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RESPONSE OF SONGBIRDS AND SMALL MAMMALS

TO WHOLE TREE HARVESTING OF ASPEN

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Laura Elizabeth Eaton

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TREE HARVESTING OF ASPEN

By

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ABSTRACT

RESPONSE OF SONGBIRDS AND SMALL MAMMALS TO WHOLE TREE HARVESTING OF ASPEN

by

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Whole tree harvesting has become increasingly popular as a harvesting technique in recent years. Questions, therefore, have been raised as to the environmental impacts of this technique. In this study, songbird and small mammal populations were compared between 8 whole tree harvested aspen clearcuts and 8 aspen clearcuts harvested by conventional pulpwood techniques.

Songbirds were censused during the breeding season using the variable-circular plot method. Small mammals were trapped in August using Sherman live-traps. Percent cover of slash, percent cover of vegetation, and density of woody stems were also measured on the sites.

Slash was found to provide an average of 380% more cover on the conventional sites than on the whole tree sites. No differences were found in vegetation cover or stem densities between the harvest types.

Sixteen species of birds and 7 species of small mammals exhibited a preference for 1 of the harvest types. Approximately half the species preferred the conventional sites and half the whole tree sites. These results suggest that in large forest tracts both methods of harvesting can be used, with a mix of the 2 methods recommended.

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INTRODUCTION

Whole tree harvesting became a production reality in the early 1970's as a means of attaining greater efficiency in the use of forest resources. Its initiation related directly to an increasing demand for fiber for pulp and chip products, and for wood fuel for industry as a supplement to conventional fossil fuels (Arola and Miyata 1981, Keays 1974).

Whole tree harvesting is a technique whereby all above-ground portions of the trees are utilized. This is usually accomplished by chipping the wood on site, immediately upon harvest. This technique both enhances time efficiency and decreases transportation costs. Herrick (1982) estimated that substituting chipping technology for conventional hardwood pulpwood harvesting increased annual production by 2 1/2 times and reduced cost by $6.45 per cord-equivalent delivered as chips. Whole tree harvesting also has the added benefit of reducing the site preparation necessary for regeneration by considerably reducing the amount of slash left on the site (Blyth and Wilhelm 1980). For these reasons, whole tree harvesting has become increasingly popular as a harvesting method in recent years.

However, since little residual material is left on the site, some questions have been raised as to the potential environmental impacts of this technique. Numerous studies have been conducted concerning nutrient loss, increased exposure of soil and litter, increased erosion, and increased leaching. Kimmins (1977) and Van Hook et al. (1982) provided literature reviews on these topics.

Only 2 studies, hence far, have dealt with the effect of whole tree harvesting on wildlife habitat. A study by Hahn and Michael (1980) investigated the response of small mammals to whole tree harvested hardwood clearcuts. They found a significant decrease in small mammal abundance in the clearcuts which lasted for 6 years after harvest. They mentioned that these results differed considerably from the results of previous studies which found that small mammal populations typically declined initially, but then quickly recovered, and even increased in abundance on clearcut sites. Hahn and Michael (1980) were unable to demonstrate in their study that the lack of logging residue on the clearcuts was responsible for the decline of the small mammal population.

A study by Beyer (1983) looked at the response of songbirds and small mammals to whole tree harvesting of aspen. He found a reduction in the diversity, numbers, and species of songbirds in the clearcuts as compared to uncut plots. The small mammal population exhibited fluctuations which could not be attributed to the harvesting treatment. Again, this study did not specifically investigate the importance of logging residue to the wildlife populations.

Slash has been documented as being utilized as a source of food or cover for a number of songbird and small mammal species on recent conventional clearcuts. Hagar (1960) discussed the importance of slash to the ground foraging dark-eyed junco (Junco hyemalis) as resting and escape cover on clearcuts, especially before the invasion of brush. Franzreb (1978) attributed the existence of a high density of gray-headed juncos (Junco phaeonatus) in cut sites to the presence of slash. Franzreb and Ohmart (1978) described the importance of slash to gray-headed juncos as foraging surfaces, observation posts, and protection for nest sites.

Hagar (1960) found that winter wrens (Troglodytes troglodytes) had a preference for cut sites and were always found in close association with logs. Similar results have been found for the house wren (Troglodytes aedon) (Franzreb and Ohmart 1978, Scott and Gottfried 1983), and for the Carolina wren (Thryothorus hidovicianus) (Connor and Adkisson 1975). Connor and Crawford (1974) found that recently clearcut areas attracted downy woodpeckers (Dendrocopus pubescens) and hairy woodpeckers (Dendrocopus villosus) because the slash and debris from logging provided an abundant source of insect prey.

Many studies have indicated a relationship between protective cover and small mammal populations (Eadie 1953, Morris 1955, Lovejoy 1971, M'Closkey and Lajoie 1975). Red-backed voles (Clethrionomys gapperi) have specifically been correlated with the presence of slash (Tevis 1956, Gunderson 1959, Ahlgren 1966, Martell and Radvanyi 1977). Dimock

(1974) mentioned that residue may serve as a potential source of food for insectivorous small mammals.

Removal of slash by burning on clearcuts has also been documented to have dramatic effects on small mammal populations. Small mammal populations are typically reduced initially. However, Peromyscus populations have been found to recover within months after a fire (Ahlgren 1966, Sims and Buckner 1972, Krefling and Ahlgren 1974, Fala 1975). Species requiring more cover, such as the red-backed vole or various species of shrews, require extensive periods of time to regain their numbers after burns (Ahlgren 1966, Dimock 1974).

Songbirds and small mammals were chosen for this study because of their usefulness as indicators of habitat quality (Graber and Graber 1976, Plunkett 1979, West et al. 1981). These populations are also integral elements in ecosystems. Birds are important to the balance of the food chain, and aid in the perpetuation of communities through seed dispersal (Marks 1974). Birds have also been documented as being important in controlling pest insect plagues (Bruns 1959, Plunkett 1979, Crawford et al. 1983). Small mammals serve as a prey base for larger predators (Hamilton and Cook 1940, Chew 1978, Potter 1978). They have also been credited with increasing soil aeration and fertility, and thus plant productivity (Hamilton and Cook 1940, Chew 1978). Small mammals may also aid in seed dispersal and in the dispersal of mycorrhizal fungi (West 1968, Chew 1978, Maser et al.

1978, Ream and Gruell 1980). In addition to their ecological importance, nongame wildlife populations have been receiving increasing attention and concern from the general public in recent years (Zagata 1978). Aspen (Populus spp.) sites were chosen for this study because aspen is typically harvested by clearcutting, and because aspen is important to the pulpwood industry in Michigan (Blyth and Smith 1980).

It is important for wildlife populations to be given proper consideration in forestry management plans. This is not possible, however, without sufficient information concerning wildlife habitat requirements. The purpose of this study was to determine if there are significant differences in small mammal and songbird populations between whole tree and conventionally harvested sites. Ultimately, the study should indicate the importance of slash to these populations on recently clearcut sites.

OBJECTIVES

The objectives of this research project were to:

1. Compare the relative population densities, species composition and species diversity of songbird and small mammal communities between whole tree harvested and conventionally harvested clearcut sites.

2. Determine the importance of cover provided by slash to these populations.

3. Determine the importance of other site characteristics, such as site size, and vegetative structure and composition, to the species observed, in order to explain the occurrence of the populations found on the sites.

STUDY SITE DESCRIPTION

Sixteen aspen clearcuts, situated in the Pigeon River Country State Forest, Michigan were selected for the study. Half of the sites were harvested by whole tree harvesting and 1/2 by conventional pulpwood techniques. Half of the sites within each harvest type were cut in 1982 and half were cut in 1984.

The Pigeon River Country State Forest consists of 33,603 ha. It is located throughout the northeast corner of Otsego County and the southeast corner of Cheboygan County, which are located in the central northern Lower Peninsula (Fig. 1). The topography of the Pigeon River area consists of morainic uplands, steep morainic slopes, sandy outwash plains, and river bottoms. Three rivers, the Black, the Sturgeon, and the Pigeon, originate from coniferous swamps along the southern edge of the area and flow north. The soils range from dry sand of low fertility on outwash plains to sandy loams of medium high fertility on till plains and moraines (Moran 1973).

The typical climate of this area is characterized by long cold winters, short cool summers, mild autumns, late cold springs, prevailing westerly winds, fairly high humidity and low evaporation. The average rainfall for the area

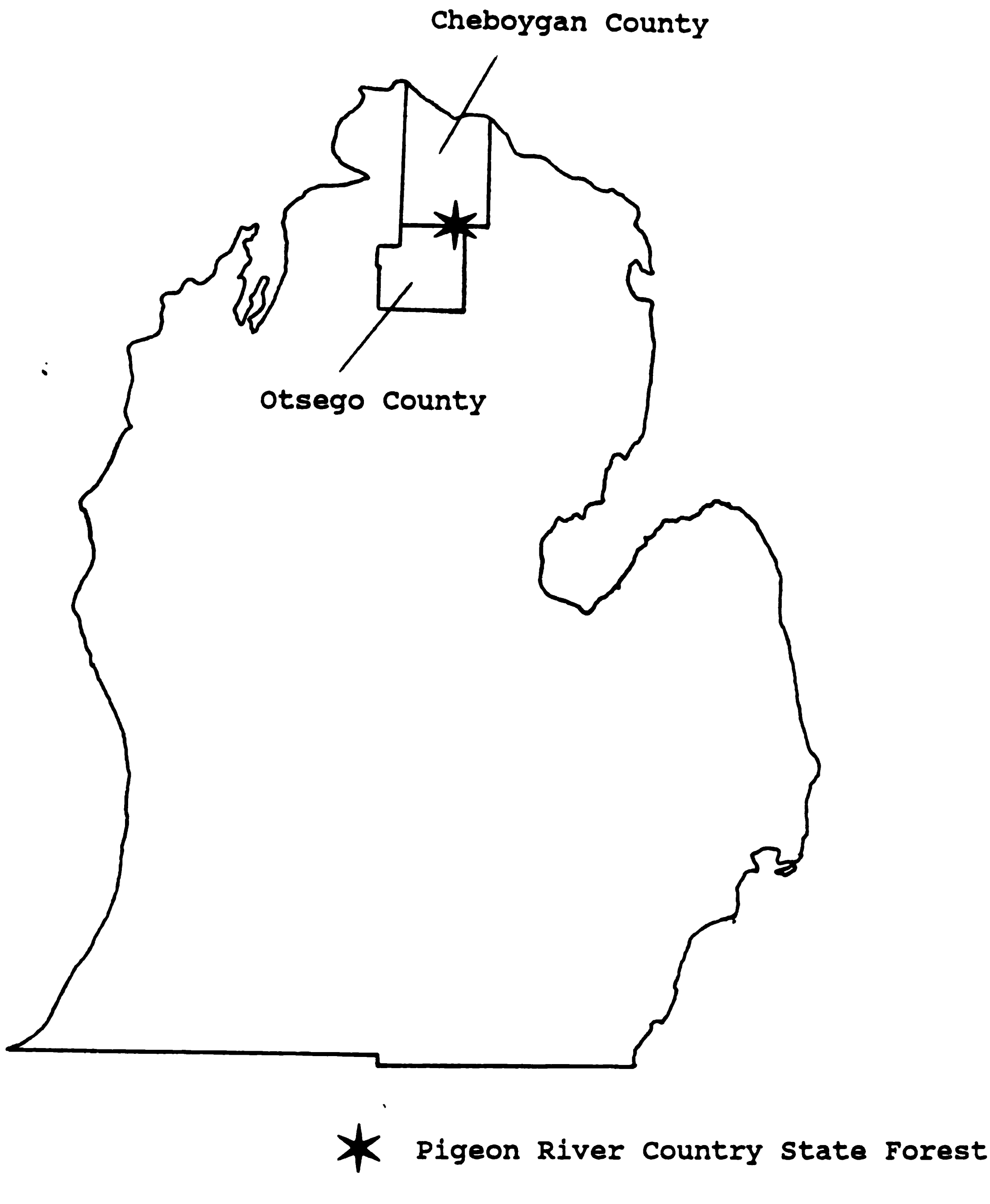

Fig. 1. The location of the Pigeon River Country State Forest in Cheboygan and Otsego Counties, Michigan.

is 10.24 cm. The average frost-free season is 116 days in the south-central part of Cheboygan County (Foster et al. 1939).

