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Elk, White-tailed Deer, and Small Mammal Responses to Thinning of Mature Red Pine Plantations

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ELK, WHITE-TAILED DEER, AND SMALL MAMMAL RESPONSES TO THINNING OF MATURE RED PINE PLANTATIONS

By

Donna Lynne Minnis

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ABSTRACT

ELK, WHITE-TAILED DEER, AND SMALL MAMMAL RESPONSES TO THINNING OF MATURE RED PINE PLANTATIONS

By

Donna Lynne Minnis

Managing forestlands for multiple uses requires integration of timber production and wildlife management objectives. Elk (*Cervus elaphus*), white-tailed deer (*Odocoileus virginianus*), and small mammal use of mature red pine plantations in Michigan at 3 stocking levels (thinned stands at 16.1 and 25.3 m^2/ha of basal area as treatments and unthinned stands averaging 34.8 m^2/ha of basal area as controls) was investigated. Understory vegetation of each stocking level was sampled. Pellet-group counts and browse utilization surveys were used as indices to ungulate use, and live-trapping provided an index to small mammal use. Annual productivity, horizontal and vertical cover from 0 - 1 m in height, number of herbaceous species, and total density of woody species increased as basal area decreased. Elk and deer use was found to significantly increase as basal area decreased likely due to increases in forage quantity. Similarly, small mammals tended to be more abundant on thinned plots than on unthinned plots likely due to increases in both forage and cover. Managing mature red pine stands on high quality sites at minimum stocking levels appears to enhance forage and cover for wildlife, particularly elk and white-tailed deer.

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To my parents, Wilma and Bill Watkins. Your encouragement and support has allowed me to be who I am and to do what I have done. Thank you.

To my puppy dog, Cinderella, who makes me very happy.

Most of all...To my best friend and husband, Richard. This thesis is as much a part of you as it is a part of me. I am thankful for your help on this thesis, but much more than that, I am thankful to have you. "Somewhere in my youth or childhood, I must have done something good."

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INTRODUCTION

Red Pine in the Great Lakes States

In the early 1800's, red pine* covered 2.8 - 3.2 million ha (7 - 8 million ac) or about one-third of all the pine forests in the Great Lakes states of Michigan, Minnesota, and Wisconsin (Benzie 1977). Extensive lumbering of the region began shortly after settlement by Europeans, and timber production peaked in the 1880's (Whitney 1986). As much as 30% of the total cut was estimated to be red pine (Kallio and Benzie 1980).

The shift of logging activity from the eastern United States to the Great Lakes states resulted in heavy cutting that leveled much of the forest, and repeated fires destroyed much of what remained (Chase et al. 1970). Most of the pine forests were so thoroughly destroyed during the early settlement period that there were doubts as to their former existence (Weaver and Clements 1929, Whitney 1986). Large-scale planting programs in the Great Lakes states began with the Civilian Conservation Corps in 1933, and by 1966 more than 404,700 ha (1 million ac) of conifers had been planted in Michigan (Gysel 1966, Ohmann 1982). Currently, red pine is one of the most widely planted conifers in the Great Lakes states, occupying about 567,000 ha (1.4 million ac) (Lundgren 1983, Dickmann et al. 1987).

Red Pine Distribution

Red pine has a broad distribution in northeastern North America, ranging from West Virginia to Newfoundland and west to Manitoba and Minnesota (Roberts 1985). Except for the West Virginia outliers, the present range of red pine from southeastern

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* Scientific names of fauna and flora mentioned are presented in Tables 15 and 16 in the Appendix.

Wisconsin eastward closely corresponds with the area glaciated during the late Pleistocene (Cook et al. 1952, Fowells 1965). The climate of the red pine range is characterized by cool-to-warm summers and cold winters, with frost-free periods ranging from about 80 to 160 days; Rainfall is low-to-moderate, and summer droughts are common, particularly in the western part of the range (Fowells 1965). Red pine is most common between 213 and 427 m (700 and 1,400 ft) in elevation (Benzie and McCumber 1983).

Red Pine Site and Growth Characteristics

Excellent growth of red pine has been reported on both sandy soils and well-drained fine-textured soils (Mader and Owen 1961, Wilde et al. 1965, DeMent and Stone 1968, Alban 1974), but it has been reported to grow best on moist, well-drained acidic sandy or loamy soils (Fowells 1965), such as Alfisols, Entisols, and Spodosols (Benzie and McCumber 1983). Naturally occurring red pine is largely restricted to sandy soils (Fowells 1965) probably because intense plant competition restricts the natural establishment of red pine on finer textured soils (i.e. >30% silt plus clay in the surface soil) (Alban et al. 1987). The optimal soil pH range for red pine is from 5.2 to 6.5 (Wilde 1966).

Site indices for most red pine plantations in the Great Lakes states range from 12.2 to 21.3 m (40 to 70 ft), reaching 25.9 m (85 ft) on the most productive sites (Schone et al. 1984). The site index for average sites in the Great Lakes states is 18.3 m (60 ft) (Lundgren 1983). Red pine is nearly unique in the rareness of polymorphism it exhibits (Alban 1985a), with height growth very often following the pattern expected from the site index curves (Alban 1979, Alban and Prettyman 1984). Mader and Owen (1961) showed that volume growth and height growth of red pine each respond differently to various levels of soil moisture and nutrients (Alban 1985b). Hoyle and Mader (1964) found that red pine height growth, which occurs primarily early in the season, was less sensitive to drought than was diameter growth, which occurs well into the fall when droughts are more likely

(Alban et al. 1987). Red pine has little genetic variation and is one of the most homogeneous pine species studied (Fowler and Lester 1970).

Red pine seed production normally begins at about 25 years in open stands and at 50 years in closed stands (Benzie and McCumber 1983) and is considered best in 50- to 150-year-old trees (Fowells 1965). Good seed crops are produced every 3 to 7 years, and bumper seed crops occur only once every 10 or 12 years (Fowells 1965). Because red pine is a weak seed producer (Van Wagner 1970), it is extremely vulnerable to local extinction (Bergeron and Gagnon 1987). Red pine seeds require close contact with mineral soil for best germination (Rouse 1988).

Red pine is relatively shade-intolerant, usually will not survive in a pre-existing stand, and generally cannot regenerate itself without the occurrence of fire (Roberts and Hruska 1986, Bergeron and Gagnon 1987, Rouse 1988). The most critical period in the life of a red pine tree is its first decade and possibly its first 2 years (Cook et al. 1952). Carmean et al. (1989) noted that red pine has slow and erratic height growth before reaching breast height, and Alban (1972) and Alban and Prettyman (1984) indicated that red pine takes about 8 years to reach breast height irrespective of site. If shaded, red pine seedlings may require 15 years to reach breast height (Fowells 1965), and red pine trees that have been overtopped for many years usually will respond when the overstory is removed (Kallio and Benzie 1980). The presence of brush greatly hinders red pine reproduction (Eyre and Zehngraff 1948).

Red pine grows in both pure and mixed stands (Benzie 1977). On drier sites, red pine is associated with American white birch, aspen, jack pine, and scrub oaks; on more moist sites, in addition to the foregoing, red pine is associated with balsam fir, red maple, red oak, white pine, and white spruce (Benzie 1977). The most common undergrowth in red pine stands includes American hazelnut, beaked hazelnut, raspberry, sweetfern, prairie willow, dwarf bush-honeysuckle, trailing arbutus, and spiraea (Benzie and McCumber 1983).

Red pine usually has thicker bark, has fewer natural enemies, and grows taller than its associates (Benzie 1973). Most woody species associated with red pine, with the exception of white pine and occasionally jack pine, typically are found in the understory (Fowells 1965). Red pine tends to form a taproot, and a wide-spreading root system mostly near the soil surface is common (Kallio and Benzie 1980). The ground surface of red pine stands typically is covered with deep, loose needle litter (Rouse 1988).

The potential longevity of red pine is over 100 years, allowing for the development of trees 0.61 m (2 ft) or more in diameter (Harlow and Harrar 1969). Growth rate from sapling stage to maturity is more rapid than in the seedling stage, and basal area growth may still be constant at 200 years of age (Fowells 1965). Red pine not only is relatively rapid growing and long-lived, it is also comparatively free of insects and diseases, and red pine prunes itself naturally the best of any conifer native to the Great Lakes states, with the possible exception of tamarack (Eyre and Zehngraff 1948). Red pine, with it rich color, attractive form, vigorous growth, and ability to be easily transplanted, is popular for ornamental plantings as well as plantations (Collingwood and Brush 1974).

Red Pine Silviculture

Red pine is considered to be the best general-purpose tree for the Great Lakes states (Eyre and Zehngraff 1948) and is the most intensively managed conifer type in that region (Benzie 1973). In 1982, red pine accounted for 88% of the conifer acreage being planted in the Great Lakes states by pulp and paper companies and for 57% of conifer acreage planted by state and federal agencies (Nicholls and Skilling 1990). Plantations or natural stands of red pine comprise about 2.5% of the Great Lakes states' commercial forests and contain nearly 1 billion cubic feet of volume (Lothner and Bradley 1984).

The typical management approach is to grow red pine in essentially pure, even-aged stands (Benzie 1973) regenerated by clearcutting and planting (Schone et al. 1984). Plantings are usually at high densities with the use of herbicides to reduce competition, and stands are thinned beginning at about age 25 (Schone et al. 1984). For certain situations, seed tree or shelterwood systems have been recommended over clearcutting for red pine regeneration (Heeney 1978, Benzie and McCumber 1983).

Red pine grows well over a wide range of stocking densities (Berry 1984) and usually produces straight, high quality timber (Eyre and Zehngraff 1948). Periodic thinning is a necessary cultural practice in managing red pine plantations for sawtimber and other products for which fairly large tree diameters are important (Rudolph et al. 1984), and red pine diameter growth response to thinning is excellent (Lundgren 1981). In red pine plantations, establishment of 2,000 trees/ha (800 trees/ac) with thinning every 10 years to a constant basal area of 27.6 m^2/ha (120 ft^2/ac) can produce close to the maximum merchantable cubic-meter volume/ha for a wide range of sites (Lundgren 1981, 1983). In general, residual basal areas after thinning of 27.6 - 32.1 m^2/ha (120 - 140 ft^2/ac) are recommended for maximum volume production of red pine (Dickmann et al. 1987).

Mean annual increment of red pine does not peak until at least age 50 (Lundgren 1981). Sixty- to 100-year rotations are commonly recommended as is the maintenance of some old growth stands to 200 years of age (Capen 1979). Currently in the Great Lakes states, rotation lengths commonly vary from 40 years on high-quality, industrial pulpwood-production sites to 120 years on public agency, sawlog-production sites (Schone et al. 1984). Red pine is adapted to the use of prescribed fire in the understory from small sawtimber size onward (Van Wagner 1970, Dickmann et al. 1987).

Red pine is highly productive and has versatile wood (Lundgren 1981, Lothner and Bradley 1984, Schone et al. 1984). In the Great Lakes states, red pine has been found to yield more volume than alternative species such as jack pine, sugar maple, white spruce, black spruce, and quaking aspen (Schlaegel 1975, Alban 1978, 1985b; Frederick and Coffman 1978). Products from red pine include pulpwood, poles, posts, cabin logs, piling, sawtimber, and veneer (Nicholls and Skilling 1990).

