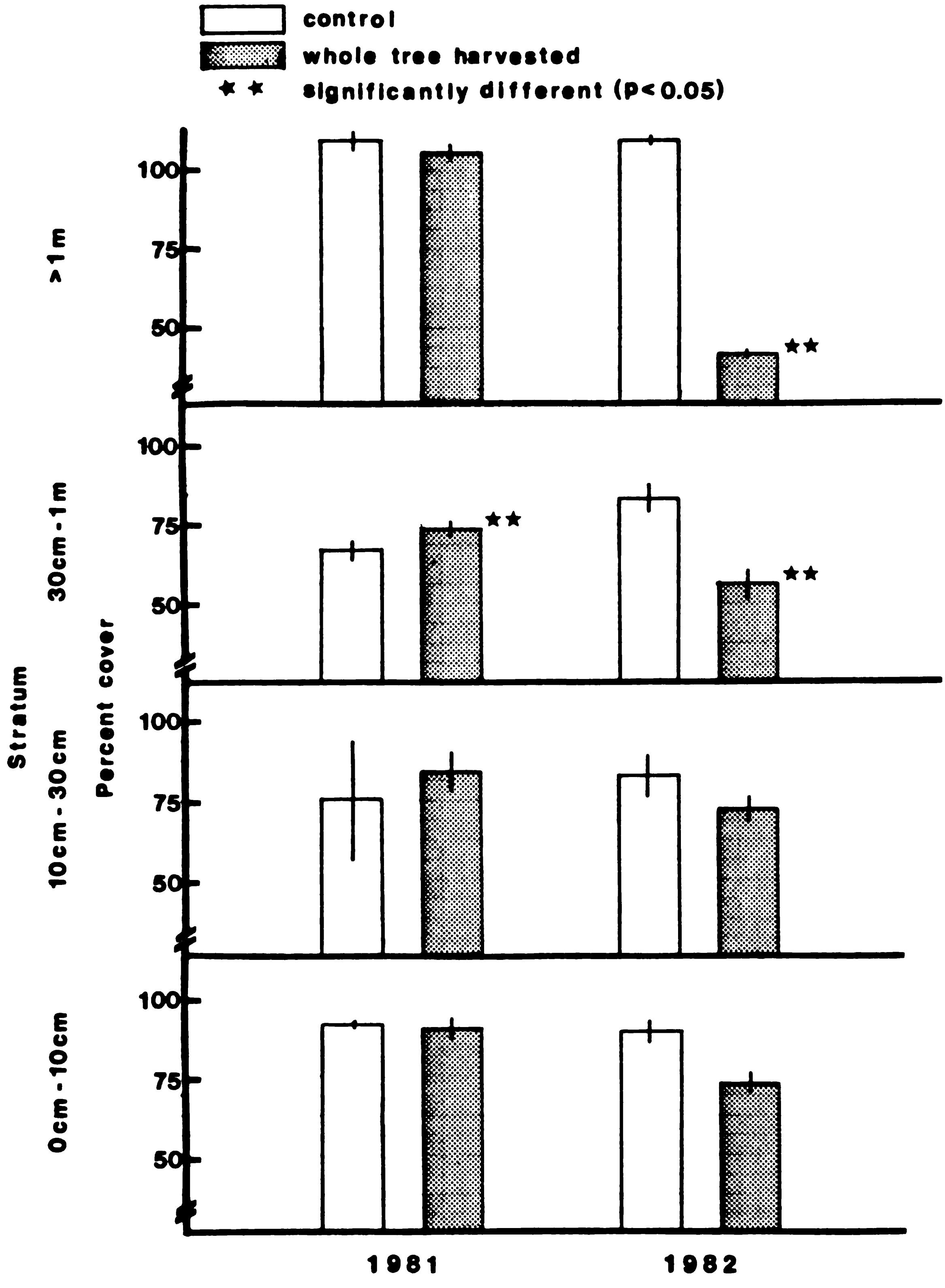


Figure 5. Mean vegetative cover and S.E. for small mammal height strata on control and whole tree harvested plots in Midland County, Michigan during 1981 and 1982.

on the treatment plots by 86%. Similarly, cover was also reduced on treatment plots in the 30cm-1m and the >1m strata by 34% and 88% respectively.

Slash cover in control and treatment plots was not significantly different ($p > 0.10$) in 1981 (Fig. 6). Whole tree harvesting significantly increased ($p < 0.05$) slash cover on treatment plots.

Vertical vegetative cover in the buffer zones surrounding the treatment plots was not significantly different ($p > 0.10$) from control plots in 1982 (Fig. 7). The amount of slash cover in the buffer zones was not significantly different than slash cover on control or treatment plots in 1982.

Foliage height diversity (H'_{FHD}) indicies of control and treatment plots were not significantly ($p > 0.10$) different for bird and small mammal strata before harvesting (Table 1). Diversity indicies of control plots were similar in 1981 and 1982. Harvesting reduced ($p < 0.05$) the foliage height diversity for both bird and small mammal strata. Mean foliage height diversity of the bird strata in the buffer zones was not different ($p > 0.10$) from control plots.

The density of woody shrubs and sprouts in the control and designated treatment plots was similar before harvesting (Fig. 8). Greater densities of wood shrubs and sprouts were found on treatment plots after harvesting. Table 2 describes the composition of overstory (trees >5cm dbh) vegetation of the control plots.

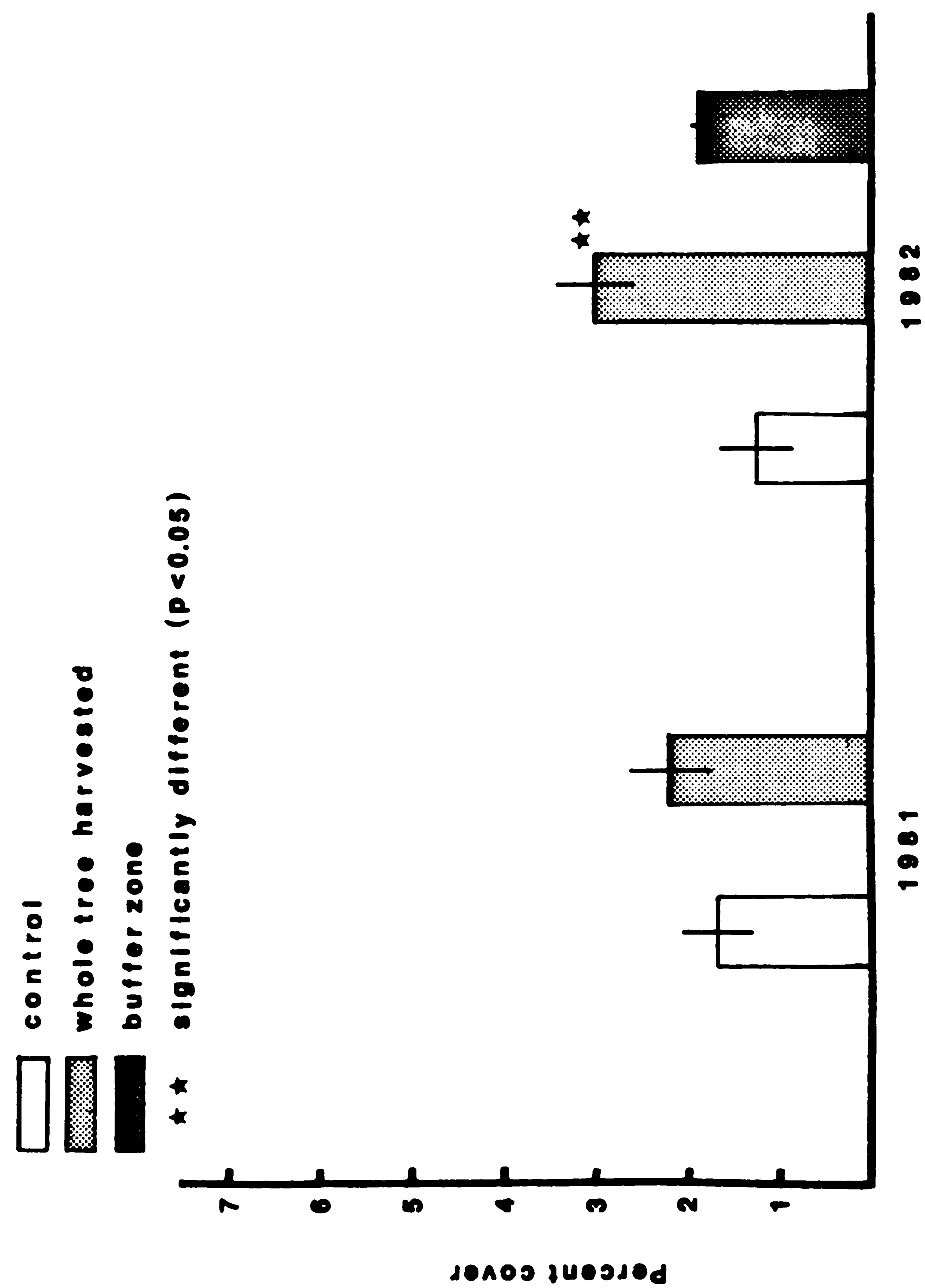


Figure 6. Mean slash cover and S.E. for <30 cm height strata on control and whole tree harvested plots and buffer zones in Midland County, Michigan during 1981 and 1982.