The clearcuts investigated ranged in size from 5 to 16 ha. The total area of the conventional sites consisted of 77 ha. The total area of the whole tree sites consisted of 93 ha. The soils of the sites ranged from well drained to poorly drained, and the extreme moisture conditions were evenly divided between the 2 harvest types.

All of the sites had both bigtooth aspen (Populus grandidentata) and trembling aspen (Populus tremuloides) present, with 1 species usually dominant over the other. A variety of hardwood species were mixed with the aspen on the sites. These included oaks (Quercus spp.), maples (Acer spp.), birch (Betula spp.), cherries (Prunus spp.), and beech (Fagus grandifolia). Conifers, such as balsam fir (Populus balsamifera) and eastern white pine (Pinus strobus) were occassionally scattered over the plots as well. Common shrubs in the clearcuts included hawthorn (Crataegus spp.), beaked hazelnut (Corylus cornuta), serviceberry (Amelanchier spp.), maple-leaf viburnum (Viburnum acerifolium), witch-hazel (Hamamelis virginiana), and brambles (Rubus spp.). Herbaceous vegetation was typically dominated by bracken fern (Pteridium aquilinum), grasses, and a variety of field flowers. A number of the sites still had large trees standing which were residual from harvest. Snags, when present, were also left standing by harvest.

METHODS

Experimental Design

This study was arranged as a completely randomized design with 4 replications. Sixteen clearcuts served as study sites. These were divided into 2 treatments: harvesting by whole tree techniques and harvesting by conventional techniques. Each treatment was divided into 2 age classes: sites cut in 1982 and sites cut in 1984. The data for the study were collected in the spring and summer of 1984 and 1985. The sites were, therefore, in their first and third growing seasons during the first field season, and in their second and fourth growing seasons during the second field season. This arrangement allowed for the examination of treatment effects over 4 age classes, and thus over a range of vegetative development.

Songbird Census

Songbirds were censused from mid-May to mid-June of each year by the variable circular-plot method, as described by Reynolds et al. (1980). As many censusing stations as possible were established on each site. Stations were established at least 150m apart and 75m from an edge. The number of stations established on the sites ranged from 2 to 7.

The period of time spent censusing at each station was 6 minutes. This period was determined from several 30 minute pre-counts. In the pre-counts, the number of species observed was plotted against time. The period at which the addition of new species began to level off was used as the counting time. All "singing males" were counted as 2 birds.

Sites were censused 10 times in 1984, and 9 times in 1985. Censuses for each site were distributed throughout the breeding season. Three observers were used for the censuses. Observers were rotated on the sites to limit observer bias. Censuses began at sunrise each morning. However, censuses were not carried out on exceptionally windy, rainy, foggy, or cold mornings. Approximately 2 sites were censused per observer per morning. Therefore, the time of the morning a site was censused was switched for each observation period. That is, if a site was censused first 1 period, it was censused second the next. Censusing was also initiated at a different station for each observation period.

Small Mammal Census

Small mammals were censused by trapping with Sherman live-traps during August of each field season. A trapping grid consisting of 6 rows and 6 columns was established on each site. Stations were established 15m apart with 2 traps per station.

Grids were established in locations which appeared as similar as possible in terms of topography, drainage, and vegetation. Grids were placed as far from the site edges as possible to limit the chances of catching edge inhabitants. However, some of the sites were small or narrow. Therefore, for consistency, all grids were established with 1 side 60m from an edge, which was the largest distance possible on the smallest site.

Sites were trapped for 5 consecutive nights. A whole tree and a conventional site of each age class (4 sites) were trapped concurrently to control variation due to weather. Traps were baited with a mixture of oats, lard, and anise extract. All animals captured were marked with ear tags or by toe clipping.

Vegetation Sampling

Vertical cover of vegetation was measured in each clearcut by the line intercept method (Gysel and Lyon 1980). Five height strata were measured: 0-10cm, 10-30cm, 30cm-1m, 1-4m, and >4m. Percent cover of slash was measured in a 0-30cm stratum. Vegetation and slash cover <1cm were ignored. Gaps in cover <5cm were also ignored. Line intercepts were run from randomly located points. All lines were run north, unless the line ran out of the clearcut, then it was run south, east, or west, respectively. Measurements were made at least 20m from the edge of the site. The length of the lines ranged between 20 and 100m, depending on the variability of the cover on the sites.

Density of woody stems was measured in rectangular plots which were 2m wide and ran the length of the line intercepts.

Stems were counted in 2 strata: <1m in height, and >1m in height and <10cm dbh. Stems were recorded by species. Frequency of herbaceous vegetation was recorded from 2m x 5m plots. The line intercept was used as 1 edge of the plot. All measurements were carried out until a required sample size, calculated at the 95% level of confidence, was met.

Trees >4m in height were counted and recorded by diameter classes. Snags $\geq$2m in height and $\geq$5cm dbh were also counted and were recorded by diameter and height.

Data Analysis

Statistically adequate sample sizes for all vegetative sampling and slash sampling were determined with the following formula from Snedecor (1956):

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

t = tabulated at the 90% confidence level

s = sample variance

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

Foliage height diversity, bird species diversity, and small mammal diversity were determined by the Shannon - Weiner diversity index (Hair 1980):

$$H' = -\sum p_i \log p_i$$

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

Analysis of the variable circular-plot method was carried out as described by Szaro and Balda (1983). Density of each species per band around census points on 40.5 ha scale was calculated by:

$$BD = \frac{4.365(10^6)(N)}{\pi(OR^2 - IR^2)(p)(f)}$$

BD = band density

N = number of observations in the band

OR = outer band radius

IR = inner band radius

p = number of sampling stations

f = frequency each station was sampled

The number of birds per 40.5 ha (by species) for each point for each count period was calculated by:

$$\text{birds/40.5 ha} = \frac{4.356(10^6)(N)}{\pi\ (IP^2)}$$

Overall density of each species was then calculated by determining the mean and the standard error of the individual estimates. In order to account for the correlation between sampling periods, standard errors were calculated by:

$$v(y) = \left(\sum_{i}^{f} s_i^2 + 2\sum_{i<j}^{f}\sum^{f} r_{ij}\ s_i\ s_i\right)/(pf^2);$$

$$SE = v(\bar{y})$$

S = among-station variance on the i sampling period

r = correlation between sampling periods i and j

Differences between the clearcut types, within age classes, were analyzed with the nonparametric randomization test. Differences were tested for: % cover of slash, % cover of vegetation, foliage height diversity, stem densities, bird species' densities, bird species diversity, songbird abundance, number of species of songbirds, small mammal abundance, number of species of small mammals, and small mammal diversity. These tests were carried out at the 95% confidence level.

Songbird and small mammal populations were tested for association with habitat parameters using Spearman-rank correlation analysis. Parameter combinations are listed in table 1. Partial correlations, holding % cover of slash constant, was further used to test for songbird associations with clearcut size.

Table 1. List of parameter combinations for correlation analyses.

X-variables	Y-variables
Foliage height diversity	Bird species diversity Bird abundance Number bird species Bird species densities
Clearcut size	Cover of slash Bird abundance Bird species densities Bird species diversity
Cover of slash	Bird species densities Small mammal species numbers
Cover of vegetation (height strata: 0-10cm, 10-30cm, 30cm-1m, 1-4m)	Bird species densities Small mammal species numbers
Cover of vegetation (height strata: >4m)	Bird species densities
Density of woody stems (strata: <1m in height, >1m in height and <10cm dbh)	Bird species densities Small mammal species numbers
Number of woody species	Small mammal species numbers

RESULTS

Slash Sampling

The mean % cover of slash was found to be significantly greater ($p<0.05$) on the conventional sites. The cover of slash on the conventional sites ranged from 17-56% with a mean of 37.39 ± 4.51%. The cover of slash on the whole tree sites ranged from 6-16% with a mean of 9.75 ± 1.26%. Slash, therefore, provided an average of 380% more cover on the conventional sites than on the whole tree sites.

Vegetation Sampling

No significant differences were found for vegetative cover (Table 2), foliage height diversity (Table 3), or stem density (Table 4) between the harvest types ($p>0.05$). However, some trends are evident. Consistently more cover was sampled on the conventional sites in the 30cm-1m and 1-4m strata in all 4 year classes. Stem density in the >1m stratum was also found to be consistently greater on the conventional sites.

Absolute and relative frequencies of herbaceous plants are provided in appendix A. No differences were noted.

Songbird Census

The overall abundance of birds was found to range from 2-12 birds/ha in 1984 and from 5-12 birds/ha in 1985. The

Table 2. Percent cover of vegetation in 5 height strata on 8 conventional (C) and 8 whole tree (W) aspen clearcuts which were harvested in 1982 and 1984. Sites were measured in 1984 and 1985 (Mean ± S.E.).

Year Class[a]	Harvest Method	Height Strata				
		0-10cm	10-30cm	30cm-1m	1-4m	> 4m
1	C	62.56±11.59	42.82±14.58	40.69±6.85	8.44±3.70	2.60±1.18
	W	33.74±10.49	32.54±7.66	29.40±3.35	2.38±0.71	0.98±0.58
2	C	54.18±15.01	37.05±10.54	41.35±9.72	7.94±1.72	0.63±0.50
	W	53.87±17.42	40.20±6.99	34.09±9.71	5.83±1.39	0.45±0.42
3	C	77.08±5.37	75.10±4.89	62.47±6.36	22.46±7.85	1.20±0.92
	W	69.07±4.74	65.68±3.56	56.84±4.11	11.15±2.09	1.80±0.62
4	C	47.98±8.50	25.57±3.96	47.95±4.37	19.68±6.77	1.20±0.92
	W	51.72±10.17	27.11±6.59	38.96±1.95	8.44±0.69	1.98±0.70

[a] 1- and 2-year-old clearcuts, and 3- and 4-year-old clearcuts were the same sites measured in different years.

Table 3. Foliage height diversity values, calculated with the Shannon-Weiner equation (Hair 1980), for 8 conventional and 8 whole tree aspen clearcuts which were harvested in 1982 and 1984. Sites were measured in 1984 and 1985 (mean ± S.E.).

Year Class[a]	Conventional	Whole tree
1	1.28 ± 0.05	1.23 ± 0.03
2	1.21 ± 0.02	1.19 ± 0.03
3	1.31 ± 0.03	1.28 ± 0.03
4	1.22 ± 0.06	1.29 ± 0.02

[a]1- and 2-year-old clearcuts, and 3- and 4-year-old clearcuts are the same sites measured in different years.

Table 4. Mean stem density per ha (±S.E.) for 2 strata (< 1m in height, and > 1m in height but < 10cm dbh) measured on 8 conventional and 8 whole tree aspen clearcuts which were harvested in 1982 and 1984. Sites were measured in 1984 and 1985.

Year Class[a]	Conventional		Whole Tree	
	< 1m	> 1m	< 1m	> 1m
1	24197 ± 2206	7371 ± 2951	27528 ± 1216	5236 ± 800
2	16506 ± 1744	9715 ± 1637	12635 ± 1087	8048 ± 1225
3	13012 ± 1959	13551 ± 2902	14798 ± 1866	11799 ± 620
4	8821 ± 1723	10729 ± 2729	9288 ± 762	7983 ± 1089

[a] 1- and 2-year-old clearcuts, and 3- and 4-year-old clearcuts were the same sites measured in different years.

species which were consistently high in abundance on the sites regardless of harvest type or age, were the chestnut-sided warbler (Dendroica pensylvanica), indigo bunting (Passerina cyanea), and song sparrow (Melospiza melodia). Other species were also abundant, but were primarily so on 1 harvest type or the other, or only within certain year classes.

Values for bird density, number of species, and bird species diversity (BSD) are listed in table 5. Bird density was found to be significantly greater ($p<0.05$) on the conventional sites in the first year class. Bird density continued to be slightly higher on the conventional sites through the fourth year class, but the differences were not significant. Also in the first year class, BSD was found to be significantly greater ($p<0.05$) on the whole tree sites. In the second year class, the number of species was found to be significantly greater ($p<0.05$) on the whole tree sites. In the third year class, the number of species was found to be significantly greater ($p<0.10$) on the conventional sites.

A complete list of bird species occurring on the sites with their mean densities on each clearcut type are provided in appendices B and C. Bird species which were determined to be present on the harvest types in significantly different numbers are listed in tables 6 and 7.

A maximum of 27 species were observed in clearcuts in their first growing season. Thirteen of these species were found to have significantly different numbers between the harvest types. Alder flycatcher (Empidonax traillii),

Table 5. Density of birds per ha, number of bird species, and bird species diversity (BSD), which was calculated with the Shannon-Weiner equation (Hair 1980), on 8 conventional (C) and 8 whole tree (W) aspen clearcuts. Sites were harvested in 1982 and 1984. Birds were censused in 1984 and 1985 (mean ± S.E.).