Red pine commands higher prices than any other softwood species in the Great Lakes states (Lothner and Bradley 1984). The Michigan market for red pine has been strong since 1983, and a large increase in red pine markets has been attributed to the recent introduction of "chip-and-saw" technology in Michigan (Smith and Blyth 1989). Because of red pine's fast growth, high productivity, and high economic value, to help meet projected needs for softwood sawtimber, it has been recommended that red pine be restored on several million acres that were converted to other cover types after the original pine logging (Benzie 1977).

Pine Stands as Wildlife Habitat

A wide assortment of grasses, forbs, and browse develops for about 3 to 5 years after a pine plantation is established, and between 5 and 8 years, crowns of young pines rapidly close and forage growth declines with the diminishing light (Blair 1968, Blair et al. 1977). Upon crown closure, wildlife forage remains sparse until trees are thinned or clearcut (Blair and Enghardt 1976, Blair et al. 1977). Plant species diversity of plantations tends to peak as young trees develop enough height to become a layer distinct from the herbs and shrubs and then tapers off as the tree canopy closes (Hunter 1990). Capen (1979:90) submitted that intensive timber management may create "biological deserts" in pine forests, and Johnson (1987) stated that the "biological desert" paradigm often is applicable to individual pine stands but only after crown closure.

Mature, unthinned red pine stands typically are close-canopied and dense with little understory development (Van Wagner 1963, Fowells 1965, Kennedy and Wilson 1971, Dickmann et al. 1987). In a New York study, hardwood seeds germinated under red pine, but few reached larger size classes possibly due to limited phosphorus uptake by the seedlings; suppression of hardwood seedlings appeared to be dependent on the density of live red pines (Tobiessen and Werner 1980). In a Michigan study, only 4.2% of the total ground area under a red pine stand was covered by crowns of trees less than 1.8 m high, most of it being pine (Gysel 1966). Furthermore, red pine has been shown to have less understory development than other plantation pines (Mergen and Malcom 1955, Tappeiner and Alm 1975). As a result, high density (>32.1 m^2/ha (>140 ft^2/ac)) red pine stands generally are considered to be of little value to most wildlife species due to the limited structural diversity and wildlife forage in the understory (Ffolliott and Worley 1965, Benzie 1977, Benzie and McCumber 1983, Dickmann et al. 1987). For instance, white-tailed deer and small mammal populations were found to be low in a red pine plantation as compared to the surrounding area in Michigan (Gysel 1966).

However, old-growth red pine stands do provide habitat for some species such as martens, red squirrels, and pileated woodpeckers (Benzie and McCumber 1983). Bald eagles have been found to build nests in large old-growth red pine trees, and several songbirds such as the red-breasted nuthatch, blackburnian warbler, pine warbler, and chipping sparrow are associated with pine forests (Benzie 1977, Benzie and McCumber 1983). Hetzel (1941) recorded the presence of starlings roosting in a red pine plantation in Pennsylvania (Grisez 1968). White-footed mice, red-backed voles, eastern chipmunks, red squirrels, snowshoe hare, and porcupines are a few of the smaller mammals that have been shown to occur in red pine stands (Eyre and Zehngraff 1948, Fowells 1965, Gysel 1966).

Multiple Use

Multiple use management applies to practically all privately and publicly owned wildlands (Driver 1990). Several statutes, such as the National Forest Management Act of 1976, mandate the U.S.D.A. Forest Service to integrate wildlife habitat needs into the planning process for national forests (Mathisen 1988, Wargo 1990). Biodiversity legislation that is pending in Congress may further require the consideration of multiple uses on both state and federal forestland (J. B. Haufler, Michigan State University, pers. comm.). Finally, forestry and wildlife integrated approaches to management of private forestland have been recommended (Kelley et al. 1983).

Multiple use raises the difficult question of which uses will be emphasized and how (Driver 1990). Current forest management typically strives to meet multiple use objectives through integration of timber, wildlife, and recreation objectives (Haufler 1990), and integrated wildlife and timber management has been noted to be a viable management opportunity on forestlands with multiple use objectives (Flather and Hoekstra 1989). However, difficulties in designing prescriptions and standards to guide management for multiple uses and the need for improved planning and management techniques are problems in achieving multiple use objectives (Driver 1990). Furthermore, precedents exist for managing to provide commodity outputs, and the change in orientation away from past practices, such as primary emphasis on timber production, has been slow by public land management agencies (Driver 1990).

Wildlife and timber management goals often are considered incompatible (Kelley et al. 1983). Typically, wildlife managers strive for woody species diversity, a relatively long rotation with trees old enough to produce good mast crops and to allow formation of cavities, and a sparsely stocked overstory to allow for understory development. In contrast, commercial timber growers typically want full-site occupancy by the commercially desired species, a short time between investment and return on the investment, high growth and yield rates, and economic efficiency in management (Johnson 1987). The wildlife objective may conflict with the "best" silviculture (Mathisen 1988), since integration of wildlife management into timber management prevents any one resource output from being maximized (Flather and Hoekstra 1989). But, for goals that do not include maximum production, wildlife and timber may be able to be produced at levels that satisfy both the wildlife manager and the forester.

Spacing distance, intermediate silvicultural treatments, timber harvesting methods, and harvest rotations can be designed to maintain or enhance the quantity and quality of wildlife habitat in pine stands (Flather and Hoekstra 1989). Planting red pine at wide spacings (e.g. up to 10 x 10 ft) favors ground vegetation (Benzie 1977), and a spacing of 2.4 x 3.0 m (8 x 10 ft) has been suggested to be a reasonable compromise between deer habitat and timber production in southern pine plantations (Halls 1973b). Maintaining an open canopy has been identified as a key for maintaining wildlife diversity in stands past the establishment phase (Hunter 1990). The frequency of intermediate cuttings will depend on the objective of the stand: A stand managed for saw logs is likely to be thinned several times,whereas a stand managed on a short pulpwood rotation is unlikely to be thinned at all (Halls 1970).

Managing red pine stands near the minimum recommended stocking level favors a greater variety of understory plants and thus increases the supply of wildlife food (Benzie 1977, Benzie and McCumber 1983). Results from Dickmann et al.'s (1987) research in Michigan indicated that lightly stocked red pine stands growing on better soils produced a diverse and abundant undergrowth that was utilized by wildlife, and studies from surrounding regions have reported similar findings (Buckman 1964, Van Wagner 1965). Generally, growing stock densities below 20.7 m^2/ha (90 ft^2/ac) of basal area will increase the wildlife value of a red pine plantation because higher densities severely limit the development of understory vegetation (Schone et al. 1984). Since stand densitites of less than 17.2 m^2/ha (75 ft^2/ac) are usually inadequate for growing profitable crops of southern timber, Halls (1970) concluded that a stocking density somewhere between 17.2 and 20.7 m^2/ha was practical for growing both timber and deer. In concurrence, Dickmann et al. (1987) concluded that residual basal areas of 16.1 - 20.7 m^2/ha (70 - 90 ft^2/ac) offered the best compromise between production of timber and wildlife habitat in red pine stands.

Prescribed burning in conjunction with heavy thinnings in mature red pine stands can allow production of valuable, large diameter trees and can provide vegetative layers available to wildlife (Dickmann et al. 1987). For instance, frequent (i.e. 5- to 10-year intervals), low-intensity fires that kill aerial portions of hardwood vegetation will promote low coppice growth and thus increase accessible wildlife browse (Benzie 1977, Rouse 1988). Furthermore, prescribed burns can increase the nutritional value of vegetation (Nagy and Haufler 1980).

A relatively open red pine stand not only can produce more forage for wildlife than a tightly closed stand, it also can produce greater water yields and is considered more aesthetically pleasing (Dickmann et al. 1987). Prescribed burning can serve to maintain an aesthetically pleasing red pine stand when recreation is an objective (Dickmann et al. 1987, Rouse 1988). Hence, managing red pine stands near the minimum recommended stocking levels, providing openings, and using prescribed burning can enhance wildlife habitat as well as recreation in mature red pine stands (Benzie 1977, Dickmann et al. 1987).

Justification

Whether thinning of pine plantations improves their suitability as wildlife habitat by extending the period during which the forest canopy is open and conducive to the production of understory plants has been identified as an important management question (Conroy et al. 1982). In addition, incomplete information on how wildlife responds to timber management activities makes integration of wildlife and forestry difficult (Flather and Hoekstra 1989). Thus, wildlife managers need information on how red pine timber practices affect the distribution and abundance of animals (Patton 1969), and foresters need information on production of red pine timber at lower basal areas. Management schemes that result in the least reduction in red pine timber production and the most improvement in wildlife habitat need to be developed in order to facilitate sound stewardship of these natural resources when both wildlife and red pine timber are objectives for a tract of land (McConnell and Smith 1970).

OBJECTIVES

The primary objective of this research was to evaluate the responses of elk, white-tailed deer, and small mammals to thinning of mature red pine stands. The secondary objective was to evaluate the response of understory vegetation to thinning of mature red pine stands in terms of wildlife habitat produced. In order to accomplish these objectives, the following were determined:

1. Elk and white-tailed deer use of thinned and unthinned mature red pine stands.

2. Small mammal abundance and diversity on thinned and unthinned mature red pine stands.

3. Composition, structure, and productivity of understory vegetation in thinned and unthinned mature red pine stands.

STUDY AREA

Research was conducted in the north-central lower peninsula of Michigan, T32,33N R1W. Study plots were within the 33,590 ha Pigeon River Country State Forest (P.R.C.S.F.) which is approximately 21 km east of Vanderbilt, Michigan, occupying portions of Cheboygan, Montmorency, and Otsego counties (Fig. 1).

The P.R.C.S.F. is within the Emmet-Alcon Hill Land, Huron Lake-Border Plain, and the Presque Isle Rolling Plain physiographic regions (Sommers 1977). Highly fertile soils on swampy areas, medium-high fertility soils on till plains and moraines, and dry, sandy soils on outwash plains are the predominant soil types of the P.R.C.S.F. (Moran 1973) and were deposited in the Pleistocene epoch (Sommers 1977). The watershed is drained by the Black River, Pigeon River, and Sturgeon River which originate in the coniferous swamps on the southern edge of the P.R.C.S.F. and flow northward (Moran 1973).

The climate of this region alternates between continental-type and semi-marine, and the area is characterized by large daily, monthly, and seasonal temperature changes (Moran 1973). Winds from Lake Superior and Lake Michigan help to moderate temperature extremes in summer and winter (Moran 1973). Mean monthly precipitation and temperature for the years of the study are presented in Figures 2 through 5 (National Oceanic and Atmospheric Administration 1987, 1988, 1989, 1990).