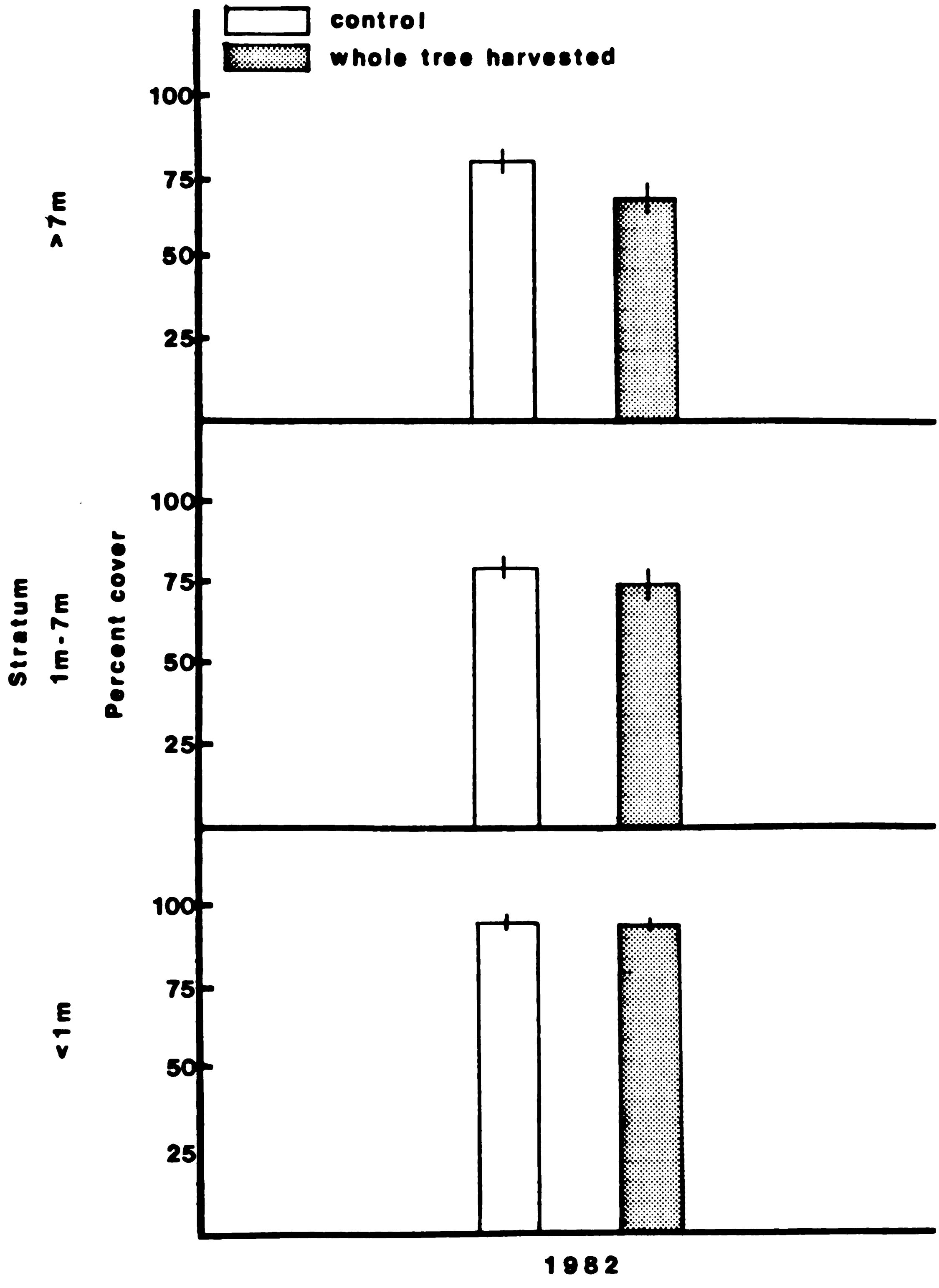


Figure 7. Mean vegetative cover and S.E. for bird height strata on control plots and buffer zones of whole tree harvested plots in Midland County, Michigan during 1981 and 1982.

Figure 8. Mean stem density and S.E. of shrubs and sprouts (<5cm dbh) on control and whole tree harvested plots in Midland County, Michigan during 1981 and 1982.

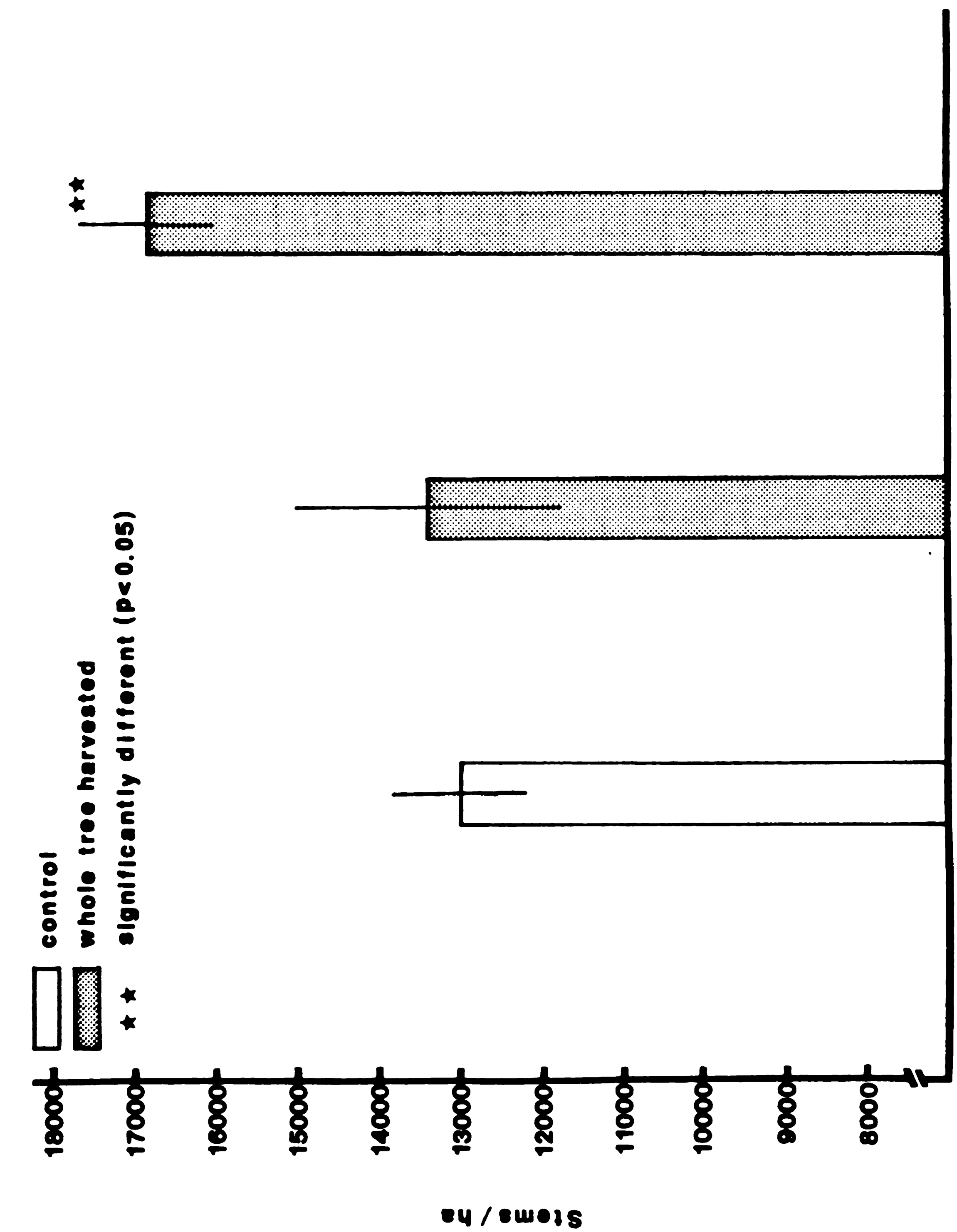

control
whole tree harvested
★★ significantly different (p<0.05)
Stems / ha
18000
17000
16000
15000
14000
13000
12000
11000
10000
9000
8000
1981
1981
1982
★★

Figure 8.

Table 1. Mean diversity and S.E. ( ) of vertical cover for bird and small mammal strata on control and whole tree harvested plots and buffer zones in Midland County, Michigan during 1981 and 1982.

	Foliage height diversity				
	1981		1982		
	Control	Treatment	Control	Treatment	Buffer Zone
Bird strata	1.03(.05)	1.05(.03)	1.06(.02)	.26(.04)[A]	1.06(.02)
Small mammal strata	1.35(.04)	1.37(.005)	1.37(.01)	1.16(.02)[A]	-

[A]Foliage height diversity on treatment plots was significantly different ($p < 0.05$) from controls.