Year Class[a]	Harvest Method	Bird Density per ha	Number Bird Species	BSD
1	C	6.3 ± 1.2**	20 ± 1.2	1.79 ± 0.10**
	W	3.0 ± 0.5	23 ± 2.7	2.58 ± 0.11
2	C	8.0 ± 1.4	24 ± 2.1**	2.73 ± 0.08
	W	7.8 ± 0.6	32 ± 1.6	2.72 ± 0.04
3	C	8.5 ± 1.8	25 ± 1.8*	2.37 ± 0.15
	W	6.1 ± 1.2	21 ± 2.2	2.35 ± 0.21
4	C	9.1 ± 1.2	30 ± 1.9	2.48 ± 0.09
	W	7.7 ± 0.6	28 ± 1.4	2.65 ± 0.12

[a] 1- and 2-year-old clearcuts, and 3- and 4-year-old clearcuts were the same sites censused in different years.

* Significant differences ($p < 0.10$) between harvest types within years.

** Significant differences ($p < 0.05$) between harvest types within years.

Table 6. Mean densities (±S.E.) of birds in 1984 which differed significantly between 8 conventional and 8 whole tree aspen clearcuts which were in their first and third growing seasons.

Bird Species	Year Class 1		Year Class 3	
	Conventional	Whole Tree	Conventional	Whole Tree
Alder flycatcher (*Empidonax traillii*)	3.9±2.5	0.0±0.0**	13.5±13.5	0.0±0.0**
American redstart (*Setophaga ruticilla*)	3.5±2.7	0.0±0.0**	1.7±1.2	0.0±0.0
Common yellowthroat (*Geothlypis trichas*)	3.2±1.3	0.1±0.1**	5.4±1.6	1.0±0.7**
Eastern bluebird (*Sialia sialia*)	0.0±0.0	2.7±1.6**	0.9±0.6	0.6±0.4
Eastern kingbird (*Tyrannus tyrannus*)	1.7±1.5	7.9±2.2**	4.9±2.0	7.7±3.0
Field sparrow (*Spizella pusilla*)	0.0±0.0	0.4±0.4	0.0±0.0	1.2±0.9**
Golden-winged warbler (*Vermivora chrysoptera*)	0.0±0.0	2.0±2.0	35.5±17.0	2.1±2.1*
Great crested flycatcher (*Myiarchus crinitus*)	0.7±0.4	0.7±0.5	0.9±0.7	0.0±0.0*
Killdeer (*Charadrius vociferous*)	0.0±0.0	9.6±7.5**	0.0±0.0	0.5±0.5

Table 6. (cont'd)

Bird Species	Year Class 1		Year Class 3	
	Conventional	Whole Tree	Conventional	Whole Tree
Mourning dove (*Zenaidura macroura*)	0.0±0.0	0.0±0.0	0.6±0.4	0.0±0.0**
Mourning warbler (*Oporornis philadelphia*)	20.2±6.5	3.4±2.0**	14.1±6.7	7.2±5.1
Northern oriole (*Icterus galbula*)	0.4±0.4	3.5±0.6**	0.2±0.2	2.5±2.2*
Rufous-sided towhee (*Pipilo erythrophthalmus*)	3.2±2.5	0.0±0.0**	25.0±5.8	11.1±4.0
Scarlet tanager (*Piranga rubra*)	0.0±0.0	1.1±0.7**	0.1±0.1	0.1±0.1
Tree swallow (*Iridoprocne bicolor*)	0.9±0.9	2.6±1.4*	5.5±2.3	0.9±0.9*
Vesper sparrow (*Pooecetes gramineus*)	0.0±0.0	1.9±1.3**	2.0±1.2	3.6±1.3
White-throated sparrow (*Zonotrichia albicollis*)	69.0±25.0	4.2±3.1**	19.1±8.5	13.7±12.0

* Significant differences ($p<0.10$) within a year class.
** Significant differences ($p<0.05$) within a year class.

Table 7. Mean densities (±S.E.) of birds in 1985 which differed significantly between 8 conventional and 8 whole tree aspen clearcuts which were in their second and fourth growing seasons.

	Year Class 2		Year Class 4	
Bird Species	Conventional	Whole Tree	Conventional	Whole Tree
American redstart (*Setophaga ruticilla*)	1.5±1.0	0.4±0.4	5.5±3.4	0.0±0.0**
Eastern bluebird (*Sialia sialia*)	0.0±0.0	4.2±1.1**	3.9±1.4	10.5±3.1
Eastern kingbird (*Tyrannus tyrannus*)	0.8±0.3	5.8±1.2**	3.1±1.5	6.9±3.1
Field sparrow (*Spizella pusilla*)	0.0±0.0	0.6±0.6**	0.0±0.0	1.8±1.2**
Mourning dove (*Zenaidura macroura*)	1.2±0.5	0.0±0.0**	1.4±1.4	0.4±0.2
Nashville warbler (*Vermivora ruficapilla*)	13.9±5.8	1.1±0.4**	17.4±6.1	8.4±3.0
Northern oriole (*Icterus galbula*)	0.5±0.5	1.5±0.6*	1.2±1.0	7.1±2.9
Rufous-sided towhee (*Pipilo erythrophthalmus*)	10.9±8.7	1.4±1.2**	12.2±3.6	19.4±4.9
Tree swallow (*Iridoprocne bicolor*)	0.0±0.0	4.0±1.3**	5.0±1.8	2.6±1.9

Table 7. (cont'd)

Bird Species	Year Class 2 Conventional	Year Class 2 Whole Tree	Year Class 4 Conventional	Year Class 4 Whole Tree
White-throated sparrow (*Zonotrichia albicollis*)	56.3±22.0	12.2±4.7	12.0±6.2	8.3±8.3

* Significant differences ($p<0.10$) within a year class.
** Significant differences ($p<0.05$) within a year class.

American redstart (Setophaga ruticilla), common yellowthroat (Geothlypis trichas), mourning warbler (Oporornis philadelphia), and rufous-sided towhee (Pipilo erythrophthalmus) were observed almost exclusively on the conventional sites. White-throated sparrow (Zonotrichia albicollis) was observed primarily on the conventional sites, but was also observed in relatively low numbers on the whole tree sites. Eastern bluebird (Sialia sialia), killdeer (Charadrius vociferus), northern oriole (Icterus galbula), scarlet tanager (Piranga rubra), tree swallow (Iridoprone bicolor), and vesper sparrow (Pooecetes gramineus) were observed almost exclusively on the whole tree sites. However, scarlet tanager, tree swallow, and vesper sparrow were observed in relatively low numbers. Eastern kingbird (Tyrannus tyrannus) was observed in significantly greater numbers on the whole tree sites, but was also observed on 2 of the conventional sites.

A maximum of 36 bird species were observed in clearcuts in their second growing season. Nine of these species were found to be present in significantly different numbers between the 2 harvest types. The bird species found in greater numbers on the conventional sites were mourning dove (Zenaidura macroura), Nashville warbler (Vermivora ruficapilla), rufous-sided towhee, and white-throated sparrow. Species found in greater numbers on the whole tree sites were eastern bluebird, eastern kingbird, field sparrow (Spizella pusilla), northern oriole, and tree swallow.

However, field sparrow, mourning dove, and northern oriole were all observed in relatively low numbers.

In the third growing season, a maximum of 28 species were observed on the sites. Of these, 9 species were found to have significantly different numbers between the harvest types. In this year class, alder flycatcher, American redstart, common yellowthroat, golden-winged warbler (Vermivora chrysoptera), great crested flycatcher (Myiarchus crinitus), mourning dove, and tree swallow were found to prefer conventional sites, while field sparrow and northern oriole were found to prefer whole tree sites. However, American redstart, great crested flycatcher, mourning dove, and field sparrow were all present in low numbers in this year class.

In the fourth growing season, a maximum of 34 species were observed on the sites. In this year class, American redstart was found to prefer conventional sites and field sparrow was found to prefer whole tree sites. Again the field sparrow was observed in relatively low numbers.
The general pattern of abundances remained the same in this year class in that the species which showed a preference for 1 harvest type in previous year classes still had a higher mean density on the preferred type in this year class.

Of the 16 species which were found to have significantly different densities between the harvest types, 10 were found to be significantly correlated with % cover of slash for at least 1 of the censusing years. These 10 species are listed in table 8 with the correlation coefficients for each year. The species which exhibited a preference for conventional

Table 8. Correlations (r_s) between bird densities and % cover of slash. Birds listed were found to have significantly different numbers between conventional and whole tree aspen clearcuts. Sites were harvested in 1982 and 1984. Birds were censused in 1984 and 1985.

	Correlation Coefficient (r_s)	
Bird Species	1984 Census	1985 Census
American redstart (Setophaga ruticilla)	.783***	.411
Common yellowthroat (Geothlypis trichas)	.674***	.535**
Eastern bluebird (Sialia sialia)	-.490*	-.612***
Eastern kingbird (Tyrannus tyrannus)	-.536**	-.557**
Field sparrow (Spizella pusilla)	-.491*	-.509**
Mourning dove (Zenaidura macroura)	.455*	.270
Mourning warbler (Oporornis philadelphia)	.516**	.505**
Nashville warbler (Vermivora ruficapilla)	-.043	.476*
Northern oriole (Icterus galbula)	-.383	-.518**
White-throated sparrow (Zonotrichia albicollis)	.499**	.433*

* Significant at $p<0.10$
** Significant at $p<0.05$
*** significant at $p<0.01$

sites were found to be positively correlated with slash, while species exhibiting a preference for whole tree sites were found to be negatively correlated with slash.

Six of the 10 species which were found to be significantly correlated with slash were consistently so for both of the censusing years. Northern oriole and Nashville warbler were found to be correlated with slash only in 1985, while American redstart and mourning dove were found to be correlated with slash only in 1984. The greatest density of redstarts in 1984 was observed on the 1-year-old conventional sites. These birds were most often observed near the ground, moving in and around the slash, and were therefore assumed to be nesting in the slash. In 1985, the greatest density of redstarts was observed on the 4-year-old conventional sites. On these sites the birds appeared to be using the upper strata of vegetation. If slash was important to this species in 1985 it was not detected by observations or by correlation analysis.

Nashville warbler was not found to be correlated with slash in 1984, but was found to be correlated with slash ($p<0.10$) in 1985. The observations of this species tend to support these findings. This species was present on the sites in much lower numbers in 1984 than in 1985. Also, in 1984 this species was primarily detected near the edges of the clearcuts, while in 1985 it was detected in substantial numbers throughout the area of the clearcuts. No explanation is evident for the differing use of slash between the

2 years by the northern oriole and mourning dove, suggesting that the significant correlations with slash for the 1 year were due to chance.

Four species which were not found to exhibit a preference for 1 of the harvest types were found to be significantly correlated with slash. However, these species were only found to be correlated with slash for 1 of the censusing years. Common flicker (Colaptes auratus) ($p<0.10$), song sparrow ($p<0.10$), and house wren ($p<0.01$) were positively correlated with slash in 1984, and brown thrasher (Toxostoma rufum) ($p<0.10$) was negatively correlated with slash in 1985. The house wren was not observed on the sites in 1985, therefore the validity of its correlation with slash is difficult to evaluate. Since the other species were abundant on the sites in both years, their correlations with slash for the 1 year are assumed to be due to chance.

The species which exhibited differences in numbers between the harvest types, but which correlation analysis did not indicate to be associated with slash, were alder flycatcher, golden-winged warbler, great crested flycatcher, killdeer, rufous-sided towhee, scarlet tanager, tree swallow, and vesper sparrow. All of these species, except the golden-winged warbler and the great crested flycatcher, exhibited differences in the first growing season. Of these species, only the rufous-sided towhee and alder flycatcher exhibited differences beyond the first growing season. The rufous-sided towhee had significantly different numbers in both the first and second growing seasons, which suggests a real preference for conventional sites. Male towhees were observed singing on slash piles on some conventional sites. However, it appears that this relationship was not strong enough to be demonstrated by the correlation analysis. Alder flycatcher had significantly different numbers in the first and third growing seasons. This inconsistency, and the lack of association with slash, suggests that this species was responding to variables other than slash. A difference for golden-winged warbler and great crested fly-catcher were only found during the third growing season. This may have been due either to chance occurrence or to a response by these species to variables other than slash.