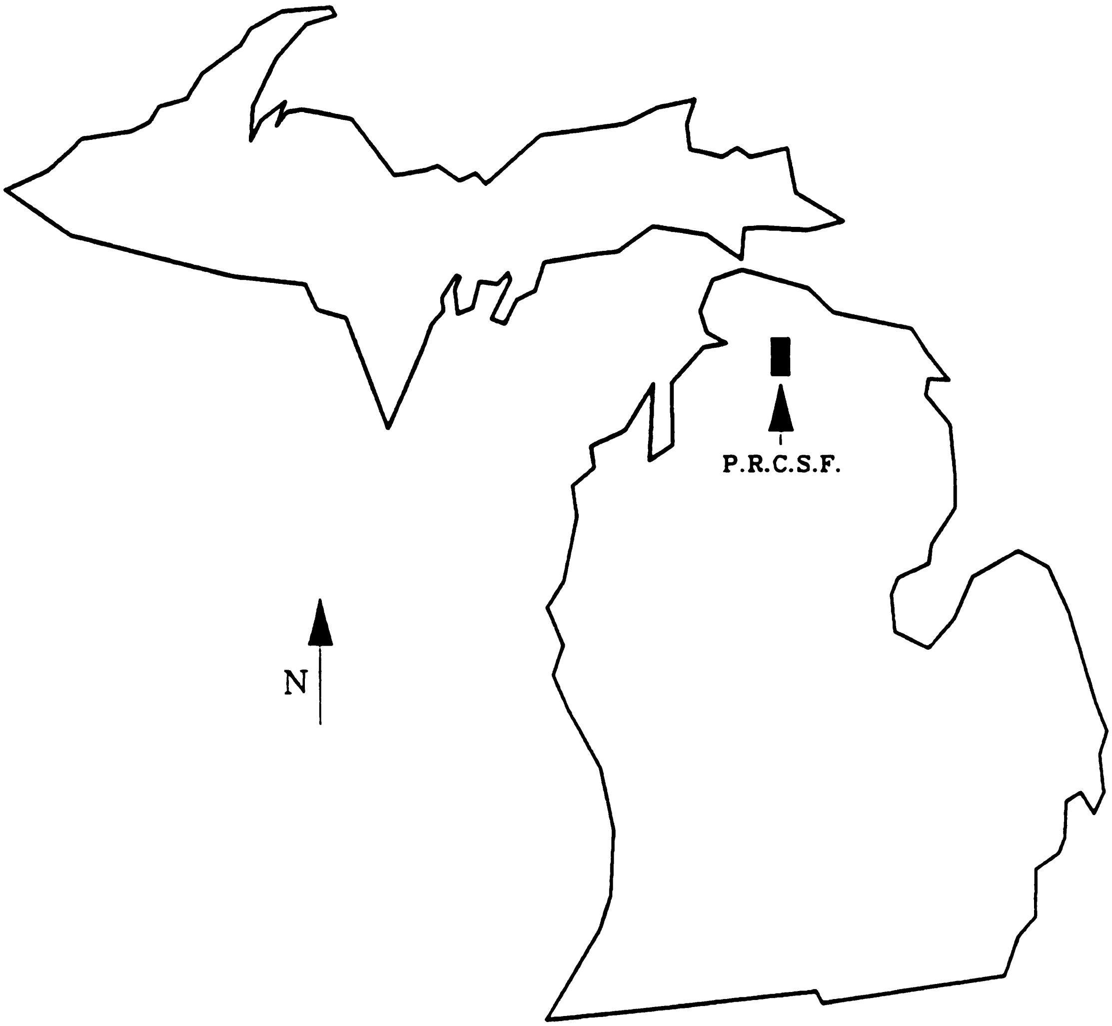


Figure 1. Location of Pigeon River Country State Forest (P.R.C.S.F.), Mich.

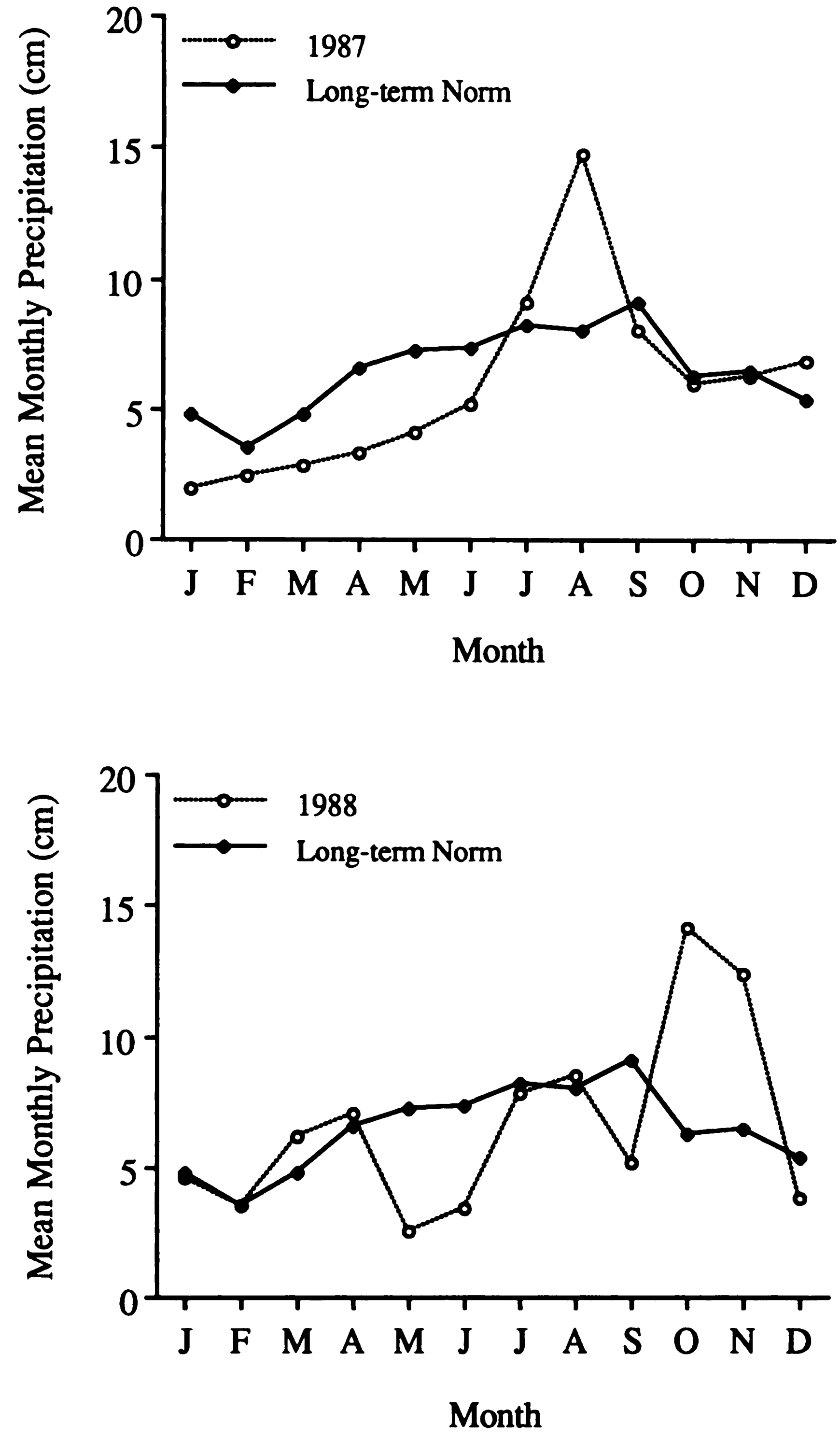


Figure 2. Mean monthly precipitation (cm) during 1987 and 1988 with the long-term average, Vanderbilt, Mich.

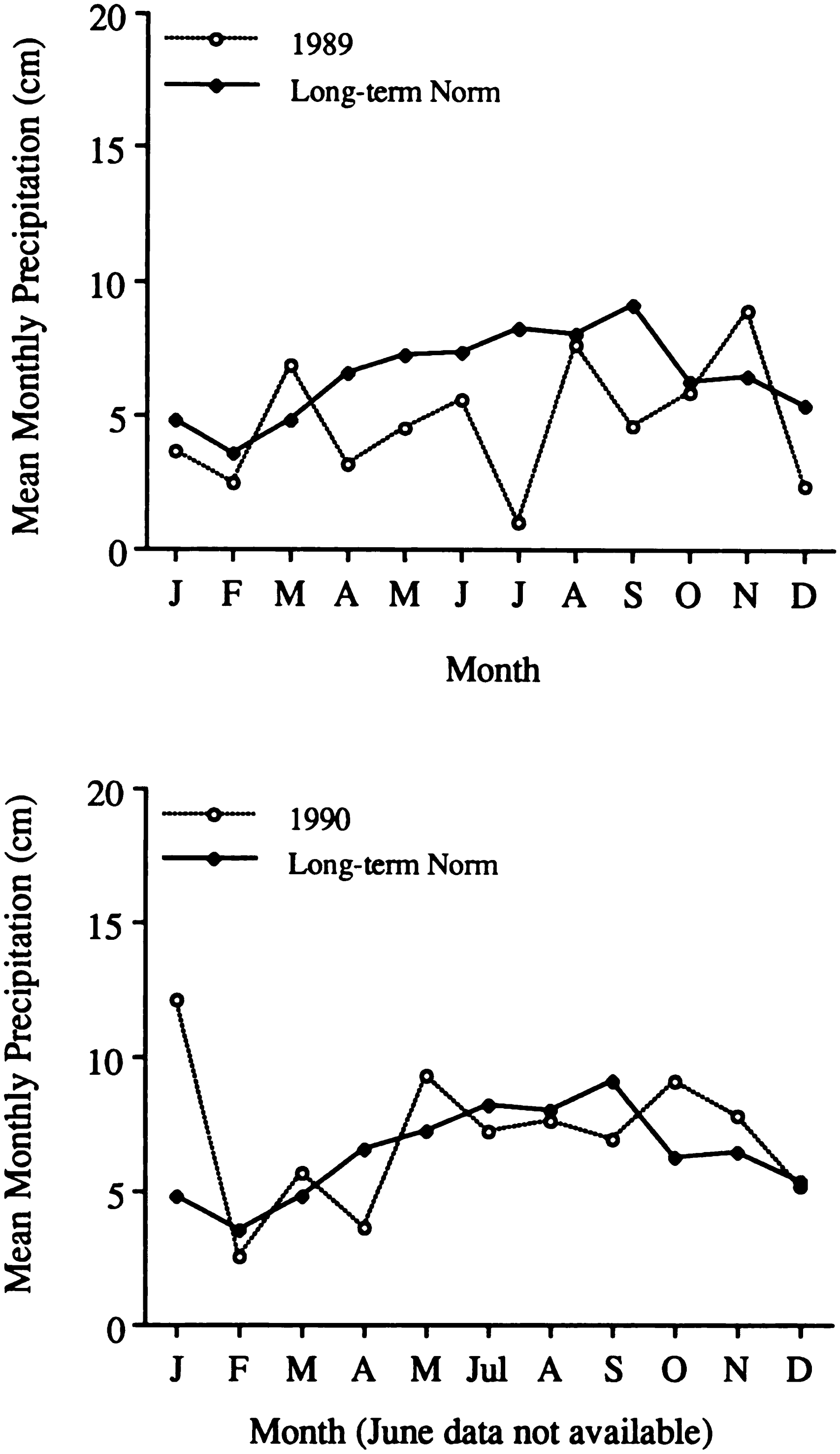
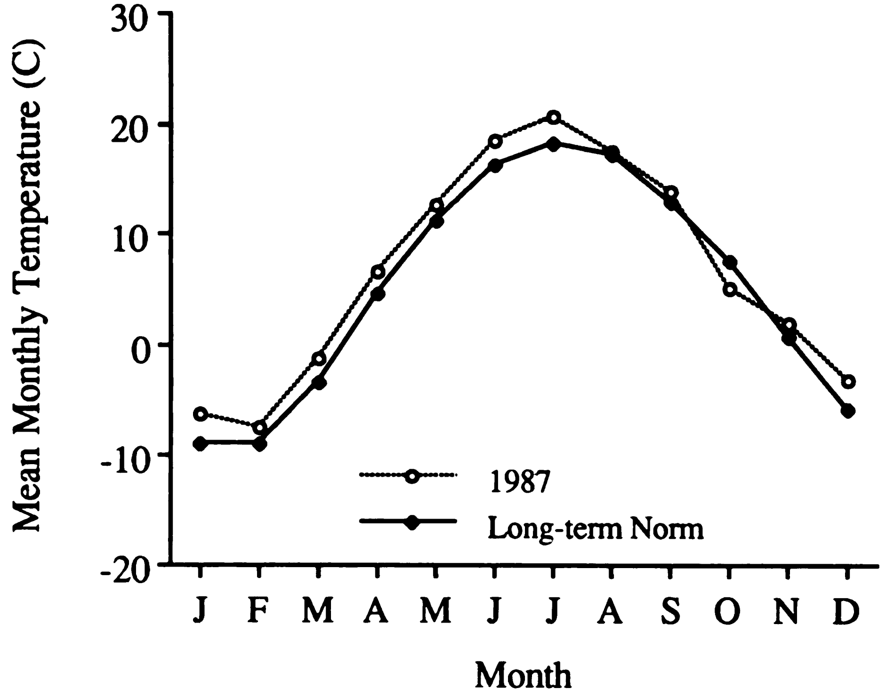