Table 2. Mean relative frequency, relative density, relative dominance, and importance values of trees (>5cm dbh) common to all control plots in Midland County, Michigan during 1982.

Species	Relative frequency (%)	Relative density (%)	Relative dominance (%)	Importance value
Bigtooth aspen	13.76	25.61	22.30	61.66
Quaking aspen	10.76	10.73	23.55	45.04
White birch	13.07	10.08	10.40	33.55
Red maple	11.75	13.00	7.50	32.25
Swamp white oak	10.44	11.47	7.57	29.48
Green ash	8.05	7.84	9.77	25.66
Slippery elm	8.79	7.47	6.68	22.94

Absolute and relative frequencies of common herbaceous species found on the study plots are presented in the appendix (Table A-6). In 1981, control and designated treatment plots were very similar in species composition. Only 1 species differed significantly ($p < 0.10$) between control and designated treatment plots. The absolute frequency of violets was higher on designated treatment plots than controls.

Harvesting caused changes in absolute frequency of only 2 herbaceous species common to both control and whole tree harvested plots. Sedge increased on clearcut plots while the occurrence of violet decreased. Shifts in the frequency of occurrence of other species may have been masked by high variability between study plots. Sixteen species were found on the whole tree harvested plots that were not present on any study plot in 1981 (Table A-5). However, these species occurred in low frequency. Of these 16 species, only 1 woody species, pin cherry, was found to invade the clearcuts.

Breeding Bird Censusing

A total of 44 species of birds were observed on the study plots during the breeding bird census in 1981. Of these 44 species, 11 species were common to all study plots, and 18 species had established breeding territories in at least 1 study plot (Table A-7). In 1982, 49 species were observed on the study plots during censusing. Seven species were common to all plots, and 28 species established breeding territories in at least 1 study plot (Table A-9). Five species were observed in 1981 but not in 1982; redheaded woodpeckers, downy woodpeckers, acadian flycatchers, blue winged warblers, and tree sparrows. However, none of these species had successfully established breeding territories on the study plots in 1981. Species recorded only in 1982 included killdeer, mourning dove, eastern kingbird, tennessee warbler, blackburnian warbler, cardinal, and field sparrow. Of these, only the eastern kingbird successfully established breeding territories on the study plots.

A total of 45 species of birds were observed in the buffer zone surrounding the treatment plots. Twenty-four of these species established breeding territories in the buffer zones.

No significant differences ($p > 0.10$) were found between the mean number of breeding birds on control ($\bar{X} = 66 \pm 4.2$) and designated treatment plots ($\bar{X} = 75 \pm 1.8$) in 1981. The number of species of breeding birds was also not significantly different ($p > 0.10$) on control ($\bar{X} = 9 \pm 1.2$) and designated treatment ($\bar{X} = 11 \pm 0.8$) plots. Breeding bird numbers on control plots ($\bar{X} = 64 \pm 2.3$) in 1982 were similar to numbers found in 1981. However, the number of species of breeding birds on control plots ($\bar{X} = 16 \pm 2.1$) was greater ($p < 0.05$) in 1982 than in 1981. Harvesting resulted in a significant decrease ($p > 0.05$) of over 80% in the number of birds found on treatment ($\bar{X} = 13 \pm 1.2$) plots. Similarly, the number of species establishing breeding territories on treatment ($\bar{X} = 4 \pm 0.3$) plots was 75% less than on control plots.

The mean number of breeding birds/5 ha in the buffer zones ($\bar{X} = 68 \pm 11.2$) was not significantly different ($p > 0.10$) from the number of breeding birds on control plots/5 ha ($\bar{X} = 56 \pm 2.1$) in 1982. Nor was the number of species of breeding birds different in the buffer zones ($\bar{X} = 17 \pm 1.5$).

Mean breeding bird species diversity (H'_{BSD}) was similar on control and designated treatment plots in 1981 (Table 3). Species diversity on control plots increased ($p < 0.10$) the second year. This was attributed to an increase in the total number of species establishing breeding territories rather than an increase in the total number of territories established per species. Harvesting significantly reduced ($p < 0.05$) species diversity on treatment plots. Breeding bird species diversity of the buffer zones was similar to control plots but different ($p < 0.05$) than treatment plots.

Bird-Vegetation Associations

In 1981 there were no significant ($p > 0.10$) associations between bird species diversity and foliage height diversity, bird species diversity and density of woody shrubs and sprouts, breeding bird abundance and foliage height diversity,

Table 3. Mean breeding bird species diversity and S.E. of control and whole tree harvested plots and buffer zones in Midland County, Michigan during 1981 and 1982.

	Bird species diversity		
Year	Control	Treatment	Buffer zone
1981	1.86(.20)	2.13(.13)[A]	-
1982	2.39(.25)[C]	1.13(.13)[B]	2.56(.20)

[A]Value determined before treatment.

[B]Significantly different ($p < 0.05$) from control 1982.

[C]Significantly different ($p < 0.10$) from control 1981.

or breeding bird abundance and woody shrubs and sprouts. In addition, no associations were found between bird species diversity or breeding bird abundance and percent cover of slash, or vegetation in any height stratum. However, the number of species of breeding birds was significantly correlated with foliage height diversity ($p < 0.05, r = 0.86$) and percent cover in the 1m-7m stratum ($p < 0.10$, $r = 0.78$).

After harvesting, bird species diversity was positively correlated ($p < 0.05$, $r = 0.99$) with foliage height diversity, and percent cover in the <1m stratum ($p < 0.10$, $r = 0.78$), the 1m-7m stratum ($p < 0.05$, $r = 0.95$), and the >7m stratum ($p < 0.05$, $r = 0.98$). Bird species diversity was negatively correlated ($p < 0.05$, $r = -0.91$) with density of woody shrubs and sprouts and percent slash cover ($p < 0.05$, $r = -0.94$). Breeding bird abundance was positively correlated ($p < 0.05$, $r = 0.99$) with foliage height diversity, and percent cover in the <1m stratum ($p < 0.10$, $r = 0.70$), the 1m-7m stratum ($p < 0.05$, $r = 0.99$), and the >7m stratum ($p < 0.05$, $r = 0.99$). However, breeding bird abundance was negatively correlated with percent slash cover ($p < 0.05$, $r = -0.93$). The number of species of breeding birds was positively correlated with foliage height diversity ($p < 0.05$, $r = 0.98$), and percent cover of all strata ($p < 0.05$, 0-1m; $r = 0.82$, 1m-7m; $r = 0.96$, >7m; $r = 0.98$). Both percent slash cover and density of woody shrubs and sprouts was negatively correlated ($p < 0.05$, $r = -0.96$; $r = -0.90$ respectively) with the number of species of breeding birds. No significant associations ($p > 0.10$)

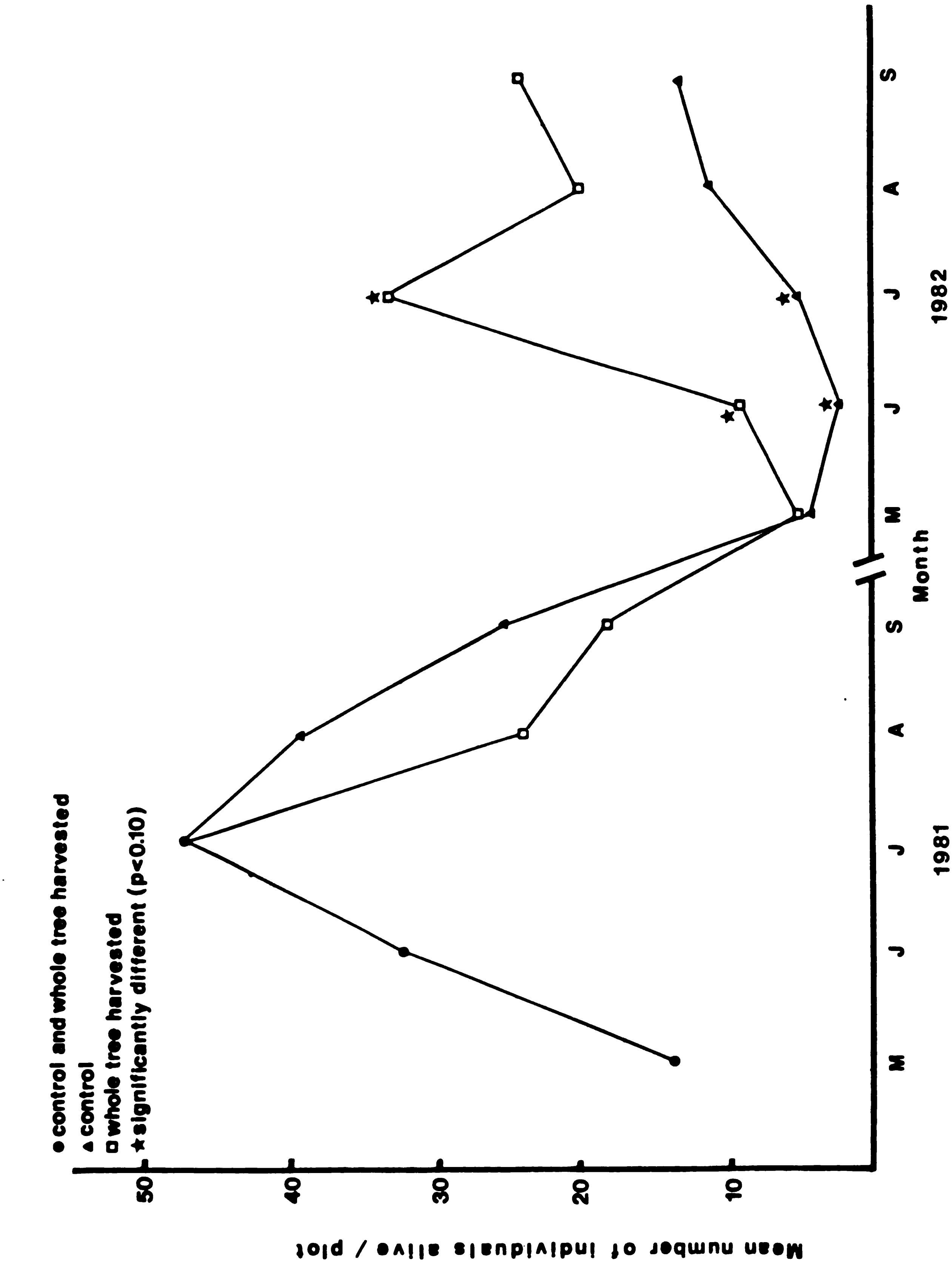
were found between vegetative characteristics and bird species diversity, breeding bird abundance, or number of species of breeding birds for the buffer zones.