Some trends evident in the data suggest a relationship between vegetative development on the sites and bird utilization. Table 5 illustrates an increase in bird abundance and number of species over the 4 year classes. Although BSD did not increase over the 4 year classes, it was greater on all the sites the second year. In examining the density of individual bird species over the 4 year classes (appendices B and C), a number of other trends are also evident. White-throated sparrow exhibited a dramatic decrease in numbers on the conventional sites and a slight increase on the whole tree sites. Indigo bunting, golden-winged warbler, and rufous-sided towhee increased substan-tially on both site types. Nashville warbler showed a slight increase in numbers on the whole tree sites.

Table 9 provides the results of correlation analysis between vegetative parameters and the bird species which exhibited differences in numbers between the harvest types. Some trends are evident in these results. Common yellow-throat, golden-winged warbler, mourning warbler, and white-throated sparrow were found to be positively correlated with slash, and were also positively correlated with vegetative cover and stem densities. Eastern bluebird, eastern king-bird, and northern oriole were found to be negatively correlated with slash, and were also either uncorrelated or were significantly negatively correlated with vegetative cover and stem densities.

A few other relationships between vegetation and bird species are also worthy of mention. American redstart was found to be strongly correlated with vegetation in the 1-4m stratum in 1985, which corroborates the observations of this species for this year. Alder flycatcher was positively correlated with these parameters for both years. In 1984, rufous-sided towhee was positively correlated with all vegetative parameters, except vegetative cover >4m and stem density <1m. In 1985, rufous-sided towhee was positively correlated with vegetative cover in the 0-10cm and 10-30cm strata. The conflicting results between the 2 years makes it difficult to draw conclusions for this species. Vesper sparrow was negatively correlated with vegetative parameters in 1985, but uncorrelated with vegetation in 1984. No important trends or associations with vegetation were

Table 9. Correlations (r_s) of bird densities with 4 strata of vegetative cover and 2 strata of stem density, (<1m in height, and >1m in height and <10cm dbh), which were measured on conventional and whole tree aspen clearcuts. Sites were harvested in 1982 and 1984, and measured in 1984 and 1985. Birds listed had significantly different densities on the 2 harvest types.

		% Cover of Vegetation					Stem Density	
Bird Species	Year	0-10cm	10-30cm	30cm-1m	1-4m	>4m	<1m	>1m
Alder flycatcher	84	.462*	.413	.315	.582**	.022	-.071	.483*
(*Empidonax traillii*)	85	-.002	.370	.482*	.593**	-.079	-.201	.713***
American redstart	84	.075	.086	.107	.082	-.091	-.139	.014
(*Setophaga ruticilla*)	85	.257	.254	.261	.608**	-.193	-.018	.758***
Common yellowthroat	84	.695***	.662***	.462*	.615**	-.250	-.299	.574**
(*Geothlypis trichas*)	85	.580**	.685***	.209	.378	-.295	.408	.553**
Eastern bluebird	84	-.005	.035	-.171	-.182	-.240	.044	-.055
(*Sialia sialia*)	85	-.384	-.322	.123	-.037	.326	-.517**	-.211
Eastern kingbird	84	-.373	-.329	-.320	-.214	.297	-.151	-.171
(*Tyrannus tyrannus*)	85	.027	.032	.071	-.291	.073	-.373	-.462*
Golden-winged warbler	84	.487*	.507**	.403	.356	-.287	.428	.338
(*Vermivora chrysoptera*)	85	.337	.436*	.313	.560**	-.016	.106	.710***
Mourning warbler	84	.425	.445*	.401	.410	-.099	-.057	.321
(*Zenaidura macroura*)	85	.667***	.708***	-.117	.110	-.307	.681***	.328
Northern oriole	84	-.504**	-.474*	-.554**	-.565**	.013	.198	-.440*
(*Icterus galbula*)	85	-.247	-.338	.061	-.181	.204	-.326	-.398
Rufous-sided towhee	84	.539**	.565**	.624***	.664***	.132	-.853***	.602**
(*Pipilo erythrophthalmus*)	85	-.550**	-.687***	.252	.201	.194	-.424	-.077

Table 9. (cont'd)

Bird Species	Year	% Cover of Vegetation 0-10cm	10-30cm	30cm-1m	1-4m	>4m	Stem Density <1m	>1m
Vesper sparrow	84	.162	.126	.088	-.107	-.079	-.256	.045
(*Pooecetes gramineus*)	85	-.307	-.541**	-.197	-.467*	.098	-.287	-.658***
White-throated sparrow	84	.181	.218	.194	.225	-.038	.062	.050
(*Zonotrichia albicollis*)	85	.421	.597**	.025	.304	-.299	.671***	.556**

* Significant difference between harvest types within years ($p<0.10$).
** Significant difference between harvest types within years ($p<0.05$).
*** Significant difference between harvest types within years ($p<0.01$).

found for field sparrow, great crested flycatcher, mourning dove, Nashville warbler, or tree swallow.

Correlation analysis between vegetative parameters and the bird species which did not exhibit differences in numbers between the harvest types may be useful in explaining the presence of these species on the sites as well. The results of the correlations which showed a consistent pattern for both censusing years are given in table 10. Chestnut-sided warbler was strongly influenced by all the vegetative parameters except cover >4m. Song sparrow was most strongly associated with vegetative cover in the lowest 2 strata. Indigo bunting and rose-breasted grosbeak were strongly negatively correlated with stem density <1m for both censusing years. In 1984, indigo bunting was also positively correlated with all strata of vegetative cover except cover in the >4m stratum. No important associations were detected between FHD and bird species' densities.

Correlations between clearcut size and % cover of slash did not indicate an association between these parameters. Partial correlation analysis, with % cover of slash held constant, indicated that number of species of birds and BSD were positively correlated with clearcut size for both censusing years. Partial correlations with individual bird species indicated that northern oriole and eastern kingbird were positively correlated with clearcut area, while common yellowthroat and mourning warbler were negatively correlated with clearcut area (table 11).

Table 10. Correlations (r_s) of bird densities with 5 strata of vegetative cover and 2 strata of stem density, (<1m in height, and >1m in height and <10cm dbh), which were measured on conventional and whole tree aspen clearcuts. Sites were measured in 1982 and 1984, and measured in 1984 and 1985. Bird species listed exhibited no differences in numbers between the harvest types.

		% Cover of Vegetation					Stem Density	
Bird Species	Year	0-10cm	10-30cm	30cm-1m	1-4m	>4m	<1m	>1m
Chestnut-sided warbler	84	.709***	.682***	.659***	.600***	-.191	-.456*	.653***
(Dendroica pensylvanica)	85	.374	.552**	.265	.564**	-.180	.044	.765***
Indigo bunting	84	.762***	.782***	.806***	.659***	-.415	-.579**	.809***
(Passerina cyanea)	85	-.047	-.094	.097	-.217	-.109	-.465*	-.135
Rose-breasted grosbeak	84	.013	.019	.058	.247	.060	-.487*	.174
(Pheucticus ludovicianus)	85	-.322	-.313	.101	-.018	.173	-.580**	-.230
Song sparrow	84	.480*	.439*	.187	.381	.058	-.331	.268
(Melospiza melodia)	85	.567**	.683***	.119	-.100	-.152	.156	-.130

* Significant difference between harvest types within years ($p<0.10$).
** Significant difference between harvest types within years ($p<0.05$).
*** Significant difference between harvest types within years ($p<0.01$).

Table 11. Results of partial correlations (r_s) between clearcut area and number of bird species, bird species diversity, and bird species' densities. Percent cover of slash was the factor held constant. Birds were censused in 1984 and 1985.

Bird	Correlation Coefficient (r_s) 1984 Census	Correlation Coefficient (r_s) 1985 Census
No. Species	.579***	.519***
Species Diversity	.415*	.398*
Common yellowthroat (*Geothlypis trichas*)	-.378*	-.394*
Eastern kingbird (*Tyrannus tyrannus*)	.704****	.559***
Mourning warbler (*Oporornis philadelphia*)	-.635****	-.503***
Northern oriole (*Icterus galbula*)	.726****	.400*

* Significant at p<0.20
** Significant at p<0.10
*** Significant at p<0.05
**** Significant at p<0.10

Small Mammal Trapping

A total of 186 small mammals were captured in 1984 and a total of 705 were captured in 1985. Nine different species were represented on the sites. The disparity in numbers of animals captured between the 2 years was thought to be due to natural fluctuations of the small mammal populations.

Table 12 outlines the total number of animals caught, the mean number of species caught, and the mean small mammal species diversity on each harvest type and year class. No differences were found in small mammal abundance or diversity between the harvest types for either 1984 or 1985. However, a pattern is evident in that in both years the greatest number of animals were caught on the youngest whole tree sites and the fewest were caught on the oldest conventional sites. Although there were no significant differences in the number of species caught on the sites within trapping years, 2 species, eastern chipmunk (Tamias striatus) and short-tailed shrew (Blarina brevicauda), were not found on the sites in 1984, but were captured in substantial numbers in 1985.

Table 13 provides the mean number of animals caught of each species on each of the harvest types for each of the trapping years. In 1984, only 2 species were caught in significantly different numbers between the harvest types. Meadow vole (Microtus pennsylvanicus) was found to prefer whole tree harvested sites during the first growing season, and masked shrew (Sorex cinereus) was found to prefer

Table 12. Total number of animals, mean number of species, and mean diversity indices, which were calculated with the Shannon-Weiner equation (Hair 1980), for small mammals live-trapped on conventional (C) and whole tree (W) harvested clearcuts. Sites were harvested in 1982 and 1984. Mammals were trapped in 1984 and 1985.

Year[a] Class	Harvest type	Total animals caught	No. Species $\bar{X} \pm$ S.E.	Diversity $\bar{X} \pm$ S.E.
1	C	59	3.8 ± 0.3	1.11 ± 0.18
	W	90	3.8 ± 0.5	0.83 ± 0.11
2	C	174	7.0 ± 0.6	1.35 ± 0.13
	W	220	5.5 ± 0.3	0.99 ± 0.11
3	C	13	1.5 ± 1.0	0.48 ± 0.30
	W	24	3.0 ± 0.4	0.92 ± 0.11
4	C	121	7.0 ± 0.6	1.35 ± 0.13
	W	220	6.8 ± 0.3	1.39 ± 0.09

[a]Sites in year classes 1 and 2, and 3 and 4 were the same sites trapped in different years.

Table 13. Mean numbers of small mammals (±S.E.) live-trapped on conventional and whole tree harvested aspen clearcuts. Sites were harvested in 1982 and 1984. Mammals were trapped in 1984 and 1985.

		Sites Harvested 1982		Sites Harvested 1984	
Species	Year	Conventional	Whole Tree	Conventional	Whole Tree
Deer/white-footed mouse	84	0.5±0.3	3.0±1.2*	7.3±3.0	15.0±3.0
(*Peromyscus* spp.)	85	15.3±2.5	23.8±4.5	23.5±8.5	35.0±7.2
Eastern chipmunk	84	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
(*Tamias striatus*)	85	1.3±0.5	1.3±0.6	1.7±0.3	0.3±0.3
Meadow jumping mouse	84	1.3±1.3	1.3±0.5	2.3±1.0	4.8±3.1**
(*Zapus hudsonius*)	85	3.3±1.3	6.5±2.3	0.8±0.3	11.5±3.2
Meadow vole	84	0.5±0.5	0.3±0.3**	0.3±0.3	1.5±0.9*
(*Microtus pennsylvanicus*)	85	0.3±0.3	4.8±1.8	3.8±1.1	3.0±0.4
Masked shrew	84	0.8±0.8	0.0±0.0**	1.3±0.5	0.0±0.0**
(*Sorex cinereus*)	85	2.3±0.5	2.5±0.5	2.5±0.3	1.3±0.6*
Red-backed vole	84	0.0±0.0	0.0±0.0**	3.3±2.4	0.5±0.3**
(*Clethrionomys gapperi*)	85	2.0±0.9	0.0±0.0	1.5±0.9	0.3±0.3
Short-tailed shrew	84	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
(*Blarina brevicauda*)	85	5.0±1.7	2.3±1.0	5.3±2.2	2.5±1.0
13-lined ground squirrel	84	0.0±0.0	0.0±0.0	0.3±0.3	0.3±0.3
(*Citellus tridecemlineatus*)	85	0.0±0.0	0.5±0.5	0.8±0.8	0.0±0.0

Table 13. (cont'd)

Species	Year	Sites Harvested 1982		Sites Harvested 1984	
		Conventional	Whole Tree	Conventional	Whole Tree
Woodland jumping mouse	84	0.0±0.0	1.3±1.3**	0.3±0.3	0.5±0.3
(*Napeozapus insignis*)	85	1.0±1.0	4.0±1.1	3.8±2.6	1.3±0.8

* Significant difference between harvest types within years ($p < 0.10$)
** Significant difference between harvest types within years ($p < 0.05$)

conventional sites during both the first and third growing seasons. In 1985, a number of differences were found. During the second growing season eastern chipmunk and masked shrew were found to prefer conventional sites, and meadow jumping mouse (Zapus hudsonius) was found to prefer whole tree sites. Peromyscus, meadow vole, and woodland jumping mouse (Napeozapus insignis) were found to prefer whole tree sites during the fourth growing season. Red-backed vole was found to prefer conventional sites in both the second and fourth growing seasons.