Figure 3. Mean monthly precipitation (cm) during 1989 and 1990 with the long-term average, Vanderbilt, Mich.



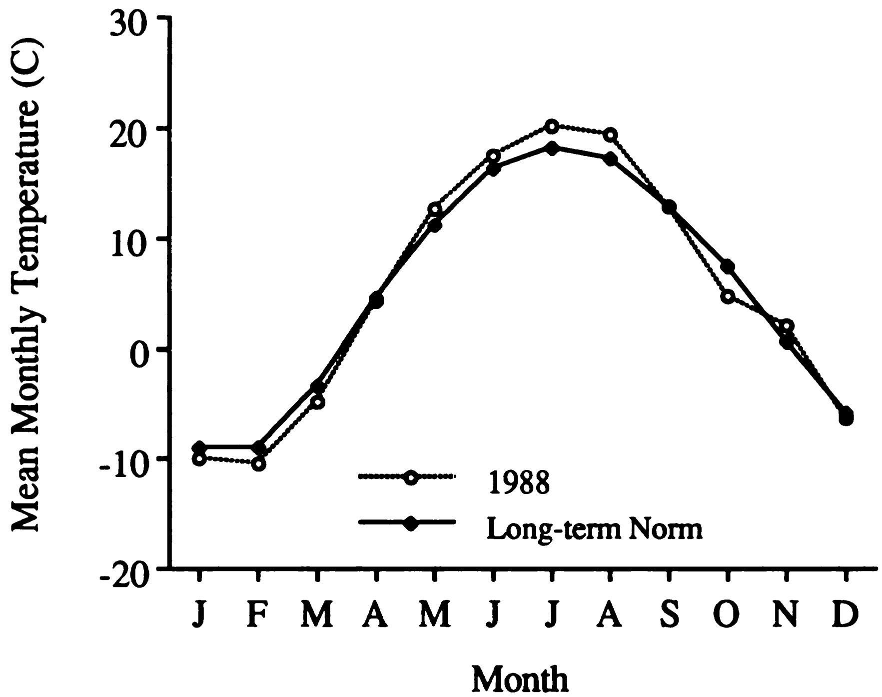
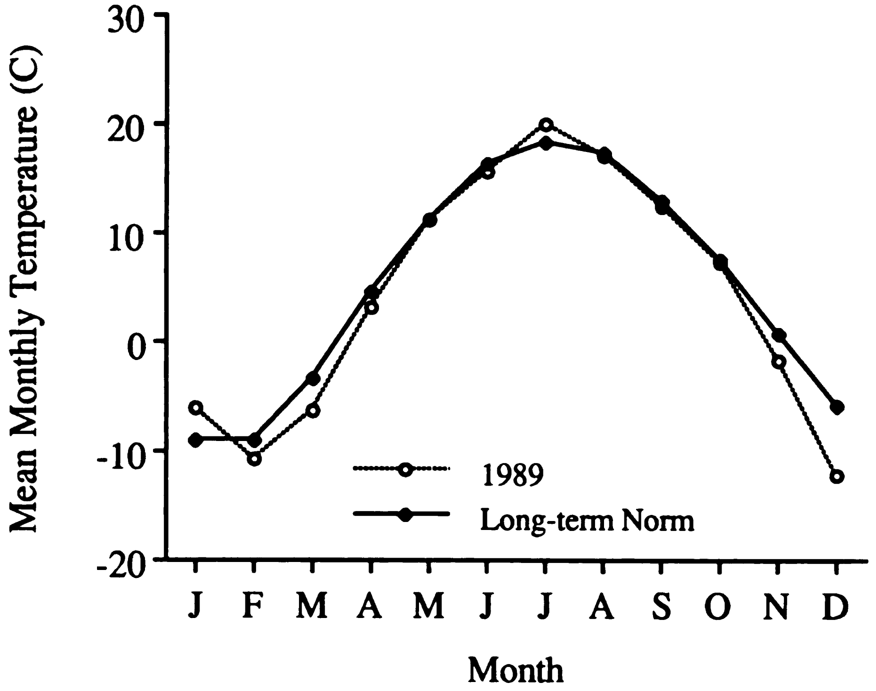


Figure 4. Mean monthly temperature (C) during 1987 and 1988 with the long-term average, Vanderbilt, Mich.



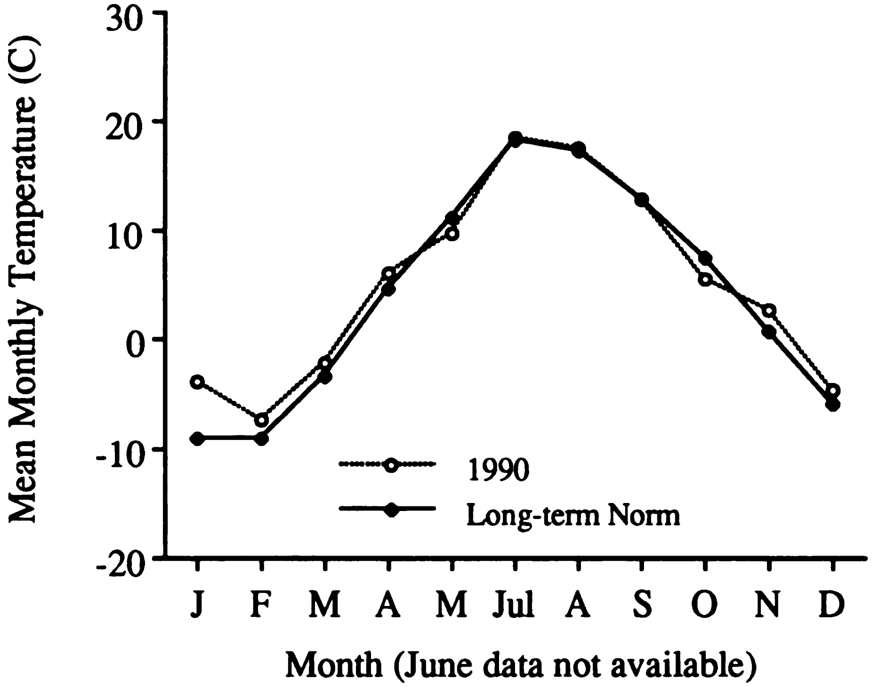


Figure 5. Mean monthly temperature (C) during 1989 and 1990 with the long-term average, Vanderbilt, Mich.

The original forests of the area were primarily mixed hardwoods and pine on the moraines and nearly pure jack pine on the sandy plains (Zon and Sparhawk 1923, Ramsdell 1937). Today the area is a complex mosaic of plant associations that is the result of revegetation of an irregular land surface left relatively sterile by the exploitative logging of the last century followed by 30-odd years of repeated slash and brush fires (Spiegel et al. 1963). The vegetative types present within the P.R.C.S.F. include (1) riverbanks and bottomlands, (2) sandy outwash plains, (3) outwash plain-morainic ecotone, (4) steep morainic slopes, (5) morainic uplands (Spiegel et al. 1963), and (6) coniferous swamps (Moran 1973). Land management practices such as farming, logging, prescribed burning, and establishment of forest plantations supplement the natural diversity of vegetation within the P.R.C.S.F. (Beyer 1987).

In 1987, 18 2-ha (5-ac) study plots were established in mature red pine plantations of relatively uniform site characteristics, age, and composition (Table 1). The overstory of the study plots was composed almost entirely of red pine with an occasional jack pine. Prior to the onset of the study, the understory was sparsely vegetated with primarily deciduous woody vegetation, and ground cover was scarce to absent (Bender 1990). High quality Emmet sandy loam was the primary soil type on the study plots, and site indices ranged from 18.3 to 23.2 m (Table 1) (Bender 1990).

Table 1. Stand and site characteristics of the 18 red pine study plots, Pigeon River Country State Forest, Mich. (Bender 1990).

	Year Planted	Year Thinned	Site Index (m)		Basal Area (SE) (m^2/ha) as of early 1988
Control Replicates					
1	1930		18.3		33.1 (5.0)
2	1931		18.3		34.4 (3.4)
3	1932		20.1		36.9 (7.0)
				mean	34.8 (1.1)
25.3 m^2/ha Treatment Replicates					
1	1928	1987	18.9		25.5 (3.6)
2	1931	1987	21.3		26.3 (5.7)
3	1931	1987	18.3		21.2 (4.7)
4	1931	1987	18.3		24.6 (4.3)
5	1932	1987	20.1		22.7 (2.3)
6	1932	1987	20.1		20.1 (5.4)
				mean	23.4 (1.0)
16.1 m^2/ha Treatment Replicates					
1	1930	1987	23.2†		18.0 (3.3)
2	1930	1987	23.2†		18.7 (3.3)
3	1930	1987	23.2†		18.1 (3.0)
4	1930	1987	23.2†		16.3 (4.0)
5	1930	1987	23.2†		18.3 (1.7)
6	1930	1987	23.2†		17.3 (3.0)
7	1931	1986	18.6		20.3 (3.6)
8	1931	1986	18.6		23.4 (3.1)
9	1931	1986	18.6		20.0 (1.1)
				mean	18.9 (0.7)

† Actual site index much more variable among plots.