Small Mammal Populations

A total of 12 species of small mammals were trapped on the study plot in 1981. Of these 12 species, red squirrels (Tamiascuruis hudsonicus), longtail weasels (Mustela frenata), southern flying squirrels (Glaucomys volans), starnose moles (Condylura cristata), and cottontail rabbits (Sylvilagus floridanus) were classified as incidental species because of infrequent capture. The 7 other species, white-footed mice (Peromyscus leucopus), short-tail shrews (Balarnia brevicauda), masked shrews (Sorex cinerus), woodland jumping mice (Napaozapus insignis), meadow voles (Microtus pennsylvanicus) and eastern chipmunks (Tamias striatus) were captured in relatively high numbers in both years. Although all positively identified specimens of the genus Peromyscus were white-footed mice, in the field,deer mice (Peromycus maniculatus) may have been mistakenly recorded as white-footed mice. In addition, longtail weasels, cottontail rabbits, and opposum (Didelphis marsupialis) were captured in 1982. However, due to low capture success, these species were classified as incidentals.

The minimum number of animals known to be alive on control and designated treatment plots during the 3 trapping periods before harvesting were essentially equal (Fig. 10).

Figure 9. Mean minimum number of small mammals known to be alive before and after whole tree harvesting, on control and treatment plots in Midland County, Michigan during 1981 and 1982.



● control and whole tree harvested
▲ control
□ whole tree harvested
★ significantly different (p<0.10)
Mean number of individuals alive / plot
50
40
30
20
10
M
J
J
A
S
M
J
J
A
S
1981
1982
Month

Figure 9.

Small mammal numbers varied after harvesting but not significantly ($p > 0.10$). White-footed mice were the most abundant species captured in 1981 (Table 4). Shorttail shrews, eastern chipmunks, woodland jumping mice, masked shrews, meadow voles, and meadow jumping mice were captured in decreasing numbers, respectively. Numbers of small mammal species captured were similar on control and treatment plots in 1981, but varied throughout the sampling period (Fig. 11). Small mammal species diversity (H'_{SMD}) was not significantly different ($p > 0.10$) on control and treatment plots in 1981 (Fig. 12) before or after harvesting.

During the 1982 trapping season there were greater numbers of small mammals on treatment plots during all trapping periods, but only significantly higher numbers ($p < 0.10$) during June and July. This is partially attributed to a decline in small mammal numbers, especially white-footed mice on control plots. In addition, reductions in numbers of shorttail shrews and eastern chipmunks observed on control plots may have also contributed to the differences between control and treatment plots. Finally, the increase in small mammal numbers on treatment plots is a result of an increase in numbers of meadow voles and meadow jumping mice. Greater ($p < 0.10$) numbers of small mammal species were found on treatment plots during only 1 trapping period. However, no differences in small mammal species diversity were found during any trapping period in 1982.

Table 4. Minimum number of small mammals known to be alive on control and whole tree harvested plots in Midland County, Michigan during 1981 and 1982.

Treatment	Species	5/18	6/14	7/16	8/15	9/7	5/10	6/9	7/9	8/6	9/1	Total 1981	Total 1982
Control													
	Peromyscus spp.	30	85	103	84	43	-	4	3	4	3	252	9
	Blarnia brevicauda	2	5	23	17	22	-	-	-	7	20	71	27
	Sorex cinerus	5	-	-	1	2	1	-	-	-	1	7	2
	Napaeozapus insignis	2	-	1	3	4	10	2	-	8	5	10	25
	Zapus hudsonicus	-	2	3	3	1	2	-	1	1	-	9	4
	Microtus pennsylvanicus	-	-	-	3	3	-	-	0	1-	0	5	18
	Tamias striatus	2	5	6	6	-	-	1	2	2	1	17	5
Total		41	97	141	117	75	13	7	15	32	39	371	90
Treatment													
	Peromyscus spp.	28	77	92	49	42	-	4	5	3	1	190	9
	Blarnia brevicauda	-	6	20	10	7	-	1	-	-	8	39	9
	Sorex cinerus	3	-	6	3	-	2	-	-	-	1	12	3
	Napeozapus insignis	5	1	3	3	1	8	-	1	2	2	13	13

Table 4. (cont'd.)

Treatment	Species	5/18	6/14	7/16	8/15	9/7	5/10	6/9	7/9	8/6	9/1	Total 1981	Total 1982
Treatment (cont'd.)													
	Zapus hudsonicus	3	-	1	-	-	2	6	26	16	23	4	69
	Microtus pennsylvanicus	-	-	2	6	3	2	15	67	40	37	9	130
	Tamias striatus	2	13	16	3	-	-	-	-	-	-	25	-
Total		41	97	140	74	53	14	26	99	61	72	292	233

Figure 10. Mean total number of small mammal species captured before and after whole tree harvesting, on control and treatment plots in Midland County, Michigan during 1981 and 1982.