A few trends are also evident. Although no other significant differences in numbers were found for Peromyscus, this species was consistently trapped in greater numbers on the whole tree sites. Similarly, no significant differences were found for short-tailed shrew. However, this species was caught in greater numbers on the conventional sites in both year classes in 1985. Meadow jumping mouse also exhibited a fairly consistent preference for whole tree sites.

Table 14 provides the results of correlations for small mammal numbers with % cover of slash and vegetative parameters. Only masked shrew was found to be correlated with slash in 1984, and this was a strong positive association. In 1985, Peromyscus, meadow jumping mouse, and woodland jumping mouse were found to be negatively correlated with slash, while red-backed vole was found to be positively correlated with slash.

Table 14. Correlations (r_s) of small mammal numbers with: % cover of slash, 3 strata of vegetative cover, and density of stems <1m in height. Sites were conventional and whole tree harvested aspen clearcuts which were harvested in 1982 and 1984. Mammals were trapped and vegetation was measured in 1984 and 1985.

Species	Year	% Cover Slash	Stem Density		% Cover of Vegetation			
			<1m	>1m	0-10cm	10-30cm	30cm-1m	1-4m
Deer/white-footed mouse	84	-.094	.844***	-.726***	-.793***	-.770***	-.753***	-.760***
(*Peromyscus* spp.)	85	-.471*	.164	-.533**	-.223	-.094	-.572**	-.827***
Meadow jumping mouse	84	-.104	.232	-.098	-.264	-.246	-.373	-.243
(*Zapus hudsonius*)	85	-.610**	-.378	-.260	.016	.220	.176	-.189
Masked shrew	84	.026	-.077	-.114	-.046	.010	.017	.035
(*Sorex cinereus*)	85	.611**	-.226	-.293	.195	-.156	-.160	.101
Red-backed vole	84	.193	.352	-.520**	-.656***	-.538**	-.437*	-.493*
(*Clethrionomys gapperi*)	85	.450*	.119	.109	-.309	-.163	.219	-.019
Short-tailed shrew	84	-	-	-	-	-	-	-
(*Blarina brevicauda*)	85	.356	.004	.394	.523**	.293	.434*	.575*
Woodland jumping mouse	84	-.163	.311	-.495**	-.524**	-.400	-.348	-.551**
(*Napeozapus insignis*)	85	-.459*	.049	-.333	-.098	-.410	-.265	-.099

* Significant difference between harvest types within years (p<0.10).
** Significant difference between harvest types within years (p<0.05).
*** Significant difference between harvest types within years (p<0.01).

Eastern chipmunk was not found to be correlated with slash. However, on one whole tree site chipmunks were only caught at the base of large oak trees which were residual on the site. If the animals caught on this site are removed from the analysis, the correlation indicates that eastern chipmunk was positively associated with cover of slash at the $p<0.10$ level of significance.

Correlations with vegetation also indicated some associations. Peromyscus was strongly negatively correlated with all strata of vegetative cover in 1984, and with cover in the 30cm-1m and 1-4m strata in 1985. This species was also negatively correlated with stem density >1m for both years, and positively correlated with stem density <1m in 1984. Red-backed vole was also consistently negatively correlated with vegetative cover in 1984, but no associations were evident for this species in 1985. Short-tailed shrew exhibited strong positive correlations with vegetative cover in the 0-10cm, 30cm-1m, and 1-4m strata in 1985, as well as with the number of woody species on the sites ($p<0.05$). Woodland jumping mouse was found to be negatively associated with woody stems >1m, and vegetative cover in the 0-10cm and 1-4m strata in 1984. No associations with vegetation were evident for the other species captured.

DISCUSSION

Significantly more slash was found on the conventional sites than on the whole tree sites. No significant differences in stem density or vegetative cover were found between the harvest types. This suggests that the observed differences in songbird and small mammal species compositions between the harvest types were due primarily to differences in the cover of slash.

Habitat characteristics which influence songbird numbers and diversity have been investigated by numerous researchers. MacArthur and MacArthur (1961) described the importance of foliage height diversity to bird species diversity. MacArthur et al. (1962) further concluded that horizontal variability, or patchiness, was a principal factor. Karr and Roth (1971) added the importance of total vegetation volume. Roth (1976) concluded that overall habitat complexity was the key. Slash, therefore, was expected to contribute to overall songbird diversity by adding another component to the habitat. It was also hypothesized that slash would be most important on recently harvested sites before extensive revegetation had occurred.

The results of this study indicated that 8 species of birds had a preference for conventional sites and 8 species had a preference for whole tree sites. Based on the correlations between bird densities and cover of slash, the differences found for 10 species could be attributed to the presence or absence of slash. The greatest differences in species composition were found in the first growing season. Differences were minimal by the fourth growing season. Differences in bird abundance and BSD were also found, but only during the first growing season. This suggests that the influence of slash on the bird populations declined as expected as the sites revegetated.

A number of the species found to prefer conventional clearcuts in this study have been documented to use slash by other sources. Titterington et al. (1979) felt that bird species that nest and forage on the ground were associated with the open ground-slash seral stage of clearcuts. Titterington et al. used the white-throated sparrow as an example, however, mourning warbler, Nashville warbler, common yellowthroat, and rufous-sided towhee also nest and forage on the ground. Bent (1963b) and Bent (1968a) also reported accounts of the mourning warbler and rufous-sided towhee using cut-over areas or "slashings". Rufous-sided towhee was not found to be correlated with slash in this study, however, it was found to prefer conventional sites during the first and second growing seasons. A possible explanation for the lack of response by towhees to the slash is that only the 0-30cm stratum of slash was measured. Towhees were observed using slash on sites where the slash had been placed in fairly large discreet piles. Perhaps if the slash had been measured in strata, or if its distribution had been analyzed, a relationship between towhees and slash would have been determined.

Nashville warbler was only found to be correlated with slash in 1985. Observations of this species indicated that it utilized the clearcuts to a much lesser degree in 1984 than in 1985. It is not clear whether this was primarily due to differences in population numbers between the 2 years, or to a general shift in habitat utilization.

The responses of some of the other species to the harvest types are not as simple to explain. American redstart, alder flycatcher, golden-winged warbler, great crested flycatcher, and mourning dove were found to prefer conventional sites for at least 1 growing season. American redstart and mourning dove were also found to be correlated with slash for 1 of the censusing years. The habitat requirements of the American redstart have been described differently by different sources. Crawford et al. (1981) described the American redstart as a closed-canopy-obligatory species. Webb (1977), however, described this species as 1 which is positively affected by habitat disturbance such as heavy logging. Bent (1963a) reported accounts of the redstart nesting in mature hardwood, mixed deciduous, and coniferous woodlands, as well as open shrubby vegetation, alder and willow thickets, and edges of woodlands. This species is obviously versatile in its nesting requirements. However, there appear to be no previous accounts of this species utilizing slash as nesting cover.

The mourning dove has been described as preferring open lands with scattered tree, shrubs, and open fields (Terres 1980). It typically feeds on the ground and has been known to nest on the ground where trees are scarce (Soutiere and Bolen 1973). It is possible that slash provided cover for mourning doves using the clearcuts. However, the small number of mourning doves observed on the sites suggests that the clearcuts were not highly preferred by this species.

Alder flycatcher, golden-winged warbler, and great crested flycatcher were not found to be correlated with slash. They also did not exhibit a consistent preference for the conventional sites over the year classes. Alder flycatcher was found to prefer conventional sites in the first and third growing seasons, and golden-winged warbler and great crested flycatcher were found to prefer conventional sites only in the third growing season. Therefore, the apparent preferences of these species are probably due to responses to other habitat variables on these sites, or to chance occurrences. The correlations with vegetative parameters suggest that alder flycatcher and golden-winged warbler were attracted to areas with dense vegetative cover and stem densities in the 1-4m stratum. Although no significant differences were found for these variables between the harvest types, it is possible that these species found more patches of dense vegetation in this stratum on the conventional sites.

Northern oriole, scarlet tanager, eastern kingbird, eastern bluebird, field sparrow, killdeer and vesper sparrow were found to prefer whole tree sites for at least 1 growing season. Eastern kingbird and northern oriole both nest and feed above the ground (Bent 1942, Bent 1958), which provides little explanation for their aversion to conventional sites.

Connor and Adkisson (1974) documented the eastern blue bird's use of young clearcuts when cavities were available for nesting. Connor and Adkisson (1975) found that eastern bluebirds preferred 1-year-old clearcuts which suggested a preference for open areas created by clearcutting. This study found the greatest abundance of bluebirds on 1-year-old whole tree sites. On 4-year-old sites eastern bluebirds were equally abundant on whole tree and conventional sites where cavities were available. This suggests that sites with less cover are preferred by eastern bluebirds, but that availability of suitable nesting cavities is the most important feature attracting this species.

Scarlet tanager is typically associated with dense deciduous woods (Bent 1958). It is possible that this species was actually associated with the surrounding woods, rather than with the clearcuts. This species was observed in very low numbers, and was typically observed near the edges of the clearcuts or in large residual trees. Its association with whole tree clearcuts may have been a factor of chance.

Bent (1968b) described the typical habitat of the field sparrow as old fields and pastures, and mentioned that it will use open "slashings" after logging operations. This species was, therefore, expected to have a preference for conventional sites, but was instead found in greater numbers on the whole tree sites.

The killdeer is a bird of meadows and grazed pastures, which nests in scrapes of bare ground (Terres 1980). Since this species appears to prefer open sites, it might be expected that it would prefer the whole tree sites. This species was indeed found almost exclusively on the 1-year-old whole tree sites. However, no association with slash was found for this species.

Vesper sparrows typically nest on the ground where vegetation is sparse and low (Bent 1968b). Since this species appears to prefer to nest in areas with little cover, it was expected that this species would prefer the whole tree sites. The vesper sparrow exhibited a preference for whole tree sites in the first growing season, but no correlation with slash was found. Several field observers had difficulty distinguishing the song of the vesper sparrow from that of the song sparrow. Therefore, it is possible that this species exhibited preferences beyond the first growing season, or had associations with habitat variables which were not detected by this study due to confusion with the song sparrow.

The tree swallow exhibited preferences for both harvest types. Tree swallows were found to prefer the whole tree sites in the first and second growing seasons, and the conventional sites in the third growing season. This may suggest a preference for the whole tree sites during the early stages of vegetative development. However, this species was not found to be correlated with slash. Also, since sites in the first and second growing seasons were the same sites censused in 1984 and 1985, it appears more likely that the tree swallows were attracted to the sites rather than to the harvest types. Since this species is a cavity nester, it is possible that availability of suitable snags was the primary feature attracting this species. The significant differences in numbers of this species between the harvest types, may again, have been a factor of chance.

A number of species that were expected to respond to the different harvest types based on previous studies were not found to respond in this study. Winter wrens have been found to be associated with slash (Hagar 1960, Titterington et al. 1979). In this study, winter wrens were heard singing along the edge of the clearcuts where sites abutted wooded swamps, however, none were observed to use the clearcuts.

Franzreb and Ohmart (1978) felt that house wrens were attracted to harvested plots because slash provided observation posts and foraging surfaces. The house wren was found to be significantly correlated with slash in this study. However, the low amounts of slash on the whole tree sites did not reduce the use of these sites by the house wren. It is possible that the availability of snags with suitable cavities was the primary factor influencing this species. Why the house wren did not return to nest on the sites in 1985 can not be explained by this study.

Connor and Crawford (1974) recommended that slash and logging debris not be treated or removed after harvest as they felt it provided important foraging substrate for hairy woodpeckers, downy woodpeckers, and common flickers. In this study, none of these species were found to show a preference for the conventional sites. Since snags were present on most of the sites, it is possible that the snags sufficiently attracted woodpeckers to compensate for the lack of slash on the whole tree sites.