METHODS

The research design included two thinned treatment groups and an unthinned control group:

(1) Nine plots thinned to a target basal area of 16.1 m^2/ha (70 ft^2/ac) each.

(2) Six plots thinned to a target basal area of 25.3 m^2/ha (110 ft^2/ac) each.

(3) Three plots (not thinned) with a basal area greater than 32.1 m^2/ha (>140 ft^2/ac) each.

After initial thinning, the treatment plots were reevaluated for basal area. The nine targeted to be 16.1 m^2/ha averaged 18.9(0.7) m^2/ha (82.3(3.0) ft^2/ac), and the six targeted to be 25.3 m^2/ha averaged 23.4(1.0) m^2/ha (101.9(4.4) ft^2/ac) (Table 1). The controls averaged 34.8(1.1) m^2/ha (151.6(4.8) ft^2/ac) in early 1988.

The thinning treatments were not performed concurrently as was desired by the proposed study design because they were contracted timber sales by the Forestry Division of the Michigan Department of Natural Resources. That is, three of the 16.1 m^2/ha plots were thinned in 1986 which was 9 to 12 months earlier than the thinning of the other 12 treatment plots. Consequently, these three plots have an additional season's growth as compared to the other study plots.

In spring and summer of 1990, each of the 15 thinned plots was once again evaluated for basal area and rethinned if necessary. To determine overstory basal area, transects were randomly placed in each of the thinned plots and readings from a 10-factor basal area prism were recorded every 20 m. Only live overstory red pine basal area was included. All trees within the prism plots were tallied; trees on the plot border were counted as one-half. Growth rates and productivity of the overstory red pine on the study plots are monitored by the Department of Forestry, Michigan State University.

Vegetation Sampling

Annual productivity was determined for herbaceous vegetation and two woody species, black cherry and red maple, using the clip and weigh technique (Gysel and Lyon 1980). Each plot was stratified into 10 blocks, and a point was randomly located within each block in order to representatively sample the plot. Only 10 samples of each were collected in each plot to minimize the effects of removing vegetation on the structure or composition of the plots. Furthermore, 10 samples of each from each plot were believed to be sufficient to provide relative comparisons between treatments and controls.

Vegetation was collected at the end of the growing season in late August of 1990. The random point became the southwest corner of a 1-m^2 plot in which all herbaceous material was clipped (Conroy et al. 1982). The current annual growth from 0 - 2 m of the nearest black cherry and red maple >1-m tall and <10.2 cm in diameter at breast height (d.b.h.) to the random point was clipped. Vegetation was stored in paper bags until dried at 65 C to a constant weight.

A coordinate system with two adjacent sides of a plot serving as coordinate axes was used to aid in location of random points to sample herbaceous frequencies, woody stem densities, horizontal cover, and vertical cover. Pairs of random numbers served as coordinates for vegetation sampling locations. Each vegetative parameter was sampled by the same individual in each plot in order to minimize observer bias. On the plots bordered by a road or an opening, a 5-m strip from the road or opening was not sampled in order to reduce edge effects.

In the summer of 1990, herbaceous vegetation and brambles were sampled in 2x5-m quadrats as present or absent in order to calculate frequencies. Densities of woody species were determined in 2x30-m quadrats in the summers of 1989 and 1990. Within each quadrat, each stem of a woody species >1-m tall and <10.2 cm in d.b.h. originating below ground was tallied.

Horizontal cover was quantified using a profile board in the summers of 1989 and 1990 (Nudds 1977). For this procedure, a profile board was held upright at a random point, and the observer went 15 m in a randomly selected cardinal direction and faced the board. The observer then recorded the percentage of each of four layers (0 - 0.5 m, 0.5 - 1.0 m, 1.0 - 1.5 m, and 1.5 - 2.0 m) obscured by vegetation. In 1989, coverage was recorded as a single digit score (1 to 5) corresponding to the mean value of a range of quintiles: 0 - 20%, 21 - 40%, 41 - 60%, 61 - 80%, or 81 - 100% (e.g. 1 corresponded to the range from 0 - 20%) (Nudds 1977, Gysel and Lyon 1980). In 1990, coverage was recorded in a similar manner except 0% and 100% coverages were recorded separately in an attempt to increase accuracy of the estimate.

Vertical cover was quantified using 30-m line intercepts in the summers of 1989 and 1990. Cover within different strata was measured by estimating the length that the vegetation in each stratum intercepted the line of the tape (MacArthur and MacArthur 1961, MacArthur and Horn 1969, Gysel and Lyon 1980). In 1989, vegetation in three height strata (0 - 1 m, 1 - 7 m, and >7 m) was sampled. In 1990, vertical cover was further stratified into 1 - 2 m and 2 - 7 m strata enabling an evaluation of the vegetation accessible to deer and elk (i.e. the vegetation <2 m).

Determining Wildlife Responses

Browse utilization surveys and pellet-group counts provided indices of elk and white-tailed deer relative use among treatments and controls. Browse utilization surveys were conducted on each study plot in early April of 1990, using a modified version of the intensive browse utilization survey technique described by Wyoming Game and Fish (1982). Three woody species considered as being low to high preference to ungulates (beech, black cherry, and red maple, respectively) (Spiegel et al. 1963, Blair and Brunett 1980, Rogers et al. 1981) were surveyed for utilization in an attempt to represent the full continuum of ungulate browse preference (Bender 1990).

A corner of each plot was randomly chosen as a starting point, and a transect to the diagonal corner was walked. Every 3 - 4 m, the nearest stem >1-m tall and <10.2-cm d.b.h. of each of the three woody species was located with the goal to survey at least 50 individuals of each species. If the tree was <2-m tall, each current annual growth twig was counted and the number browsed noted. If the tree was >2-m tall, then a branch on the tree below 2 m was randomly selected and the percent of current annual growth twigs browsed on that branch was recorded. Trees were surveyed for browsing below 2 m in height in order to represent what is typically available to deer and elk (Philleo et al. 1978, Conroy et al. 1982).

In April of 1990, pellet-group counts were conducted in three 6x100-m quadrats that had been systematic-randomly established on each study plot in 1987. Counts were made after snowmelt because the possibility of missing groups is minimized by making counts prior to new growth of grasses and forbs, and the influence of dung beetles upon counts is also minimized (Robinette et al. 1958). A group of more than five pellets was considered a pellet group (Rowland et al. 1984). Pellet groups that were on the border of the quadrat were counted when at least half of the group was within the quadrat (Robinette et al. 1958).

Pellet groups were identified to species by size and shape. Counts from each of the three quadrats per plot were added to produce one value per plot for both deer pellet groups and elk pellet groups. These two values were then added to produce a total pellet group per plot value, since identification of pellet groups to species is not always feasible where more than one pellet-forming ruminant is present (Murie 1954, Neff 1968). Also, determining a total ungulate pellet-group count provided a larger value for comparisons, possibly better enabling detection of differences among treatments and controls. Each count was made by the same individual to minimize observer bias, and once a pellet group was counted, it was removed from the quadrat in order to minimize seasonal and double count biases (Neff 1968).

Small mammals were live-trapped using Sherman live traps (H. B. Sherman Co., Tallahassee, Fla.) during trapping periods of 5 consecutive days each in both July and August of 1989 and 1990. A 6x6 point grid, centered on the plot, had been established on each plot in 1987, and trap locations were spaced about 20 m apart (Smith et al. 1975). Capture results from 1987 using two traps per location were so low as to warrant subsequent use of only one trap per location (Bender 1990), so one trap was selectively placed at each location to maximize the likelihood of capture. The bait was a mixture of about 510 gm (18 oz) peanut butter to 3.8 l (1 gallon) of rolled oats to three drops of anise extract. Each trap was checked early each morning of the trapping periods, and the order in which the plots were checked was rotated each day. All captured small mammals were ear-tagged, and species, tag number, and trap location were recorded.

Data from the 16.1 m^2/ha treatment group (referred to as the low basal area treatments [LBAT]), the 25.3 m^2/ha treatment group, (referred to as the high basal area treatments [HBAT]), and the control group were compared within a year to evaluate treatment effects. When data from 1988 (Bender 1990) were available, comparisons of the same treatment over years were made to identify any short-term trends. Data from controls and pretreatment HBAT plots (1987), but not from pretreatment LBAT plots, are available in Bender (1990) for comparison to subsequent-year data. Comparisons within a year were also made of 16.1 m^2/ha plots that were thinned in different years in order to evaluate effects, if any, of not applying the treatment concurrently. Plots that were thinned to 16.1 m^2/ha of basal area in 1986 are referred to as LBAT86, and those thinned to that basal area in 1987 are referred to as LBAT87.

Data Analysis

A statistically adequate sample size for each measurement was determined using Freese's (1978) sample size determination formula:

$$n = (t^2 s^2)/E^2, \text{ where}$$

t = tabulated *t* value at the 90% probability level

s^2 = sample variance

E = allowable error = (mean x 0.10)

The Shapiro-Wilk test for normality was performed on each data set. The parametric assumption of normal distribution was not met, so nonparametric statistical tests were used (Siegel 1956). Comparisons of data among the 16.1 m^2/ha, 25.3 m^2/ha, and control plots (hereon referred to as plot-groups) were made using the Kruskal-Wallis one-way analysis of variance. Comparisons of data between any two plot-groups were made using the Mann-Whitney *U* test. A significance level of p = 0.10 was used for all comparisons.

Small mammal diversity was calculated using the Shannon-Weaver function which measures the average degree of uncertainty of predicting the species of a given individual picked at random from a community (Hair 1980). It was computed with the following formula (Poole 1974):

$$H' = -\sum_{i=1}^{S} p_i (\ln p_i), \text{ where}$$

S = the total number of species

p_i = the proportion of the total number of individuals consisting of the i th species

$\ln p_i$ = the natural log of p_i

The minimum number of individuals of each species known alive (i.e. the minimum population size) on each plot during each of the two sampling periods in both 1989 and

1990 was used as an index of small mammal abundance. It was determined by a count of captures of each species minus the recaptures of that species.

From the vertical cover data, foliage height diversity (F.H.D.) was calculated also by using the Shannon-Weaver function, where

S = the total number of strata sampled

p_i = the proportion of the total cover in the i^{th} stratum

$\ln p_i$ = the natural log of p_i

RESULTS

Annual Productivity

In 1990, annual productivity of herbaceous vegetation was significantly greater on LBAT [534.7(45.3) kg/ha] and HBAT [473.3(81.0) kg/ha], which did not significantly differ, than on controls [101.7(33.4) kg/ha]. Red maple annual productivity on LBAT was significantly greater than that on either HBAT or controls in 1990 (Fig. 6).