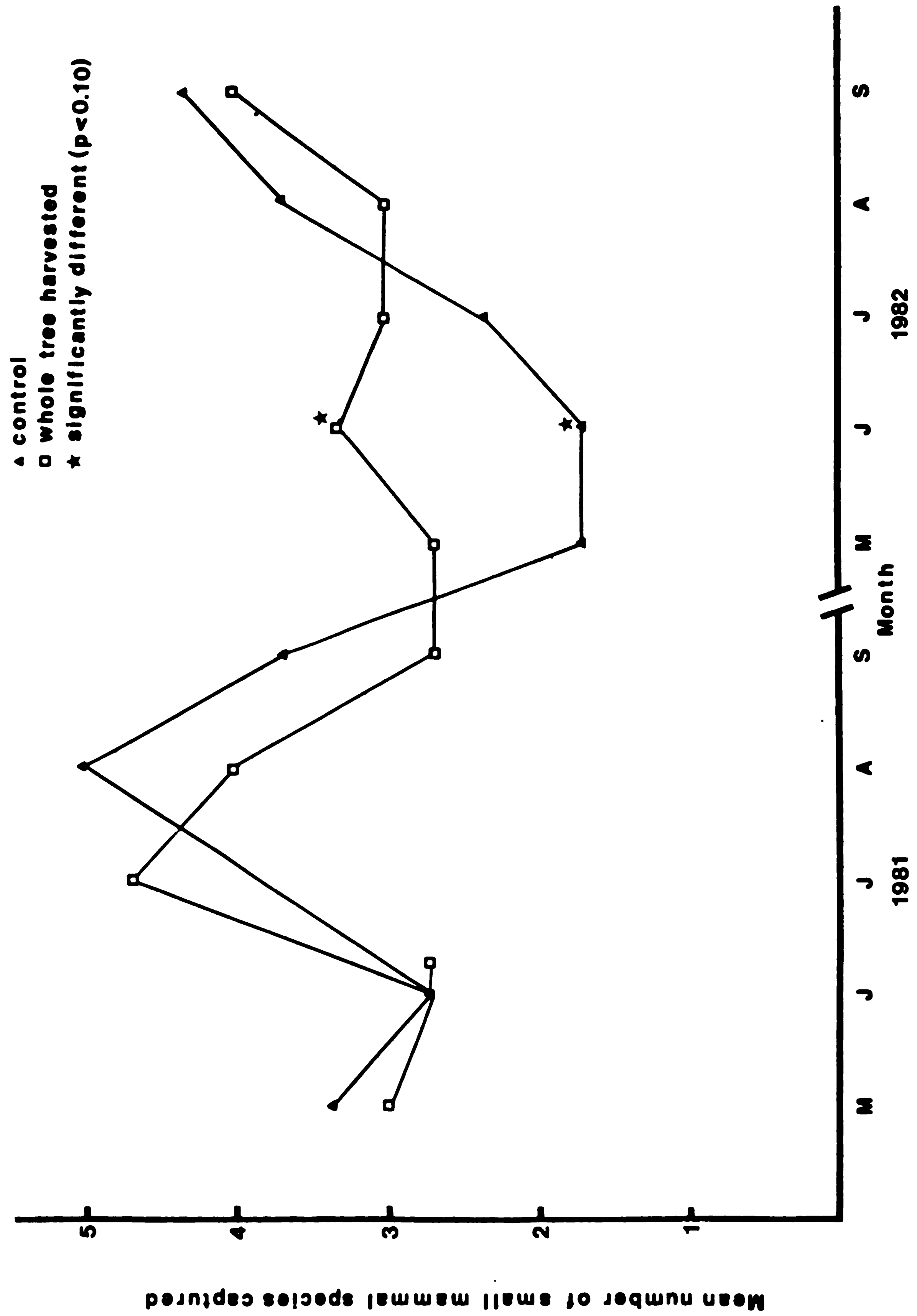
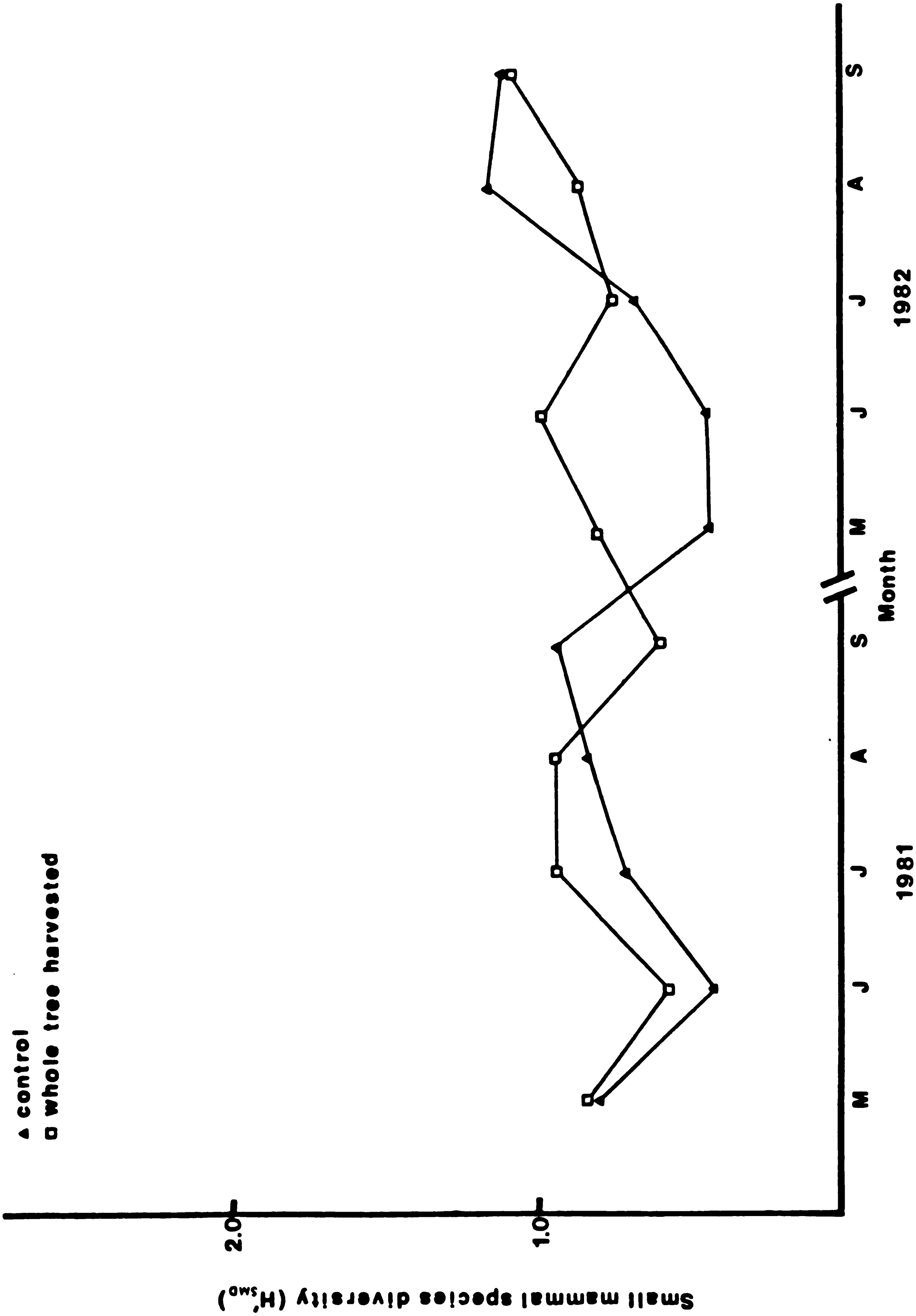

control
whole tree harvested
significantly different (p<0.10)
Mean number of small mammal species captured
5
4
3
2
1
M
J
J
A
S
M
J
J
A
S
1981
1982
Month

Figure 10.

Figure 11. Mean small mammal species diversity on control and whole tree harvested plots in Midland County, Michigan during 1981 and 1982.



control
whole tree harvested
Small mammal species diversity (H'smd)
2.0
1.0
M
J
J
A
S
M
J
J
A
S
1981
1982
Month

Figure 11.

Small Mammal-Vegetation Associations

Small mammal species diversity calculated at the time of vegetation sampling was positively correlated ($p < 0.05$, $r = 0.84$) with slash cover in 1981. No associations between small mammal species diversity and foliage height diversity or percent vegetative cover were found in 1981. Small mammal species diversity for the first 3 trapping periods were not significantly correlated ($p > 0.10$) with density of woody shrubs and sprouts.

The minimum number of animals known to be alive during the third trapping period was only correlated ($p < 0.05$, $r = 0.78$) to the percent cover in the >1m stratum. Foliage height diversity, vegetative cover in the remaining strata, and slash cover did not correlate well with the number of animals known to be alive. However, the number of woody stems/ha was significantly, negatively ($p < 0.05$, $r = -0.90$) correlated with animal numbers in the first trapping period in 1981.

Small mammal species diversity was negatively correlated with foliage height diversity ($p < 0.05$, $r = -0.81$) and percent cover in the >1m stratum ($p < 0.10$, $r = -0.78$) in 1982.

The minimum number of animals known to be alive during the vegetation sampling period (2nd trapping period) was negatively correlated ($p < 0.05$, $r = -0.87$) with foliage height diversity and percent cover in the >1m stratum

($p < 0.05$, $r = -0.82$). Numbers, however, were positively correlated ($p < 0.05$, $r = 0.93$) with slash cover. The density of woody shrubs and sprouts was associated ($p < 0.05$) with numbers of animals known to be alive in the second and third trapping periods. The trend was positive ($r = 0.84$; $r = 0.79$ respectively).

DISCUSSION

Pretreatment sampling indicated that control and designated treatment plots were similar in vegetative composition and structure. Differences such as greater percent cover in the 30cm - 1m stratum and higher absolute frequency of violets on designated treatment plots did not seem to have an effect on small mammal or bird communities. None of the measured parameters which characterized the small mammal and bird populations differed between control and designated treatment plots.

The year to year increase in cover on the control plots may be attributed to natural succession of the area. The natural thinning occurring in this overly mature aspen stand allowed increased growth in the understory producing increased cover in the 30cm - 1m and 1m - 7m strata.

Whole tree harvesting, as with any other clearcutting practice, drastically altered the structure of the vegetation. The amount of cover in all strata >30cm was significantly reduced. Although harvesting resulted in an increased density of woody vegetation, the regeneration had not yet grown high enough to provide substantial amounts of cover in the upper strata. The complete removal of the overstory did not cause as large of a shift in herbaceous species composition as expected. Although many species invade the clearcut areas, only 2 species, marsh thistle and New England aster were found in all 3 clearcuts. In addition, these and other invading species occurred in low frequencies. This may be attributed to the condition of the stand prior to harvesting. Because the aspen stand was overly mature, many early successional species were already established before harvesting, thus the species shift was lessened.

As previously mentioned, the amount of wood obtained by using whole tree harvesting techniques can almost double the amount that is obtained by using conventional clearcutting practices. This increase is a product of utilization of tree tops, rotten trees, and small sound trees which would be left as slash on a conventional clearcut. Although whole tree harvesting increased the amount of slash cover, the increase can not be as large as found on conventional clearcuts.

