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WILDLIFE RESPONSE TO
CONVERSION OF
HARDWOOD FOREST TO RED PINE

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Suzanne Tomassi

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Jonathan Haufler
Major professor

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WILDLIFE RESPONSE TO
CONVERSION OF
HARDWOOD FOREST TO RED PINE

by

Suzanne Tomassi

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ABSTRACT

WILDLIFE RESPONSE TO CONVERSION OF HARDWOOD FOREST TO RED PINE

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Small mammal, bird, and deer populations were compared between 5 red pine plantations converted from clearcuts and 5 naturally regenerating clearcuts. The conversion process included mechanical and chemical site preparation. Measured vegetation variables differed significantly between the converted sites and controls in all years. Total small mammal abundance increased with treatment and increases were negatively correlated with vegetative abundance and structural complexity. Bird density, species richness, and species diversity were lower on treated plots than controls. Changes in bird populations were correlated with decreasing vegetative complexity. No significant changes in deer use were observed after treatment. Control sites provided potentially better summer deer habitat than converted sites.

Results suggest that the conversion process may cause undesirable shifts in some wildlife populations, particularly bird species, and that the preservation of a hardwood component in converted plantations might improve the suitability of these areas for wildlife.

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INTRODUCTION

Red pine (*Pinus resinosa*) plantations and natural stands comprise about 567,000 hectares of commercial forest in the Lake States (Dickmann et al. 1987). The species historically made up about 1/3 of all pine forests in this area (Benzie 1977). Red pine is highly valued as a timber species because of its straight and rapid growth, adaptability to a range of soil types (Eyre and Zehngraff 1948), response to thinning (Dickmann et al. 1987), and relatively high resistance to disease and insects (Benzie 1977). It transplants easily, is successful in commercial plantations, and is the most intensely managed conifer in the Lake States (Capen 1979).

Red pine, in natural stands, is commonly associated with jack pine (*P. banksiana*), quaking aspen (*Populus tremuloides*), paper birch (*Betula papyrifera*), and scrub oak (*Quercus ilicifolia*) on drier sites, and additionally with white pine (*P. strobus*), red maple (*Acer rubrum*), northern red oak (*Quercus rubra*), balsam fir (*Abies balsamea*), white spruce (*Picea glauca*), black spruce (*P. mariana*), black cherry (*Prunus serotina*), and chestnut oak (*Q. prinus*) on moister sites (Fowells 1965, Benzie 1977). On loamy soils, American basswood (*Tilia americana*), yellow birch (*B. lutea*), American beech (*Fagus grandifolia*), eastern hemlock (*Tsuga canadensis*), white ash (Fraxinus americana), red spruce (P. rubens), northern white-cedar (Thuja occidentalis), and eastern hop hornbeam (Ostrya virginiana) are also common associates (Fowells 1965). Red pine also grows naturally in relatively pure stands in the Lake States (Fowells 1965, Benzie 1977). Because the species is long-lived, it often remains dominant after other shade intolerant associates have died. It is in turn replaced by more tolerant associates as succession proceeds (Benzie 1977). Associated understory species typically include Canada blueberry (Vaccinium canadense), lowbush blueberry (V. angustifolium), sweetfern (Comptonia peregrina), American hazel (C. cornuta), bearberry (Arctostaphylos uva-ursi), prairie willow (Salix humilis), striped maple (A. pensylvanicum), dwarf bush-honeysuckle (Dieruilla lonicera), Jerseytea ceanothus (Ceanothus americanus), sand cherry (Prunus pumila), and American fly honeysuckle (Lonicera canadensis) (Fowells 1965), as well as most common overstory associates except jack pine.

Unthinned mature red pine stands are typically closed-canopy, and the amount of understory is inversely related to the density of the overstory (Dickmann et al. 1987). Total area of ground cover by woody vegetation less than 1.8m in height was only 4.2% in a mature red pine stand in Michigan (Gysel 1966). Tappeiner and Alm (1975) and Dickmann et al. (1987) also noted a lack of understory vegetation in red pine stands.

Because of red pine's intolerance to shade, the species responds best to even-aged management methods. Dense stocking (up to 2000 trees/ha) of red pine in plantations is recommended for maximum timber production (Eyre and Zehngraff 1948, Lundgren 1983), and intensive site preparation is often necessary to reduce hardwood competition. To increase softwood production, foresters have converted hardwood sites to red pine. Site preparation may involve the application of herbicides to reduce hardwood competition. Slay et al. (1987) compared 4 types of site preparation (chop and burn, windrow, fuelwood harvest, and fuelwood harvest plus herbicide) and reported higher seedling growth rates, greater groundline diameters, greater volume, and lower biomass of competing species on herbicided plots. Loblolly pines (P. taeda) on sites treated with hexazinone for 2 years following planting averaged 1.5 to 2.0 times greater in height than trees on untreated sites after 4 growing seasons. In addition, trees on treated plots were 2cm to 5cm greater in groundline diameter and up to 7 times greater in volume than those on untreated plots (Knowe et al. 1985). Creighton et al. (1987) observed similar height and diameter responses for loblolly, longleaf (P. australis) and slash pine (P. elliottii) plots treated with hexazinone and other herbicides for 1 year, and they reported additional height and diameter increases on treated plots after a second year of herbicide application. They also observed a significant increase in pine survival after 1 year of treatment. Nelson et al. (1981) demonstrated a positive response in loblolly growth in plots treated with hexazinone during the first 3 growing seasons and attributed the increase to a reduction in competition for water by weeds. McKee and Wilhite (1988) estimated a rotation length decrease of 1 year in loblolly pine as a result of herbicide treatment. Loblolly plantations treated with hexazinone in the first growing season showed a decrease in herbaceous vegetation after that growing season, but differences between treatment and control plots disappeared by the end of the second growing season (Blake et al. 1987). Michael (1985) compared herbicides and recommended the use of hexazinone on soils with high organic matter content.

Results of studies investigating forage and cover changes associated with conversion practices suggest that the cultivation of pine monocultures with the sole objective of maximizing timber production would adversely affect wildlife. In addition to decreasing vegetative structural complexity and diversity, conversion to red pine alters natural succession and eliminates snags (Meslow 1978). Planting essentially eliminates the grass-forb sere. It is widely accepted that certain wildlife species are characteristic of different stages of succession. Clearly, truncation of the successional process could negatively impact species dependent on those seres eliminated or shortened.

Due to these vegetative changes and the resulting lack of wildlife food and cover species, red pine plantations are generally considered poor wildlife habitat (Benzie 1977, Johnson 1987). A red pine plantation in Michigan supported fewer bird species and individuals than surrounding natural pin oak (Quercus ellipsoidalis) and jack pine communities (Gysel 1966). The plantation also supported significantly fewer white-tailed deer (Odocoileus virginianus) than surrounding communities, and small mammal numbers decreased with decreasing cover. Hurst and Warren (1982) reported reduction of deer forage, elimination of hard and soft mast, and a decrease in cover on a converted pine plantation. Forage reduction has been shown to be more extreme when herbicides are used, when compared to plantations prepared by mechanical methods alone (McComb and Hurst 1987).

Some wildlife species may temporarily benefit from site preparation with herbicide. Herbicides improved mourning dove (Zenaida macroura) feeding grounds on a Mississippi loblolly plantation by decreasing ground cover and increasing wooly croton (Croton capitatus) and poke weed (Phytulacca americana) abundance (Blake et al. 1987), and vegetation changes following herbicide treatment in Oregon resulted in temporary increases in some seed eaters (Morrison and Meslow 1983). Conversion without the use of herbicides has been shown to improve habitat for some species by increasing low growth (Felix et al. 1986). This method has also resulted in increased deer forage, when compared to conversion with herbicides (McComb and Hurst 1987).

The benefits derived from populations of wildlife species emphasize the importance of considering wildlife when managing forested land for timber production. Wildlife in forest ecosystems has both consumptive and nonconsumptive uses, as well as ecological value. Birds and small mammals are instrumental in seed dispersal and reduction of populations of some detrimental insects (Bruns 1959, Sloan and Coppel 1968, Shugart et al. 1975, Chew 1978, West 1968, Ream and Gruell 1980, Crawford et al. 1983). Bird species sensitive to habitat disturbance are early indicators of forest degradation. Small mammals are an important prey base (Chew 1978, Potter 1978), and they have been shown to aid aeration of soil and movement of organic matter into the soil (Chew 1978, Ream and Gruell 1980). Chew (1978) also suggested that the cutting of runways and feeding of small mammals increase fertility and rate of nutrient cycling in soil. Deer are the most popular game species in the United States (U.S. Fish and Wildlife Service 1987) and are the main prey of the timber wolf (Canis lupus) in the Great Lakes Region (Rogers et al. 1981). Wildlife species are valuable for nonconsumptive recreation as well. A total of 64 million people spent $14.3 billion on nonconsumptive wildlife related activities in 1985 (U.S. Fish and Wildlife Service 1987). Birds, small mammals, and deer, in addition to being of demonstrated importance in forest ecosystems, are generally present in relatively large numbers in Michigan forested land. Thus, these animals were selected as indicators of habitat quality in this study.

An increasing demand is being placed on both timber and wildlife resources, but present silvicultural practices are often incompatible with the needs of wildlife. The effects of converting hardwood sites to red pine need to be documented for wildlife to be given proper consideration in forest management practices.

OBJECTIVES

The overall objective of this study was to evaluate bird, small mammal, and white-tailed deer responses to conversion of hardwood sites to red pine. Specifically, the study evaluated:

1. Differences in vegetative structure and composition between converted red pine plots and naturally regenerating clearcuts.

2. The effects of conversion to red pine on small mammal populations.

3. Differences in species composition and relative densities of bird populations between converted red pine plots and clearcuts.

4. The effects of conversion to red pine on deer use.

5. The relative suitability of converted red pine plantations as deer summer habitat.

STUDY AREA DESCRIPTION

The study was conducted in the northwestern part of Menominee County in the Menominee hill land region on Michigan's central Upper Peninsula (Fig. 1).

The physiographic region is a rolling ground moraine consisting of ridges, drumlins, moderate slopes, and outwash plains (Schwenner 1989). Numerous wet areas and ridges with slopes of up to 25% occur in the region. The study area is drained by the Big Cedar River, which flows southeasterly and empties into Green Bay.

Soil types on the study area include deep, well drained, moderately permeable Onaway and Nadeau fine sandy loams and soils of the Lupton, Tawas, Cathro, Deford, and Ensley series. The Lupton, Tawas, and Cathro series occur on moraines and outwash plains and consist of deep, very poorly to poorly drained, moderately permeable loamy to sandy soils. The Deford series consists of deep, poorly drained, rapidly permeable fine sandy soils. The Ensley series soils are similar to those of the Deford series, except that permeability may be somewhat slower. All soil types occur on 0% to 2% slopes with the exception of Onaway and Nadeau fine sandy loams, which may occur on slopes of up to 12% (Schwenner 1989).

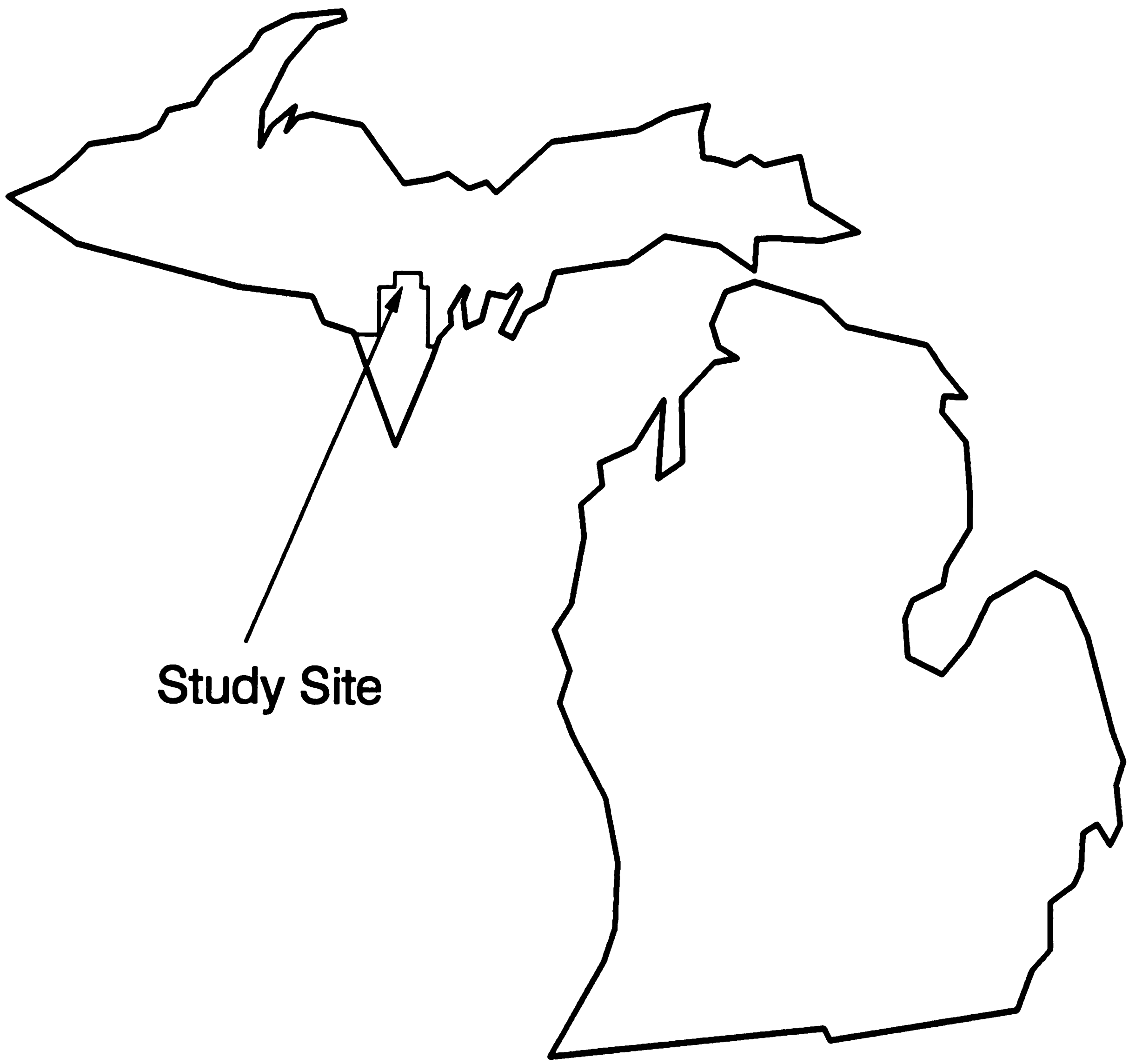


Figure 1. Location of the study area in Menominee County, Michigan.

The climate of the region is semi-continental, with the prevailing wind from the southwest. The mean annual temperature of the area is 5.8°C, ranging from a high of 19.7°C in July to a low of -9.9°C in January. Annual precipitation averages 82.9cm, with 65.6% of the total occurring in April through September. Mean annual snowfall is 165.9cm. Mean monthly temperatures during the study period are shown in Figure 2 (NOAA 1986, 1987, 1988, 1989, 1990). Mean monthly precipitation during the study period is shown in Figure 3 (NOAA 1986, 1987, 1988, 1989, 1990).

Due to the treatment effects, treated sites were sparsely vegetated. Planted red pine predominated, and other woody species included balsam fir, balsam poplar (*Populus balsamifera*), paper birch, cherry (*Prunus* spp.), speckled alder (*Alnus rugosa*), quaking aspen, white spruce, and less commonly, bigtooth aspen (*Populus grandidentata*, dogwood (*Cornus* spp.), red maple, sugar maple (*Acer saccharum*), serviceberry (*Amelanchier* spp.), and willow (*Salix*). Quaking aspen predominated on the control plots. Other tree species present on controls sites were most of those species found on treated sites. Understory vegetation included most overstory species plus brambles (*Rubus* spp.), blueberry (*Vaccinium* spp.), elderberry (*Sambucus* spp.), currant (*Ribes* spp.), grape (*Vitis* spp.), Virginia creeper (*Parthenocissus quinquefolia*), and viburnum (*Viburnum* spp.). All control plots and most treatment plots had thick ground cover composed of numerous herbaceous species.

Figure 2. Mean monthly long term temperature and mean monthly temperatures during the study period for Stephenson, Michigan.