In general, the species observed on the sites in this study were birds which typically nest or forage in brushy openings or edge areas. The fact that certain birds are associated with particular habitat types or successional stages suggests the importance of vegetation to bird distributions. The results of the correlation analyses between bird numbers and vegetative parameters in this study indicated the vegetative components important to each species. The trends found in this study of bird abundance, number of species, and BSD increasing over the 4 age classes indicated an increase in utilization of the clear-cuts with increasing vegetative development.

A number of studies have documented that bird abundance and diversity increase with site ecological age (Johnston and Odum 1956, Hagar 1960, Connor and Adkisson 1975, Titterington et al. 1979). This has been attributed to the increasing spatial complexity and thus niche availability with the increasing vegetative development.

Titterington et al. (1979) found that each seral stage following clearcutting was dominated by a characteristic group of bird species. They found that bird species that nest and forage on the ground, such as the white-throated sparrow, dark-eyed junco, and winter wren, were associated with the earliest stage -- the open ground-slash stage. The next stage -- the bramble-herbaceous stage -- was dominated by species which typically nest and forage in vegetation close to the ground. Examples of these species included the white-throated sparrow, common yellowthroat, chestnut-sided warbler, and mourning warbler. All of these species, with the exception of the dark-eyed junco and winter wren, were observed on the sites in this study and were also found to be associated with vegetative cover in lower height strata. Titterington et al. (1979) used the American redstart as an example of a species associated with the third stage -- the shrub-sapling stage. In this study, American redstart was found to be strongly associated with cover in the 1-4m stratum. The rose-breasted grosbeak was used as an example of a species associated with the fourth seral stage -- the immature second growth stage. In this study, the rose-breasted grosbeak was found on sites of all 4 age classes. It was, however, found to slightly increase in numbers over the 4 age classes, which may suggest a preference for older sites.

In summary, it appears that slash had the greatest influence on the bird populations on the 1-year-old sites because it provided structure on otherwise barren sites. As vegetation developed on the sites, the cover provided by the slash became obsolete. By the fourth growing season, the bird populations were primarily influenced by the vegetation. As the vegetative structure was relatively similar on all the sites of the same age, the bird species compositions were also similar.

The effect of clearcut size on bird species was also examined. Correlations with this variable suggested that BSD and number of bird species increased with clearcut size. Correlations with individual species indicated that 2 species were positively influenced by the area of the clearcuts and 2 negatively.

The issue of forest fragmentation, and thus the importance of stand size to bird species, has been of increasing concern to researchers. According to Anderson and Robbins (1981), there is a minimum size for each vegetation type at which all the typical species of that type are likely to be present. Most of the studies investigating the importance of stand size to bird populations have looked at second growth and mature forest stands (Forman et al. 1976, Whitcomb et al. 1977, Anderson and Robbins 1981, Ambuel and Temple 1983). Only 1 paper appears to be available which addresses the importance of forest openings to bird species (Taylor and Taylor 1980). Taylor and Taylor felt that breeding birds associated with large openings were different from those associated with small openings. They, therefore, attempted to list the bird species they felt were sensitive to opening size, and the preferences of these species for large or small openings. Species listed as sensitive to opening size by Taylor and Taylor which were also observed on the sites in this study are listed in table 15.

Only the results for the common yellowthroat and mourning warbler from this study corresponded to the relationships suggested by Taylor and Taylor. However, this study was not specifically designed to address the importance of site size to bird numbers. Although an attempt was made to compensate for the differences in harvest method by using partial correlation analysis, other factors, such as site configuration, were not held constant. The range of site sizes examined was also limited. It should also be noted that Taylor and Taylor derived their information from their own observations, and those of other studies, rather than from a well designed study of the subject. Therefore, their information should also be looked at conservatively. Although more work is needed to specify species relationships with opening size, it is apparent that relationships do exist. This suggests that site size should be taken into consideration in forest management planning.

A number of other factors which could have had a minor influence on the bird populations were not considered in this study. The importance of horizontal diversity has been emphasized in a number of studies (MacArthur et al. 1962,

Table 15. Bird species of upland openings which appear to be sensitive to opening size. Small openings were < 5 ha. Large openings were not defined (Taylor and Taylor 1980).

Species	Opening Size Preferred
Black-and-white warbler (*Mniotilta varia*)	Small
Black-capped chickadee (*Parus atricapillus*)	Small
Brown thrasher (*Toxostoma rufum*)	Small
Chestnut-sided warbler (*Dendroica pensylvanica*)	Small
Chipping sparrow (*Spizella passerina*)	Small
Common yellowthroat (*Geothlypis trichas*)	Small
Downy woodpecker (*Dendrocopos pubescens*)	Small
House wren (*Troglodytes aedon*)	Small
Killdeer (*Charadrius vociferus*)	Large
Morning dove (*Zenaidura macroura*)	Large
Mourning warbler (*Oporornis philadelphia*)	Small
Nashville warbler (*Vermivora ruficapilla*)	Small
Vesper sparrow (*Pooecetes gramineus*)	Large

Roth 1976, Rotenberry and Wiens 1980). In this study, only vertical cover was measured. However, horizontal cover was seldom uniform over the sites. There is little doubt that the horizontal distribution of cover influenced the occurrence of some species and thus overall species diversity on the sites. Swift et al. (1984) and Petit et al. (1985) examined the influence of soil moisture on breeding birds. Soil moisture is felt to have an effect on vegetative structure, species composition, and invertebrate fauna. No attempts were made to test for such associations in this study. Other factors which may have been influential include: the surrounding vegetation types; nearness to special features such as open water, streams, or swamps; the number and quality of snags; the number, size, and species of residual trees; and availability of food such as fruits.

The factors influencing small mammal abundance and diversity have not been as well defined as for birds. However, the need for cover by many small mammal species has been well documented. Slash was, therefore, expected to enhance small mammal numbers and diversity by providing cover on clearcuts, particularly before the sites revegetated. Also, by contributing another component to the site slash was expected to provide additional niches on the conventional sites.

The results of the second year of small mammal trapping suggest a similar response to the harvest types as that found for the songbirds in that approximately the same number of species showed a preference for each of the harvest types. Nine species of small mammals were caught on the sites. Of these, 7 exhibited a significant difference in numbers for at least 1 of the growing seasons. Three of the species showed a preference for conventional sites and 4 showed a preference for whole tree sites.

An inadequate number of animals were caught the first year to draw conclusions concerning the response of small mammals to the harvest types during that year. However, trends found the first year are useful for corroborating results found the second year.

Correlations with % cover of slash were useful for explaining the differences found between the harvest types. Peromyscus and meadow jumping mouse were found to prefer whole tree sites and were also found to be negatively correlated with % cover of slash. However, the preferences of meadow voles and woodland jumping mice for whole tree sites could not be attributed to the absence of slash on these sites. In 1985, the red-backed vole was found to prefer conventional sites, and was also found to be positively correlated with slash. In 1984, similar results were found for masked shrew.

The red-backed vole is the only species which has consistently been associated with logs and slash in the literature. Gunderson (1959) felt that the distribution of red-backed voles was most closely correlated with the presence of stumps, rotting logs, and root systems in forests. Tevis (1956), and Martell and Radvanyi (1977) found slash to be important to red-backed voles on recently cut sites.

Slash has also been suspected to provide a source of insects for insectivorous small mammals such as shrews (Dimock 1974). Hooven and Black (1976) listed species of beetles which are attracted to fresh slashings. Burt (1957) described the habitat of the masked shrew as woodlands with logs and litter on the forest floor. He also mentioned that short-tailed shrews frequently nest under logs. In this study, only the masked shrew was found to be correlated with slash. Both species of shrews were also found to be abundant on both harvest types. It is possible that the shrews were positively influenced by slash. However, it is apparent that slash was not the primary factor influencing their distribution.

Both red-backed voles and short-tailed shrews have been found to have high water requirements and are often associated with moist sites (Gunderson 1959, Getz 1968, Miller and Getz 1977). These species were caught on both moist and upland sites in this study. However, there is some possibility that slash could help maintain soil moisture, particularly before sites have revegetated. However, the potential importance of slash as a source of food and cover suggests that its contribution to site quality extends beyond this possible feature.

Peromyscus appear to have an affinity for barren sites. This small mammal is typically the first to reinvade sites after a severe disturbance such as clearcutting or burning (Jameson 1955, Tevis 1956, Gashwiler 1970, Sims and Buckener

1972, Krefting and Ahlgren 1974, Fala 1975, Hooven and Black 1976). Therefore, the preference for whole tree sites was not surprising for this species.

No previous information suggested explanations for the preferences of the meadow vole, the meadow jumping mouse, or the woodland jumping mouse for whole tree sites. The correlations between these species and cover of slash suggest that the preferences of the meadow and woodland jumping mice for the whole tree sites can be attributed to the lack of slash on these sites, but the response of the meadow vole must be attributed to factors other than slash.

The correlations with the vegetation parameters indicate that the small mammals were greatly influenced by vegetation. Consistent with its response to cover of slash, Peromyscus was found to respond negatively to vegetative cover. This response perhaps explains this species' preference for the younger sites. Previous studies corroborate these results. Hahn and Michael (1980) found Peromyscus to be negatively correlated with % blackberry (Rubus spp.) which grew in thick tangles on their sites. Krefting and Ahlgren (1974) also felt that vegetative development made sites less attractive to Peromyscus. Some other studies, however, have found Peromyscus to be positively associated with vegetation. M'Closkey and Lajoie (1975) found a positive correlation between Peromyscus abundance and ground cover in the 0-7.6cm stratum. Hahn and Michael (1980) found deer mice to be positively correlated with % herbaceous vegetation. Duesar and Shugart (1978) found Peromyscus to be associated with a high density of shrub-understory vegetation in the forest. They felt that this was consistent with the arboreal behavior of this mouse. This preference by *Peromyscus* for shrubs may explain the positive correlation found in this study with stem density <1m. However, since this association was not repeated the second year it is difficult to have confidence in this finding. Getz (1961a) also found that *Peromyscus* only inhabited areas with trees and shrubs. They found no indication that *Peromyscus* avoided herbaceous vegetation. They suggested that habitat preference of *Peromyscus* was primarily associated with food supply.

No correlations with vegetation were found for meadow jumping mouse. A study by Quimby (1951) found the greatest number of meadow jumping mice in moist meadows and marshy areas with woody and herbaceous vegetation. Nests were found in grasses or sedges. It was, therefore, expected that meadow jumping mice would be positively correlated with the lower strata of vegetation.

Woodland jumping mouse was negatively correlated with vegetative cover in the 0-10cm and 1-4m strata, and with stem density >1m. These findings are opposite to results found by Miller and Getz (1977). They found woodland jumping mice to be less abundant in areas with lesser tree, shrub, and herbaceous cover.

Meadow vole was not found to be associated with any vegetative parameters. However, meadow vole has been documented to inhabit dense grassy areas (Burt and Grossenheider 1976). Getz (1961b) felt that the presence of graminoids for food was the major factor responsible for the occurrence of meadow voles in grassy areas. He also found that meadow voles avoided areas with woody vegetation and areas containing only forbs.

Red-backed vole was found to be negatively correlated with all strata of vegetative cover in 1984, as well as stem density >1m. However, since these results were not replicated in 1985 their validity is questionable. Previous studies have found red-backed voles to be associated with availability of food, water, and slash (Gunderson 1959, Getz 1968). No previous studies have found red-backed voles to be associated with vegetation.

Masked shrew was not found to be associated with any vegetative parameters in either year. However, according to Burt (1957), masked shrews are frequently found in brushy or grassy areas where they build runways or use runways built by other mice. Hooven and Black (1976) found 4 species of shrews to require a mat of ground vegetation for cover. Therefore, a positive association with vegetative cover was expected for this species.

Short-tailed shrew was only caught on the sites in 1985, therefore, no replication of the correlations was possible. For the 1 year, this species was found to be positively correlated with vegetative cover in the 0-10cm, 30cm-1m, and 1-4m strata, with stem density >1m, and with the total number of woody species on the sites. A study by Miller and

Getz (1977) corroborated these results. They found short-tailed shrews to be more abundant on sites with greater vegetative cover, particularly of the herbaceous layer. They also suggested that the diversity of invertebrates was positively correlated with the diversity of the leaf litter, especially that from trees and shrubs.