The correlations between the response of the bird and small mammal communities and the vegetative structure after harvesting must be viewed with caution. The correlations are between 2 widely separated and distinct groups of values, those corresponding to the control plots and those corresponding to the whole tree harvested plots, rather than being formed by a gradient of values. Because of the severity of the treatment any changes in the bird or small mammal communities are likely to be correlated with the vegetative changes.

The first year response of the bird community to the changes in vegetative structure was a decrease in both numbers and species. This overall decrease resulted in a reduction in bird species diversity. The association of bird species diversity to foliage height diversity in temperate forests has been documented (MacArthur and MacArthur 1961, MacArthur 1964, Karr 1968, Karr and Roth 1971). MacArthur and MacArthur (1961) have suggested that all height strata are equally important to the birds. The hightest correlation between bird species diversity and foliage height diversity would occur when the height classes are divided into the levels which are used by the bird communities (Moss 1978). In this study, the height strata were selected to represent the herbaceous layer, shrub layer, and overstory. It is assumed that these layers have biological significance, however it is not certain (MacArthur 1964). Moss (1978) has suggested that each layer of vegetation contains niches for several bird species. Therefore, increasing the number of layers increases the number of niches, which in turn increases the number of bird species. By removing layers, as whole tree harvesting did, the number of available niches decreased resulting in fewer bird species. Similar responses of bird communities have been documented in association with conventional clearcuts (Shugart and James 1973, Conner and Adkission 1975, Shugart et al. 1978, Crawford et al. 1981).

The low rate of colonization of the whole tree harvested plots may be partially attributed to 2 factors. The first is the relatively small size of the clearcuts. Studies in several vegetation types have indicated the relationship between block size and the number of species present (Sampson 1980). Forman et al. (1976) reviewed biogeographic studies and concluded that block size was the top or near the top predictor of species number. The larger the block of vegetation the greater the rate of immigration (Whitcomb 1977).

The second factor, which may have affected colonization of the clearcuts by low shrub nesting species, was the growth form of the first year aspen. Aspen suckers do not branch out until their second year, therefore available nest sites were limited to the patches of vegetation that remained after harvesting.

The species that established breeding territories within the clearcuts were typically open or brushy area nesters, with the exception of the veery, which usually nests in the forest. The atypical veery nest was unsucessful due to cowbird parasitisim and eventual destruction by a mammalian predator. Catbirds, which typically nest in brush areas (Bent 1964a) were found nesting in those patches of brush that were not knocked down by harvesting equipment and were within 40m of the edge of the clearcut. Robins and rufous-sides towhees are more general nesters (Bent 1964b, Bent 1968a), occurring in both open and forested areas. The 3 other species nesting in the clearcuts, kingbirds, mourning warblers, and song sparrows, typically nest in open areas (Bent 1942, Bent 1963, Bent 1968).

Very few snags remained standing after whole tree harvesting. Several cavity nesting species, bluebirds, house wrens, and yellow-shafted flickers, successfully nested in the buffer zones surrounding the clearcuts. Increased use of the whole tree harvested areas by these species may have occurred if the appropriate size snags had been left in the clearcuts.

Although whole tree harvesting significantly increased the amount of slash cover, it is unknown if this increase benefited wildlife species which used the slash for food and/or cover. Downy and hairy woodpeckers and yellow-shafted flickers have been observed feeding on logging slash in conventional clearcuts (Conner and Crawford 1974). Very low numbers of these species were observed using the whole tree harvested clearcuts. This could either be caused by low populations of these species in the surrounding area or by too small an amount of slash remaining after whole tree harvesting to attract these species.

The induced edge created by clearcutting was narrow and of high contrast. As a result, the number of bird species commonly associated with edges did not substantially increase. Species such as the song sparrow which feed and nest close to the ground in open areas, but need high singing perches, may have benefited from the abrupt edge. However, the clearcuts were not complete. Many small trees and shrubs remained after harvesting, providing ample singing perches. Observations of displaying song sparrows on the clearcut support their use of these scattered trees within the clearcut rather than the trees on the edge.

The buffer zone is part of the ecotone created by the edge. The species of birds inhabiting this area did not differ from those inhabiting the control plots. The actual size of ecotone produced by the edge is unknown and may not be equal to the width of the buffer zone. Numbers of breeding birds expressed per 5 ha in the buffer zones were not different from those found on control plots. This may be attributed to the variability in the number of birds establishing territories in the buffer zones. Of the 3 buffer zones censused, 2 had higher population levels than any of the 3 control plots while the remaining buffer zone had fewer breeding birds than any of the control plots. The source of this variability is unknown.

In summary, it does not appear that the first year response of bird populations to whole tree harvesting was different from typical response to conventional clear-cutting. However, differences may be noted in areas with different species composition. For example, responses may be different in areas which have higher population levels of woodpeckers or other species which typically feed or nest around or in dead and downed woody material. Another important factor to be considered is the time since clear-cutting. Shifts in the breeding bird community will occur as the structure of the vegetation changes.

The effect of conventional clearcutting on small mammal populations has been investigated. The majority of these studies have examined small mammal responses to clearcutting of conifer stands (Tevis 1956, Gashwiler 1959, Harris 1968, Gashwiler 1970, Hooven and Black 1973, Martell and Radvanyi 1977, Sullivan 1979). Other studies have investigated small mammal responses to clearcutting of hardwood stands (Krull 1970, Lovejoy 1971, Kirtland 1977). However, no specific pattern of response has emerged from these studies. Tevis (1956), Sims and Buckner (1973), Hooven and Black (1976), and Kirtland (1977) concluded that clearcutting resulted in an increase in total small mammal abundance. Harris (1968) found clearcutting to reduce total small mammal abundance as did Hahn and Michael (1980) in their study investigating responses to whole tree harvesting. Other studies concluded that clearcutting had no significant effect on small mammal abundance (Krull 1970, Lovejoy 1971, Martell and Radvanyi 1977, Sullivan 1979). These variations may be due to regional differences such as geographic location, forest type, climate, and species associations in the small mammal community (Kirtland 1977b). Another potential source of variation is the differences in the post-harvest site preparation treatment each area received. Different sampling techniques and sampling time periods may have also contributed to the differing results. Sullivan (1979) suggested that the higher populations found in clearcuts reported in the literature are a result of the lack of spring trapping and the common practice of trapping after the summer and fall recruitment.

Analysis of the effects of whole tree harvesting on the small mammal community is confounded by the decrease in small mammal numbers, most notably deer mice, on control plots in the second year. Population declines were also noted for shorttail shrews, masked shrews, and chipmunks. Declines in small mammal numbers were not restricted to the study area. Small mammal population declines were also recorded in Cadillac and Atlanta, Michigan (D. Woodyard, pers. comm.). These declines throughout the state may be attributed to the severity of the 1981-1982 winter.

Several studies have reported associations between small mammal community characteristics (i.e. species, numbers) and vegetative composition and structure (Rosengweig and Winakur 1969, Miller and Getz 1977, Dueser and Brown 1980). In this study the associations found between vegetative structure and small mammal numbers and diversity may be an artifact of the shift in the small mammal community which occurred from 1981 to 1982. Because this shift was not a result of the treatment, the results are potentially and probably biased. However, the changes in vegetative composition and structure following whole tree harvesting appeared to benefit 2 species. Both meadow voles and meadow jumping mice increased their populations on the harvested plots.

The relationship of relative meadow vole abundance and the amount of grass-like cover has been shown in several studies (Eadie 1953, Mossman 1955, Woodyard 1982). The presence of meadow voles on the study plots before harvesting is attributed to the mature growth stage of the stand which had allowed substantial ground cover to develop. Getz (1961) concluded that the type of food present was also an important factor influencing the occurrence of voles in an area. In his study in southeastern Michigan, Getz found grasses and sedges to be the preferred food item. Sedges were especially important in the winter. It appears that increases in meadow vole numbers on the whole tree harvested plots were at least partially the result of increases in the occurrence of sedge.

Meadow jumping mice, although less specific in their habitat preferences than meadow voles, have been found to reach their highest population levels in open moist lowlands and willow-alder thickets (Quimby 1951). The significant decrease in cover >30cm may have produced more favorable conditions for this species. Ahlgren (1966) suggested that food was the primary factor influencing small mammal populations. Whole tree harvesting may have increased the availability of food for jumping mice, which feed on both seeds and insects (Quimby 1951). Increased small mammal populations resulting from increased production after clearcutting has been reported by Ahlgren (1966). Huhta et al. (1967) and Huhta (1976) have found significant increases in invertebrate biomass following clearcutting.

This was attributed to the organic matter in the form of slash providing good invertebrate habitat. Because whole tree harvesting increased the amount of slash, the increase in meadow jumping mouse numbers may be a response to greater invertebrate availability. However, the length of the invertebrate response to slash may be shortened because of the lesser amount of slash produced by whole tree harvesting relative to conventional clearcutting.