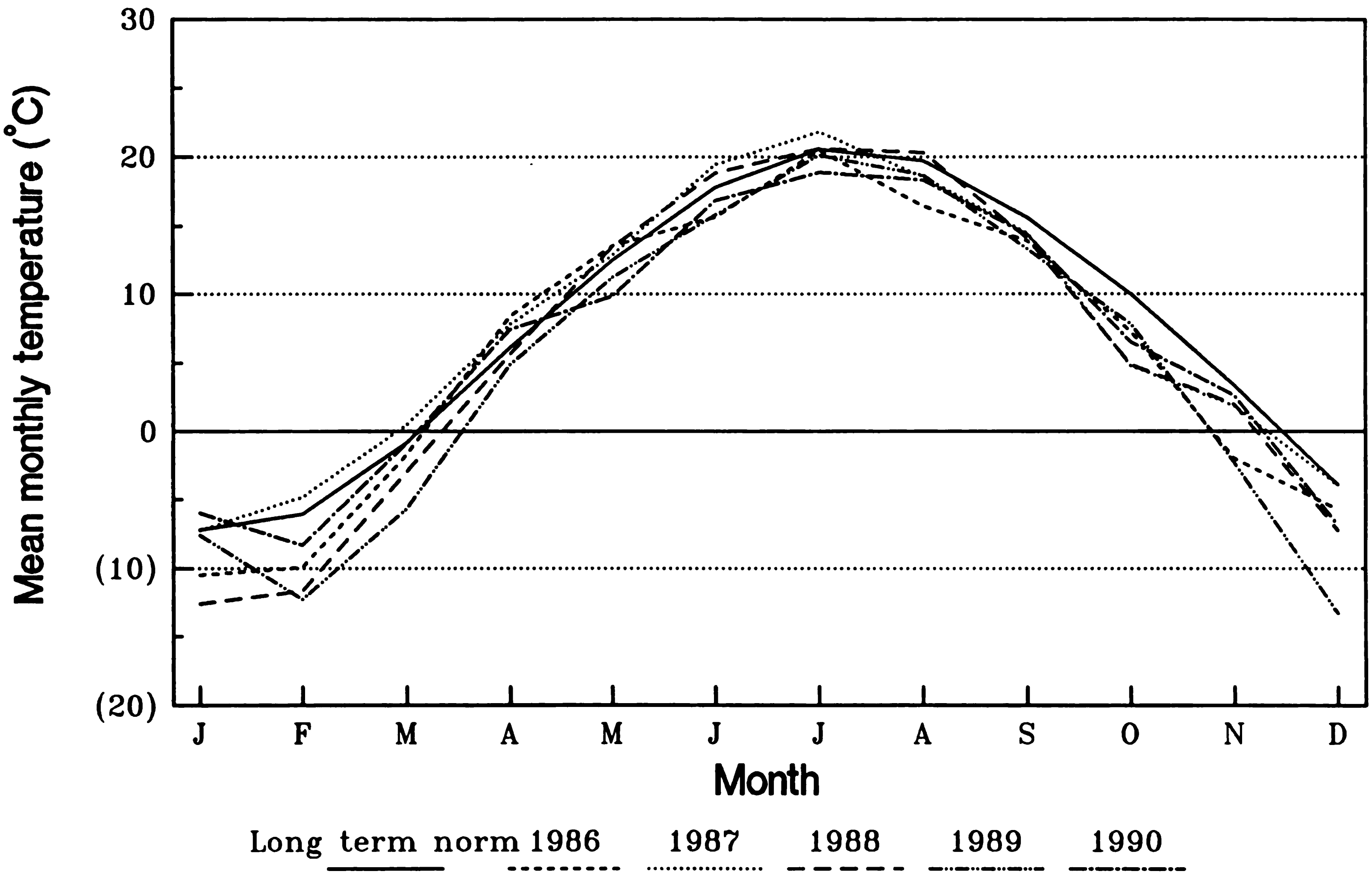
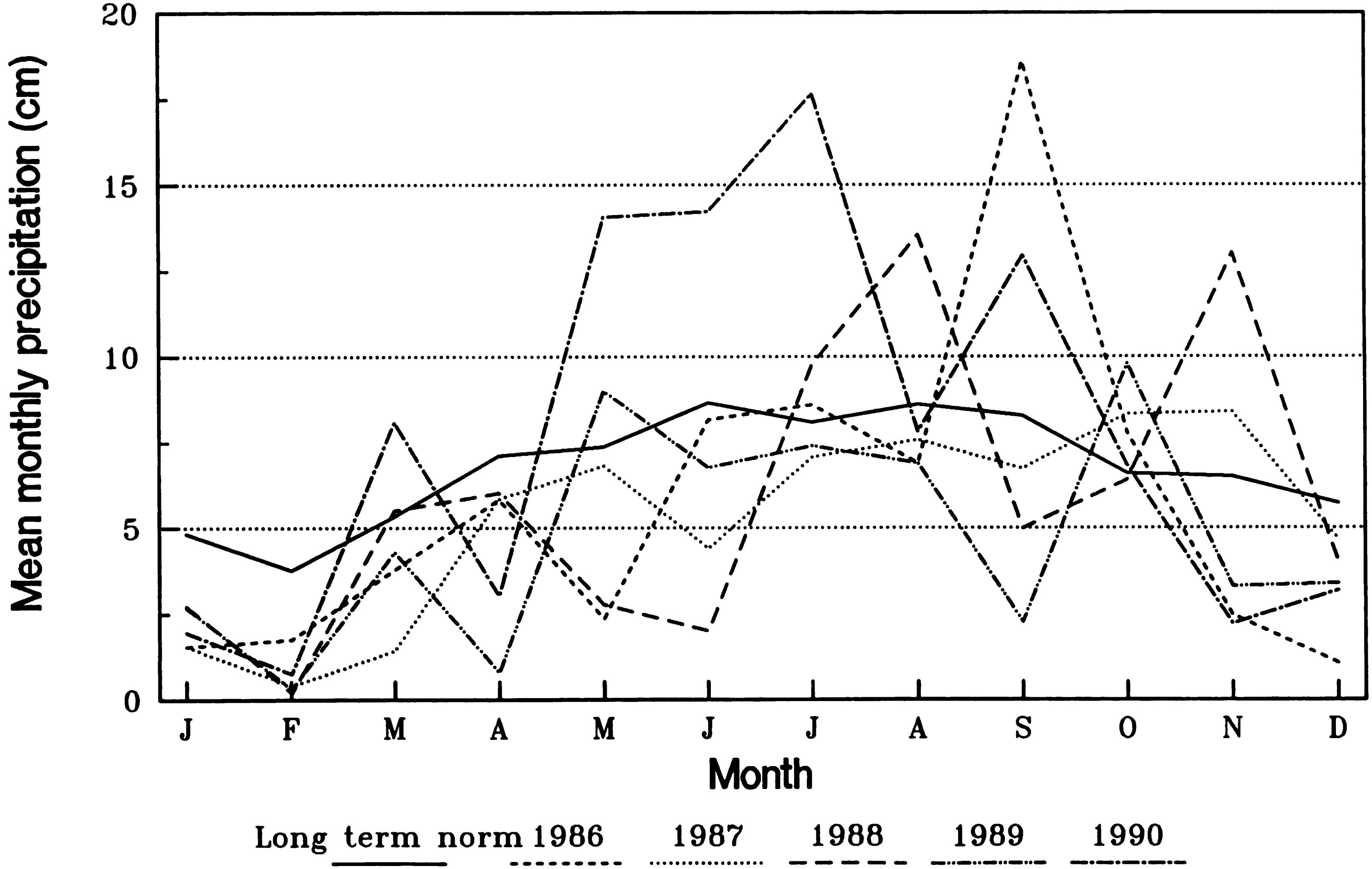

Mean monthly temperature (°C)
30
20
10
0
(10)
(20)
J F M A M J J A S O N D
Month
Long term norm 1986 1987 1988 1989 1990

Figure 3. Mean monthly long term precipitation and mean monthly precipitation during the study period for Stephenson, Michigan.



Mean monthly precipitation (cm)
20
15
10
5
0
J
F
M
A
M
J
J
A
S
O
N
D
Month
Long term norm
1986
1987
1988
1989
1990

METHODS

Ten study plots of 8 ha each were established in newly clearcut hardwood stands on the study area. Plots were selected based on their similarity in vegetative composition and date of clearcutting. Plots were of irregular shape. Hexazinone, in the herbicide Velpar, was applied to all treatment sites. All sites had previous mechanical manipulations (Table 1).

VEGETATIVE SAMPLING

Vertical cover was measured on all plots by the line intercept method (Canfield 1941). Percent cover was measured in 3 height strata: <1m, 1-7m, and >7m. Vegetation covering a measuring tape was recorded in centimeters with gaps of <5cm ignored. Transects were located randomly and run in the same direction. In 1986, 1987, and 1988, numbers and lengths of transects were varied to meet efficiency and sample size requirements. Due to the wide variation in vegetative cover within sites in 1990, a maximum of 30 transects 30m in length was located on each study site. In 1986, cover was not measured in 3 unplanted treatment plots because of the nearly total lack of vegetation on these sites. In all years, a 5m-

Table 1. Treatment histories of converted red pine plantations and naturally regenerating clearcuts in the Upper Peninsula, Michigan.

SITE NAME (SITE TYPE)	DATE PLANTED	MECHANICAL AND CHEMICAL TREATMENT HISTORY
Broken Pine (Treatment)	9/85	Roundwood harvest 1/84 Brushraked 12/84 Velpar treated 6/85 (5 qts/ac.) Disc trenched 6/85 Velpar treated 5/87 (4.2 qts/ac.) Velpar treated 5/88 (4.3 qts/ac.)
Camp 7 (Treatment)	9/83	Roundwood harvest 1/82 Brushraked, burned 1/82 Disc trenched 8/83 Velpar treated 8/83 (5-6 qts/ac.) Velpar treated 6/85 (3 qts/ac.) Velpar treated 5/86 (4 qts/ac.) Velpar treated 5/88 (4.4 qts/ac.)
Sand Road (Treatment)	9/86	Roundwood harvest 1/85 Brushraked 5/86 Velpar treated 5/86 (5.2 qts/ac.) Velpar treated 6/86 (4.7 qts/ac.) Velpar treated 5/89 (4.2 qts/ac.)
Cut Across (Treatment)	9/86	Whole tree harvest 1/85 Disc trenched 6/86 Velpar treated 6/86 (3.2 qts/ac.) Velpar treated 7/86 (5.1 qts/ac.) Velpar treated 5/89 (4 qts/ac.)
Indian Head (Treatment)	9/86	Whole tree harvest 12/84 Velpar treated 5/86 (5.9 qts/ac.) Disc trenched 6/86 Velpar treated 6/86 (4 qts/ac.) Velpar treated 5/88 (4.2 qts/ac.)
Burnt Stump (Control)		Roundwood harvest 1/83
Slessinger (Control)		Roundwood harvest 12/82
North Ridge (Control)		Roundwood harvest 12/82

Table 1 (cont'd).

SITE TYPE (SITE TYPE)	DATE PLANTED	MECHANICAL AND CHEMICAL TREATMENT HISTORY
Cut Across (Control)		Whole tree harvest 1/85
Railroad Grade (Control)		Roundwood harvest 1/84

10m buffer at plot edges was left unsampled to minimize edge effects.

Randomly located nested plots were used to determine density of woody species and frequency of woody and herbaceous species. Density of woody vegetation >1m in height was measured in randomly located 2m x 30m plots. The number of plots varied with sample size requirements. Frequency of woody species <1m in height was recorded in 2m x 10m plots, and frequency of herbaceous vegetation was recorded in 2m x 5m plots, except in 1987, when 1m x 1m plots were used. In 1986, 1987, and 1988, frequency was measured in 20 plots, and in 1990, 30 plots were located on each study plot. Grasses, brambles, and some tree species were recorded by genera, while forbs and most trees and shrubs were recorded by species.

WILDLIFE RESPONSES

Small Mammal Census

Small mammals were censused by live trapping twice annually, in July and August of 1987, 1988, and 1990. A 6 x 6 trapping grid with 2 Sherman live-traps (H.B. Sherman Co., Tallahassee, Fla.) per station and trap spacing of 15m was established at the center of each study plot. Traps were placed next to logs and in other small mammal travel lanes and covered with vegetation. Bait was a mixture of oats, beef fat, and anise extract. Each treatment plot was randomly paired with a control, and pairs were trapped on the same nights. Trapping was conducted in 2 groups (1 group of 6 plots and 1 group of 4 plots). Each group was trapped for 5 consecutive days in each month. Newly captured animals were ear tagged, and species, tag number, and grid location were recorded.

Bird Census

Bird populations were censused from mid-May to mid-June, 1987 and 1990, using the variable circular-plot method (Reynolds et al. 1980). Four stations were established on each plot and marked before censusing. Stations were placed so that there was at least a 10m buffer between circular plots, in order to avoid double counting. A 10m buffer was also left between the circular plots and study plot borders to minimize edge effects. Each treated site was randomly paired with a control, and each of 2 observers censused 1 pair each morning. Each observer censused all plots an equal number of times. The order in which the plots, and stations within plots, were censused was rotated to eliminate biases caused by changes in bird activity throughout the census period. Censuses began at sunrise, when breeding bird detectability is greatest (Kendeigh 1944, Hall 1964, Jarvinen et al. 1977, 1978, Connor and Dickson 1980). Censusing periods were 10 minutes in duration, and 1 minute was allowed before each census for birds to resume normal behavior. Birds were not censused in rain, wind, fog, and unseasonable cold, since these conditions may alter bird behavior and detectability

(Robbins 1981).

In 1987, 3 treatment plots and their controls were censused 4 times each. The radius of each sampling station was 50m. In 1990, all 5 treatment plots and their controls were censused 8 times each and the sampling radius was reduced to 25m to increase sighting efficiency and identification accuracy. Different observers conducted the censuses in each year. Singing males were recorded separately from all other observations. The number of singing males was doubled and compared to the number of males plus all other observations and found to be less. Therefore, all observations were used in the final analysis. Bird density, species richness, and species diversity were calculated.

Deer Census

Deer response to conversion was assessed using track counts in 1986, 1987, and 1988 and pellet counts in 1990. Plots usable for track counts were limited by the presence of suitable road surface. Sample sizes in 1986 and 1987 were too small for analysis of results. In July 1988, counts were conducted on 3 treatment and 3 control plots. A 0.15km-0.30km section of road bordering each sampled plot was dragged in the evening and checked in the morning for tracks. Five replications were conducted and results standardized to tracks/0.20km of road.

In August 1990, pellet-group counts were conducted on all study plots. Four 10m x 10m plots were located randomly on each plot and cleared of all pellets. After 5 days, plots were checked for pellet groups. Five or more pellets in a line or cluster were considered a group. All counts were made by the same observer to eliminate observer bias (Neff 1968). Results were expressed as pellet groups/ha and used for relative comparisons between treatments and controls.

DATA ANALYSIS

A completely randomized design was used for this study. The linear model for this design is:

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

μ = mean of all observations

τ_i = variability due to treatments

e_{ij} = variability due to errors.

Statistically adequate sample sizes for vegetative sampling were determined using Freese's (1978) sample size formula:

$$n = t^2s^2/E^2$$

t = tabulated t value at the 90% confidence limit

s^2 = sample variance

E = allowable error (mean x 0.10).

A maximum of 30 samples per plot were taken for any measurement when required sample sizes were extremely large, as they were for the upper stratum of vegetative cover.

The nonparametric Mann-Whitney U test (Seigel 1956) was used to test density of woody vegetation, frequency of woody vegetation, frequency of herbaceous vegetation, percent cover, foliage height diversity, bird density, bird species richness, bird species diversity, small mammal abundance, small mammal species richness, small mammal species diversity, and deer use. The Spearman Rank Correlation Coefficient was used to describe associations between vegetative responses and bird, small mammal, and deer responses.

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

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

P_i = decimal fraction of total individuals or total cover of the ith category.

The numbers of individual small mammals of each species captured for the first time on each plot were used for comparison in all trapping periods.

RESULTS

VEGETATIVE RESPONSES

Vegetative Frequencies

All vegetative species found on the study plots are listed in the Appendix (Table A-1). Of the 67 herbaceous species identified in 1986, 32 occurred on treated sites and 63 on controls. Absolute and relative frequencies of 19 common (>5% absolute frequency) herbaceous species are listed in Table 2. Of these, 15 were found on both treatments and controls. Bedstraw (*Galium* spp.), Canada mayflower (*Maianthemum canadense*), moss (*Lycopus uniflorus*), and spreading dogbane (*Apocynum androsaemifolium*) were found on controls only, and all common species except dandelion (*Taraxacum* spp.) and horseweed (*Erigeron canadensis*) were more abundant on controls than on treated sites. Bedstraw, moss, round-lobed hepatica (*Hepatica americana*), spreading dogbane, and wild strawberry (*Fragaria virginiana*) were significantly higher in both absolute and relative frequency on control sites. Cinquefoil (*Potentilla* spp.), grass (*Poa* spp.), hawkweed (*Hieracium* spp.), and bunchberry (*Cornus canadensis*) exhibited significantly higher absolute frequencies on controls, and dandelion and violet (*Viola* spp.) were higher in

Table 2. Absolute (AF) and relative frequencies (RF) of common herbaceous species occurring on converted red pine plantations (treatments) and clearcuts (controls) in the Upper Peninsula, Michigan, in 1986.

SPECIES	TREATMENTS				CONTROLS			
	% AF	(SE)	% RF	(SE)	% AF	(SE)	% RF	(SE)
Aster	27.0	(15.1)	5.7	(2.4)	56.0	(9.3)	5.9	(0.8)
Bedstraw	0.0	(0.0)**	0.0	(0.0)**	24.0	(9.0)	2.5	(0.9)
Bunchberry	10.0	(2.8)**	3.5	(1.3)	42.0	(9.8)	4.6	(1.2)
Canada mayflower	0.0	(0.0)	0.0	(0.0)	6.0	(2.6)	0.6	(0.2)
Chickweed	6.0	(4.3)	0.9	(0.5)	12.0	(8.6)	1.0	(0.6)
Cinquefoil	3.0	(1.1)*	1.2	(0.5)	18.0	(5.2)	1.8	(0.4)
Dandelion	32.0	(6.7)	8.7	(0.8)***	24.0	(5.0)	2.5	(0.5)
Fern	41.0	(12.2)	14.2	(6.7)	65.0	(13.9)	7.3	(1.7)
Goldenrod	5.0	(2.8)	1.0	(0.6)	22.0	(14.0)	2.8	(1.8)
Grass	48.0	(12.1)*	12.3	(1.8)	94.0	(2.6)	10.3	(0.8)
Hawkweed	6.0	(2.6)*	1.0	(0.9)	30.0	(12.4)	2.9	(1.0)
Horsetail	5.0	(3.5)	2.1	(1.3)	13.0	(4.6)	1.3	(0.5)

Table 2 (cont'd).

SPECIES	TREATMENTS				CONTROLS			
	% AF	(SE)	% RF	(SE)	% AF	(SE)	% RF	(SE)
Horseweed	24.0	(15.3)	4.0	(2.0)	4.0	(3.6)	0.5	(0.5)
Moss	0.0	(0.0)**	0.0	(0.0)**	6.0	(1.7)	0.7	(0.2)
Round-lobed hepatica	1.0	(0.9)**	0.1	(0.1)**	15.4	(4.0)	1.6	(0.4)
Spreading dogbane	0.0	(0.0)**	0.0	(0.0)**	14.0	(9.2)	1.7	(1.2)
Thistle	34.0	(11.0)	9.0	(3.1)	39.0	(11.6)	3.9	(1.0)
Violet	25.0	(4.7)	7.0	(0.9)**	43.0	(7.7)	4.6	(0.7)
Wild strawberry	9.0	(2.6)***	2.5	(0.7)***	70.0	(8.6)	7.5	(0.7)

*Significantly different from controls ($P < 0.10$)

**Significantly different from controls ($P < 0.05$)

***Significantly different from controls ($P < 0.01$)

relative frequency on treated sites.

All 16 woody species <1m in height occurring on the study area in 1986 were present on both treatment and control sites, with the exception of blueberry, which was not found on treated sites (Table 3). All species were more common on controls, though not all differences were statistically significant. Species which differed significantly in absolute frequency were aspen, balsam fir, balsam poplar, cherry, and dogwood, and balsam fir and balsam poplar also differed in relative frequency.

Seventy-five herbaceous species were found on the study plots in 1987. Of these, 62 occurred on treated sites and 54 on controls. Absolute and relative frequencies of common species are listed in Table 4. Daisy fleabane (E. annuus), fern (family Polypodiaceae), and yellow avens (Geum aleppicum) were significantly more common on controls than on treatments, and daisy fleabane, grass, and yellow avens were significantly higher in relative abundance on controls.

Thirteen woody species <1m in height were identified on the study plots in 1987 (Table 5). Balsam poplar and dogwood were found only on controls, and vaccinium, hop hornbeam, and northern white-cedar were found only on treatments. Aspen and balsam poplar were significantly higher in both absolute and relative abundance on controls than on treatments, and pine (red and white) was significantly higher in absolute and relative frequency on treated sites. Birch had a higher relative frequency on treated sites.

Table 3. Absolute (AF) and relative frequencies (RF) of woody species <1m in height occurring on converted red pine plantations (treatments) and clearcuts (controls) in the Upper Peninsula, Michigan, in 1986.

SPECIES	TREATMENTS				CONTROLS			
	% AF	(SE)	% RF	(SE)	% AF	(SE)	% RF	(SE)
Alder	3.0	(1.8)	1.8	(1.1)	6.0	(1.7)	1.3	(0.4)
Ash	12.0	(6.4)	2.7	(3.1)	22.0	(9.4)	3.3	(2.1)
Aspen	34.0	(7.8)***	7.7	(5.6)	95.0	(1.4)	14.1	(2.4)
Balsam fir	6.0	(2.6)**	1.4	(0.9)**	22.0	(6.7)	3.3	(0.9)
Balsam poplar	4.0	(2.6)**	1.6	(1.0)*	20.0	(4.9)	4.3	(1.0)
Birch	44.0	(12.0)	9.9	(3.2)	59.0	(13.9)	8.8	(3.1)
Cherry	37.0	(11.2)*	8.4	(2.6)	68.0	(7.3)	10.1	(1.3)
Currant	9.0	(1.7)	3.8	(0.5)	19.0	(4.3)	4.0	(1.0)
Dogwood	1.0	(1.0)*	0.5	(0.5)	18.0	(9.1)	3.2	(1.4)
Hazelnut	10.0	(4.2)	5.3	(2.6)	26.0	(10.1)	5.6	(2.1)
Hornbeam	3.0	(1.8)	1.2	(0.7)	13.0	(4.1)	3.4	(1.1)
Red maple	25.0	(3.2)	5.7	(1.9)	39.0	(12.1)	5.8	(2.4)

Table 3 (cont'd).