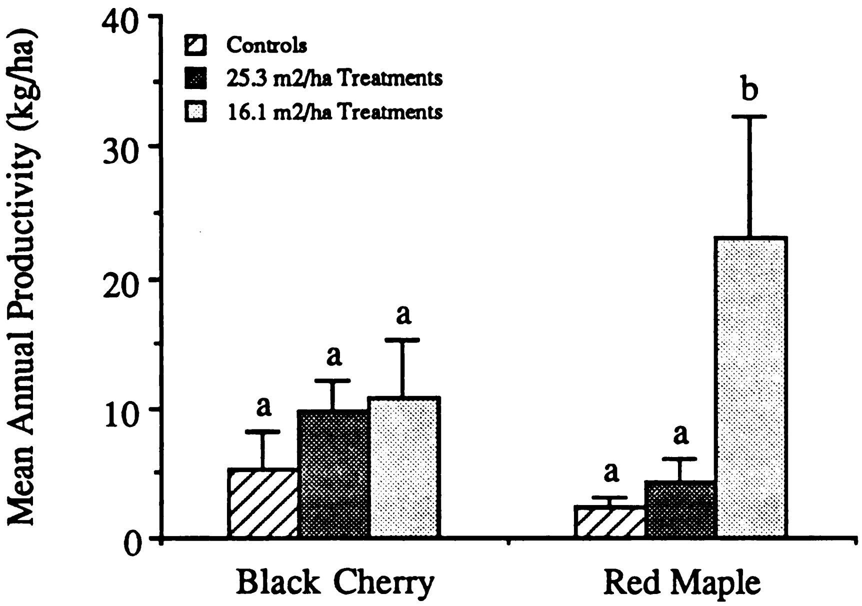


Figure 6. Mean annual productivity (kg/ha) of black cherry and red maple on red pine study plots, Pigeon River Country State Forest, Mich., 1990.

a,b Means with the same letters within the same species are not significantly different ($p > 0.10$).

Frequencies

Absolute and relative frequencies of herbaceous species and brambles for 1990 are presented in Table 2. Burdock, clover, common chickweed, daisy, daisy fleabane, evening primrose, mullein, St. johnswort, and yarrow were found on both treatments but not on controls. Yet, of the 80 species sampled, few significant differences were found. Absolute and relative frequencies of brambles and mullein were significantly higher on treatments than on controls. Absolute frequencies of clover and pearly everlasting were significantly higher on the HBAT than on controls. The relative frequency of field sorrel was significantly higher on LBAT than on either the HBAT or controls. The average number of identified herbaceous species was significantly higher on the HBAT than on either the controls or the LBAT, and the total number of identified species increased with decreasing basal area.

Comparisons of absolute frequencies of herbaceous species between 1988 and 1990 are presented in Table 3. The total number of herbaceous species recorded for all three plot-groups increased from 43 in 1988 to 80 in 1990. Canada mayflower was the only herbaceous species that was significantly more frequent on each of the three plot-groups in 1990 than in 1988. Wild sarsaparilla was significantly more frequent in 1990 than in 1988 on HBAT and on LBAT but not on controls. Mullein increased significantly from 1988 to 1990 on the HBAT, and aster and pussytoes were significantly more frequent in 1990 than in 1988 on the LBAT. Aster and mullein were the only two species that increased from 0% AF in 1988 to a significantly higher AF in 1990, and each of these emergences occurred on a treatment (LBAT and HBAT, respectively). In summary, each of the significant differences detected from 1988 to 1990 was a result of an increase in frequency.

Table 2. Mean absolute frequencies (AF) (%) and mean relative frequencies (RF) (%) with standard errors of herbaceous vegetation and brambles found on red pine study plots, Pigeon River Country State Forest, Mich., summer 1990.

	Control Plots		25.3 m^2/ha Plots		16.1 m^2/ha Plots	
Species	AF	RF	AF	RF	AF	RF
Anemone	11.1(5.9)	1.5(0.9)	4.4(1.9)	0.4(0.2)	3.0(0.7)	0.3(0.1)
Aniseroot	23.3(21.7)	2.6(2.3)	12.2(7.1)	1.1(0.6)	3.0(1.5)	0.3(0.2)
Arrow-leaved aster	45.6(14.4)	6.2(1.9)	30.6(4.0)	3.3(0.5)	33.3(5.3)	3.7(0.5)
Aster	5.6(1.1)	0.8(0.1)	7.8(4.0)	0.9(0.5)	6.3(2.0)	0.7(0.2)
Bedstraw	47.8(18.7)	6.2(1.7)	60.0(10.7)	6.3(0.8)	34.4(7.0)	3.9(0.7)
Bitter dock	0.0(0.0)	0.0(0.0)	0.6(0.6)	0.1(0.1)	0.0(0.0)	0.0(0.0)
Blueberry	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.4(0.4)	0.1(0.1)
Bracken fern	35.6(20.2)	5.8(3.4)	64.4(14.7)	7.6(2.1)	47.8(7.7)	5.4(0.7)
Bramble	23.4(6.7)^{a}	3.1(0.4)^{A}	63.3(6.0)^{b}	6.9(0.6)^{B}	81.9(2.7)^{c}	9.8(0.9)^{C}
Bristly sarsaparilla	3.3(1.9)	0.4(0.2)	1.1(0.7)	0.1(0.1)	0.4(0.4)	0.1(0.1)
Bunchberry	1.1(1.1)	0.2(0.2)	8.9(4.4)	1.0(0.6)	7.8(3.9)	0.8(0.4)
Burdock	0.0(0.0)	0.0(0.0)	1.1(0.7)	0.1(0.1)	0.4(0.4)	0.0(0.0)
Canada anemone	0.0(0.0)	0.0(0.0)	3.9(2.0)	0.4(0.2)	0.0(0.0)	0.0(0.0)
Canada mayflower	51.1(11.8)	7.5(2.4)	60.6(13.5)	6.5(1.3)	50.7(8.1)	5.7(0.8)
Cinquefoil	0.0(0.0)	0.0(0.0)	1.7(1.7)	0.2(0.2)	0.0(0.0)	0.0(0.0)
Clover	0.0(0.0)^{a}	0.0(0.0)	11.7(4.4)^{b}	1.2(0.4)	4.8(2.6)^{ab}	0.5(0.3)
Columbine	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	1.1(0.8)	0.1(0.1)
Common chickweed	0.0(0.0)	0.0(0.0)	2.2(1.1)	0.6(0.4)	0.4(0.4)	0.1(0.1)
Common cinquefoil	0.0(0.0)	0.0(0.0)	0.6(0.6)	0.1(0.1)	0.0(0.0)	0.0(0.0)
Common plantain	1.1(1.1)	0.1(0.1)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)
Cowwheat	1.1(1.1)	0.2(0.1)	4.5(2.1)	0.4(0.2)	2.2(1.5)	0.3(0.2)
Cranesbill	1.1(1.1)	0.1(0.1)	0.0(0.0)	0.0(0.0)	0.7(0.7)	0.1(0.1)
Daisy	0.0(0.0)	0.0(0.0)	0.6(0.6)	0.1(0.1)	0.4(0.4)	0.0(0.0)
Daisy fleabane	0.0(0.0)	0.0(0.0)	1.7(1.7)	0.2(0.2)	1.5(0.8)	0.2(0.1)
Dandelion	6.7(1.9)	0.9(0.2)	11.1(3.5)	1.2(0.3)	10.0(2.3)	1.3(0.3)
Downy plantain	1.1(1.1)	0.2(0.2)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)
Evening primrose	0.0(0.0)	0.0(0.0)	0.6(0.6)	0.1(0.1)	0.4(0.4)	0.0(0.0)
Fern	2.2(2.2)	0.2(0.2)	2.8(1.0)	0.3(0.1)	0.7(0.5)	0.1(0.1)

Table 2 (cont'd).

Species	Control Plots		25.3 m^2/ha Plots		16.1 m^2/ha Plots	
	AF	RF	AF	RF	AF	RF
Field bindweed	3.3(1.9)	0.4(0.2)	5.0(2.8)	0.6(0.4)	0.0(0.0)	0.0(0.0)
Field hawkweed	1.1(1.1)	0.2(0.2)	1.1(1.1)	0.2(0.2)	1.5(0.6)	0.2(0.1)
Field sorrel	1.1(1.1)	0.2(0.2)^{A}	3.9(2.8)	0.4(0.3)^{A}	8.5(2.0)	1.1(0.3)^{B}
Goldenrod	15.6(9.7)	1.9(1.0)	11.1(5.0)	1.2(0.5)	8.2(2.3)	0.9(0.2)
Goldthread	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.7(0.7)	0.1(0.1)
Grass/Grasslike	87.8(4.5)	12.4(1.1)	94.5(1.6)	10.5(0.7)	94.8(1.5)	11.2(0.7)
Hairy hawkweed	1.1(1.1)	0.2(0.2)	3.9(1.6)	0.5(0.2)	3.3(2.6)	0.4(0.3)
Hawkweed	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	3.7(3.7)	0.7(0.7)
Hooked crowsfoot	0.0(0.0)	0.0(0.0)	0.6(0.6)	0.1(0.1)	0.0(0.0)	0.0(0.0)
Horsetail	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.4(0.4)	0.0(0.0)
Indian pipe	1.1(1.1)	0.1(0.1)	4.4(2.8)	0.5(0.3)	0.4(0.4)	0.0(0.0)
Ladies' tresses	4.4(4.4)	0.7(0.7)	0.0(0.0)	0.0(0.0)	0.7(0.5)	0.1(0.1)
Leathery grape-fern	1.1(1.1)	0.1(0.1)	0.6(0.6)	0.1(0.1)	1.9(0.8)	0.2(0.1)
Lily/Orchis	6.7(3.9)	1.1(0.6)	0.6(0.6)	0.1(0.1)	3.3(1.1)	0.4(0.2)
Milkweed	24.5(13.5)	3.4(2.2)	7.2(4.0)	0.8(0.4)	14.4(4.8)	1.6(0.5)
Mint	17.8(11.8)	2.1(1.2)	11.7(3.8)	1.3(0.4)	5.2(1.5)	0.6(0.2)
Moneywort	5.6(2.2)	0.9(0.4)	5.0(1.4)	0.5(0.1)	5.2(2.4)	0.6(0.3)
Moss/Lichen	100.0(0.0)	14.4(1.9)	95.6(2.0)	10.7(0.9)	98.2(1.3)	11.6(0.7)
Mullein	0.0(0.0)^{a}	0.0(0.0)^{A}	13.9(2.6)^{b}	1.5(0.3)^{B}	8.2(2.7)^{c}	1.0(0.3)^{B}
Narrow-leaved pinweed	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.4(0.4)	0.1(0.1)	0.0(0.0)
Orange hawkweed	25.6(13.7)	3.5(2.1)	47.8(8.6)	5.1(0.7)	58.5(7.9)	6.5(0.9)
Oxeye daisy	13.3(6.9)	1.9(1.1)	5.6(3.9)	0.6(0.4)	1.1(0.8)	0.1(0.1)
Pearly everlasting	1.1(1.1)^{a}	0.2(0.2)	12.8(3.6)^{b}	1.4(0.4)	10.4(3.7)^{ab}	1.2(0.4)
Pinesap	1.1(1.1)	0.1(0.1)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)
Plantain	0.0(0.0)	0.0(0.0)	0.6(0.6)	0.1(0.1)	0.0(0.0)	0.0(0.0)
Poison ivy	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.7(0.5)	0.1(0.1)
Pussytoes	1.1(1.1)	0.2(0.2)	2.8(1.0)	0.3(0.1)	3.7(0.9)	0.4(0.1)
Pyrola	1.1(1.1)	0.1(0.1)	4.5(1.1)	0.5(0.1)	4.4(1.4)	0.5(0.2)

Table 2 (cont'd).