Chipmunks were not captured on any of the clearcut plots, although populations on control plots were very low. Kirtland (1977) reported the exclusion of chipmunks on both deciduous and coniferous clearcuts. Friday (1978) found greater chipmunk activity in forest and transition zones and less activity in open fields. He attributed this to the availability of mast and the predatory behavior of chipmunks on nesting birds. Krull (1970) however, concluded that clearcutting had no effect on chipmunk populations. He observed almost equal use of clearcuts and hardwood forests by this species.

The relationship between whole tree harvesting and the response of the 4 other species (deermice, shorttail shrews, masked shrews, and woodland jumping mice) can not be examined because of the year to year variability which resulted in low population levels.

SUMMARY

Whole tree harvesting drastically altered the structure of the vegetation by significantly reducing all cover >30cm. The shift in vegetative species composition following clear-cutting was lessened by the old growth stage of the stand which allowed many early successional species to be established before treatment. Both the bird and small mammal communities responded to the vegetative changes. The diversity of the bird community, including both species and numbers was significantly reduced. Forest dwelling species were replaced by early successional species. The assessment of differences between whole tree harvesting and conventional clearcutting was hindered by low woodpecker populations. It is not known if woodpecker populations in the surrounding area were low, or if there was too small an amount of slash present to attract these species.

The effect of whole tree harvesting on the small mammal community was confounded by population fluctuations of several species which could not be attributed to the treatment. However, meadow voles and meadow jumping mice appeared to have responded favorably to the vegetative changes produced by whole tree harvesting.

The results of this study suggest the response of wildlife populations to whole tree harvesting was similiar to responses observed on conventional clearcuts. However, differences may be noted in areas which have bird and small mammal communities containing higher numbers of species which depend on slash for food and/or cover.

Hahn and Michael (1980) suggested several management options to benefit small mammals and other wildlife on whole tree harvested areas. One option would be to leave all cull logs too large to be chipped in the clearcuts. This would provide cover and foraging areas for both small mammals and birds. These logs could also provide drumming stages for ruffed grouse. A second option would be to leave a predetermined density of snags of a certain dbh standing. Both cavity nesting birds and small mammals would benefit. When the regenerating vegetation grows to a point which closes the canopy and reduces the understory vegetative cover, the large cull logs and the snags which had fallen since clearcutting would still provide cover.

Additional research is needed to evaluate wildlife responses to whole tree harvesting of other vegetation types. Furthermore, long term research is necessary to evaluate both potential long term effects such as possible decreases in soil fertility and the response of naturally fluctuating populations such as the small mammal populations in this study.

APPENDIX

Table A-5. Species of vegetation found on the study plots in Midland County, Michigan during 1981 and 1982.

American elm	(*Ulnus americana*)
Balsam poplar	(*Populus balsamifera*)
Basswood	(*Tilia americana*)
Bigtooth aspen	(*Populus grandidentata*)
Black cherry	(*Prunus serotina*)
Blueberry	(*Vaccinium* spp.)
Bush honeysuckle	(*Diervillia lonicera*)
Catbrier	(*Smilax glauca*)
Choke cherry	(*Prunus virginiana*)
Currant	(*Ribes* spp.)
Elderberry	(*Sambucus canadensis*)
Flowering dogwood	(*Cornus florida*)
Green ash	(*Fraxinus pennsylvanica*)
Gray stem dogwood	(*Cornus racemosa*)
Grey willow	(*Salix humilis*)
Hawthorne	(*Crataegus* spp.)
Hazelnut	(*Corylus americana*)
Ironwood	(*Carpinus caroliniana*)
Maple leaf viburnum	(*Viburnum aurifolium*)
Musclewood	(*Ostrya virginiana*)
Nannyberry	(*Viburnum lentago*)
Pin cherry*	(*Prunus pennsylvanica*)
Pussy willow	(*Salix discolor*)
Quaking aspen	(*Populus tremuloides*)
Red maple	(*Acer rubrum*)
Red oak	(*Quercus rubra*)
Red osier dogwood	(*Cornus stolonifera*)
Rubus	(*Rubus* spp.)
Serviceberry	(*Amelanchier* spp.)
Silky dogwood	(*Cornus obliqua*)
Slippery elm	(*Ulnus rubra*)
Smooth alder	(*Alnus serrulata*)

Table A-5. (cont'd.)

Speckled alder	(Alnus rugosa)
Spirea	(Spiraea latifolia)
White ash	(Fraxinus americana)
White birch	(Betula papyrifera)
White oak	(Quercus alba)
Wild grape	(Vitis spp.)
Witch hazel	(Hamamelis virginiuna)
Bearberry	(Artostaphylos uva-ursi)
Bedstraw	(Galuim boreale)
Black snake root	(Sanicula marilondica)
Blood root	(Sangunaria canadensis)
Bottlebrush	(Elymus hystrix)
Bracken fern	(Pteridium aquilinum)
Bunch berry	(Cornus canadensis)
Bush honeysuckle	(Diervillin lonicera)
Canada lily	(Lilium canadense)
Carex	(Carex spp.)
Cattail	(Typha latifolia)
Cinquifoil*	(Potertilla spp.)
Common fleabane	(Erigeron philadelphious)
Dandelion*	(Taraxacum spp.)
Dovesfoot-cranebill*	(Geranium molle)
Dwarf ginseng	(Panax trifolrus)
False solomon seal	(Smilacina racemosa)
Fescue	(Festuca spp.)
Fringed loose strife	(Lysimachia cilcata)
Gall of the earth	(Prenanthes trifoliata)
Germanium	(Germanium spp.)
Hair grass	(Agrostia scabra)
Hairy solomon seal	(Polygonatum pubescens)
Hog peanut	(Amphicorpa bracteata)
Horsetail	(Equisetum arvense)

Table A-5. (cont'd.)

Lesser stichwart*	(Stellaria graminea)
Maple leaf goosefoot*	(Chempondium hybridum)
Marsh thistle*	(Circium palustre)
Meadow rue	(Thalictrum dioicum)
Mullein	(Verbascum spp.)
New England aster*	(Aster rovae-angliae)
New York fern	(Thelypteris noveboracensis)
Oak fern	(Gymnocarpium dryopteris)
Oat grass	(Danthonia spp.)
Orange hawkweed*	(Hieracium aurantiacum)
Ostrich fern	(Matteuccia struthropteris)
Pale corydalis*	(Corydalis sempervirens)
Poison ivy	(Rhus rodicans)
Rattle snake fern	(Botrychium virginianum)
Red baneberry	(Actrea rubro)
Redtop*	(Agrostis alba)
Royal fern	(Osmurda regalis)
Rue anemone	(Anemonella thalictroidc)
Sensitive fern	(Onoclea sensibilis)
Shinleaf	(Pyrolia elliptica)
Short-toothed mountain mint*	(Pycranthemum spp.)
Smooth solomon seal	(Polygonatum biflorum)
Solidago	(Solidago spp.)
Spinulose wood fern	(Dryopteris spinulosa)
Spreading dog bane	(Apocynam androsaemifolium)
Strawberry	(Fragaria virginiana)
Sweet cicely	(Osmorhiza claytoni)
Tall meadow rue	(Thalictrum polygamum)
Tartarian honeysuckle*	(Lonicera taterica)
Tick trefoil	(Desmodium canadense)
Thimbleweed	(Anemona virginiana)
Trillium	(Trillium spp.)
Violet	(Viola spp.)

Table A-5. (cont'd.)

Virginia creeper	(*Parthenocissus quinquetolin*)
Water hemlock	(*Cicuta maculata*)
Water parsnip	(*Sium suave*)
White avens*	(*Geum* spp.)
White clover*	(*Trifolium repens*)
White lettuce*	(*Prenanthes alba*)
Wild sasparillia	(*Aralin nudicalis*)
Wood anenome	(*Anemone quinquefolia*)
Yarrow	(*Achillea millefolium*)

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*Found only on whole tree harvested plots in 1982.

Table A-6. Absolute (AF) and relative frequencies (RF) of common herbaceous vegetation found on the study plots in Midland County, Michigan during 1981 and 1982.

Species	1981 Control		1981 Treatment		1982 Treatment	
	%AF (SE)	%RF (SE)	%AF (SE)	%RF (SE)	%AF (SE)	%RF (SE)
Bearberry	37.2(31.6)	4.3(1.2)	22.2(19.5)	6.6(1.9)	18.5(10.3)	1.7(1.1)
Bedstraw	59.3(28.0)	4.3(1.9)	72.2(19.5)	6.0(1.4)	44.4(20.0)	3.1(1.3)
Bracken fern	75.9(16.4)	7.1(3.9)	77.8(5.5)	6.7(0.5)	87.0(1.9)	6.9(1.0)
Bunchberry	25.9(13.3	2.6(1.5)	22.2(17.0)	2.1(1.7)	11.1(8.5)	1.0(0.9)
Gall of the earth	20.4(7.4	1.9(0.8)	22.2(11.1)	1.9(1.0)	-	-
Geranium	3.7(1.8)	0.3(0.1)	14.8(9.8)	1.1(0.7)	18.5(8.0)	1.3(0.5)
Hairy solomon seal	37.0(23.6)	2.7(1.5)	13.0(7.4)	1.0(.47)	-	-
Hog peanut	57.4(21.3)	4.4(1.2)	72.2(22.5)	6.0(1.7)	16.7(11.5)	1.1(0.8)
Horsetail	22.2(8.5)	1.7(0.5)	38.9(11.1)	3.6(1.2)	27.8(11.5)	2.2(0.8)
Poison ivy	20.4(14.8)	1.5(0.9)	11.1(6.4)	0.9(0.5)	5.5(0.0)	0.4(0.1)
Sedge	57.4(17.7)	4.4(.94)	72.2(0.0)	6.8(0.9)	85.2(3.7)[B]	6.7(0.6)
Sensitive fern	50.0(22.5)	3.7(1.6)	33.3(8.4)	2.8(0.4)	20.4(9.8)	1.4(0.6)
Solidago	92.6(3.7)	8.1(1.3)	96.3(1.8)	8.4(0.9)	94.4(3.2)	7.5(1.0)
Spinulose wood fern	25.9(14.5)	1.3(0.7)	16.7(8.5)	1.3(0.6)	5.6(3.2)	0.4(0.2)

Table A-6. (cont'd.)