SPECIES	TREATMENTS				CONTROLS			
	% AF	(SE)	% RF	(SE)	% AF	(SE)	% RF	(SE)
White spruce	7.0	(4.1)	3.3	(2.0)	14.0	(3.6)	2.9	(0.7)
Willow	3.0	(1.1)	1.4	(0.5)	21.0	(8.6)	4.0	(1.5)

*Significantly different from control ($P < 0.10$)

**Significantly different from control ($P < 0.05$)

***Significantly different from control ($P < 0.01$)

Table 4. Absolute (AF) and relative frequencies (RF) of common herbaceous species occurring on converted red pine plantations (treatments) and clearcuts (controls) in the Upper Peninsula, Michigan, in 1987.

SPECIES	TREATMENTS				CONTROLS			
	% AF	(SE)	% RF	(SE)	% AF	(SE)	% RF	(SE)
Aster	4.7	(2.2)	1.8	(0.7)	10.6	(3.3)	3.4	(1.3)
Black bindweed	6.0	(4.4)	1.8	(1.1)	7.3	(7.3)	2.0	(1.0)
Bunchberry	2.7	(1.9)	1.2	(1.0)	5.3	(3.1)	1.6	(0.9)
Chickweed	7.3	(2.0)	2.6	(0.7)	4.0	(2.0)	1.2	(0.7)
Daisy fleabane	0.7	(0.6)*	0.3	(0.3)*	7.3	(2.2)	2.1	(0.6)
Dandelion	5.3	(1.5)	1.9	(0.5)	2.7	(1.3)	0.7	(0.4)
Fern	21.2	(8.7)*	8.0	(3.7)	46.6	(9.3)	10.0	(2.6)
Goldenrod	5.3	(2.4)	1.9	(0.5)	12.0	(2.8)	3.6	(0.8)
Grass	39.3	(10.1)	14.0	(2.6)*	66.0	(10.8)	20.0	(3.2)
Horseweed	14.0	(5.9)	6.6	(3.7)	5.3	(3.1)	1.5	(0.9)
Moss	6.0	(2.9)	2.2	(1.8)	2.0	(1.3)	0.6	(0.4)
Thistle	23.3	(8.1)	11.1	(5.4)	17.3	(3.5)	5.4	(1.2)

Table 4 (cont'd).

SPECIES	TREATMENTS				CONTROLS			
	% AF	(SE)	% RF	(SE)	% AF	(SE)	% RF	(SE)
Violet	4.7	(1.8)	2.1	(0.9)	6.0	(2.2)	1.7	(0.7)
Yellow avens	1.3	(1.2)*	0.4	(0.4)	7.3	(2.2)	2.4	(0.9)

*Significantly different from controls ($P < 0.10$)

Table 5. Absolute (AF) and relative frequencies (RF) of woody species <1m in height occurring on converted red pine plantations (treatments) and clearcuts (controls) in the Upper Peninsula, Michigan, in 1987.

SPECIES	TREATMENTS				CONTROLS			
	% AF	(SE)	% RF	(SE)	% AF	(SE)	% RF	(SE)
Aspen	5.3	(2.5)*	4.6	(3.1)*	46.7	(27.8)	22.8	(7.4)
Balsam poplar	0.0	(0.0)***	0.0	(0.0)***	42.7	(7.8)	25.8	(3.5)
Birch	27.9	(11.6)	26.2	(2.8)*	22.7	(12.7)	10.4	(7.7)
Cherry	8.0	(4.9)	7.9	(5.8)	24.0	(10.7)	17.4	(6.9)
Dogwood	0.0	(0.0)	0.0	(0.0)	1.3	(1.3)	0.6	(0.6)
Hop hornbeam	1.3	(1.3)	2.0	(2.0)	0.0	(0.0)	0.0	(0.0)
Pine	40.0	(11.2)**	43.8	(8.4)**	13.3	(3.7)	11.4	(8.1)
Northern white-cedar	1.3	(1.3)	0.6	(0.6)	0.0	(0.0)	0.0	(0.0)
Red maple	5.3	(3.9)	4.7	(3.8)	6.7	(6.7)	2.6	(2.6)
White spruce	2.7	(2.7)	3.8	(3.8)	6.7	(3.0)	3.6	(1.7)

Table 5 (cont'd).

SPECIES	TREATMENTS				CONTROLS			
	% AF	(SE)	% RF	(SE)	% AF	(SE)	% RF	(SE)
Willow	4.0	(2.7)	5.0	(4.3)	10.7	(4.5)	4.8	(2.9)

*Significantly different from controls ($P < 0.10$)

**Significantly different from controls ($P < 0.05$)

***Significantly different from controls ($P < 0.01$)

In 1988, 64 and 73 herbaceous species were found on treatments and controls, respectively, and a total of 89 species was recorded. Forty-one of these species were present in frequencies greater than 5% (Table 6). Aster (Aster spp.), bedstraw, fringed polygala (Polygala paucifolia), grass and sedge (Carex spp.), pearly everlasting (Anaphalis margaritacea), round-lobed hepatica, tall cinquefoil (P. arguta), thimbleweed (Anemone virginiana), wild columbine (Aquilegia canadensis), wild lettuce (Lactuca canadensis), wild strawberry, wood anemone (A. quinquefolia), and yellow hawkweed (H. pratense) were significantly more abundant on control sites, while common mullein (Verbascum thapsus), horseweed, and yellow goatsbeard (Tragopogon dubius) were higher in both absolute and relative frequency on treatments. In addition to these species, common plantain (Plantago major), moss, thistle (Cirsium spp.), and yellow goatsbeard were higher in relative abundance on treated sites. Relative frequencies of fringed polygala, orange hawkweed (H. aurantiacum), pearly everlasting, round-lobed hepatica, wild columbine, wild lettuce, wood anemone, and yellow hawkweed were significantly higher on controls than treatments.

Thirty-two woody species occurred on the study area in 1988, all of which except for elderberry (Sambucus canadensis), elm (Ulmus spp.), red pine, and Virginia creeper were found on the controls (Table 7). Dogwood, hairy honeysuckle (Lonicera hirsuta), hop hornbeam, northern white-cedar, pasture rose (Rosa virginiana), sugar maple, tamarack

Table 6. Absolute (AF) and relative frequencies (RF) of common herbaceous species occurring on converted red pine plantations (treatments) and clearcuts (controls) in the Upper Peninsula, Michigan, in 1988.

SPECIES	TREATMENTS				CONTROLS			
	% AF	(SE)	% RF	(SE)	% AF	(SE)	% RF	(SE)
Aster	25.3	(13.1)**	3.3	(1.7)	82.0	(6.7)	7.0	(0.2)
Bedstraw	2.7	(1.2)*	0.5	(0.3)	30.7	(12.6)	2.6	(1.1)
Black medick	5.3	(3.4)	0.7	(0.4)	11.3	(9.0)	0.8	(0.8)
Bunchberry	6.0	(1.6)	0.8	(0.2)	13.3	(9.0)	1.2	(0.5)
Canada mayflower	6.0	(5.2)	0.8	(0.7)	18.7	(6.7)	1.5	(0.6)
Common mullein	18.7	(3.4)***	2.8	(0.6)***	0.0	(0.0)	0.0	(0.0)
Common plantain	8.7	(2.5)	1.3	(0.3)*	6.0	(1.9)	0.5	(0.2)
Daisy fleabane	8.7	(4.9)	1.1	(0.6)	11.3	(4.9)	0.9	(0.4)
Dandelion	47.3	(10.2)	6.6	(1.0)	60.1	(7.1)	5.3	(0.8)
Fern	52.7	(17.1)	7.0	(2.4)	80.0	(9.6)	6.9	(0.8)
Fringed bindweed	6.0	(3.7)	0.8	(0.5)	6.7	(5.2)	0.7	(0.6)
Fringed polygala	0.0	(0.0)***	0.0	(0.0)***	14.0	(8.5)	1.0	(0.5)

Table 6 (cont'd).

SPECIES	TREATMENTS % AF	(SE)	% RF	(SE)	CONTROLS % AF	(SE)	% RF	(SE)
Fungus	19.3	(8.1)	3.4	(1.9)	16.7	(5.7)	1.7	(0.6)
Goldenrod	19.3	(6.9)	2.5	(0.8)	62.0	(9.0)	5.2	(0.6)
Grasses and sedges	79.3	(13.3)*	11.0	(1.2)	98.7	(1.3)	8.7	(0.8)
Horsetail	3.3	(1.5)	0.4	(0.2)	12.0	(7.6)	1.2	(0.8)
Horseweed	46.0	(14.7)***	6.9	(2.1)***	0.0	(0.0)	0.0	(0.0)
Lamb's quarters	10.7	(8.3)	2.4	(2.1)	0.0	(0.0)	0.0	(0.0)
Lichen	18.7	(5.2)	2.9	(0.9)	28.0	(5.9)	2.6	(0.7)
Moss	58.0	(9.2)	9.1	(2.1)*	40.7	(8.5)	3.5	(0.7)
Orange hawkweed	7.3	(3.4)***	0.9	(0.4)***	50.0	(8.5)	4.2	(0.4)
Oxeye daisy	2.7	(1.6)	0.3	(0.2)	18.0	(12.5)	1.2	(0.9)
Pearly everlasting	0.7	(0.7)*	0.1	(0.1)*	11.3	(5.1)	0.9	(0.4)
Queen Anne's lace	1.3	(1.3)	0.2	(0.2)	10.0	(6.3)	0.7	(0.4)
Red clover	0.7	(0.7)	0.1	(0.1)	18.7	(12.0)	1.3	(0.8)

Table 6 (cont'd).

SPECIES	TREATMENTS				CONTROLS			
	% AF	(SE)	% RF	(SE)	% AF	(SE)	% RF	(SE)
Rough cinquefoil	18.7	(12.3)	2.5	(1.7)	12.0	(4.0)	1.2	(0.5)
Round-lobed hepatica	0.7	(0.7)*	0.1	(0.1)*	32.7	(15.1)	2.4	(1.0)
Selfheal	4.0	(1.6)	0.5	(0.2)	5.3	(2.3)	0.4	(0.2)
Spreading dogbane	6.7	(5.1)	0.9	(0.6)	12.7	(8.6)	0.9	(0.5)
Tall cinquefoil	0.7	(0.7)*	0.1	(0.1)	8.7	(4.0)	0.8	(0.4)
Thimbleweed	2.7	(1.9)*	0.3	(0.2)	8.0	(2.9)	0.7	(0.3)
Thistle	56.0	(7.0)	8.5	(1.4)*	48.0	(10.0)	4.3	(1.1)
Trillium	0.0	(0.0)	0.0	(0.0)	6.0	(3.2)	0.4	(0.2)
Violet	47.3	(8.3)	6.9	(1.0)	69.3	(6.1)	6.1	(0.8)
White clover	1.3	(0.8)	0.2	(0.1)	16.0	(6.8)	1.3	(0.6)
Wild columbine	5.3	(3.4)*	0.7	(0.4)*	29.3	(10.4)	2.4	(0.8)
Wild lettuce	1.3	(0.8)***	0.2	(0.1)***	25.3	(8.7)	2.0	(0.5)
Wild Strawberry	27.3	(10.7)**	3.7	(1.5)**	87.3	(8.0)	7.7	(1.0)

Table 6 (cont'd).

SPECIES	TREATMENTS				CONTROLS			
	% AF	(SE)	% RF	(SE)	% AF	(SE)	% RF	(SE)
Wood anemone	0.0	(0.0)**	0.0	(0.0)**	18.7	(7.2)	1.5	(0.5)
Yarrow	2.0	(1.3)	0.3	(0.2)	10.7	(9.9)	1.1	(1.0)
Yellow goatsbeard	20.0	(13.6)*	2.7	(1.9)**	0.7	(0.7)	0.0	(0.0)
Yellow hawkweed	2.0	(2.0)*	0.3	(0.3)*	28.7	(14.9)	2.1	(1.0)

*Significantly different from controls ($P < 0.10$)

**Significantly different from controls ($P < 0.05$)

***Significantly different from controls ($P < 0.01$)

Table 7. Absolute (AF) and relative frequencies (RF) of woody species <1m in height occurring on converted red pine plantations (treatments) and clearcuts (controls) in the Upper Peninsula, Michigan, in 1988.

SPECIES	TREATMENTS				CONTROLS			
	% AF	(SE)	% RF	(SE)	% AF	(SE)	% RF	(SE)
American beech	2.7	(2.7)	1.1	(1.1)	0.7	(0.7)	0.1	(0.1)
Ash	5.3	(3.1)	1.9	(1.3)	25.3	(14.6)	4.8	(3.3)
Balsam fir	18.0	(10.7)	5.4	(3.0)	32.0	(9.0)	4.9	(1.2)
Balsam poplar	0.7	(0.7)***	0.2	(0.2)***	54.4	(8.4)	8.9	(2.1)
Bigtooth aspen	4.7	(2.9)	1.5	(1.0)	0.7	(0.7)	0.1	(0.1)
Birch	62.0	(7.1)	20.9	(3.1)***	43.3	(12.2)	6.2	(1.5)
Blueberry	0.7	(0.7)	0.7	(0.2)	10.0	(6.2)	1.4	(0.8)
Brambles	44.0	(14.2)*	13.7	(3.0)	93.3	(3.2)	15.2	(1.8)
Cherry	27.3	(6.9)	8.4	(1.6)	61.3	(16.0)	9.0	(2.2)
Currant	5.3	(3.3)**	1.2	(1.2)	32.0	(7.9)	5.1	(1.2)
Dogwood	0.0	(0.0)***	0.0	(0.0)***	18.7	(9.2)	2.7	(1.2)
Elderberry	2.7	(2.7)	1.0	(1.0)	0.0	(0.0)	0.0	(0.0)

Table 7 (cont'd).

SPECIES	TREATMENTS				CONTROLS			
	% AF	(SE)	% RF	(SE)	% AF	(SE)	% RF	(SE)
Elm	2.0	(2.0)	0.8	(0.8)	0.0	(0.0)	0.0	(0.0)
Grape	1.3	(1.3)	0.4	(0.4)	1.3	(1.3)	0.2	(0.2)
Hairy honeysuckle	0.0	(0.0)	0.0	(0.0)	2.0	(2.0)	0.3	(0.3)
Hop hornbeam	0.0	(0.0)**	0.0	(0.0)**	14.0	(5.4)	2.2	(0.8)
Northern bush-honeysuckle	0.7	(0.7)	0.2	(0.2)	9.3	(4.0)	1.4	(0.6)
Northern white-cedar	0.0	(0.0)	0.0	(0.0)	3.3	(2.6)	0.5	(0.3)
Pasture rose	0.0	(0.0)	0.0	(0.0)	4.0	(4.0)	0.6	(0.6)
Quaking aspen	14.7	(8.1)***	4.0	(2.0)***	93.3	(2.4)	15.0	(1.3)
Red maple	10.0	(4.6)	3.0	(1.4)	35.3	(11.2)	5.3	(1.6)
Red pine	90.7	(5.4)***	31.2	(4.0)***	0.0	(0.0)	0.0	(0.0)
Serviceberry	0.0	(0.0)***	0.0	(0.0)***	20.0	(5.3)	3.1	(0.7)
Speckled alder	1.3	(1.3)	0.4	(0.4)	5.3	(3.1)	0.7	(0.4)
Sugar maple	0.0	(0.0)	0.0	(0.0)	2.0	(1.3)	0.4	(0.2)

Table 7 (cont'd).

SPECIES	TREATMENTS				CONTROLS			
	% AF	(SE)	% RF	(SE)	% AF	(SE)	% RF	(SE)
Tamarack	0.0	(0.0)	0.0	(0.0)	1.3	(0.8)	0.2	(0.1)
Waxberry	0.0	(0.0)	0.0	(0.0)	0.7	(0.7)	0.1	(0.1)
White pine	0.0	(0.0)	0.0	(0.0)	6.0	(5.2)	0.7	(0.7)
White spruce	10.0	(3.3)	3.2	(0.9)	25.3	(10.0)	3.8	(1.3)
Willow	1.3	(1.3)**	0.3	(0.3)**	44.7	(12.4)	6.6	(2.0)
Viburnum	0.0	(0.0)	0.0	(0.0)	2.0	(1.3)	0.3	(0.2)
Virginia creeper	0.7	(0.7)	0.2	(0.2)	0.0	(0.0)	0.0	(0.0)

*Significantly different from controls ($P < 0.10$)

**Significantly different from controls ($P < 0.05$)

***Significantly different from controls ($P < 0.01$)

(Larix laricina), waxberry (Symporicarpus racemosus), white pine, and viburnum occurred on controls only. Balsam poplar, brambles, currant, dogwood, hop hornbeam, quaking aspen, serviceberry, and willow were all significantly more common on control sites, and all of these species except brambles and currant also differed significantly in relative frequency. Birch had a significantly higher relative frequency on treated sites, and red pine was higher in both absolute and relative frequency on treatments.

In 1990, a total of 108 herbaceous species were identified on the study plots, with 81 species occurring on treated sites and 83 species on controls. Common St. Johnswort (Hypericum perforatum) and lamb's quarters (Chenopodia album) were present only on treated sites, while ground cedar (Lycopodium complanatum), sweet coltsfoot (Petasites palmatus), and trillium (Trillium spp.) were found only on controls. Aster, bedstraw, fern, fringed polygala, fungus, grass and sedge, lichen, orange hawkweed, sweet coltsfoot, and wood anemone were significantly more common on controls than treatments, and all of these except fern, fungus, and grasses and sedges differed in relative frequency as well. Treated sites had significantly more chickweed (Stellaria spp., Cerastium spp.), common mullein, horseweed, rough cinquefoil (P. norvegica), and yellow goatsbeard, and all of these species, along with thistle, also had higher relative frequencies on treatments. Table 8 lists absolute and relative frequencies of common herbaceous species

Table 8. Absolute (AF) and relative frequencies (RF) of common herbaceous species occurring on converted red pine plantations (treatments) and clearcuts (controls) in the Upper Peninsula, Michigan, in 1990.

SPECIES	TREATMENTS				CONTROLS			
	% AF	(SE)	% RF	(SE)	% AF	(SE)	% RF	(SE)
Aster	30.7	(10.6)**	3.7	(1.3)**	82.0	(8.1)	7.9	(0.6)
Bedstraw	1.3	(0.8)***	0.1	(0.1)***	27.3	(7.6)	2.6	(0.7)
Black medick	6.7	(3.8)	0.8	(0.5)	7.3	(6.5)	0.5	(0.4)
Bunchberry	6.7	(1.8)	0.8	(0.2)	29.3	(11.5)	3.2	(1.3)
Canada mayflower	12.7	(7.4)	1.3	(0.7)	6.7	(2.4)	0.6	(0.2)
Chickweed	18.7	(7.5)*	2.1	(0.7)*	2.0	(1.3)	0.2	(0.1)
Common mullein	35.3	(7.6)***	5.0	(1.4)***	2.0	(1.3)	0.2	(0.1)
Common St. Johnswort	9.3	(6.1)**	1.7	(1.3)**	0.0	(0.0)	0.0	(0.0)
Daisy fleabane	12.7	(8.7)	1.4	(0.7)	4.7	(2.9)	0.4	(0.3)
Dandelion	53.3	(14.6)	6.4	(1.8)	38.7	(7.4)	3.6	(0.6)
Fern	42.0	(14.9)*	5.7	(2.3)	75.3	(7.6)	7.2	(0.6)
Fringed bindweed	4.0	(1.3)	0.5	(0.1)	9.3	(5.8)	0.9	(0.6)

Table 8 (cont'd).