Species	Control Plots		25.3 m^2/ha Plots		16.1 m^2/ha Plots	
	AF	RF	AF	RF	AF	RF
Rattlesnake fern	4.5(2.2)	0.6(0.3)	10.6(5.1)	1.1(0.5)	8.2(2.7)	0.9(0.3)
Sanicle	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.4(0.4)	0.1(0.1)
Shinleaf	14.4(4.4)	1.9(0.3)	17.8(3.2)	1.9(0.3)	25.9(4.6)	2.9(0.4)
Solomon's seal	2.2(2.2)	0.4(0.4)	3.3(2.1)	0.4(0.2)	3.0(1.3)	0.4(0.2)
Spreading dogbane	6.7(6.7)	1.1(1.1)	23.3(7.6)	2.5(0.7)	29.6(5.0)	3.6(0.6)
St. johnswort	0.0(0.0)	0.0(0.0)	1.1(0.7)	0.1(0.1)	4.8(4.8)	0.5(0.5)
Starflower	15.6(4.0)	2.1(0.3)	27.8(4.6)	2.9(0.4)	28.5(6.7)	3.3(0.7)
Strawberry	8.9(5.9)	1.1(0.6)	27.2(6.9)	2.9(0.7)	34.4(9.8)	3.6(1.0)
Sumac	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.4(0.4)	0.1(0.1)
Sweet clover	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.4(0.4)	0.1(0.1)
Thimbleweed	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.7(0.5)	0.1(0.1)
Thistle	5.6(4.0)	0.7(0.4)	5.0(1.9)	0.5(0.2)	1.9(0.6)	0.2(0.1)
Touch-me-not	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.4(0.4)	0.1(0.1)
Trillium	1.1(1.)	0.2(0.2)	1.7(1.1)	0.2(0.1)	0.7(0.7)	0.1(0.1)
Twisted stalk	3.3(3.)	0.6(0.6)	1.1(0.7)	0.1(0.1)	0.0(0.0)	0.0(0.0)
Upright bindweed	1.1(1.1)	0.2(0.2)	7.2(3.7)	0.7(0.4)	0.0(0.0)	0.0(0.0)
Violet	41.1(11.6)	5.6(1.2)	37.8(7.9)	3.9(0.5)	29.6(3.6)	3.3(0.3)
Virgin's bower	2.2(2.2)	0.2(0.2)	1.7(1.1)	0.2(0.1)	0.0(0.0)	0.0(0.0)
Wild basil	4.4(4.4)	0.7(0.4)	11.1(8.5)	1.1(0.9)	15.2(3.3)	1.8(0.4)
Wild geranium	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.4(0.4)	0.0(0.0)
Wild lettuce	12.2(5.9)	1.4(0.7)	8.9(1.9)	0.9(0.2)	13.7(3.8)	1.6(0.4)
Wild sarsaparilla	11.1(2.9)	1.7(0.6)	27.2(8.1)	2.9(0.8)	31.1(7.5)	3.3(0.7)
Wood anemone	1.1(1.1)	0.1(0.1)	2.2(1.4)	0.2(0.2)	0.4(0.4)	0.0(0.0)
Yarrow	0.0(0.0)	0.0(0.0)	5.0(3.7)	0.5(0.4)	0.4(0.4)	0.0(0.0)

Table 2 (cont'd).

Species	Control Plots AF	Control Plots RF	25.3 m^2/ha Plots AF	25.3 m^2/ha Plots RF	16.1 m^2/ha Plots AF	16.1 m^2/ha Plots RF
Other	13.3(8.4)	1.6(0.8)	14.5(2.8)	1.5(0.3)	15.9(4.3)	1.7(0.4)
Mean No. (SE) of Identified Species	**31.3(4.5)^{a}**		**38.5(4.1)^{b}**		**34.6(3.8)^{a}**	
Total No. of Identified Species	**52**		**62**		**67**	

a,b,c Mean absolute frequencies with the same letters within the same row are not significantly different ($p > 0.10$).

A,B,C Mean relative frequencies with the same letters within the same row are not significantly different ($p > 0.10$).

Table 3. Mean absolute frequencies (%) with standard errors of herbaceous species compared between 1988 (Bender 1990) and 1990, red pine study plots, Pigeon River Country State Forest, Mich.

	Control Plots		25.3 m^2/ha Plots		16.1 m^2/ha Plots	
Species	1988	1990	1988	1990	1988	1990
Aster	14.4(14.4)	5.6(1.1)	7.8(5.6)	7.8(4.0)	0.0(0.0)^a	6.3(2.0)^b
Bedstraw	34.4(12.8)	47.8(18.7)	55.3(13.0)	60.0(10.7)	26.7(4.3)	34.4(7.0)
Bracken fern	54.4(11.6)	35.6(20.2)	60.4(14.1)	64.4(14.7)	45.2(7.8)	47.8(7.7)
Canada mayflower	11.1(11.1)^a	51.1(11.8)^b	6.8(5.4)^a	60.6(13.5)^b	3.7(2.0)^a	50.7(8.1)^b
Clover	0.0(0.0)	0.0(0.0)	9.3(3.8)	11.7(4.4)	4.4(1.9)	4.8(2.6)
Goldenrod	22.2(13.5)	15.6(9.7)	14.7(8.7)	11.1(5.0)	4.4(1.6)	8.2(2.3)
Milkweed	20.0(11.6)	24.5(13.5)	8.3(3.9)	7.2(4.0)	8.9(3.9)	14.4(4.8)
Moneywort	5.6(5.6)	5.6(2.2)	2.7(1.7)	5.0(1.4)	0.7(0.7)	5.2(2.4)
Mullein	0.0(0.0)	0.0(0.0)	0.0(0.0)^a	13.9(2.6)^b	10.4(4.0)	8.2(2.7)
Pussytoes	2.2(2.2)	1.1(1.1)	5.5(2.2)	2.8(1.0)	1.5(1.5)^a	3.7(0.9)^b
Starflower	20.0(10.2)	15.6(4.0)	30.7(8.1)	27.8(4.6)	23.7(3.9)	28.5(6.7)
Strawberry	12.2(7.8)	8.9(5.9)	24.5(9.2)	27.2(6.9)	23.7(11.2)	34.4(9.8)
Wild lettuce	8.9(2.2)	12.2(5.9)	13.4(4.8)	8.9(1.9)	16.3(2.8)	13.7(3.8)
Wild sarsaparilla	5.6(5.6)	11.1(2.9)	2.7(1.7)^a	27.2(8.1)^b	9.6(5.3)^a	31.1(7.5)^b
Yarrow	13.3(10.2)	0.0(0.0)	2.2(2.2)	5.0(3.7)	0.7(0.7)	0.4(0.4)

^{a,b} Means with the same letters within the same row and plot-group are not significantly different ($p > 0.10$).

Densities

Densities and relative densities of woody vegetation in 1989 are presented in Tables 4 and 5, respectively. Balsam poplar, beaked hazelnut, and mapleleaf viburnum were found on both treatments but not on controls in 1989. The LBAT had a significantly higher total density than control plots, but no significant differences were detected in the average number of species. The total number of species was similar among plot-groups.

Densities and relative densities of woody vegetation in 1990 are presented in Tables 6 and 7, respectively. Balsam poplar, black oak, mapleleaf viburnum, red oak, and white oak were found on both treatments but not on controls in 1990. As in 1989, the total density on LBAT was significantly higher than that on controls, but no significant difference in the average number of species was found. A similar total number of species was found on LBAT and HBAT, and the least number of species was found on the controls.

Table 4. Mean densities (stems/ha) with standard errors of woody vegetation >1-m tall and <10.2-cm d.b.h. on red pine study plots, Pigeon River Country State Forest, Mich., summer 1989.

Species	Control Plots	25.3 m^2/ha Plots	16.1 m^2/ha Plots
American elm	2.2(2.2)[a]	45.8(21.8)[b]	7.7(4.8)[a]
American white birch	1.9(1.9)	0.0(0.0)	0.6(0.6)
Balsam fir	20.0(10.2)	10.2(6.6)	13.7(8.2)
Balsam poplar	0.0(0.0)[a]	43.5(12.0)[b]	99.1(61.4)[ab]
Beaked hazelnut	0.0(0.0)	3.2(2.1)	225.9(200.7)
Beech	181.7(98.8)	94.0(22.2)	125.8(12.6)
Black cherry	308.0(105.8)[a]	139.4(40.8)[ab]	116.7(43.5)[b]
Bramble	17.8(17.8)[a]	10.7(7.2)[a]	206.7(53.5)[b]
Choke cherry	105.0(37.5)	53.2(18.2)	83.6(42.2)
Common witch-hazel	4.4(4.4)	5.1(3.7)	39.2(25.6)
Currant	0.0(0.0)	0.0(0.0)	0.6(0.6)
Gooseberry	24.4(24.4)	0.0(0.0)	2.8(2.8)
Hawthorn	18.0(18.0)	0.0(0.0)	0.0(0.0)
Highbush cranberry	0.0(0.0)	0.0(0.0)	6.8(5.5)
Ironwood	239.0(111.2)	352.6(239.0)	204.7(95.8)
Mapleleaf viburnum	0.0(0.0)	34.0(33.2)	15.7(11.9)
Ninebark	3.7(3.7)	0.0(0.0)	0.0(0.0)
Quaking aspen	16.9(14.2)[a]	1897.7(1221.4)[ab]	464.8(148.5)[b]
Red maple	129.5(37.0)[ab]	92.6(38.6)[a]	695.3(293.2)[b]
Red oak	3.4(1.7)	8.3(5.3)	16.7(8.8)
Red pine	3.0(3.0)	6.3(3.7)	0.9(0.9)
Siberian crab	77.4(59.0)[a]	84.7(65.5)[ab]	0.0(0.0)[b]
Slippery elm	0.0(0.0)	2.3(1.5)	0.0(0.0)
Striped maple	4.5(4.5)	6.3(6.3)	2.5(2.5)
Sugar maple	64.6(64.6)	34.7(24.5)	151.4(105.4)
White ash	37.8(19.4)[a]	105.1(76.6)[a]	802.8(165.9)[b]
White oak	0.0(0.0)[a]	0.0(0.0)[a]	18.6(6.2)[b]
White pine	6.0(6.0)	0.0(0.0)	0.0(0.0)
TOTAL	**1269.1(269.0)[a]**	**3029.6(1260.5)[a b]**	**3320.7(359.2)[b]**
Mean No. (SE) of Species	**12.3(0.6)**	**12.2(2.0)**	**12.4(2.6)**
Total No. of Species	**21**	**20**	**23**

[a,b] Means with the same letters within the same row are not significantly different ($p > 0.10$).

Table 5. Mean relative densities (%) with standard errors of woody vegetation >1-m tall and <10.2-cm d.b.h. on red pine study plots, Pigeon River Country State Forest, Mich., summer 1989.