Species	1981 Control		1981 Treatment		1982 Treatment	
	%AF (SE)	%RF (SE)	%AF (SE)	%RF (SE)	%AF (SE)	%RF (SE)
Strawberry	53.7(15.8)	4.2(0.8)	66.7(27.9)	5.6(2.3)	87.0(4.9)	6.8(0.5)
Sweet cicely	22.2(12.8)	1.3(0.9)	7.4(4.9)	0.6(0.5)	5.6(3.2)	0.4(0.2)
Tick trefoil	22.2(16.7)	1.6(1.1)	42.6(19.3)	3.4(1.3)	37.0(18.2)	2.6(1.1)
Violet	77.8(5.5)	6.9(1.6)	98.2(1.8)[A]	8.5(0.8)	81.9(3.5)[B]	6.5(0.8)
Virginia creeper	42.6(29.8)	3.0(2.0)	50.0(17.0)	4.1(1.2)	22.2(14.7)	1.5(1.0)
Wild sasparrllia	81.5(12.9)	7.4(2.2)	64.8(10.3)	5.5(0.7)	50.0(13.0)	3.8(0.9)

[A]Significantly different ($p < 0.10$) from control 1981.

[B]Significantly different ($p < 0.10$) from treatment 1981.

Table A-7. Numbers of bird species sighted and territories present for all plots and buffer zones in Midland County, Michigan during 1981 and 1932.

Species	Plot No	1981						1982					
		1	2	3	4	5	6	1	2	3	4	5	6
Goshawk (*Accipiter gentilis*)		(1)[A]						X					
Killdeer (*Charadrius vociferus*)											X/		
Mourning dove (*Zenaida macroura*)									/E[C]		X/E		
Yellow-billed cuckoo (*Coccyzus americanus*)				X[B]			X		/E	X	/E		/E
Black-billed cuckoo (*Cocyzus erythrophthalumus*)			X	X	X		X	X	/E	X			
Yellow-shafted flicker (*Colaptes auratus*)		X		X			1	X	/E	X	X(1)	X	X/E
Red-headed woodpecker (*Melanerpes erythrocephalus*)					1								
Hairy woodpecker (*Picoides vilosus*)		X	X	X			X	X/E	X	/E	X		
Downy woodpecker (*Picoides pubescens*)						X							
Eastern kingbird (*Tyrannus tyrannus*)									1/		1		X/1
Great crested flycatcher (*Myiarchus crinitus*)		2	3	2			1	2	X/1	1	1		X/1

Table A-7. (cont'd.)

Species	Plot No	1981						1982					
		1	2	3	4	5	6	1	2	3	4	5	6
Eastern phoebe (Sayornis phoebe)		1	X	X				1					
Acadian flycatcher (Empidonax virescens)				X		X							
Least flycatcher (Empidonax minimus)		10	X	X	1	X	2	3	/1	X	X/2	2	/9
Eastern wood peewee (Contopus virens)		3	4	4	4	3	3	1	/1	4	X/E	1	X/2
Bluejay (Cyanocitta cristata)		X	X	X	X	X	X	X	X/E	2	X/1	1	X/E
Common crow (Coruus brachyrhynchos)			X				X						
Black-capped chickadee (Parus atricapillus)		X	X	X	X	X	X	X	/E	X	/E	X	
White-breasted nuthatch (Sitta carolinensis)		X	X	X				1	/E	X	/E	X	
Brown creeper (Certhia familiaris)								1		1			
House wren (Troglodytes aedon)		3	1	2	1	5	10	4	/2	x	/2	5	/5
Catbird (Dumetella carolinesis)			1	X					1/E	X	X/E		1/1

Table A-7. (cont'd.)

Species	Plot No	1981						1982					
		1	2	3	4	5	6	1	2	3	4	5	6
Robin (_Turdus migratorius_)		X	X	X		X	X	X	1/1	1	X/4	3	X/1
Wood thrash (_Hylocichla mustelina_)		3	3	X	2		X	X		X	/1	1	
Veery (_Catharus fuscescens_)		4	9	6	5	5	4	5	/1	7	1/1	3	X/4
Eastern bluebird (_Sialia sialis_)									X/1	X/			
Bluegray gnatcatcher (_Polioptila caeruela_)								X	/E		/E	1	/1
Cedar waxwing (_Bombycilla cedrorum_)			X	X		X	X		/E	X	/E		
Starling (_Sturnus vulgaris_)		X	X	X							X/		
Red eyed vireo (_Vireo olivaceus_)		1	1	X	X	X	X	1	/E	X	/E	X	/9
Yellow-throated vireo (_Vireo flavifrons_)													/E
Warbling vireo (_Vireo gilbus_)													/E
Black and white warbler (_Mniotilta varia_)												/E	

Table A-7. (cont'd.)

Species	Plot No	1981						1982					
		1	2	3	4	5	6	1	2	3	4	5	6
Golden-winged warbler (_Vermivora chrysoptera_)			1	1	4		2		X/2	1	X/E	1	X/E
Blue-winged warbler (_Vermivora pinus_)								X					
Tennessee warbler (_Vermivora peregrina_)								X	/E	X	/E	X	/E
Yellow warbler (_Dendrocia petcchia_)					X			X	/E		/E		X/
Cape May warbler (_Dendrocia tigrina_)													/E
Blackburnian warbler (_Dendrocia fusca_)											/E	X	
Chestnut-sided warbler (_Dendrocia pensylvanica_)		X	X	X	X	X	X	X	/E	X	X/1	X	/1
Bay-breasted warbler (_Dendrocia castanea_)											/E		
Oven bird (_Seiurus aurocapillus_)		8	10	7	7	9	8	10	X/E	7	/1	6	/E
Northern waterbrush (_Seiurus noveboracensis_)		X						1	/E	X			

Table A-7. (cont'd.)

Species	1981						1982					
Plot No	1	2	3	4	5	6	1	2	3	4	5	6
Mourning warbler (*Oporornis philadelphia*)	X	X	2	3	1	X			X	1/2	2	X/X
Yellow throat (*Geothlypis trichas*)			X	X	X	X		/1	1	/1	X	X/2
American redstart (*Setophaga virescens*)	X	X					1	/1	X	/1	X	/1
Redwinged blackbird (*Agelaius phoeniceus*)			X		X	X	X	X/X	X	X/1	1	X/1
Northern oriole (*Icterus galbula*)	X	1	4	5	1	3	X	X/3	2	X/4	3	X/4
Rusty blackbird (*Euphagus carolinus*)		X										
Common grackle (*Quiscalus quiscala*)	X			X		X	X	X/X	X	X/		X/X
Brown-headed cowbird (*Molthrus ater*)	X		X	X	X	X	X	X/X	X	X/X	X	X/X
Scarlet tananger (*Piranga olivacea*)				X		X	X	X/X	1	/X	X	/X
Cardinal (*Cardinalis cardinalis*)												X

Table A-7. (cont'd.)

Species	Plot No	1981						1982					
		1	2	3	4	5	6	1	2	3	4	5	6
Rose-breasted grosbeak		1	2	4	3	6	2	2	X/4	6	X/4	3	X/2
(*Pheucticus ludovicianus*)		1	2	4	3	6	2	2	X/4	6	X/4	3	X/2
Indigo bunting (*Passerina cyanea*)			X						X/X		X/X		
American goldfinch (*Carduelis tristis*)											X/	X	
Rufous-sided towhee (*Pipilo erythrophthalmus*)		X	X	X		X	X	1	X/1		X/2	1	2/1
Tree sparrow (*Spizella arborea*)			X				X						
Field sparrow (*Spizella pusilla*)									X/X				
Song sparrow (*Melospiza melodia*)		X	1	X	X		X		3/1		4/1	1	4/1
Number breeding territories		37	37	32	36	30	36	34	6/21	37	7/33	37	7/39

[A]Number of territories present on the plot

[B]Species sighted on the plot

[C]Species sighted on the buffer zone

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