SPECIES	TREATMENTS				CONTROLS			
	% AF	(SE)	% RF	(SE)	% AF	(SE)	% RF	(SE)
Fringed polygala	0.7	(0.7)**	0.1	(0.1)**	12.0	(5.4)	1.3	(0.6)
Fungus	5.3	(3.1)**	0.7	(0.4)	16.0	(2.9)	1.6	(0.3)
Goldenrod	12.7	(8.6)	1.1	(0.7)	28.0	(7.5)	2.6	(0.6)
Grasses and sedges	82.0	(9.3)**	10.3	(0.8)	100.0	(0.0)	9.9	(1.0)
Ground cedar	0.0	(0.0)	0.0	(0.0)	9.3	(6.5)	0.9	(0.7)
Horsetail	10.7	(5.9)	1.1	(0.5)	8.0	(2.9)	0.9	(0.4)
Horseweed	66.0	(7.2)***	8.7	(1.4)***	1.3	(1.3)	0.2	(0.2)
Lamb's quarters	5.3	(2.5)	0.9	(0.5)	0.0	(0.0)	0.0	(0.0)
Large-leaved avens	13.3	(9.4)	1.3	(0.7)	16.0	(8.7)	1.8	(1.1)
Lichen	8.7	(4.9)**	1.0	(0.5)**	34.7	(9.2)	3.2	(0.8)
Moss	34.0	(5.4)	4.3	(0.8)	40.7	(9.7)	3.8	(0.8)
Northern bugleweed	1.3	(1.3)	0.3	(0.3)	5.3	(3.7)	0.7	(0.5)
Orange hawkweed	3.3	(3.3)**	0.3	(0.3)**	21.3	(7.8)	2.1	(0.8)

Table 8 (cont'd).

SPECIES	TREATMENTS				CONTROLS			
	% AF	(SE)	% RF	(SE)	% AF	(SE)	% RF	(SE)
Oxeye daisy	7.3	(4.0)	0.7	(0.4)	18.0	(12.7)	1.4	(0.9)
Pearly everlasting	8.0	(5.0)	0.7	(0.4)	6.0	(2.2)	0.6	(0.2)
Purple-leaved willowherb	2.7	(2.7)	0.2	(0.2)	12.0	(10.4)	1.5	(1.4)
Rough cinquefoil	20.7	(5.7)**	2.6	(0.9)***	2.7	(1.3)	0.3	(0.1)
Rough-fruited cinquefoil	7.3	(4.0)	0.7	(0.3)	6.7	(6.7)	0.4	(0.4)
Round-lobed hepatica	1.3	(0.8)	0.1	(0.1)	23.3	(11.2)	1.9	(1.8)
Selfheal	8.0	(6.4)	0.7	(0.5)	10.7	(5.1)	1.2	(0.7)
Spreading dogbane	10.0	(3.8)	1.3	(0.6)	24.7	(12.5)	2.5	(1.4)
Sweet coltsfoot	0.0	(0.0)***	0.0	(0.0)***	6.7	(1.1)	0.7	(0.1)
Thistle	62.7	(11.9)	7.8	(1.7)*	28.0	(16.5)	3.3	(2.2)
Trillium	0.0	(0.0)	0.0	(0.0)	5.3	(4.6)	0.4	(0.3)
Violet	59.3	(10.8)	7.3	(1.0)	63.3	(12.3)	5.8	(0.7)
White clover	5.3	(4.6)	0.6	(0.6)	27.3	(12.7)	2.3	(0.9)

Table 8 (cont'd).

SPECIES	TREATMENTS				CONTROLS			
	% AF	(SE)	% RF	(SE)	% AF	(SE)	% RF	(SE)
Wild columbine	12.0	(5.6)	1.1	(0.5)	23.3	(5.1)	2.2	(0.5)
Wild lettuce	8.7	(7.1)	0.7	(0.6)	12.0	(5.8)	1.1	(0.6)
Wild strawberry	44.7	(15.6)	4.7	(1.0)	68.0	(15.9)	6.2	(1.4)
Wood anemone	2.7	(1.9)*	0.3	(0.2)*	24.7	(11.7)	2.0	(0.8)
Yarrow	6.0	(4.4)	0.7	(0.5)	6.0	(2.5)	0.6	(0.2)
Yellow goatsbeard	8.7	(4.0)*	0.9	(0.4)**	0.7	(0.7)	0.6	(0.6)
Yellow hawkweed	20.7	(5.9)	2.3	(0.5)	41.3	(15.4)	3.6	(0.9)

*Significantly different from controls ($P < 0.10$)

**Significantly different from controls ($P < 0.05$)

***Significantly different from controls ($P < 0.01$)

occurring in 1990.

All of the 31 woody species found in 1990, with the exceptions of poison ivy (Rhus radicans) and red pine, occurred on the controls, and American beech, basswood, blueberry, ironwood (Carpinus caroliniana), pasture rose, tamarack, and white pine occurred on control sites exclusively (Table 9). Balsam poplar, blueberry, brambles, cherry, dogwood, elm, quaking aspen, red maple, serviceberry, Virginia creeper, and white pine had significantly greater absolute frequencies on controls than on treatments, and blueberry, dogwood, serviceberry, and Virginia creeper also had greater relative frequencies. Birch was significantly higher in relative frequency on treated sites than on controls, and red pine was higher in both absolute and relative frequency on treatments.

Woody Stem Densities

Total density of woody species >1m in height was significantly greater on controls than treatments in all years ($P < 0.01$) (Table 10). In 1988, balsam poplar and quaking aspen had significantly higher absolute and relative densities on controls than treatments (Table 11). In 1990, bigtooth aspen, cherry, balsam poplar, quaking aspen, speckled alder, white spruce, and willow had significantly higher absolute densities on controls than treatments (Table 12). In addition, quaking aspen, balsam poplar, bigtooth aspen, and white spruce had higher relative densities on controls.

Table 9. Absolute (AF) and relative frequencies (RF) of woody species <1m in height occurring on converted red pine plantations (treatments) and clearcuts (controls) in the Upper Peninsula, Michigan, in 1990.

SPECIES	TREATMENTS				CONTROLS			
	% AF	(SE)	% RF	(SE)	% AD	(SE)	% RF	(SE)
American beech	0.0	(0.0)	0.0	(0.0)	12.7	(8.6)	1.6	(1.2)
Ash	10.7	(6.9)	3.3	(2.2)	30.7	(10.5)	4.3	(1.4)
Balsam fir	15.3	(9.8)	4.5	(2.7)	27.3	(8.6)	4.2	(1.3)
Balsam poplar	7.3	(3.6)*	2.4	(1.1)	26.0	(7.8)	3.9	(1.2)
Basswood	0.0	(0.0)	0.0	(0.0)	6.0	(3.7)	0.8	(0.4)
Bigtooth aspen	9.3	(5.8)	3.5	(2.2)	6.0	(3.1)	0.8	(0.4)
Birch	50.0	(10.8)	16.3	(3.1)*	60.7	(7.8)	9.3	(1.6)
Blueberry	0.0	(0.0)**	0.0	(0.0)**	12.0	(5.6)	1.6	(0.6)
Brambles	61.3	(7.1)***	21.3	(3.1)	96.0	(1.9)	14.6	(1.2)
Cherry	14.7	(5.1)***	4.6	(1.4)	66.7	(12.7)	10.3	(2.2)
Currant	15.3	(7.6)	5.6	(2.8)	20.7	(1.9)	3.2	(0.5)
Dogwood	2.7	(1.9)**	0.7	(0.5)**	32.7	(11.3)	4.6	(1.2)

Table 9 (cont'd).

SPECIES	TREATMENTS				CONTROLS			
	% AF	(SE)	% RF	(SE)	% AF	(SE)	% RF	(SE)
Elderberry	2.7	(1.9)	0.8	(0.6)	6.7	(2.6)	1.0	(0.5)
Elm	1.3	(0.8)*	0.4	(0.3)	19.3	(8.8)	2.9	(1.2)
Grape	2.7	(2.7)	0.8	(0.8)	1.3	(1.3)	0.2	(0.2)
Ironwood	0.0	(0.0)	0.0	(0.0)	4.7	(2.3)	0.7	(0.3)
Northern bush-honeysuckle	0.7	(0.7)	0.2	(0.2)	4.0	(1.6)	0.7	(0.3)
Pasture rose	0.0	(0.0)	0.0	(0.0)	1.3	(1.3)	0.2	(0.2)
Poison ivy	0.7	(0.7)	0.2	(0.2)	0.0	(0.0)	0.0	(0.0)
Quaking aspen	17.3	(7.1)***	6.3	(2.6)	78.0	(4.5)	11.9	(1.2)
Red maple	5.3	(3.9)*	1.8	(1.4)	36.7	(15.8)	5.1	(1.8)
Red pine	56.0	(18.0)***	18.9	(5.8)***	0.0	(0.0)	0.0	(0.0)
Serviceberry	3.3	(1.8)**	1.0	(0.5)**	15.3	(1.7)	2.4	(0.4)
Speckled alder	2.7	(1.3)	0.9	(0.4)	10.7	(5.5)	1.8	(1.0)
Sugar maple	5.3	(5.3)	1.7	(1.7)	5.3	(3.1)	0.7	(0.4)

Table 9 (cont'd).

SPECIES	TREATMENTS % AF	(SE)	% RF	(SE)	CONTROLS % AF	(SE)	% RF	(SE)
Tamarack	0.0	(0.0)	0.0	(0.0)	7.3	(5.8)	0.9	(0.7)
Viburnum	3.3	(2.6)	1.1	(0.8)	9.3	(7.8)	1.5	(1.4)
Virginia creeper	0.7	(0.7)**	0.2	(0.2)**	22.7	(12.3)	3.0	(1.3)
White pine	0.0	(0.0)	0.0	(0.0)	3.3	(1.8)	0.5	(0.3)
White spruce	6.7	(2.8)	2.0	(0.8)	24.7	(12.5)	3.2	(1.5)
Willow	6.0	(4.4)	1.7	(1.2)	26.7	(8.8)	4.0	(1.3)

*Significantly different from controls ($P < 0.10$)

**Significantly different from controls ($P < 0.05$)

***Significantly different from controls ($P < 0.01$)

Table 10. Mean densities of woody species >1m in height occurring on converted red pine plantations (treatments) and clearcuts (controls) in the Upper Peninsula, Michigan, in 1986, 1987, 1988, and 1990.

YEAR	TREATMENTS		CONTROLS	
	Stems/ha	(SE)	Stems/ha	(SE)
1986	41.7	(24.3)*	8786.7	(2068.7)
1987	51.0	(39.4)*	2186.0	(641.0)
1988	326.7	(92.0)*	10556.9	(1893.8)
1990	983.0	(319.4)*	7838.2	(540.2)

*Significantly different from controls ($P < 0.01$)

Table 11. Absolute (AD) and relative densities (RD) of woody species >1m in height occurring on sites converted to red pine (treatments) and clearcuts (controls) in the Upper Peninsula, Michigan, in 1988.

SPECIES	TREATMENTS				CONTROLS			
	% AD	(SE)	% RD	(SE)	% AD	(SE)	% RD	(SE)
American beech	1.1	(1.1)	0.7	(0.7)	0.0	(0.0)	0.0	(0.0)
Balsam fir	16.7	(8.4)	8.1	(5.8)	118.9	(55.8)	1.0	(0.5)
Balsam poplar	2.2	(2.2)*	0.1	(0.1)*	2135.6	(1537.7)	14.4	(7.8)
Bigtooth aspen	26.7	(17.2)	7.8	(7.4)	130.0	(95.7)	1.4	(0.9)
Birch	8.9	(5.7)	4.6	(2.8)	12.2	(7.9)	0.2	(0.1)
Brambles	565.6	(553.2)	22.1	(17.1)	701.1	(486.2)	10.1	(6.9)
Cherry	23.3	(5.7)	7.5	(3.6)	216.7	(141.1)	2.1	(1.3)
Currant	6.7	(5.4)	2.5	(2.5)	5.6	(5.6)	0.1	(0.1)
Dogwood	0.0	(0.0)	0.0	(0.0)	3.3	(3.3)	0.1	(0.1)
Hop hornbeam	0.0	(0.0)	0.0	(0.0)	2.2	(1.4)	0.0	(0.0)
Quaking aspen	42.2	(34.3)*	4.7	(2.8)*	6882.4	(1146.2)	66.9	(5.4)
Red maple	0.0	(0.0)	0.0	(0.0)	1.1	(1.1)	0.0	(0.0)

Table 11 (cont'd).

SPECIES	TREATMENTS				CONTROLS			
	% AD	(SE)	% RD	(SE)	% AD	(SE)	% RD	(SE)
Red pine	138.9	(136.1)	20.1	(18.8)	0.0	(0.0)	0.0	(0.0)
Serviceberry	4.4	(4.4)	0.1	(0.1)	0.0	(0.0)	0.0	(0.0)
Speckled alder	25.6	(19.4)	11.1	(10.9)	172.2	(166.7)	1.7	(1.6)
White pine	0.0	(0.0)	0.0	(0.0)	13.3	(13.3)	0.1	(0.1)
White spruce	23.3	(14.4)	10.6	(9.4)	68.9	(22.9)	0.8	(0.3)
Willow	1.1	(1.1)	0.0	(0.0)	93.3	(51.2)	1.4	(0.8)
TOTAL	326.7	(92.0)*			10556.9	(1893.8)		

*Significantly different from controls ($P < 0.01$)

Table 12. Absolute (AD) and relative densities (RD) of woody species >1m in height occurring on converted red pine plantations (treatments) and clearcuts (controls) in the Upper Peninsula, Michigan, in 1990.

SPECIES	TREATMENTS				CONTROLS			
	% AD	(SE)	% RD	(SE)	% AD	(SE)	% RD	(SE)
Ash	3.3	(3.0)	1.0	(0.9)	1.1	(1.0)	0.0	(0.0)
Balsam fir	36.7	(19.9)	3.3	(1.1)	94.5	(31.7)	1.1	(0.4)
Balsam poplar	7.8	(4.9)***	1.7	(1.5)**	668.3	(156.8)	8.7	(1.9)
Bigtooth aspen	1.1	(1.0)**	0.1	(0.1)**	100.1	(32.8)	1.3	(0.4)
Birch	38.9	(27.6)	2.6	(1.2)	23.4	(16.2)	0.3	(0.2)
Blueberry	0.0	(0.0)	0.0	(0.0)	1.1	(1.0)	0.0	(0.0)
Brambles	114.5	(38.5)	16.3	(6.4)*	196.8	(74.0)	2.7	(1.1)
Cherry	14.5	(8.0)**	2.8	(1.7)	147.9	(56.2)	1.8	(0.7)
Currant	0.0	(0.0)	0.0	(0.0)	2.2	(1.2)	0.0	(0.0)
Dogwood	1.1	(1.0)	0.3	(0.3)	21.1	(10.7)	0.3	(0.2)
Elm	0.0	(0.0)	0.0	(0.0)	2.2	(2.0)	0.0	(0.0)
Quaking aspen	14.5	(10.5)***	3.4	(2.6)***	6242.5	(557.0)	79.0	(2.6)

Table 12 (cont'd).

SPECIES	TREATMENTS % AD	(SE)	% RD	(SE)	CONTROLS % AD	(SE)	% RD	(SE)
Red maple	1.1	(1.0)	0.3	(0.2)	2.2	(2.0)	0.0	(0.0)
Red pine	690.6	(282.9)**	57.6	(13.3)**	0.0	(0.0)	0.0	(0.0)
Serviceberry	1.1	(1.0)	0.3	(0.3)	2.2	(2.0)	0.0	(0.0)
Speckled alder	6.7	(6.0)*	0.7	(0.6)	94.5	(32.5)	1.1	(0.4)
Tamarack	2.2	(2.0)	0.1	(0.1)	6.7	(4.8)	0.1	(0.1)
Viburnum	1.1	(1.0)	0.1	(0.0)	0.0	(0.0)	0.0	(0.0)
White pine	0.0	(0.0)	0.0	(0.0)	5.6	(3.9)	0.1	(0.1)
White spruce	42.3	(10.3)*	7.9	(3.9)**	83.4	(17.2)	1.2	(0.4)
Willow	5.6	(3.2)*	1.5	(0.8)	142.3	(64.3)	2.1	(1.0)
TOTAL	983.0	(319.4)***			7838.2	(540.2)		

*Significantly different from controls ($P < 0.10$)

**Significantly different from controls ($P < 0.05$)

***Significantly different from controls ($P < 0.01$)

Relative densities of brambles and red pine were higher on treated sites, as was absolute density of red pine.

Cover and FHD

Percent cover in the lowest height stratum was significantly greater on controls than treatments in all years of the study, as was percent cover in the middle height stratum (Table 13). No statistically significant differences in percent cover in the highest stratum were observed. Foliage height diversity also differed between treatment and control sites in all years (Table 14).

WILDLIFE RESPONSES

Small Mammals

A total of 9 small mammal species were trapped during the study. Small mammal species composition varied somewhat from year to year. Only 3 species, deer mouse (*Peromyscus maniculatus*), least chipmunk (*Eutamias minimus*), and thirteen-lined ground squirrel (*Citellus tridecemlineatus*), were trapped on both treatment and control sites in all trapping periods. Deer mouse was the most abundant species on treated sites. Thirteen-lined ground squirrel was the most commonly captured species on controls until 1990, when numbers were exceeded by jumping mouse (*Zapus* spp.), least chipmunk, and masked shrew (*Sorex cinereus*). Shorttail shrews (*Blarina brevicauda*) were captured consistently, but in low numbers.

Table 13. Percent cover of vegetation in 3 height strata on converted red pine plantations (treatments) and clearcut (controls) in the Upper Peninsula, Michigan, in 1986, 1987, 1988, and 1990.

YEAR	SITE TYPE	HEIGHT STRATUM <1m	(SE)	1-7m	(SE)	>7m	(SE)
1986	TREATMENT	18.4	(13.0)*	0.0	(0.0)**	0.0	(0.0)
	CONTROL	74.7	(10.0)	12.4	(6.2)	0.0	(0.0)
1987	TREATMENT	45.4	(11.4)*	0.0	(0.0)**	0.0	(0.0)
	CONTROL	89.4	(5.3)	29.6	(8.9)	0.0	(0.0)
1988	TREATMENT	36.2	(9.5)**	1.0	(0.4)**	0.0	(0.0)
	CONTROL	95.7	(1.8)	20.3	(5.1)	0.7	(0.3)
1990	TREATMENT	42.7	(8.8)**	2.5	(0.8)**	0.0	(0.0)
	CONTROL	97.1	(1.4)	44.7	(4.2)	0.5	(0.2)

*Significantly different from controls ($P < 0.05$)

**Significantly different from controls ($P < 0.01$)

Table 14. Foliage height diversity (FHD) values for converted red pine plantations (treatments) and clearcuts (controls) in the Upper Peninsula, Michigan, in 1986, 1987, 1988, and 1990.

YEAR	SITE TYPE	FHD	(SE)
1986	TREATMENT	0.01	(0.01)*
	CONTROL	0.13	(0.04)
1987	TREATMENT	0.00	(0.00)**
	CONTROL	0.22	(0.02)
1988	TREATMENT	0.05	(0.01)**
	CONTROL	0.20	(0.03)
1990	TREATMENT	0.09	(0.02)**
	CONTROL	0.28	(0.01)

*Significantly different from controls ($P < 0.05$)

**Significantly different from controls ($P < 0.01$)

Masked shrews and meadow voles (Microtus pennsylvanicus) were trapped consistently in 1988 and 1990, but were not present in 1987. Jumping mouse, eastern chipmunk (Tamias striatus), and redback vole (Clethrionomys gapperi) were trapped inconsistently on a limited number of sites. Total numbers of individual animals captured were consistently higher on treated sites, though not always significantly so.