Eastern chipmunk was not found to be correlated with any vegetative parameters. However, previous studies have found associations. Duesar and Shugart (1978) found eastern chipmunk to occur at sites with primarily a deciduous canopy, high tree density, and low shrub density. They also found them more commonly in forested than in shrub vegetation types. Krefting and Ahlgren (1974) found the eastern chipmunk to be attracted to areas with a wide variety of seeds.

In summary, it appears that the small mammal population was influenced by the presence of slash. Correlations with slash and differences in species numbers during the fourth growing season indicate that slash continued to influence the small mammals after the sites revegetated. Responses to cover of slash and vegetative parameters were individual for each species, and suggest the differing habitat requirements of each.

SUMMARY AND RECOMMENDATIONS

Cover of slash was found to influence both the songbird and small mammal populations. This influence was equally negative and positive in that approximately 1/2 the species that responded had a preference for 1 or the other of the harvest types. Songbirds found to prefer conventional sites were primarily species which typically nest on or near the ground. Bird species preferring whole tree sites were species which nest and feed above the ground, or species which are typically associated with open areas. Small mammal species found to prefer conventional sites appeared to be species requiring cover, species adapted to specifically woody cover, and insectivorous species. Small mammal species found to prefer the whole tree sites appeared to be species whose habitat preferences were for areas with little cover.

Differences in songbird species composition moderated as vegetation developed on the sites. By the fourth growing season differences were minimal. Small mammals responded to vegetation, but responses to slash were still evident in the fourth growing season. Because small mammals are decidedly more dependent on the ground layer than are birds, it is perhaps logical that slash would have a more lasting influence on the mammals. How long slash continues to influence small mammal populations will require further study to determine.

The results of this study suggest that in large forest tracts both methods of harvesting should be used. This may be a minor consideration for the songbirds as differences between the site types were minimal by the fourth growing season. However, responses by the small mammals were still evident through the fourth growing season. This indicates that slash has a more lasting effect on small mammals, and also leaves open to question whether other species are affected by the presence of slash as well.

The results of the correlations with clearcut size suggest that maintaining a variety of clearcut sizes is desirable for songbird management. However, further studies of the importance of forest opening size to songbirds is needed to corroborate the findings of this study. Back (1980) felt that the minimum cut size of 4-8 ha needed to make pulpwood operations feasible is probably compatible with songbird management. Back (1980) also recommended that for cuts greater than 20 ha, efforts should be made to maximize the ratio of edge to area. The response of the bird species in this study further emphasize the importance of maintaining snags in clearcuts that are suitable for use by cavity nesting species.

APPENDICES

Appendix A. Frequency for herbaceous vegetation in conventional and whole tree clearcuts that were harvested in 1982 and 1984, and were measured in 1984.

Appendix A1. Frequency of herbaceous vegetation in conventional clearcuts that were harvested in 1984 and measured in 1984.

Plants	Abs. Freq.		Rel. Freq.	
	$\bar{x}$	SE	$\bar{x}$	SE
Bedstraw (Galium spp.)	23.02	13.47	3.13	1.81
Bracken (Pteridium aquilinum)	80.54	9.72	37.74	20.27
Bramble (Rubus spp.)	53.30	13.65	8.26	1.44
Bunchberry (Cornus canadensis)	21.58	11.90	2.89	1.60
Canada mayflower (Maianthemum canadense)	22.67	7.66	3.25	1.13
Common mullein (Verbascum thapsus)	4.39	1.57	0.87	0.36
Dandelion (Taraxacum officinale)	9.71	7.01	1.30	0.89
Goldenrod (Solidago spp.)	30.14	6.10	5.10	0.65
Grass (Poa spp.)	84.40	6.10	16.62	4.48
Ground pine (Lycopodium spp.)	6.58	4.47	6.31	5.95
Hawkweed (Hieracium spp.)	20.89	14.67	3.10	2.27
Heart-leaved aster (Aster cordifolius)	12.47	4.22	1.78	0.61
Honeysuckle (Lonicera spp.)	13.56	9.60	1.93	1.41
Horsetail (Equisetum spp.)	4.29	2.68	0.64	0.40
Joe-pye weed (Eupatorium spp.)	6.67	3.53	0.66	0.48
Large-leaved aster (Aster macrophyllus)	24.76	20.23	3.48	3.03
Large-leaved avens (Geum macrophyllum)	2.87	1.66	0.41	0.24
Low-bush blueberry (Vaccinium angustifolium)	6.06	4.21	0.88	0.62
Moss	4.39	1.57	0.50	0.35
Poison ivy (Rhus radicans)	10.36	5.29	1.33	0.81
Purple clematis (Clematis verticillaris)	2.87	1.66	0.41	0.24
Sedge (Carex spp.)	3.88	2.24	2.62	2.58
Spreading dogbane (Apocynum androsaemifolium)	11.83	3.81	4.69	2.07
Star flower (Trientalis borealis)	7.08	4.10	0.97	0.57
Strawberry (Fragaria spp.)	42.06	14.26	6.17	1.83
Tall buttercup (Ranunculus acris)	5.82	2.85	0.80	0.36
Thistle (Cirsium spp.)	3.79	1.36	0.54	0.20
Violet (Viola spp.)	6.99	3.14	0.78	0.54
White clover (Trifolium repens)	7.76	4.69	6.50	5.90
Wild sasparilla (Aralia nudicaulis)	8.26	5.31	4.26	3.26
Wintergreen (Gaultheria procumbens)	7.39	5.52	2.13	1.86

Appendix A2. Frequency of herbaceous vegetation in whole tree clearcuts that were harvested in 1984 and measured in 1984.

Plants	Abs. Freq.		Rel. Freq.	
	$\bar{x}$	SE	$\bar{x}$	SE
Aster (Aster spp.)	3.27	2.03	0.50	0.30
Bedstraw (Galium spp.)	11.91	7.32	1.90	1.16
Black bindweed (Polygonum spp.)	8.73	5.67	1.37	0.91
Bracken (Pteridium aquilinum)	71.07	10.07	11.21	1.59
Bramble (Rubus spp.)	77.03	6.59	12.26	1.33
Canada mayflower (Maianthemum canadense)	11.42	5.22	1.83	0.86
Common mullein (Verbascum thapsus)	46.47	14.29	7.33	2.32
Daisy (Chrysanthemum leucanthemum)	1.92	1.17	0.31	0.19
Dandelion (Taraxacum officinale)	14.28	6.65	2.19	0.96
Goldenrod (Solidago spp.)	29.24	11.60	4.55	1.82
Grass (Poa spp.)	83.26	10.70	41.98	16.92
Hawkweed (Hieracium spp.)	29.47	11.74	4.55	1.68
Heart-leaved aster (Aster cordifolius)	27.09	13.21	4.29	2.09
Honeysuckle (Lonicera spp.)	3.89	2.42	0.62	0.40
Horsetail (Equisetum spp.)	2.10	1.39	0.34	0.22
Large-leaved aster (Aster macrophyllus)	13.11	4.87	2.06	0.77
Maple-leaved goosefoot (Chenopodium hybridum)	4.52	2.02	1.34	0.64
Moss	4.11	1.38	0.64	0.22
Rough-fruited cinquefoil (Potentilla recta)	2.75	1.14	0.43	0.17
Spreading dogbane (Apocynum androsaemifolium)	27.59	4.53	4.34	0.65
Star flower (Trientalis borealis)	5.85	4.12	0.96	0.68
Strawberry (Fragaria spp.)	37.08	2.91	5.85	0.44
Strawberry blite (Chenopodium capitatum)	6.05	4.60	0.91	0.68
Sundrops (Oenothera fruticosa)	2.56	1.49	0.40	0.23
Sweet white clover (Melilotus alba)	1.89	1.16	0.30	0.19
Thistle (Cirsium spp.)	4.31	3.40	0.69	0.55
Tower mustard (Arabis glabra)	19.76	14.19	3.16	2.30
Trillum spp. (Trillium spp.)	2.66	1.55	0.43	0.25
Violet (Viola spp.)	14.71	5.53	2.36	0.91
White clover (Trifolium repens)	2.12	1.34	0.32	0.20
Wild sasparilla (Aralia nudicaulis)	8.05	4.68	1.31	0.76
Wintergreen (Gaultheria procumbens)	15.22	13.33	2.52	2.22

Appendix A3. Frequency of herbaceous vegetation in conventional clearcuts that were harvested in 1982 and measured in 1984.

Plants	Abs. Freq.		Rel. Freq.	
	$\bar{x}$	SE	$\bar{x}$	SE
Aster (Aster spp.)	6.25	2.15	1.16	0.41
Bedstraw (Galium spp.)	4.26	0.66	0.76	0.14
Bracken (Pteridium aquilinum)	90.64	4.04	16.00	1.14
Bramble (Rubus spp.)	78.60	9.26	13.67	1.33
Canada mayflower (Maianthemum canadense)	8.72	3.95	1.62	0.77
Club moss (Lycopodium spp.)	1.70	0.90	0.41	0.14
Common milkweed (Ascelepias syriaca)	3.45	1.85	0.56	0.28
Common mullein (Verbascum thapsus)	3.05	1.19	0.54	0.21
Daisy fleabane (Erigeron annuus)	3.46	1.85	0.58	0.28
Dandelion (Taraxacum officinale)	4.23	1.52	0.73	0.27
Field pussytoes (Antennaria neglecta)	1.95	1.28	0.36	0.24
Goldenrod (Solidago spp.)	27.32	8.71	4.60	1.27
Grass (Poa spp.)	92.63	5.71	16.21	0.81
Hawkweed (Hieracium spp.)	32.20	8.32	5.40	1.27
Heart-leaved aster (Aster cordifolius)	14.90	2.11	2.62	0.40
Honeysuckle (Lonicera spp.)	7.03	2.82	1.20	0.47
Large-leaved aster (Aster macrophyllus)	17.13	10.12	3.11	2.01
Low-bush blueberry (Vaccinium angustifolium)	22.80	13.04	4.78	3.87
Sheep sorrel (Rumex acetillosa)	2.77	2.05	0.44	0.31
Spreading dogbane (Apocynum androsaemifolium)	10.57	2.69	1.28	0.56
Star flower (Trientalis borealis)	2.37	0.90	0.41	0.14
Strawberry (Fragaria spp.)	59.38	17.15	20.23	8.51
Sweet white clover (Melilotus alba)	2.37	1.34	0.40	0.24
Thimbleweed (Anemone virginiana)	5.54	4.11	0.88	0.63
Violet (Viola spp.)	3.53	2.32	0.64	0.44
White clover (Trifolium repens)	13.39	5.46	2.23	0.85
Wild basil (Satureja vulgaris)	1.68	1.05	0.27	0.16
Wild sasparilla (Aralia nudicaulis)	4.06	2.81	0.68	0.49
Wintergreen (Gaultheria procumbens)	18.94	12.24	3.56	2.28

Appendix A4. Frequency of herbaceous vegetation in whole tree clearcuts that were harvested in 1982 and measured in 1984.

Plants	Abs. Freq.		Rel. Freq.	
	$\bar{x}$	SE	$\bar{x}$	SE
Aster (*Aster* spp.)	7.81	4.94	1.30	0.81
Bedstraw (*Galium* spp.)	8.71	7.76	1.52	1.36
Bracken (*Pteridium aquilinum*)	89.49	6.75	15.43	1.06
Bramble (*Rubus* spp.)	63.37	13.34	10.83	2.06
Bunchberry (*Cornus canadensis*)	6.38	6.38	1.12	1.12
Canada mayflower (*Maianthemum canadense*)	8.35	5.54	1.47	0.97
Common mullein (*Verbascum thapsus*)	2.66	2.66	0.47	0.47
Daisy (*Chrysanthemum leucanthemum*)	2.22	1.51	0.39	0.26
Dandelion (*Taraxacum officinale*)	4.58	1.54	0.78	0.24
False solomon's seal (*Smilacina racemosa*)	1.36	0.79	0.23	0.13
Goldenrod (*Solidago* spp.)	27.52	1.85	4.74	0.23
Grass (*Poa* spp.)	88.88	6.76	15.32	1.05
Ground pine (*Lycopodium* spp.)	1.16	0.67	0.20	0.12
Hawkweed (*Hieracium* spp.)	26.38	3.28	4.53	0.47
Heart-leaved aster (*Aster cordifolius*)	16.75	6.21	2.93	1.10
Honeysuckle (*Lonicera* spp.)	6.46	4.09	1.10	0.71
Large-leaved aster (*Aster macrophyllus*)	41.39	7.63	7.13	1.29
Low-bush blueberry (*Vaccinium angustifolium*)	38.47	18.48	6.77	3.28
Moss	2.10	1.40	0.35	0.22
Poison ivy (*Rhus radicans*)	1.27	0.75	0.21	0.21
Rose (*Rosa* spp.)	4.21	2.36	0.75	0.48
Sedge (*Carex* spp.)	3.19	3.19	0.56	0.56
Sheep sorrel (*Rumex acetosella*)	3.71	2.14	0.66	0.38
Spreading dogbane (*Apocynum androsaemifolium*)	13.82	5.36	2.41	0.97
Strawberry (*Fragaria* spp.)	51.33	8.69	8.78	1.28
Sweet fern (*Comptonia peregrina*)	4.08	2.37	0.69	0.40
Sweet white clover (*Melolitus alba*)	4.33	2.50	0.73	0.42
Thistle (*Cirsium* spp.)	2.69	1.57	0.46	0.26
Violet (*Viola* spp.)	9.01	2.81	1.53	0.46
Wintergreen (*Gaultheria procumbens*)	18.76	4.36	3.27	0.79
Wood betony (*Pedicularis canadensis*)	4.27	4.27	0.76	0.76

Appendix B. Mean densities per ha (±S.E.) of all bird species observed in 1984 on 8 conventional and 8 whole tree aspen clearcuts which were in their first and third growing seasons.