Of the 6 species captured in 1987, only one, deer mouse, was common (Table 15). Shorttail shrews were found on controls only in July, and only 1 individual was captured. One jumping mouse and 1 redback vole were trapped in August on a control site. The total number of individual animals was significantly greater on treated sites than controls in August ($P < 0.05$). No other significant differences were observed, but a few associations were apparent. August abundance was negatively correlated with percent cover in the lowest height stratum, and August deer mouse abundance was negatively correlated with both percent cover <1m in height and density of woody stems >1m in height. Correlation coefficients for statistically significant associations between abundance of small mammal population variables and vegetative characteristics in all years are listed in Table A-2.

A total of 8 species were trapped in 1988 (Table 16). Eastern chipmunks were captured on controls only, and 2 species, shorttail shrew and jumping mouse, were captured only during the August trapping period. The only significant difference found was in deer mice, which were more abundant on

Table 15. Mean (SE) small mammal abundance (recaptures not included), species richness, and species diversity on converted red pine plantations (treatments) and clearcuts (controls) in the Upper Peninsula, Michigan, in July and August of 1987.

PERIOD	SPECIES	ABUNDANCE	
		Treatments	Controls
July	Deer mouse	7.00 (2.67)	1.20 (0.72)
	Least chipmunk	0.60 (0.36)	0.40 (0.22)
	Shorttail shrew	0.00 (0.00)	0.20 (0.18)
	Thirteen-lined ground squirrel	1.80 (1.61)	2.20 (1.21)
	TOTAL INDIVIDUALS	9.40 (2.96)	4.00 (0.75)
	SPECIES RICHNESS	1.40 (0.36)	1.40 (0.22)
	DIVERSITY	0.15 (0.06)	0.10 (0.06)
August	Deer mouse	8.40 (4.28)	2.20 (0.87)
	Jumping mouse	0.00 (0.00)	0.20 (0.18)
	Least chipmunk	0.80 (0.44)	0.20 (0.18)
	Redback vole	0.00 (0.00)	0.20 (0.18)
	Shorttail shrew	1.00 (0.89)	0.40 (0.36)
	Thirteen-lined ground squirrel	2.60 (2.33)	3.20 (1.95)
	TOTAL INDIVIDUALS	12.80 (3.92)*	6.40 (1.19)
	SPECIES RICHNESS	1.60 (0.22)	1.80 (0.44)
	DIVERSITY	0.16 (0.06)	0.16 (0.09)

*Significantly different from controls ($P < 0.05$)

Table 16. Mean (SE) small mammal abundance (recaptures not included), species richness, and species diversity on converted red pine plantations (treatments) and clearcuts (controls) in the Upper Peninsula, Michigan, in July and August of 1988.

PERIOD	SPECIES	ABUNDANCE Treatments	ABUNDANCE Controls
July	Deer mouse	10.60 (2.93)	1.20 (0.87)
	Eastern chipmunk	0.00 (0.00)	0.60 (0.54)
	Least chipmunk	5.60 (3.21)	2.60 (1.28)
	Masked shrew	0.00 (0.00)	0.40 (0.36)
	Meadow vole	0.20 (0.18)	0.80 (0.52)
	Thirteen-lined ground squirrel	1.40 (1.25)	2.60 (0.22)
	TOTAL INDIVIDUALS	17.80 (5.10)	8.20 (0.87)
	SPECIES RICHNESS	1.80 (0.44)	2.60 (0.22)
	DIVERSITY	0.22 (0.05)	0.32 (0.05)
August	Deer mouse	8.00 (1.81)*	1.60 (0.83)
	Eastern chipmunk	0.00 (0.00)	0.60 (0.36)
	Jumping mouse	0.20 (0.18)	1.20 (0.44)
	Least chipmunk	4.20 (1.31)	1.60 (1.00)
	Masked shrew	0.40 (0.22)	1.00 (0.57)
	Meadow vole	1.80 (1.00)	3.40 (2.43)
	Shorttail shrew	0.40 (0.22)	0.20 (0.18)
	Thirteen-lined ground squirrel	3.00 (1.70)	4.00 (0.94)
	TOTAL INDIVIDUALS	18.00 (2.21)	13.60 (2.22)
	SPECIES RICHNESS	4.00 (0.40)	4.00 (0.94)

Table 16 (cont'd).

PERIOD	SPECIES	ABUNDANCE TREATMENTS	CONTROLS
	DIVERSITY	0.48 (0.05)	0.39 (0.09)

*Significantly different from controls (P < 0.05) treated sites than controls in August ($P < 0.05$).

As in 1987, total August abundance in 1988 was negatively correlated with percent cover <1m in height, and July abundance was negatively correlated with density of woody vegetation >1m in height. Small mammal species richness increased with percent cover in the 1-7m height stratum and FHD in July. Deer mouse abundance decreased with increasing percent cover in both the <1m and 1-7m height strata and with density of woody vegetation in August.

All of the 8 species trapped in 1990 occurred on both treatment and control sites, although 4 species (jumping mouse, meadow vole, redback vole, and shorttail shrew) were captured in very small numbers (Table 17). Redback voles were found only during the July trapping period, and only 1 individual was trapped on each site type. Deer mice were significantly more abundant on treated sites in both July and August ($P < 0.05$), and masked shrews were more abundant on controls in August ($P < 0.10$). The total number of individuals was greater on treatments in July ($P < 0.05$), and species diversity was higher on controls in August ($P < 0.05$).

A number of associations between small mammal populations and vegetative characteristics were observed in 1990. Total abundance was negatively correlated with percent cover in both the <1m and 1-7m height strata in July, while species diversity was positively correlated with percent cover in the lowest stratum and density of woody vegetation in August. Deer mouse abundance decreased as FHD and percent cover in the

Table 17. Mean (SE) small mammal abundance (recaptures not included), species richness, and species diversity on converted red pine plantations (treatments) and clearcuts (controls) in the Upper Peninsula, Michigan, in July and August of 1990.

PERIOD	SPECIES	ABUNDANCE Treatments	ABUNDANCE Controls
July	Deer mouse	19.80 (4.69)**	2.40 (1.15)
	Jumping mouse	0.00 (0.00)	4.40 (1.66)
	Least chipmunk	8.40 (2.84)	0.40 (0.22)
	Masked shrew	0.00 (0.00)	2.80 (1.31)
	Meadow vole	1.00 (0.57)	1.20 (0.44)
	Redback vole	0.20 (0.18)	0.20 (0.18)
	Shorttail shrew	0.00 (0.00)	0.40 (0.22)
	Thirteen-lined ground squirrel	4.60 (1.99)	0.40 (0.22)
	TOTAL INDIVIDUALS	29.40 (5.59)**	12.20 (1.91)
	SPECIES RICHNESS	3.60 (0.22)	4.00 (0.69)
	DIVERSITY	0.37 (0.05)	0.44 (0.06)
August	Deer mouse	19.00 (5.62)**	5.00 (2.16)
	Jumping mouse	2.00 (0.93)	1.67 (1.05)
	Least chipmunk	3.83 (1.14)	5.83 (2.44)
	Masked shrew	0.50 (0.34)*	3.83 (1.40)
	Meadow vole	0.00 (0.00)	0.67 (0.49)
	Shorttail shrew	0.17 (0.17)	0.67 (0.42)
	Thirteen-lined ground squirrel	1.83 (0.95)	0.83 (0.54)
	TOTAL INDIVIDUALS	27.33 (6.91)	18.50 (5.89)

Table 17 (cont'd).

PERIOD	SPECIES	ABUNDANCE Treatments	Controls
	SPECIES RICHNESS	3.33 (0.76)	3.50 (0.81)
	DIVERSITY	0.40 (0.05)**	0.55 (0.03)

*Significantly different from controls ($P < 0.10$)

**Significantly different from controls ($P < 0.05$)

lowest and middle height strata increased in both trapping periods. In addition, deer mouse abundance was negatively correlated with density of woody vegetation in August. Also in August, masked shrew abundance was positively associated with percent cover in the lowest height stratum and density of woody vegetation.

Birds

Forty-nine bird species were identified in censuses on the study plots in 1987 and 1990, 20 of which were common to both years (Table A-3). The most abundant species were American goldfinch (*Carduelis tristis*), American robin (*Turdus migratorius*), chipping sparrow (*Spizella passerina*), eastern kingbird (*Tyrannus tyrannus*), song sparrow (*Melospiza melodia*), and white-throated sparrow (*Zonotrichia albicollis*). Of the 33 species censused in 1987, white-throated sparrow was the most common, followed by red-winged blackbird (*Agelaius phoeniceus*) and song sparrow (Table 18). These species were relatively common on both treatment and control sites. A single observation was made for 9 species; American crow (*Corvus brachyrhynchos*), American woodcock (*Philohela minor*), black-capped chickadee (*Parus atricapillus*), northern raven (*C. corax*), red-breasted nuthatch (*Sitta canadensis*), red-tailed hawk (*Buteo jamaicensis*), upland sandpiper (*Bartramia longicauda*), yellow-bellied sapsucker (*Sphyrapicus varius*), and yellow warbler (*Dendroica coronata*). Blue jays (*Cyanocitta cristata*), brown thrashers (*Toxostoma rufum*), and

Table 18. Bird density, species richness, and species diversity on converted red pine plantations (treatments) and clearcuts (controls) in the Upper Peninsula, Michigan, in 1987.

SPECIES	TREATMENTS		CONTROLS	
	Birds/ha	(SE)	Birds/ha	(SE)
American crow	0.00	(0.00)	0.03	(0.02)
American goldfinch	0.48	(0.17)	0.45	(0.21)
American robin	0.43	(0.15)	0.40	(0.04)
American woodcock	0.03	(0.02)	0.00	(0.00)
Black-capped chickadee	0.00	(0.00)	0.03	(0.02)
Blue jay	0.00	(0.00)*	0.21	(0.06)
Brown-headed cowbird	0.13	(0.06)	0.00	(0.00)
Brown thrasher	0.00	(0.00)	0.13	(0.11)
Chipping sparrow	0.48	(0.31)	0.50	(0.09)
Clay-colored sparrow	0.03	(0.02)*	0.21	(0.02)
Common flicker	0.19	(0.03)	0.08	(0.07)
Common grackle	0.03	(0.02)	0.05	(0.04)
Common snipe	0.00	(0.00)	0.11	(0.09)
Eastern bluebird	0.13	(0.06)	0.00	(0.00)
Eastern kingbird	0.24	(0.11)	0.13	(0.11)
European starling	0.11	(0.09)	0.00	(0.00)
Fox sparrow	0.05	(0.04)	0.16	(0.08)
Killdeer	0.13	(0.08)	0.11	(0.09)
Nashville warbler	0.05	(0.04)	0.11	(0.04)
Northern raven	0.03	(0.02)	0.00	(0.00)
Ovenbird	0.24	(0.16)	0.24	(0.13)

Table 18 (cont'd).

SPECIES	TREATMENTS Birds/ha	(SE)	CONTROLS Birds/ha	(SE)
Red-breasted nuthatch	0.00	(0.00)	0.03	(0.02)
Red-tailed hawk	0.00	(0.00)	0.03	(0.02)
Red-winged blackbird	1.06	(0.31)	0.19	(0.12)
Rufous-sided towhee	0.08	(0.07)	0.00	(0.00)
Song sparrow	0.90	(0.21)	1.35	(0.11)
Tennessee warbler	0.03	(0.02)	0.08	(0.08)
Tree swallow	0.03	(0.02)	0.08	(0.04)
Upland sandpiper	0.03	(0.02)	0.00	(0.00)
White-throated sparrow	1.25	(0.22)	1.94	(0.21)
Yellow-bellied sapsucker	0.00	(0.00)	0.03	(0.02)
Yellow-rumped warbler	0.05	(0.02)	0.24	(0.11)
Yellow warbler	0.00	(0.00)	0.03	(0.02)
TOTAL INDIVIDUALS	6.18	(0.80)	6.92	(0.45)
SPECIES RICHNESS	14.00	(0.47)	16.00	(1.70)
DIVERSITY	0.95	(0.02)	0.98	(0.03)

*Significantly different from controls ($P < 0.05$)

common snipes (*Capella gallinago*) were found on controls exclusively in multiple sightings. Brown-headed cowbirds (*Molothrus ater*), eastern bluebirds (*Sialia sialis*), European starlings (*Sturnus vulgaris*), and rufous-sided towhees (*Pipilo erythrophthalmus*) were identified only on treated sites and in several sightings. Two species, blue jay and clay-colored sparrow (*S. pallida*), were found in significantly higher densities on controls than treatments ($P < 0.05$). No correlations between bird population variables and vegetative characteristics were apparent in 1987.

A total of 36 bird species were identified during the 1990 census period (Table 19). Of these, 7 were sighted only once; American woodcock, Carolina wren (*Thryothorus ludovicianus*), house wren (*Troglodytes aedon*), northern oriole (*Icterus galbula*), ruby-throated hummingbird (*Archilochus colubris*), ruffed grouse (*Bonasa umbellus*), and white-eyed vireo (*Vireo griseus*). Of the species that were counted more than once, black-capped chickadee, cedar waxwing (*Bombycilla cedrorum*), chestnut-sided warbler (*D. pensylvanica*), common flicker (*Colaptes auratus*), hermit thrush (*Catharus guttatus*), Nashville warbler (*Vermivora ruficapilla*), rufous-sided towhee, and whip-poor-will (*Caprimulgus vociferus*) occurred on controls exclusively, and common yellowthroat (*Geothlpis trichas*), field sparrow (*S. pusilla*), killdeer (*Charadrius vociferus*), tree swallow (*Iridoprocne bicolor*), and vesper sparrow (*Pooecetes gramineus*) occurred only on treatments. All of the 4 species that exhibited significant differences in

Table 19. Bird density, species richness, and species diversity on converted red pine plantations (treatments) and clearcuts (controls) in the Upper Peninsula, Michigan, in 1990.

SPECIES	TREATMENTS Birds/ha	(SE)	CONTROLS Birds/ha	(SE)
American goldfinch	0.77	(0.26)	1.18	(0.39)
American robin	0.67	(0.15)	0.57	(0.34)
American woodcock	0.00	(0.00)	0.03	(0.03)
Black and white warbler	0.03	(0.03)	0.13	(0.08)
Black-capped chickadee	0.00	(0.00)*	0.38	(0.12)
Blue jay	0.06	(0.06)*	0.67	(0.14)
Brown-headed cowbird	0.03	(0.03)	0.13	(0.08)
Brown thrasher	0.06	(0.06)	0.19	(0.11)
Carolina wren	0.03	(0.03)	0.00	(0.00)
Cedar waxwing	0.00	(0.00)	0.06	(0.06)
Chestnut-sided warbler	0.00	(0.00)	0.10	(0.06)
Chipping sparrow	1.59	(0.58)	1.40	(0.15)
Clay-colored sparrow	0.06	(0.04)	0.10	(0.04)
Common flicker	0.00	(0.00)	0.10	(0.09)
Common grackle	0.03	(0.03)	0.26	(0.15)
Common yellowthroat	0.06	(0.04)	0.00	(0.00)
Eastern bluebird	0.10	(0.06)	0.06	(0.06)
Eastern kingbird	0.92	(0.32)	0.32	(0.16)
Field sparrow	0.06	(0.06)	0.00	(0.00)
Hermit thrush	0.00	(0.00)	0.22	(0.09)
House wren	0.00	(0.00)	0.03	(0.03)

Table 19 (cont'd).

SPECIES	TREATMENTS Birds/ha	(SE)	CONTROLS Birds/ha	(SE)
Indigo bunting	0.29	(0.11)	1.27	(0.37)
Killdeer	0.10	(0.09)	0.00	(0.00)
Nashville warbler	0.00	(0.00)**	2.04	(0.41)
Northern oriole	0.00	(0.00)	0.03	(0.03)
Red-eyed vireo	0.03	(0.03)	0.16	(0.08)
Red-winged blackbird	0.16	(0.09)	0.10	(0.06)
Ruby-throated hummingbird	0.00	(0.00)	0.03	(0.03)
Ruffed grouse	0.00	(0.00)	0.03	(0.03)
Rufous-sided towhee	0.00	(0.00)	0.10	(0.06)
Song sparrow	1.85	(0.51)	1.18	(0.30)
Tree swallow	0.16	(0.09)	0.00	(0.00)
Vesper sparrow	0.10	(0.06)	0.00	(0.00)
Whip-poor-will	0.00	(0.00)	0.13	(0.05)
White-eyed vireo	0.00	(0.00)	0.03	(0.03)
White-throated sparrow	0.06	(0.06)*	1.21	(0.22)
TOTAL INDIVIDUALS	7.23	(0.92)*	12.23	(0.69)
SPECIES RICHNESS	10.00	(0.85)*	16.20	(0.52)
DIVERSITY	0.83	(0.05)**	1.04	(0.01)

*Significantly different from controls ($P < 0.05$)

**Significantly different from controls ($P < 0.01$)

density were more common on controls. These were black-capped chickadee, blue jay, white-throated sparrow, and Nashville warbler. In addition, total density, species richness ($P < 0.05$), and species diversity ($P < 0.01$) were higher on controls than treatments.

A number of significant trends in bird population variables and vegetative characteristics were observed in 1990 (Table A-4). Total bird density, species richness, and species diversity increased with percent cover in all height strata. Species richness and diversity were highly positively correlated with FHD and density of woody vegetation, and bird density also increased with FHD. Densities of 2 species were correlated with vegetative variables; American robin density tended to decrease as density of woody vegetation increased, and indigo bunting density (Passerina iliaca) exhibited positive correlations with FHD, density of woody vegetation, and percent cover in the middle stratum.

Deer

A mean of 19.93 ±2.32 tracks/0.2km was counted on treated sites in 1988, and 30.07 ±3.73 tracks/0.2km were counted on controls. In 1990, 35.00 ±8.94 and 25.00 ±12.25 pellet groups/ha were found on treatments and controls, respectively. No statistically significant differences were found.

DISCUSSION

VEGETATIVE RESPONSES

Herbaceous species richness differed to varying degrees between treated sites and controls in all years, with the greatest difference occurring in 1986, when controls supported nearly twice as many herbaceous species as treatments. This difference was most likely the result of heavy herbicide treatments on 4 of the 5 treated plots in this year. Although hexazinone is used primarily to reduce woody vegetation, it is also effective against herbaceous species (Nelson et al. 1981, Blake et al. 1987). The slight increasing trend in species richness over the course of the study is characteristic of newly-cut stands but may also have been the result of a decrease in herbicide applications after 1986.

Although the number of herbaceous species was not significantly different between treated sites and controls, total plant frequencies were higher on control sites in all years. Occurrence of herbaceous species should be of interest to land managers managing red pine because many of the species found on the study sites are important wildlife forages. Effects of hexazinone on herbaceous species have been short-lived, with measurable differences in herb response disappearing by the end of the second growing season (Blake et al. 1987). In this study, however, the effect of the herbicide on the frequency of occurrence of herbaceous plants is apparent for up to 3 years. Although soil profiles reveal the sites to be similar in overall soil quality, the scarcity of deciduous leaves in plantations may have retarded invasion of new species and reproduction of established species. Deciduous leaf litter decomposes rapidly and increases nutrient availability. It is thus assumed that residual and secondary effects of heavy herbicide treatments early in the study, along with the effects of scattered additional treatments in 1987, 1988, 1989, and 1990, were sufficient to suppress herbaceous growth throughout the study period.

It is interesting to note that a number of the species which were more common on treatment plots were species which tend to do well in highly disturbed areas. This group of species included thistle, horseweed, lamb's quarters, common St. Johnswort, common mullein, and yellow goatsbeard, which are generally poor wildlife forages, except for certain granivorous species such as the American goldfinch.

A number of the woody species occurring on the study area are important wildlife cover and forage species, and analysis of woody vegetative structure and composition reveals extreme differences between the treatment and control sites. In addition, the presence of hardwood species may affect site suitability by providing high quality leaf litter. The most valuable of these species to wildlife are aspen, maple, cherry, willow, birch, dogwood, serviceberry, blueberry, raspberry, and honeysuckle.

Frequencies of woody species <1m in height generally showed the same trends as those of herbaceous species. Only rarely was a woody species more common on treated plots than controls. Brambles, birch, cherry, red maple, white spruce, and balsam fir on treatments were comparable in frequency to controls in some years, but only birch and brambles regularly reached heights of >1m in significant numbers on treatments. Density of woody vegetation >1m in height increased temporally on controls as would be expected in natural regeneration, and the drastic differences in density between treatment and control sites illustrates clearly the effect of repeated herbicide treatment. The result is a loss of biomass of woody vegetation. Blake et al. (1987) reported a nearly 50% decrease in total plant biomass after the first growing season on a loblolly plantation treated with hexazinone. Similar results have been reported by Hurst and Warren (1982), Slay et al. (1987), and Hurst (1989), although effects were short-lived. Brambles and honeysuckles have exhibited tolerance to hexazinone in the past (Michael 1985, Hurst 1989), and brambles appeared to be at least partially resistant in this study. Biomass was not measured directly in this study, but analysis of percent cover, frequency, and density data clearly show a reduction in plant material on treated plots. The similarity in species richness between treated sites and controls suggests that site to site variation was not a major factor; the increased densities are the result of greater occurrence of species already present on both site types, and not of invasion by new species. Woody plants reached heights of >1m relatively infrequently on treated sites in the 2 years following any herbicide application. Those trees which were able to keep a tenuous but consistent foothold on plantations were fast-growing species, such as balsam fir, birch, and cherry, all of which are capable of reaching 1m in height in 1 to 2 years. These species occurred most frequently on sites that had not been treated in the 2 years before the sampling period. Other evidence suggests that repeated applications are necessary to prevent establishment of woody species (Carter et al. 1975, Hurst 1989). The extreme sparseness of trees on sites that had been treated up to 1 year before sampling in this study is further evidence of hexazinone's initial efficiency.

Analysis of available cover and FHD revealed a greater structural complexity and better developed under- and midstories on control plots. The importance of cover and vegetative complexity to wildlife is well documented. The near absence of cover >1m in height on treated plots illustrates one of the most obvious and extreme differences between treated sites and controls, and results in significantly lower FHD values on these plots. This consequence of herbicide treatment, along with a significant decrease in cover <1m in height, has serious implications concerning the suitability of pine plantations for wildlife.

However, this reduction in competing vegetation is the primary reason for the increase in softwood production that has been demonstrated on plantations.

WILDLIFE RESPONSES

Small Mammals

Small mammal abundance, species richness, and species diversity were low throughout the study, but tended to increase temporally. Several species were represented by only a few individuals, making accurate comparisons difficult, but some general trends were apparent. Invariably, abundance was higher on treated sites than controls, largely due to the high deer mouse populations on the plantations. Deer mice inhabit a variety of vegetation types and were relatively abundant in recent clearcuts (Gashwiler 1970, Kirkland 1977), as well as plantations prepared with herbicides (Borrecco et al. 1979, Santillo 1987). Deer mouse abundance in this study consistently increased in abundance with herbicide treatment, and the correlations between abundance and some vegetative variables suggest that the increase was a response to decreases in vegetative cover and stem density. A similar abundance-cover relationship was reported by Eaton (1986) for this species, while M'Closkey and Lajoie (1975) observed a positive association between white-footed mice (*P. leucopus*) and cover. The diet of deer mice contains insects, seeds, and vegetation (Hamilton 1941). Vegetative cover was clearly less abundant on treated sites, and thus it is apparent that cover was not a limiting factor for deer mice. Although insect response was not measured in this study, herbicide treatment has increased insect numbers (Santillo 1987), and some invertebrates, particularly ants, appeared to be more abundant on plantations than controls. Possibly an increase in invertebrates allowed for a greater population of deer mice on the treated plots.

A number of species appeared to prefer controls to treatments, but sample sizes were rarely large enough to show a significant difference. Masked shrews were consistently more abundant on control sites, although significantly so only in August 1990, when coinciding positive correlations with cover <1m in height and density of woody vegetation were observed. Decreases in vagrant shrew (*Sorex vagrans*) populations have been reported after herbicide treatment in Oregon clearcuts (Borrecco et al. 1979), when grass cover was reduced. Masked shrews have been associated with moist habitats in Michigan (Getz 1961), due to their high water requirements (Chew 1951). The moist microclimate maintained by thick grass cover was probably the primary factor affecting use of control sites by masked shrews.

Decreases in abundance with herbicide treatment have been observed in field voles (*Microtus agrestis*) (Teivainen et al. 1986), Oregon voles (*M. oregoni*) (Borrecco et al. 1979), and redback voles (Santillo 1987). Meadow voles were captured on a limited number of plots, making sample sizes too small to accurately show differences. However, the species was present solely on moist sites. The preference of meadow voles for moist habitats with dense grass cover (Eadie 1953, Yahner 1983) and their largely vegetarian diet (Burt 1946) were the most likely factors to affect abundance on the study area.

Least chipmunk abundance was greater on treated plots in all years and trapping periods except August 1990, despite the species' tendency to prefer forest habitat. No associations between abundance and vegetative characteristics were observed, and given the wide range of food and cover requirements of chipmunks (Hamilton and Whitaker 1979), no conclusions can be drawn. Different capture probabilities may exist between treatment and control sites for this species, and may be the result of animals spending less time on the ground when trees are available; least chipmunks use trees not only for escape (Caras 1967), but for sunning, resting, and occasionally nesting (Hamilton and Whitaker 1979).

Abundance, species richness, and species diversity increased somewhat from July to August in 1987 and 1988, as well as increasing from 1987 to 1990. Differences were due mainly to the additions of or increased numbers of shorttail shrews, redback voles, jumping mice, masked shrews, and meadow voles. Shorttail shrews have a breeding season in late summer (Burt 1957), and the presence of young may have increased captures of this species. Rainfall may also have been a significant factor influencing occurrence of some species. Small mammal populations are sensitive to precipitation (Getz

1968) and may have fluctuated in response to spring and summer rainfall levels. Jumping mice, redback voles, meadow voles, shorttail shrews, and masked shrews all prefer moist habitats (Burt 1946, Caras 1967, Getz 1968, Hamilton and Whitaker 1979, Yahner 1986), and the study area experienced below average rainfall in spring of 1987 and 1988. The slight increase in rainfall from June through August 1987 was accompanied by slight increases in small mammal abundance, species richness, and species diversity. Similarly, near-drought conditions in May and June of 1988 were followed by average rainfall in July and above average rainfall in August, and again, small mammal population variables increased from July to August. In 1990, rainfall was unusually high from May through July, dropping to just below the norm in August, and no trends in abundance or species richness were apparent in this year. Further evidence that rainfall may have affected small mammal populations is the overall increase in small mammal abundance from 1987 to 1990, corresponding with an increase in total spring and summer rainfall over these years. Small mammal populations fluctuate to relatively large degrees from year to year (Haufler, pers. commun.), however, and the temporal changes observed in this study may simply have been the result of normal population variations.

Birds

Bird density, species richness, and species diversity were consistently higher on controls than treatments, although statistically significant differences were detected only in 1990, by which time controls had developed substantial structural diversity. A shift in species composition occurred from 1987 to 1990, with the loss of 13 species from the study area and the addition of 16 species. Much of the variation between years can be explained by observer bias, since different observers were used for the 2 censuses. Many of the species present in 1 year and absent in the other, such as American crow, northern raven, common snipe, European starling, red-breasted nuthatch, red-tailed hawk, Tennessee warbler (Vermivora peregrina), upland sandpiper, yellow-bellied sapsucker, yellow warbler, Carolina wren, house wren, northern oriole, ruby-throated hummingbird, ruffed grouse, field sparrow, white-eyed vireo, and cedar waxwing, were identified in very low numbers and were most likely just passing through the study area rather than breeding there. The variable circular-plot method involves counting all birds using an area, including individuals feeding, hunting, and resting. The record of 1 species, ovenbird (Seiurus aurocapillus), in 1987 was likely due to observers including birds identified by call from surrounding forest. Several species present in 1990, including black and white warbler (Mniotilta varia), chestnut-sided warbler, red-eyed vireo (Vireo olivaceus), hermit thrush, and whip-poor-will, are characteristic of young or early successional forest, and the study area habitat in 1987 may not have been mature enough to support them. Common yellowthroats were observed only on plots bordered by low, flooded areas after a wet spring in 1990, and these areas may have been too dry for the species in 1987. One species, indigo bunting, appeared late in the census period in 1990 and may have been absent during the 1987 census period, which was shorter than that in 1990. Additionally, the 1987 census was conducted on three plots of each site type while the 1990 census utilized all 10 plots. This change may have resulted in some of the less ubiquitous species appearing only in the 1990 census.

Of the 5 species exhibiting a statistically significant preference for control sites, only 1, blue jay, was significant in both years. Blue jay diet consists of nuts, fruits, and berries (Wilmore 1977), and the relative sparseness of fruit-producing vegetation on plantations may have limited the species on these sites.

Clay-colored sparrows inhabit grasslands, thick brush, and forest edges (Bent 1968), and the 1987 plantations were probably too barren for even some grassland species. Treated sites in 1990 lacked the semi-open mixed stands and thick brush preferred by white-throated sparrows (Bent 1968). Eaton (1986) reported a positive correlation between this species and amount of slash, and treated sites in 1987 could have contained enough slash to accommodate some individuals. It is also possible that the record of this species in 1987 was the result of miscalculation of birds' distances from census stations; like the ovenbird, this sparrow has a very loud call.

The abundance of black-capped chickadees on control plots was probably related to their feeding habits; the species feeds on insects in trees of conifer and deciduous forests, and such habits would have been severely limiting on young pine plantations, which lacked the density of trees available on controls.

In 1990, Nashville warblers were much more abundant on controls, due to the deficiency of cover in pine plantations in the 1-7m height stratum. Nashville warblers inhabit young mixed stands of aspen, birch, and balsam poplar and require a developed midstory (Griscom and Sprunt 1957), and controls clearly provided better habitat for the species than treated sites.

In general, species commonly observed on the control sites inhabit young forest or brushy areas, and species found on the plantations usually occur in more open vegetation types, such as grasslands and fields. In this study, treatments and controls can be categorized into open field and second growth forest vegetation types, respectively. Some factors contributing to the bird population differences between treatments and controls are apparent from the associations observed between bird population variables and vegetative measures. The consistent, positive correlations between number and variety of birds and habitat variables suggest that vegetative density and structural complexity enabled the control sites to support a denser and more diverse avifauna than the treated sites. Such associations have been examined and documented previously. In general, bird species diversity has increased with successional development (Balda 1975, Weins 1975, Edgerton and Thomas 1978, Shugart et al. 1978, Weins 1978, Capen 1979). Positive correlations between bird diversity and vegetative structural complexity have been demonstrated by Balda (1975), Thomas et al. (1975), Weins (1975), Meslow (1978), Shugart et al. (1978), and Capen (1979).

Increases in overall bird densities on the naturally regenerating plots were likely due to greater resource availability, especially for species limited by cover or food on plantations. A red pine plantation in Michigan supported fewer bird species and individuals than surrounding natural pin oak and jack pine communities (Gysel 1966). Slagsvold (1977) reported a 30% reduction in breeding bird abundance after spraying of deciduous scrub with herbicide, with numbers remaining low for 5 years post-treatment. Bird abundance also decreased on a Jeffrey pine (P. jeffreyi) plantation prepared with herbicide, and all avian species dependent on snowbush (Ceanthus velutinus) were eliminated from the treated plot (Savidge 1978). The controls sites in this study provided more cover for both ground and tree nesters; this cover not only increases potential nest sites, but may also provide greater protection from predators, possibly increasing survival rates. The greater availability of seed- and fruit-producing plants on control sites also provides food for granivores and frugivores, as evidenced by the presence of cedar waxwings, blue jays, clay-colored sparrows, chipping sparrows, fox sparrows (Passerella iliaca), white-throated sparrows, indigo buntings, and American goldfinches. These species also prefer open woods or brush vegetation types to grasslands.

The effects of herbicides on insect populations are not well documented, but Santillo (1987) observed an increase in invertebrate numbers after herbicide treatment on conifer plantations, and Johansen (1981) reported an abundance of insects on young loblolly pine plantations. It has also been suggested that insect hawkers have difficulty maneuvering in dense stands (Willson 1974). These factors suggest that treated sites would support greater numbers of insectivores than controls. Three insectivorous species were found in greater numbers on treated sites, though differences were not statistically significant. Eastern bluebirds, eastern kingbirds, and tree swallows capture their prey in flight and may have been limited on control sites by the density of trees >1m in height. Eastern bluebirds and tree swallows are cavity nesters, and occurrence of these species was very likely related to the availability of snags in areas surrounding the study plots. Other insectivores were able to inhabit control sites in relative abundance, indicating that insect food was not severely limited on controls. These species included brown thrashers, hermit thrushes, chestnut-sided warblers, red-eyed vireos, and whip-poor-wills, as well as Nashville warblers and black-capped chickadees, which showed a significant preference for controls over treatments. Clearly, treated sites were more suitable for species limited to grassland areas, such as killdeer, vesper sparrow, and field sparrow. Species with broad food habitats, such as song sparrow, red-winged blackbird, common grackle (Quiscalus quiscula), and brown-headed cowbird also seemed to fare particularly well on the plantations.

Despite the affinity of some insectivores and grassland species to the treated plots, the naturally regenerating controls in this study possess a number of features that enable them to support more avian species than plantations. Pine forests generally support fewer species than mixed forests (Tramer 1969, Thomas et al. 1975, Weins 1975, Driscoll 1977, Dickson 1978, Meyers and Johnson 1978); however, this is largely due to the early canopy closure and sparse understory typical of mature pine stands. Johnson (1987) reported canopy closure to occur earlier in slash pine (P. elliottii) plantations than in natural stands, and noted a corresponding decrease in summer bird populations on plantations. The use of herbicides reduced low vegetative cover, thereby decreasing bird species richness even on young plantations. Controls, on the other hand, had significantly more cover in all height strata. Finally, species with wide distributions have been found in pure pine stands, while these species are joined by others with more specific habitat requirements in mixed and broadleaf forest (Eiberle and von Hirschheydt 1983).

The differences in bird density and species richness resulted in higher species diversity on controls than treatments. Thus, the relationship of bird species diversity to vegetative characteristics can be explained in terms of the variation in resource availability and vegetation structure between treated plantations and naturally regenerating stands.

Deer

This study yielded no statistically significant results pertaining to deer use of herbicided pine plantations. Results do indicate that deer made use of both treated sites and controls. Assumptions and biases associated with both the track count and pellet-count techniques must be considered before it can be concluded that conversion did not affect deer use of the study area.

In 1988, track counts were conducted on roads bordering 3 treated and 3 control plots. Road surfaces varied from sand and mud, which provided good substrate, to gravel, which did not show tracks as clearly. Roads surrounding plantations were generally better maintained and had less vegetation growing on them, due to their frequent use for herbicide application and growth monitoring. Thus, tracks would tend to be more visible on these roads. Van Dyke et al. (1986) found the track method to be less sensitive to changes in mountain lion (*Felis concolor*) density when tracking conditions were poor, suggesting that track counts on poor road surfaces may not be a reliable indicator of density. A difference in accuracy between site types would invalidate comparisons of relative densities. It is also likely that the roads in close proximity to plantations were more frequently used by vehicles, since they were generally in better condition. Any difference in the amount of such disturbance between site types could affect the tendency for deer to cross roads. The locations of the roads used for track counts may have biased results; tracks on the roads could have been an indication of deer use of surrounding vegetation types, rather than the plots themselves. Roads may have been used by deer as travel lanes to and from areas adjacent to study plots, resulting in the inclusion of tracks made by deer that may never have entered the study area. Finally, deer use of plantations can be expected to differ with distance to an edge, and deer could have avoided most of a plantation while still leaving tracks on boundary roads.

In an attempt to eliminate these potential sources of error, pellet-group counts were employed to assess deer use in 1990. Estimates were used only to rank relative use of the study plots. This method has received criticism because of its associated assumptions (Fuller 1991). It must be assumed that no groups are lost during the census period and there is no observer bias in locating, aging, and identifying groups. It is further assumed that defecation rates are constant over time spent in an area. Collins (1981) recorded different defecation rates during various activities in mule deer (*Odocoileus hemionus*), and Neff (1968) summarized data indicating that defecation rates varied with range condition and forage quality. It is therefore possible that differences in vegetative characteristics between site types could affect defecation rates. Thus, the assumption that defecation rates are linearly related to time spent in an area is of questionable validity, but was accepted in this study. However, because of the small total number of pellet-groups counted on the study plots, intraspecific variations in defecation rates could have affected results. Allowing a longer time for pellet deposition might improve accuracy of results by increasing the total number groups counted.

DEER SUMMER HABITAT SUITABILITY

Food quality and abundance are usually limiting for white-tailed deer in the southern United States (Hurst and Warren 1982), and availability of preferred forage appears to be the primary factor influencing deer summer habitat use in the Upper Great Lakes Region (Kohn and Mooty 1971). Summer diet of deer is varied, consisting of new growth of browse, herbaceous vegetation, shrubs, and tree foliage (Blouch 1984), especially aspen leaves (McCaffery et al. 1974). Fruit, berries, and mushrooms are also readily eaten (Rogers et al. 1981, Blouch 1984). Pine is eaten only under stress conditions (Halls and Boyd 1982), and spruce, balsam fir, tamarack, and speckled alder are also poor foods (Rogers et al. 1981, Blouch 1984). A hardwood or herbaceous component is necessary to support a healthy deer population (Johnson 1987). A number of studies evaluating deer forage in pine plantations have been conducted. Gysel (1966) attributed a decline in white-tailed deer numbers in a Michigan red pine plantation due to a lack of low-growing foods. Deer forage was reduced more drastically on pine plantations prepared with hexazinone when compared to plantations prepared by mechanical methods (McComb and Hurst 1987), and Savidge (1978) reported a significant difference in mule deer use between a Jeffrey pine plantation treated with herbicide and an untreated plantation. Favorable browse species were virtually eliminated by the herbicide treatment, and deer were not observed on treated areas. Conversion of mature pine-hardwood forests to loblolly pine through the use of herbicides not only reduced deer forage, but also removed hard and soft mast and mushrooms (Hurst and Warren 1982). Hurst and Warren also noted a lack of cover on intensely prepared sites. Blake et al. (1987) reported a decrease in forage biomass on a loblolly plantation following treatment with hexazinone. They noted, however, resistance of 3 key forages; blackberry, honeysuckle, and greenbrier (Smilax spp.).

Rogers et al. (1981) listed results from several deer forage utilization studies conducted in the northern Great Lakes Region. Analysis of these data indicated approximately 50% to 60% of white-tailed deer diets in July and August to be woody browse, and 30% to 40% mushrooms and forbs. Grasses and sedges made up 6% or less of the summer diet. Woody species eaten in the greatest quantities were aspen, hazelnut (Corylus spp.), bush-honeysuckle (Diervilla spp.), red maple, cherry, brambles, birch, and willow. Of these species, birch, brambles, cherry, and aspen were present in significant amounts on plantations in this study. By comparison, naturally regenerating plots contained all of these species, and all except birch were higher in frequency and density on controls. Additional common woody species on treated sites were generally poor forage species, including balsam fir, red pine, and white spruce. While adequate browse for small numbers of individuals may exist on plantations in the form of birch, cherry, and brambles, the browse component of controls was superior in both species composition and biomass.