Bird Species	Year Class 1		Year Class 3	
	Conventional	Whole Tree	Conventional	Whole Tree
Alder flycatcher (*Empidonax traillii*)	3.9±2.5	0.0±0.0	13.5±13.5	0.0±0.0
American goldfinch (*Spinus tristis*)	2.1±1.4	4.6±3.0	6.3±1.7	5.7±1.6
American redstart (*Setophaga ruticilla*)	3.5±2.7	0.0±0.0	1.7±1.2	0.0±0.0
American robin (*Turdus migratorius*)	6.1±1.5	6.4±2.7	3.2±2.7	4.1±2.0
Blue jay (*Cyanocitta cristata*)	1.5±0.6	1.2±0.5	2.1±1.4	1.1±0.7
Brown-headed cowbird (*Molothrus ater*)	4.9±3.2	6.5±1.0	5.5±1.0	6.7±3.6
Brown thrasher (*Toxostoma rufum*)	6.4±3.9	2.1±1.3	7.9±1.9	8.5±5.0
Cedar waxwing (*Bombycilla cedrorum*)	2.8±0.5	6.6±6.6	5.4±3.2	3.9±1.9
Chestnut-sided warbler (*Dendroica pensylvanica*)	31.8±18.1	8.5±4.7	81.3±45.5	35.2±16.6
Chipping sparrow (*Spizella passerina*)	5.0±4.3	5.1±2.5	6.6±3.4	8.8±3.1

Appendix B. (cont'd)

Bird Species	Year Class 1		Year Class 3	
	Conventional	Whole Tree	Conventional	Whole Tree
Common flicker (*Colaptes auratus*)	3.4±1.1	1.8±0.8	3.5±0.8	1.4±0.8
Common grackle (*Quiscalus quiscula*)	0.0±0.0	1.2±0.8	1.2±0.5	4.8±2.5
Common yellowthroat (*Geothlypis trichas*)	3.2±1.3	0.1±0.1	5.4±1.6	1.0±0.7
Eastern bluebird (*Sialia sialis*)	0.0±0.0	2.7±1.6	0.9±0.6	0.6±0.4
Eastern kingbird (*Tyrannus tyrannus*)	1.7±1.5	7.9±2.2	4.9±2.0	7.7±3.0
Field sparrow (*Spizella pusilla*)	0.0±0.0	0.4±0.4	0.0±0.0	1.2±0.9
Golden-winged warbler (*Vermivora chrysoptera*)	0.0±0.0	2.0±2.0	32.5±17.0	2.1±2.1
Great crested flycatcher (*Myiarchus crinitus*)	0.7±0.4	0.7±0.5	0.9±0.7	0.0±0.0
Hairy woodpecker (*Dendrocopus villosus*)	0.0±0.0	0.8±0.4	0.0±0.0	0.0±0.0
House wren (*Troglodytes aedon*)	2.0±1.0	1.6±1.6	5.9±5.2	0.0±0.0

Appendix B. (cont'd)

Bird Species	Year Class 1		Year Class 3	
	Conventional	Whole Tree	Conventional	Whole Tree
Indigo bunting (*Passerina cyanea*)	13.4±4.3	12.3±4.3	35.1±10.9	34.0±5.0
Killdeer (*Charadrius vociferus*)	0.0±0.0	9.6±7.5	0.0±0.0	0.5±0.5
Mourning dove (*Zenaidura macroura*)	0.0±0.0	0.0±0.0	0.6±0.4	0.0±0.0
Mourning warbler (*Oporornis philadelphia*)	20.2±6.5	3.4±2.0	14.1±6.7	7.2±5.1
Nashville warbler (*Vermivora ruficapilla*)	5.2±3.0	1.4±0.6	6.3±3.3	5.1±3.1
Northern oriole (*Icterus galbula*)	0.4±0.4	3.5±0.6	0.2±0.2	2.5±2.2
Red-winged blackbird (*Agelaius phoeniceus*)	0.6±0.4	2.7±1.5	0.7±0.4	0.0±0.0
Rose-breasted grosbeak (*Pheucticus ludovicianus*)	2.1±0.8	2.2±0.8	6.2±1.6	5.0±2.0
Rufous-sided towhee (*Pipilc erythrophthalmus*)	3.2±2.5	0.0±0.0	25.0±5.8	11.1±4.0
Scarlet tanager (*Piranga olivacea*)	0.0±0.0	1.0±0.7	0.0±0.0	0.0±0.0

Appendix B. (cont'd)

Bird Species	Year Class 1		Year Class 3	
	Conventional	Whole Tree	Conventional	Whole Tree
Song sparrow (*Melospiza melodia*)	27.2 ± 9.2	16.8 ± 7.4	36.1 ± 3.4	27.7 ± 9.0
Starling (*Sturnus vulgaris*)	0.0 ± 0.0	0.9 ± 0.6	0.0 ± 0.0	0.0 ± 0.0
Tree swallow (*Iridoprocne bicolor*)	0.9 ± 0.9	2.6 ± 1.4	5.5 ± 2.3	0.9 ± 0.9
Vesper sparrow (*Pooecetes gramineus*)	0.0 ± 0.0	1.9 ± 1.3	2.0 ± 1.2	3.6 ± 1.3
White-throated sparrow (*Zonotrichia albicollis*)	69.0 ± 25.0	4.2 ± 3.1	19.1 ± 8.5	13.7 ± 12.0

Appendix C. Mean densities per ha (±S.E.) of all bird species observed in 1985 on 8 conventional and 8 whole tree aspen clearcuts which were in their second and fourth growing seasons.

Bird Species	Year Class 2 Conventional	Year Class 2 Whole Tree	Year Class 4 Conventional	Year Class 4 Whole Tree
Alder flycatcher (*Empidonax traillii*)	0.0±0.0	0.6±0.3	2.2±1.5	3.0±3.0
American goldfinch (*Spinus tristis*)	7.0±2.0	24.5±7.4	17.2±6.4	13.7±6.1
American redstart (*Setophaga ruticilla*)	1.5±1.0	0.4±0.4	5.5±3.4	0.0±0.0
American robin (*Turdus migratorius*)	8.7±1.3	11.4±2.0	8.1±1.3	7.9±2.2
Black-and-white warbler (*Mniotilta varia*)	2.4±1.2	1.7±0.7	0.0±0.0	0.0±0.0
Black-capped chickadee (*Parus atricapillus*)	1.5±1.5	1.0±1.0	1.2±1.0	1.5±0.9
Blue jay (*Cyanocitta cristata*)	4.5±1.3	7.3±3.6	6.0±1.2	5.3±1.0
Brown-headed cowbird (*Molothrus ater*)	7.0±5.7	4.7±1.3	6.7±1.2	8.5±3.4
Brown thrasher (*Toxostoma rufum*)	3.5±3.3	2.3±0.5	5.4±1.8	19.1±7.4
Cedar waxwing (*Bombycilla cedrorum*)	3.5±3.5	13.4±2.8	7.7±4.7	10.5±4.2

Appendix C. (cont'd)

Bird Species	Year Class 2 Conventional	Year Class 2 Whole Tree	Year Class 4 Conventional	Year Class 4 Whole Tree
Chestnut-sided warbler (*Dendroica pensylvanica*)	38.1±11.4	33.0±5.2	53.5±24.4	31.2±14.7
Chipping sparrow (*Spizella passerina*)	7.2±5.6	5.4±2.8	11.4±4.0	9.4±6.5
Common flicker (*Colaptes auratus*)	1.7±0.5	3.6±1.1	3.0±0.8	2.0±0.6
Common grackle (*Quiscalus quiscula*)	2.5±1.5	4.1±2.3	2.3±1.2	5.1±1.9
Common yellowthroat (*Geothlypis trichas*)	20.4±7.4	4.0±3.4	5.0±2.2	6.8±6.8
Eastern bluebird (*Sialia sialis*)	0.0±0.0	4.2±1.1	3.9±1.4	10.5±3.1
Eastern kingbird (*Tyrannus tyrannus*)	0.8±0.3	5.8±1.2	3.1±1.5	6.9±3.1
Field sparrow (*Spizella pusilla*)	0.0±0.0	0.6±0.6	0.0±0.0	1.8±1.2
Golden-winged warbler (*Vermivora chrysoptera*)	27.3±17.5	6.7±5.2	31.3±17.8	6.0±6.0
Great crested flycatcher (*Myiarchus crinitus*)	3.1±1.6	2.6±0.9	2.8±0.8	1.4±0.3

Appendix C. (cont'd)

Bird Species	Year Class 2		Year Class 4	
	Conventional	Whole Tree	Conventional	Whole Tree
Hairy woodpecker (*Dendrocopos villosus*)	1.0±0.6	0.5±0.3	0.4±0.3	0.3±0.3
Indigo bunting (*Passerina cyanea*)	31.8±5.2	49.4±7.1	50.1±14.8	42.5±1.8
Mourning dove (*Zenaidura macroura*)	1.2±0.5	0.0±0.0	1.4±1.4	0.4±0.2
Mourning warbler (*Oporornis philadelphia*)	34.7±7.4	19.9±2.4	20.9±5.9	11.0±6.7
Nashville warbler (*Vermivora ruficapilla*)	13.9±5.8	1.1±0.4	17.4±6.1	8.4±3.0
Northern oriole (*Icterus galbula*)	0.5±0.5	1.5±0.6	1.2±1.0	7.1±2.9
Pine siskin (*Spinus pinus*)	0.5±0.5	18.6±14.6	3.2±2.5	0.0±0.0
Purple finch (*Carpodacus purpureus*)	0.0±0.0	1.1±0.7	0.0±0.0	0.0±0.0
Red-winged blackbird (*Agelaius phoeniceus*)	0.6±0.6	5.5±5.2	1.7±1.7	0.8±0.8
Rose-breasted grosbeak (*Pheucticus ludovicianus*)	5.2±2.3	7.7±2.3	12.9±3.7	9.1±4.1

Appendix C. (cont'd)

Bird Species	Year Class 2		Year Class 4	
	Conventional	Whole Tree	Conventional	Whole Tree
Ruby-throated hummingbird (*Archilochus colubris*)	0.0±0.0	2.7±2.1	1.1±1.1	1.9±0.7
Rufous-sided towhee (*Pipilo erythrophthalmus*)	10.9±8.7	1.4±1.2	12.2±3.6	19.4±4.9
Song sparrow (*Melospiza melodia*)	32.6±13.8	43.1±12.1	37.5±10.1	37.2±9.1
Starling (*Sturnus vulgaris*)	0.0±0.0	1.3±0.5	2.3±1.4	3.0±2.2
Tree swallow (*Iridoprocne bicolor*)	0.0±0.0	4.0±1.3	5.0±1.8	2.6±1.9
Vesper sparrow (*Pooecetes gramineus*)	1.6±1.2	2.4±2.0	0.7±0.5	3.4±1.6
White-breasted nuthatch (*Sitta carolinensis*)	0.9±0.5	0.3±0.3	0.2±0.2	0.4±0.4
White-throated sparrow (*Zonotrichia albicollis*)	56.3±22.0	12.2±4.7	12.0±6.2	8.3±8.3

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