Herbaceous species constitute a significant portion of summer white-tailed deer food. Considerable amounts of wild strawberry, goldenrod (Solidago spp.), aster, bracken fern (Pteridium aquilinum), rough cinquefoil, clover (Trifolium spp.), violet, sarsaparilla (Aralia spp.), vetch (Vicia spp.), spreading dogbane, and hawkweed were consumed by deer in the Upper Great Lakes Region (Rogers et al. 1981). Most of these species, in addition to several other desirable herbaceous species, were abundant on both controls and treatments. Availability of herbaceous forage would probably not limit deer on the study plots if an adequate woody browse component was available. However, the relative lack of woody forage on plantations might necessitate an increase in consumption of herbaceous species, in which case overall food availability may become limiting to deer on treated sites. When both woody and herbaceous foods are considered, it is evident that controls were more suitable for deer in forage species composition and availability.

Hiding cover is also an important summer deer habitat component. Thomas et al. (1979) defined hiding cover as vegetation capable of concealing 90% or more of an adult animal from human vision at a distance of 61m or less. Heaviest deer use occurs within 183m of the edge between cover and forage areas (Thomas et al. 1979). Deer are capable of running through dense vegetation, and therefore cover can be used for both hiding and escape. Suitable cover for deer occurs at a density of 3000 stems/ha >1m in height (Bender and Haufler, unpubl.). By this standard, adequate cover was not available on treated plots in any year. Density was sufficient on control sites in all years except 1987 (see Table 10). The low density estimate in this year resulted from extremely low density values obtained on 2 plots. Both of these plots yielded higher estimates in the other years. Different field personnel collected data in each year, and variations may have been due to sampling biases.

SUMMARY AND RECOMMENDATIONS

Results of this study illustrate the extensive habitat alteration caused by the convertion of hardwood forest to red pine. Structural changes in vegetation following herbicide treatment were evident in percent cover, stem density, and FHD estimates. Woody and herbaceous species composition was similar between site types, but total absolute frequencies were consistently greater on controls. These vegetative differences have implications for wildlife, particularly avian species.

Small mammal numbers were low throughout the study period but increased slightly over time. Abundance was consistently higher on plantations than on naturally regenerating plots, significantly so in August 1987 and July 1990, due largely to the affinity of deer mice to the plantations. Treated sites and control sites supported similar numbers of species, but species diversity was significantly higher on controls in August 1990. Analysis of correlations suggests that percent of low cover is one variable affecting small mammal population dynamics, but moisture and food availability may also have affected populations.

Bird density, species richness, and species diversity were higher on controls than treatments, and differences between site types were significant in 1990. Between-year differences were largely explained by observer differences and small sample size. Site type differences were mainly the result of vegetative composition and structure alteration by herbicide treatment, although indirect effects, such as changes in insect abundance, may also have influenced habitat selection by birds. Treatments and controls belonged to different vegetation types. Treatments were basically open grasslands while controls more closely resembled second growth forest and thickets. Predictable shifts in avian species composition occurred as vegetative features of treatment and control plots diverged.

Deer track counts and pellet-group counts yielded no significant results. Inherent biases, assumptions, and sources of error, along with small sample sizes, made deer use estimation extremely difficult. Deer did make use of both treated sites and controls. The effects of conversion on deer were more easily measured indirectly by qualifying the sites as deer habitat. Assessment of available forage species, forage abundance, and security cover indicated that converted sites provided sub-optimum deer habitat, while controls were more suitable due to their mixture of woody browse, herbaceous forage, and cover.

The vegetative changes after herbicide treatment are severe enough to alter wildlife use of plantations. Considering the amount of land in the Upper Great Lakes Region presently or prospectively being used for softwood production, it is imperative that wildlife be considered in management practices. The results of this study, as well as those in the literature, suggest that the preservation of a hardwood component in red pine stands would allow for a more diverse avifauna, better deer habitat, and possibly higher diversity of small mammal species. This might be achieved by encouraging regeneration of red pine on sites where the species occurs naturally. However, good seed crops occur relatively infrequently, and planting may be necessary to meet minimum timber stocking requirements. Because red pine grows most successfully on low quality sites, planting pine in such areas would reduce the need for competition control. Limiting site preparation to burning or a mechanical treatment would allow the survival of other woody vegetation. In addition, low stocking densities (1000 trees/ha) and thinning beginning at age 25 would improve understory for wildlife, as well as increase red pine growth rate.

Important variables not considered in this study are plantation size and spacing. Plantations may be used by deer as forage areas provided cover is accessible. Recommended maximum width of forage areas is generally 220m, and deer forage areas should be no more than 183m from cover at any point. This would allow for plantations to be approximately 13 ha in size if square. At least 40% of a section should be left in cover.

Consideration should also be given to the possibility of forest fragmentation. Complete interspersion of a management area with plantations could allow edge species and predators to invade forest blocks, and may result in declines in interior species, particularly some nongame birds. Large areas in plantations of varying ages will produce an unnatural and fragmented forest landscape. Therefore, some blocks of mature forest should be preserved, although additional research is needed to determine the exact stand size necessary to maintain populations of interior species.

The effects of conversion to red pine are not well documented for all plantation ages. Vegetation and wildlife populations need to be monitored on plantations throughout the entire rotation to determine the success of management procedures on both timber and wildlife. With the knowledge gained from this additional research, multi-purpose management techniques can be employed to ensure a future for wildlife while maintaining red pine timber production.

LITERATURE CITED

Balda, R.P. 1975. Vegetation structure and breeding bird diversity. Pages 59-80 in D.R. Smith, tech. coord. Proceedings of the symposium on management of forest and range habitats for nongame birds. May 6-9, Tucson, Ariz. U.S.D.A. For Serv. Gen. Tech. Rep. WO-1.

Bender, L.C., and J.B. Haufler. 1991. A white-tailed deer HSI for the Upper Great Lakes Region. Unpublished.

Bent, A.C. 1968. Life Histories of North American cardinals, grosbeaks, buntings, towhees, finches, sparrows, and allies. Part 3. Dover Publications, Inc., New York. 640pp.

Benzie, J.W. 1977. Manager's handbook for red pine in the north-central states. U.S.D.A. For. Serv. Gen. Tech. Rep. NC-33. 22pp.

Blake, P.M., G.A. Hurst, and T.A. Terry. 1987. Responses of vegetation and deer forage following application of hexazinone. South. J. Appl. For. 11:176-180.

Blouch, R.I. 1984. Northern Great Lakes and Ontario Forest. Pages 391-410 in L.K. Halls. ed. White-tailed deer ecology and management. Stackpole Books, Harrisburg, Penn. 810pp.

Borrecco, J.E., H.C. Black, and E.F. Hooven. 1979. Response of small mammals to herbicide-induced habitat changes. Northwest Sci. 53:97-106.

Bruns, H. 1959. The economic importance of birds in forests. Bird Study 7:193-205.

Burt, W.H. 1946. The mammals of Michigan. University of Michigan Press, Ann Arbor, Mich. 288pp.

———, 1957. Mammals of the Great Lakes Region of Michigan. University of Michigan Press, Ann Arbor, Mich. 246pp.

Canfield, R.H. 1941. Application of the line intercept method in sampling range vegetation. J. For. 39:388-394.

Capen, D.E. 1979. Management of northeastern pine forests for nongame birds. Pages 90-105 in R.M. DeGraaf, ed. Workshop Proceeding: Management of north central and northeastern forests for nongame birds. U.S.D.A. For. Serv. Tech. Rep. NC-51. 268pp.

Caras, R.A. 1967. North American mammals. Meredith Press, N.Y. 578pp.

Carter, M.C., J.W. Martin, J.E. Kennamer, and M.K. Causey. 1975. Impact of chemical and mechanical site preparation on wildlife habitat. Down to Earth 31:14-18.

Chew, R.M. 1951. The water exchanges of some small mammals. Ecol. Monogr. 21:215-225.

———. 1978. The impact of small mammals on ecosystem structure and function. Pages 167-180 in D.P. Snyder, ed. Populations of small mammals under natural conditions. Pymatuning Lab. of Ecol. Spec. Publ. Ser. Vol. 5. Univ. Pittsburgh. 237pp.

Collins, W.B. 1981. Habitat preferences of mule deer as rated by pellet group distributions. J. Wildl. Manage. 45:969-972.

Connor, R.N., and J.G. Dickson. 1980. Strip transect sampling and analysis for avian habitat studies. Wildl. Soc. Bull. 8:4-10.

Crawford, H.S., R.W. Titterington, and D.J. Jenning. 1983. Bird predation and spruceworm populations. J. For. 81:433-435;478.

Creighton, J.L., B.R. Zutter, G.R. Glover, and D.H. Gjerstad. 1987. Planted pine growth and survival responses to vegetation control, treatment duration, and herbicide application technique. South. J. Appl. For. 11:223-227.

Dickmann, D.I., W.J. O'Neill, Jr., and N. Caveney. 1987. Wide-spaced red pine: a multiple use opportunity. North. J. Appl. For. 4:44-45.

Dickson, J.G. 1978. Forest bird communities in the bottomland hardwoods. Pages 66-73 in Proceedings of the workshop: management of southern forests for nongame birds. U.S.D.A. For. Serv. Gen. Tech. Rep. SW-14.

Driscoll. P.V. 1977. Comparison of bird counts from pine forests and indigenous vegetation. Austral. Wildl. Res. 4:281-288.

Driscoll. P.V. 1977. Comparison of bird counts from pine forests and indigenous vegetation. Austral. Wildl. Res. 4:281-288.

Eadie, W.R. 1953. Response of Microtus to vegetative cover. J. Mammal. 34:263-264.

Eaton, L.E. 1986. Response of songbirds and small mammals to whole tree harvesting of aspen. M.S. Thesis, Michigan State Univ., East Lansing. 90pp.

Edgerton, P.J., and J.W. Thomas. 1978. Silvicultural options and habitat values in coniferous forests. Pages 56-65 in R.M. DeGraaf, ed. Proceedings of the workshop on nongame bird habitat management in the coniferous forests of the western United States. U.S.D.A. For. Serv. Gen. Tech. Rep. PNW-64.

Eiberle, K., and J. von Hirschheydt. 1983. Effect of the mixture of tree species on the population of breeding birds. [Uber den Einfluss der Baumartenmis chung auf den Brutvogel bestand.] Waldhygiene 15:33-48.

Eyre, F.H., and P. Zehngraff. 1948. Red pine management in Minnesota. U.S.D.A. For. Serv. Circ. No. 778. Washington, D.C. 70pp.

Felix, A.C. III, T.L. Sharik, and B.S. McGinnes. 1986. Effects of pine conversion on food plants of northern bobwhite quail, eastern wild turkey, and white-tailed deer in the Virginia Piedmont. South. J. Appl. For. 10:47-52.

Fowells, H.A. 1965. Red pine. Pages 432-446 in H.A. Fowells, comp. Silvics of the forest trees of the United States. U.S.D.A. Agric. Handb. No. 271.

Freese, F. 1978. Elementary forest sampling. U.S.D.A. For. Serv. Agric. Handb. 232. 91pp.

Fuller, T.K. 1991. Do pellet counts index white-tailed deer number and population change? J. Wildl. Manage. 55:393-396.

Gashwiler, J.S. 1970. Plant and animal changes on a clearcut in west-central Oregon. Ecology 51:1018-1026.

Getz, L.L. 1961. Factors influencing the local distribution of shrews. Am. Midl. Nat. 65:67-88.

———. 1968. Influence of water balance and microclimate on the local distribution of the redback vole and white-footed mouse. Ecology 49:276-286.

Griscom, L., and A. Sprunt, Jr. 1957. The warblers of America: a popular account of the wood warblers as they occur in the western hemisphere. The Devin-Adair Company, NY. 356pp.

———, and L.J. Lyon. 1980. Habitat analysis and evaluation. Pages 305-327 in S.D. Schemnitz, ed. Wildlife management techniques manual. The Wildlife Society, Washington, D.C. 686pp.

Hair, J.D. 1980. Measurement of ecological diversity. Pages 269-275 in Schemnitz, ed. Wildlife management techniques manual. The Wildlife Society, Washington, D.C. 686pp.

Hall, G.A. 1964. Breeding bird censuses - why and how. Aud. Field Notes 18:413-416.

Halls, L.K., and L.E. Boyd. 1982. Influence of managed red pine stands and mixed pine/hardwood stands on well being of deer. U.S.D.A. For. Serv. Res. Pap. SO-183. 18pp.

Hamilton, W.J., JR. 1941. The food of small forest mammals in eastern United States. J. Mammal. 22:250-263.

———, and J.O. Whitaker, Jr. 1979. Mammals of the eastern United States. 2nd ed. Cornell University Press, NY. 346pp.

Haufler, J.B. 1991. Personal communication. Department of Fisheries and Wildlife, Michigan State Univ., East Lansing.

Hurst, G.A. 1989. Forestry chemicals and wildlife habitat. For. Farm. Feb. 1989:10-11

———, and R.C. Warren. 1982. Impacts of silvicultural practices in loblolly pine plantations on white-tailed deer habitat. Pages 484-487 in E. James, Jr., ed. Proceedings of the 2nd biennial southern silvicultural research conference. Nov. 4-5, Atlanta, GA.

Jarvinen, O., R.A. Vaisanen, and Y. Haila. 1977. Bird census results in different years, stages of the breeding season, and times of day. Ornis Fennica 54:108-118.

———, ———, and ———. 1978. Efficiency of the line transect method in mountain birch forest. Ornis Fennica 55:16-23.

Johansen, P.R. 1981. Invertebrate biomass in various aged loblolly pine plantations and upland hardwood stands in the central Piedmont of Virginia. M.S. Thesis. Virginia Polytech. Inst. and State Univ., Blacksburg. 134pp.

Johnson, A.S. 1987. Pine plantations as wildlife habitat: a perspective. Pages 12-18 in J.G. Dickson and O.E. Maughan, eds. Managing southern forests for fish and wildlife: a proceedings. U.S.D.A. For. Serv. Gen. Tech. Rep. SO-65. 85pp.

Kendeigh, S.C. 1944. Measurement of bird populations. Ecol. Monogr. 14:68-106.

Kirkland, G.L. 1977. Responses of small mammals to the clearcutting of northern Appalachian forests. J. Mammal. 58:600-609.

Knowe, S.A., L.R. Nelson, D.H. Gjerstad, B.R. Zutter, G.R. Glover, P.J. Minogue, and J.H. Dukes, Jr. 1985. Four-year growth and development of planted loblolly pine on sites with competition control. South. J. Appl. For. 9:11-15.

Kohn, B.E., and J.J. Mooty. 1971. Summer habitat of white-tailed deer in north-central Minnesota. J. Wildl. Manage. 35:476-487.

Lundgren, A.L. 1983. New site productivity estimates for red pine in the Lake States. J. For. 81:714-717.

McCaffery, K.R., J. Tranetzki, and J. Piechura, Jr. 1974. Summer foods of deer in northern Wisconsin. J. Wildl. Manage. 38:215-219.

McComb, W.C., and G.A. Hurst. 1987. Herbicides and wildlife in southern forests. Pages 28-36 in J.G. Dickson and O.E. Maughan, eds. Managing southern forests for fish and wildlife: a proceedings. U.S.D.A. For. Serv. Gen. Tech. Rep. SO-65. 85pp.

McKee, W.H., Jr., and L.P. Wilhite. 1988. Response of newly planted loblolly pines to herbicide and nitrogen. South. J. Appl. For. 12:33-36.

M'Closkey, R.T., and D.T. Lajoie. 1975. Determinants of local distribution and abundance in white-footed mice. Ecology 59:799-809.

Meslow, E.C. 1978. The relationship of birds to habitat structure - plant communities and successional stages. Pages 12-18 in R.M. DeGraaf, ed. Proceedings of the workshop on nongame bird habitat management in the coniferous forests of the western United States. U.S.D.A. For. Serv. Gen. Tech. Rep. PNW-64.

Meyers, J.M., and A.S. Johnson. 1978. Bird communities associated with succession and management of loblolly-shortleaf pine forests. Pages 50-65 in R.M. DeGraaf, ed. Proceedings of the workshop: management of southern forests for nongame birds. U.S.D.A. For. Serv. Gen. Tech. Rep. SE-14.

Michael, J.L. 1985. Growth of loblolly pine treated with hexazinone, sulfometuron methyl, and metasulfuron methyl for herbaceous weed control. South. J. Appl. For. 9:20-26.

Morrison, M.L., and E.C. Meslow. 1983. Impacts of forest herbicides on wildlife: toxicity and habitat alteration. Trans. N. Am. Wildl. Conf. 48:175-185.

Neff, D.J. 1968. The pellet-group count technique for big game trend, census, and distribution: a review. J. Wildl. Manage. 32:597-614.

Nelson, L.R., R.C. Pedersen, L.L. Autry, S. Dudley, and J.D. Walstad. 1981. Impacts of herbaceous weeds in young loblolly pine plantations. South. J. Appl. For. 5:153-158.

NOAA. 1986. National Oceanic and Atmospheric Administration. Climatological Data, Annual Summary, Michigan. Vol. 101.

NOAA. 1987. National Oceanic and Atmospheric Administration. Climatological Data, Annual Summary, Michigan. Vol. 102.

NOAA. 1988. National Oceanic and Atmospheric Administration. Climatological Data, Annual Summary, Michigan. Vol. 103.

NOAA. 1989. National Oceanic and Atmospheric Administration. Climatological Data, Annual Summary, Michigan. Vol. 104.

NOAA. 1990. National Oceanic and Atmospheric Administration. Climatological Data, Annual Summary, Michigan. Vol. 105.

Potter, G.L. 1978. The effect of small mammals on forest ecosystem structure and function. Pages 181-187 in D.P. Snyder, ed. Populations of small mammals under natural conditions. Pymatuning Lab. of Ecol., Spec. Publ. Ser. vol. 5. Univ. Pittsburgh. 273pp.

Ream, C.H., and G.E. Gruell. 1980. Influences of harvesting and residue treatments on small mammals and implications for forest management. Pages 455-466 in Environmental consequences of timber harvesting in Rocky Mountain conifer forests. Symp. Proc. 1979, Missoula, Mt. U.S.D.A. For. Serv. Gen. Tech. Rep. INT-90. 526pp.

Reynolds, R.T., J.M. Scott, and R.A. Nussbaum. 1980. A variable circular-plot method for estimating bird numbers. Condor 82:309-313.

Robbins, C.S. 1981. Bird activity levels related to weather. Pages 301-310 in C.J. Ralph and J.M. Scott, eds. Estimating numbers of terrestrial birds. Stud. Avian Biol. No. 6. 630pp.

Rogers, L.L., J.J. Mooty, and D. Dawson. 1981. Foods of white-tailed deer in the Upper Great Lakes Region: a review. U.S.D.A. For. Serv. Gen. Tech. Rep. NC-65. 24pp.

Santillo, D.J. 1987. Response of small mammals and breeding birds to herbicide-induced habitat changes on clearcuts in Maine. M.S. Thesis, Univ. of Maine, Orono. 76pp.

Savidge, J.A. 1978. Wildlife in a herbicide-treated Jeffrey pine plantation in eastern California. J. For. 76:476-478.

Schwenner, C. 1989. Soil survey of Menominee County, Michigan. U.S.D.A. Soil Conservation Service. 221pp.

Shugart, H.H., S.H. Anderson, and R.H. Strand. 1975. Dominant patterns in bird populations of the eastern deciduous forest biome. Pages 90-95 in Publ. No. 697, Environ. Sci. Div., Oak Ridge Natl. Lab.

———, T.M. Smith, J.T. Kitchings, and R.L. Kroodsma. 1978. The relationship of nongame birds to southern forest types and successional stages. Pages 5-16 in R.M. DeGraaf, tech. coord. Proceedings of the workshop: management of southern forests for nongame birds. Jan. 24-26, Atlanta, GA. U.S.D.A. For. Serv. Gen. Tech. Rep. SE-14. 176pp.

Siegel, S. 1956. Nonparametric statistics for the behavioral sciences. McGraw Hill, NY. 312pp.

Slagsvold, T. 1977. Bird population changes after clearance of deciduous scrub. Biol. Conserv. 12:229-243.

Slay, J.M., B.G. Lockaby, J.C. Adams, and C.G. Vidrine. 1987. Effects of site preparation on soil physical properties, growth of loblolly pine, and competing vegetation. South. J. Appl. For. 11:83-85.

Sloan, N.F., and H.C. Coppel. 1968. Ecological implications of bird predators on the larch casebearer in Wisconsin. J. Econ. Ent. 61:1067-1070.

Tappeiner, J.C., and A.A. Alm. 1975. Undergrowth vegetation effects on the nutrient content of litterfall and soils in red pine and birch stands in northern Minnesota. Ecology 56:1193-1200.

Teivainen, T., E.L. Jukola-Sulonen, and E. Maenpaa. 1986. The effect of ground vegetation suppression using herbicide on the field vole, Microtis agrestis (L.), population. Folia Forestalia, Institutum Forestale Fenniae No. 651. 19pp.

Thomas, J.W., G.L. Crouch, R.S. Bumstead, and L.D. Bryant. 1975. Silvicultural options and habitat values in coniferous forests. Pages 272-287 in D.R. Smith. tech. coord. Proceedings of the symposium on management of forest and range habitats for nongame birds. May 6-9, Tucson, AZ. U.S.D.A. For. Serv. Gen. Tech. Rep. WO-1.

———, H. Black, R.J. Scherzinger, and R.J. Pedersen. 1979. Deer and elk. Pages 104-127 in J.W. Thomas, ed. Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. U.S.D.A. For. Serv. Agric. Handb. No. 553. 512pp.

Tramer, E.J. 1969. Bird species diversity: components of Shannon's formula. Ecology 50:927-930.

U.S. Fish and Wildlife Service. 1987. National survey of hunting, fishing, and wildlife-associated recreation. U.S.D.I., Washington, D.C. 100pp.

Van Dyke, F.G., R.H. Brocke, and H.G. Shaw. 1986. Use of road track counts as indices of mountain lion presence. J. Wildl. Manage. 50:102-109.

West, N.E. 1968. Rodent-influenced establishment of ponderosa pine and bitterbrush seedlings in central Oregon. Ecology 49:1009-1011.

Weins, J.A. 1975. Avian communities, energetics, and functions in coniferous forest habitats. Pages 226-261 in D.R. Smith, tech. coord. Proceedings of the symposium on management of forest and range habitats for nongame birds. May 6-9, Tucson, AZ. U.S.D.A. For. Serv. Gen. Tech. Rep. WO-1.

———. 1978. Nongame bird communities in northwestern coniferous forests. Pages 19-31 in R.M. DeGraaf, ed. Proceedings of the workshop on nongame bird habitat management in the coniferous forests of the western United States. U.S.D.A. For. Serv. Gen. Tech. Rep. PNW-64.

Willson, M.F. 1974. Avian community organization and habitat structure. Ecology 55:1017-1029.

Wilmore, S.B. 1977. Crows, jays, ravens, and their relatives. David and Charles, BC. 208pp.

Yahner, R.H. 1983. Small mammals in farmstead shelterbelts. J. Wildl. Manage. 47:74-104.

Yahner, R.H. 1986. Microhabitat use by small mammals in even-aged forest stands. Am. Midl. Nat. 115:174-180.

APPENDIX

Table A-1. Vegetative species found on converted red pine plantations and clearcuts in the Upper Peninsula, Michigan, in 1986, 1987, 1988, and 1990.

COMMON NAME	SCIENTIFIC NAME
HERBACEOUS	
Agrimony	*Agrimonia gryposepala*
American pennyroyal	*Hedeoma pulegioides*
Aster	*Aster* spp.
Bluebead lily	*Clintonia borealis*
Bedstraw	*Galium* spp.
Bicknell's cranesbill	*Geranium bicknelli*
Black-eyed Susan	*Rudbeckia hirta*
Black bindweed	*Polygonum convolvulus*
Black medick	*Medicago lupulina*
Black mustard	*Brassica nigra*
Bladder campion	*Silene cucubalus*
Blue cohosh	*Caulophyllum thalictroides*
Bristly crowfoot	*Ranunculus pensylvanicus*
Bristly sarsaparilla	*Aralia hispida*
Bunchberry	*Cornus canadensis*
Butter-and-eggs	*Linaria vulgaris*
Canada mayflower	*Maianthemum canadense*
Chickweed	*Stellaria* spp., *Cerastium* spp.
Common burdock	*Arctium minus*
Common buttercup	*Ranunculus acris*

Table A-1 (cont'd).

COMMON NAME	SCIENTIFIC NAME
Common cattail	*Typha latifolia*
Common milkweed	*Asclepias syriaca*
Common mullein	*Verbascum thapsus*
Common nightshade	*Solanum americanum*
Common plantain	*Plantago major*
Common St. Johnswort	*Hypericum perforatum*
Coneflower	*Rudbeckia* spp.
Cow vetch	*Vicia cracca*
Curled dock	*Rumex crispus*
Creeping snowberry	*Gaultheria hispidula*
Daisy fleabane	*Erigeron annuus*
Dandelion	*Taraxacum* spp.
Downy wood mint	*Blephilia ciliata*
Dwarf enchanter's nightshade	*Circaea alpina*
Early meadow rue	*Thalictrum dioicum*
Enchanter's nightshade	*Circaea quadrisulcata*
Erect bindweed	*Convolvulus spithamaeus*
Eyebane	*Euphorbia maculata*
Fern	*Pteris* spp.
Field bindweed	*Convolvulus arvensis*
Field pussytoes	*Antennaria neglecta*
Fireweed	*Epilobium angustifolium*
Fringed bindweed	*Polygonum cilinode*

Table A-1 (cont'd).

COMMON NAME	SCIENTIFIC NAME
Fringed loosestrife	Lysimachia ciliata
Fringed polygala	Polygala paucifolia
Fungus	Various
Goldenrod	Solidago spp.
Goldthread	Coptis groenlandica
Grasses and sedges	Poa spp., Carex spp.
Great lobelia	Lobelia siphilitica
Great St. Johnswort	Hypericum pyramidatum
Ground cedar	Lycopodium complanatum
Hairy Solomon's seal	Polygonatum pubescens
Hare figwort	Scrophularia lanceolata
Hemp nettle	Galeopsis tetrahit
Hooked crowfoot	Ranunculus recurvatus
Hop clover	Trifolium agrarium
Horsetail	Equisetum spp.
Horseweed	Erigeron canadensis
Hound's tongue	Cynoglossum officinale
Indian paintbrush	Castilleja coccinea
Indian tobacco	Lobelia inflata
Lamb's quarters	Chenopodia album
Large blue flag iris	Iris versicolor
Large-leaved avens	Geum macrophyllum
Least hop clover	Trifolium dubium

Table A-1 (cont'd).

COMMON NAME	SCIENTIFIC NAME
Lichen	Various
Mad-dog skullcap	*Scutellaria lateriflora*
Maple-leaved goosefoot	*Chenopodium hybridum*
Marsh marigold	*Caltha palustris*
Marsh skullcap	*Scutellaria epilobiifolia*
Moss	Various
Narrow-leaved willowherb	*Epilobium leptophyllum*
Night flowering catchfly	*Silene noctiflora*
Northern bugleweed	*Lycopus uniflorus*
Northern willowherb	*Epilobium glandulosum*
Orange hawkweed	*Hieracium aurantiacum*
Oxeye daisy	*Chrysanthemum leucanthemum*
Oxeye sunflower	*Heliopsis helianthoides*
Oyster plant	*Tragopogon porrifolius*
Pale corydalis	*Corydalis sempervirens*
Pale smartweed	*Polygonella lapathifolium*
Pale touch-me-not	*Impatiens pallida*
Partridgeberry	*Mitchella repens*
Pearly everlasting	*Anaphalis margaritacea*
Peppermint	*Mentha piperita*
Plantain-leaved pussytoes	*Antennaria plantaginifolia*
Poison ivy	*Rhus radicans*
Poke milkweed	*Asclepias exaltata*

Table A-1 (cont'd).

COMMON NAME	SCIENTIFIC NAME
Prickly lettuce	*Lactuca scariola*
Purple-leaved willowherb	*Epilobium coloratum*
Pyrola	*Pyrola* spp.
Queen Anne's lace	*Daucus carota*
Rattlesnake roots	*Prenanthes* spp.
Red baneberry	*Actaea rubra*
Red clover	*Trifolium pratense*
Rose twisted stalk	*Streptopus roseus*
Rough cinquefoil	*Potentilla norvegica*
Rough-fruited cinquefoil	*Potentilla recta*
Round-lobed hepatica	*Hepatica americana*
Selfheal	*Prunella vulgaris*
Sheep sorrel	*Rumex acetosella*
Shinleaf	*Pyrola elliptica*
Shrubby St. Johnswort	*Hypericum spathulatum*
Spotted joe-pye weed	*Eupatorium maculatum*
Spotted knapweed	*Centaurea maculosa*
Spotted touch-me-not	*Impatiens capensis*
Spreading dogbane	*Apocynum androsaemifolium*
Starflower	*Trientalis borealis*
Stinging nettle	*Urtica dioica*
Strawberry blight	*Chenopodium captatum*
Swamp milkweed	*Asclepias incarnata*

Table A-1 (cont'd).

COMMON NAME	SCIENTIFIC NAME
Sweet cicely	*Osmorhiza claytoni*
Sweet coltsfoot	*Petasites palmatus*
Sweet everlasting	*Gnaphalium obtusifolium*
Tall cinquefoil	*Potentilla arguta*
Tansy	*Tanacetum vulgare*
Thimbleweed	*Anemone virginiana*
Thistle	*Cirsium* spp.
Trillium	*Trillium* spp.
Turtlehead	*Chelone glabra*
Twisted stalk	*Streptopus amplexifolius*
Violet	*Viola* spp.
Water horehound	*Lycopus americanus*
Water parsnip	*Sium suave*
White campion	*Lychnis alba*
White clover	*Trifolium repens*
White lettuce	*Prenanthes alba*
White sweet clover	*Melilotus alba*
White vervain	*Verbena urticifolia*
Wild basil	*Satureja vulgaris*
Wild bergamot	*Monarda fistulosa*
Wild columbine	*Aquilegia canadensis*
Wild lettuce	*Lactuca canadensis*
Wild mint	*Mentha arvensis*

Table A-1 (cont'd).

COMMON NAME	SCIENTIFIC NAME
Wild sarsaparilla	*Aralia nudicaulis*
Wild strawberry	*Fragaria virginiana*
Wild thyme	*Thymus serpyllum*
Wintergreen	*Gaultheria procumbens*
Wood anemone	*Anemone quinquefolia*
Yarrow	*Achillea millefolium*
Yellow avens	*Geum aleppicum*
Yellow corydalis	*Corydalis flavula*
Yellow goatsbeard	*Tragopogon dubius*
Yellow hawkweed	*Hieracium pratense*
Yellow stargrass	*Hypoxis hirsuta*
Yellow sweet clover	*Melilotus officinalis*
Yellow wood sorrel	*Oxalis europaea*
WOODY	
American basswood	*Tilia americana*
American Beech	*Fagus grandifolia*
Ash	*Fraxinus* spp.
Balsam fir	*Abies balsamea*
Balsam poplar	*Populus balsamifera*
Bigtooth aspen	*Populus grandidentata*
Birch	*Betula* spp.
Blueberry	*Vaccinium* spp.
Brambles	*Rubus* spp.

Table A-1 (cont'd).

COMMON NAME	SCIENTIFIC NAME
Cherry	*Prunus* spp.
Currant	*Ribes* spp.
Dogwood	*Cornus* spp.
Elderberry	*Sambucus canadensis*
Elm	*Ulmus* spp.
Grape	*Vitis* spp.
Hairy honeysuckle	*Lonicera hirsuta*
Hazelnut	*Corylus* spp.
Hornbeam	*Ostrya virginiana*
Ironwood	*Carpinus caroliniana*
Jack pine	*Pinus banksiana*
Northern bush-honeysuckle	*Diervilla lonicera*
Northern white-cedar	*Thuja occidentalis*
Pasture rose	*Rosa virginiana*
Poison ivy	*Rhus radicans*
Quaking aspen	*Populus tremuloides*
Red maple	*Acer rubrum*
Red pine	*Pinus resinosa*
Serviceberry	*Amelanchier* spp.
Speckled alder	*Alnus rugosa*
Sugar maple	*Acer saccharum*
Tamarack	*Larix laricina*
Viburnum	*Viburnum* spp.

Table A-1 (cont'd).

COMMON NAME	SCIENTIFIC NAME
Virginia creeper	_Parthenocissus quinquefolia_
Waxberry	_Symphoricarpus racemosus_
White pine	_Pinus strobus_
White spruce	_Picea glauca_
Willow	_Salix_ spp.

Table A-2. Correlation coefficients (r_s) for statistically significant associations between small mammal population variables and vegetative characteristics on converted red pine plantations and clearcuts in the Upper Peninsula, Michigan, in 1987, 1988, and 1990.

DATE	POPULATION VARIABLE	VEGETATIVE CHARACTERISTIC	CORRELATION COEFFICIENT (r_s)
1987 August	Deer mouse abundance	Percent cover <1m in height	-0.84**
1987 August	Deer mouse abundance	Density of woody vegetation	-0.64*
1987 August	Total small mammal abundance	Percent cover <1m in height	-0.65*
1988 August	Deer mouse abundance	Percent cover <1m in height	-0.79**
1988 August	Deer mouse abundance	Percent cover 1-7m in height	-0.61*
1988 August	Deer mouse abundance	Density of woody vegetation	-0.82**
1988 August	Total small mammal abundance	Percent cover <1m in height	-0.70**
1988 July	Total small mammal abundance	Density of woody vegetation	-0.67**
1988 July	Small mammal species richness	Percent cover 1-7m in height	0.66**
1988 July	Small mammal species richness	FHD	0.70**
1990 July	Deer mouse abundance	Percent cover <1m in height	-0.78**
1990 August	Deer mouse abundance	Percent cover <1m in height	-0.81**
1990 July	Deer mouse abundance	Percent cover 1-7m in height	-0.79**

Table A-2 (cont'd).

DATE	POPULATION VARIABLE	VEGETATIVE CHARACTERISTIC	CORRELATION COEFFICIENT (r_s)
1990 August	Deer mouse Abundance	Percent cover 1-7m in height	-0.72^{*}
1990 July	Deer mouse abundance	FHD	-0.67^{*}
1990 August	Deer mouse abundance	FHD	-0.59^{*}
1990 August	Deer mouse abundance	Density of woody vegetation	-0.67^{*}
1990 August	Masked shrew abundance	Percent cover <1m in height	0.60^{*}
1990 August	Masked shrew abundance	Density of woody vegetation	0.62^{*}
1990 July	Total small mammal abundance	Percent cover <1m in height	-0.68^{**}
1990 July	Total small mammal abundance	Percent cover 1-7m in height	-0.67^{**}
1990 August	Small mammal species diversity	Percent cover <1m in height	0.73^{**}
1990 August	Small mammal species diversity	Density of woody vegetation	0.67^{**}

$^{*}P < 0.10$
$^{**}P < 0.05$

Table A-3. Bird species identified on converted red pine plantations and clearcuts in the Upper Peninsula, Michigan, in 1987 and 1990.

COMMON NAME	SCIENTIFIC NAME
American crow	Corvus brachyrhynchos
American goldfinch	Carduelis tristis
American robin	Turdus migratorius
American woodcock	Philohela minor
Black and white warbler	Mniotilta varia
Black-capped chickadee	Parus atricapillus
Blue jay	Cyanocitta cristata
Brown-headed cowbird	Molothrus ater
Brown thrasher	Toxostoma rufum
Carolina wren	Thryothorus ludovicianus
Cedar waxwing	Bombycilla cedrorum
Chestnut-sided warbler	Dendroica pensylvanica
Chipping sparrow	Spizella passerina
Clay-colored sparrow	Spizella pallida
Common flicker	Colaptes auratus
Common grackle	Quiscalus quiscula
Common snipe	Capella gallinago
Common yellowthroat	Geothlpis trichas
Eastern bluebird	Sialia sialis
Eastern kingbird	Tyrannus tyrannus
European starling	Sturnus vulgaris
Field sparrow	Spizella pusilla

Table A-3 (cont'd).

COMMON NAME	SCIENTIFIC NAME
Fox sparrow	*Passerella iliaca*
Hermit thrush	*Catharus guttatus*
House wren	*Troglodytes aedon*
Indigo bunting	*Passerina cyanea*
Killdeer	*Charadrius vociferus*
Nashville warbler	*Vermivora ruficapilla*
Northern oriole	*Icterus galbula*
Northern raven	*Corvus corav*
Ovenbird	*Seiurus aurocapillus*
Red-breasted nuthatch	*Sitta canadensis*
Red-eyed vireo	*Vireo olivaceus*
Red-tailed hawk	*Buteo jamaicensis*
Red-winged blackbird	*Agelaius phoeniceus*
Ruby-throated hummingbird	*Archilochus colubris*
Ruffed grouse	*Bonasa umbellus*
Rufous-sided towhee	*Pipilo erythrophthalmus*
Song sparrow	*Melospiza melodia*
Tennessee warbler	*Vermivora peregrina*
Tree swallow	*Iridoprocne bicolor*
Upland sandpiper	*Bartramia longicauda*
Vesper sparrow	*Pooecetes gramineus*
Whip-poor-will	*Caprimulgus vociferus*
White-eyed vireo	*Vireo griseus*

Table A-3 (cont'd).

COMMON NAME	SCIENTIFIC NAME
White-throated sparrow	*Zonotrichia albicollis*
Yellow-bellied sapsucker	*Sphyrapicus varius*
Yellow-rumped warbler	*Dendroica coronata*
Yellow warbler	*Dendroica petachia*

Table A-4. Correlation coefficients (r_s) for statistically significant associations between bird population variables and vegetative characteristics on converted red pine plantations and clearcuts in the Upper Peninsula, Michigan, in 1990.

POPULATION VARIABLE	VEGETATIVE CHARACTERISTIC	CORRELATION COEFFICIENT (r_s)
Indigo bunting density	Percent cover 1-7m in height	0.66^{*}
Indigo bunting density	FHD	0.72^{*}
Indigo bunting density	Density of woody vegetation	0.57^{*}
American robin density	Density of woody vegetation	-0.66^{*}
Total bird density	Percent cover <1m in height	0.84^{***}
Total bird density	Percent cover 1-7m in height	0.81^{***}
Total bird density	Percent cover >7m in height	0.68^{**}
Total bird density	FHD	0.64^{*}
Species richness	Percent cover <1m in height	0.71^{**}
Species richness	Percent cover 1-7m in height	0.71^{**}
Species richness	Percent cover >7m in height	0.79^{**}
Species richness	FHD	0.82^{***}
Species richness	Density of woody vegetation	0.84^{***}
Species diversity	Percent cover <1m in height	0.73^{**}

Table A-4 (cont'd).

POPULATION VARIABLE	VEGETATIVE CHARACTERISTIC	CORRELATION COEFFICIENT (r_s)
Species diversity	Percent cover 1-7m in height	0.68**
Species diversity	Percent cover >7m in height	0.82***
Species diversity	FHD	0.80***
Species diversity	Density of woody vegetation	0.83***

*P < 0.10
**P < 0.05
***P < 0.01