Species	Control Plots	25.3 m^2/ha Plots	16.1 m^2/ha Plots
American elm	0.1(0.1)[ab]	2.9(0.7)[a]	0.2(0.0)[b]
American white birch	0.3(0.1)	0.0(0.0)	0.0(0.0)
Balsam fir	2.1(0.8)	0.8(0.3)	0.3(0.1)
Balsam poplar	0.0(0.0)[a]	3.7(0.9)[b]	3.7(0.8)[ab]
Beaked hazelnut	0.0(0.0)	0.1(0.0)	4.8(1.4)
Beech	14.6(3.7)	6.8(1.0)	4.4(0.3)
Black cherry	26.5(5.1)[a]	12.2(2.4)[ab]	4.2(0.6)[b]
Bramble	1.1(0.6)[ab]	0.8(0.3)[a]	8.3(1.0)[b]
Choke cherry	7.6(0.9)[a]	4.7(1.1)[ab]	2.1(0.3)[b]
Common witch-hazel	0.3(0.2)	1.0(0.4)	1.0(0.2)
Currant	0.0(0.0)	0.0(0.0)	0.0(0.0)
Gooseberry	1.5(0.9)	0.0(0.0)	0.2(0.1)
Hawthorn	1.2(0.7)	0.0(0.0)	0.0(0.0)
Highbush cranberry	0.0(0.0)	0.0(0.0)	0.1(0.0)
Ironwood	16.0(4.0)	11.3(2.1)	6.1(0.8)
Mapleleaf viburnum	0.0(0.0)	0.6(0.2)	0.4(0.1)
Ninebark	0.5(0.3)	0.0(0.0)	0.0(0.0)
Quaking aspen	1.3(0.5)[a]	32.2(6.1)[ab]	13.9(1.5)[b]
Red maple	12.6(3.6)[a]	3.2(0.4)[b]	19.4(2.5)[a]
Red oak	0.4(0.1)	0.7(0.2)	0.4(0.1)
Red pine	0.2(0.1)	0.8(0.2)	0.0(0.0)
Siberian crab	5.7(2.0)[a]	9.2(2.9)[ab]	0.0(0.0)[b]
Slippery elm	0.0(0.0)	0.3(0.1)	0.0(0.0)
Striped maple	0.3(0.2)	0.3(0.1)	0.1(0.0)
Sugar maple	4.4(2.6)	2.4(0.8)	4.2(0.9)
White ash	2.9(0.7)[a]	6.1(1.7)[a]	25.5(1.6)[b]
White oak	0.0(0.0)[a]	0.0(0.0)[a]	0.6(0.1)[b]
White pine	0.4(0.2)	0.0(0.0)	0.0(0.0)

[a,b] Means with the same letters within the same row are not significantly different ($p > 0.10$).

Table 6. Mean densities (stems/ha) with standard errors of woody vegetation >1-m tall and <10.2-cm d.b.h. on red pine study plots, Pigeon River Country State Forest, Mich., summer 1990.

Species	Control Plots	25.3 m^2/ha Plots	16.1 m^2/ha Plots
American basswood	0.0(0.0)	0.0(0.0)	1.2(0.8)
American elm	25.9(25.9)	4.7(3.1)	4.3(1.8)
American white birch	13.0(7.4)[a]	0.0(0.0)[b]	0.6(0.6)[b]
Balsam fir	29.6(21.8)	12.0(8.8)	15.4(8.3)
Balsam poplar	0.0(0.0)	17.6(14.5)	34.6(17.4)
Beaked hazelnut	25.9(6.7)	41.7(27.8)	585.8(528.8)
Beech	220.4(90.5)	124.1(39.9)	119.8(15.3)
Black cherry	303.7(106.7)	405.5(83.5)	327.2(104.3)
Black oak	0.0(0.0)[a]	0.9(0.9)[a]	7.4(1.9)[b]
Bramble	22.2(22.2)[a]	76.9(55.5)[a]	851.9(397.7)[b]
Choke cherry	61.1(27.4)	38.9(14.6)	51.2(12.1)
Common witch-hazel	1.9(1.9)	55.6(38.0)	8.0(7.4)
Crabapple	101.9(78.2)[a]	49.1(33.5)[ab]	0.0(0.0)[b]
Gooseberry	83.3(83.3)[ab]	21.3(11.0)[a]	3.1(1.9)[b]
Hawthorn	22.2(19.5)	2.0(1.9)	1.2(1.2)
Honeysuckle	0.0(0.0)	0.0(0.0)	1.2(1.2)
Ironwood	257.4(147.7)	486.2(301.7)	180.9(81.1)
Juneberry	7.4(4.9)	2.8(2.8)	5.6(3.7)
Mapleleaf viburnum	0.0(0.0)[a]	3.8(2.8)[a]	32.7(12.9)[b]
Mossycup oak	1.9(1.9)	0.0(0.0)	0.0(0.0)
Mulberry	0.0(0.0)	0.9(0.9)	0.0(0.0)
New Jersey tea	0.0(0.0)	14.8(14.8)	0.0(0.0)
Plum	0.0(0.0)	0.9(0.9)	0.0(0.0)
Quaking aspen	33.3(33.3)	1950.0(1130.1)	601.9(275.4)
Red maple	131.5(36.9)[a]	177.8(73.9)[a]	993.2(368.2)[b]
Red oak	0.0(0.0)[a]	10.2(4.9)[ab]	10.5(3.1)[b]
Red pine	9.3(4.9)	3.7(2.8)	2.5(1.4)
Slippery elm	14.8(14.8)	12.0(6.2)	4.3(2.4)
Spruce	0.0(0.0)	0.0(0.0)	0.6(0.6)
Striped maple	11.1(11.1)	10.1(5.8)	0.0(0.0)
Sugar maple	53.7(53.7)	15.7(8.5)	22.8(14.9)
Swamp oak	0.0(0.0)	0.0(0.0)	8.6(3.9)
White ash	33.3(14.7)[a]	127.8(91.8)[a]	904.9(188.7)[b]
White oak	0.0(0.0)	0.9(0.9)	8.6(7.3)
Willow	0.0(0.0)	0.9(0.9)	0.0(0.0)
TOTAL	**1464.8(322.2)[a]**	**3668.7(1232.3)[a b]**	**4790.1(722.1)[b]**
Mean No. (SE) of Species	**14.0(1.7)**	**14.8(3.3)**	**15.7(1.7)**
Total No. of Species	**22**	**29**	**28**

[a,b] Means with the same letters within the same row are not significantly different ($p > 0.10$).

Table 7. Mean relative densities (%) with standard errors of woody vegetation >1-m tall and <10.2-cm d.b.h. on red pine study plots, Pigeon River Country State Forest, Mich., summer 1990.

Species	Control Plots	25.3 m^2/ha Plots	16.1 m^2/ha Plots
American basswood	0.0(0.0)	0.0(0.0)	0.0(0.0)
American elm	1.5(0.9)	0.1(0.0)	0.1(0.0)
American white birch	0.8(0.2)^a	0.0(0.0)^b	0.0(0.0)^b
Balsam fir	3.2(1.6)	0.9(0.3)	0.3(0.1)
Balsam poplar	0.0(0.0)	0.7(0.2)	1.0(0.2)
Beaked hazelnut	1.8(0.2)	0.8(0.2)	7.2(2.0)
Beech	15.5(2.7)^a	4.7(0.5)^{ab}	2.7(0.1)^b
Black cherry	25.3(6.7)^{ab}	22.5(3.6)^a	8.9(1.3)^b
Black oak	0.0(0.0)^a	0.0(0.0)^a	0.2(0.0)^b
Bramble	1.3(0.7)^a	2.0(0.3)^a	18.1(2.0)^b
Choke cherry	3.8(0.7)^a	2.7(0.9)^{ab}	1.2(0.1)^b
Common witch-hazel	0.1(0.1)	3.6(1.2)	0.2(0.1)
Crabapple	6.9(2.5)^a	5.4(1.9)^{ab}	0.0(0.0)^b
Gooseberry	4.8(2.8)^{ab}	0.6(0.1)^a	0.1(0.0)^b
Hawthorn	1.2(0.6)	0.1(0.0)	0.0(0.0)
Honeysuckle	0.0(0.0)	0.0(0.0)	0.0(0.0)
Ironwood	15.1(4.3)^a	11.3(1.8)^{ab}	3.3(0.4)^b
Juneberry	0.5(0.2)	0.0(0.0)	0.1(0.0)
Mapleleaf viburnum	0.0(0.0)^a	0.1(0.0)^a	0.6(0.1)^b
Mossycup oak	0.2(0.1)	0.0(0.0)	0.0(0.0)
Mulberry	0.0(0.0)	0.1(0.0)	0.0(0.0)
New Jersey tea	0.0(0.0)	0.2(0.1)	0.0(0.0)
Plum	0.0(0.0)	0.1(0.0)	0.0(0.0)
Quaking aspen	1.8(1.1)	31.1(5.7)	14.5(2.2)
Red maple	8.8(0.5)^{ab}	5.4(0.8)^a	19.4(2.3)^b
Red oak	0.0(0.0)^a	0.6(0.1)^{ab}	0.2(0.0)^b
Red pine	0.9(0.3)	0.1(0.0)	0.1(0.0)
Slippery elm	0.8(0.5)	0.4(0.1)	0.2(0.0)
Spruce	0.0(0.0)	0.0(0.0)	0.0(0.0)
Striped maple	0.6(0.4)	0.8(0.2)	0.0(0.0)
Sugar maple	2.9(1.7)	0.6(0.1)	0.6(0.1)
Swamp oak	0.0(0.0)	0.0(0.0)	0.2(0.0)
White ash	2.0(0.4)^a	4.9(1.5)^a	20.5(1.2)^b
White oak	0.0(0.0)	0.0(0.0)	0.2(0.1)
Willow	0.0(0.0)	0.0(0.0)	0.0(0.0)

^{a,b} Means with the same letters within the same row are not significantly different ($p > 0.10$).

A total of 19 woody species were recorded for all three plot-groups in 1988, 28 in 1989, and 35 in 1990. Twelve woody species that were found in 1990 were not found in 1989. Densities of woody vegetation on control plots from 1988 to 1990 are presented in Table 8. On controls, only one significant difference was detected: The density of beaked hazelnut was significantly higher in 1990 than in 1989. Densities of woody vegetation on treatment plots from 1988 to 1990 are presented in Table 9. The density of woody vegetation was significantly higher in 1990 than in 1988 and nearly significantly higher ($p = 0.102$) in 1990 than in 1989 on LBAT. The mean number of species found significantly increased on the LBAT, but not on the HBAT or on controls, from 1989 to 1990.

Table 8. Mean densities (stems/ha) with standard errors of woody vegetation >1-m tall and <10.2-cm d.b.h. on red pine control plots compared over 1988 (Bender 1990), 1989, and 1990, Pigeon River Country State Forest, Mich.

Species	1988	1989	1990
American white birch	5(5)	2(2)	13(7)
Balsam fir	32(22)	20(10)	30(22)
Beaked hazelnut	96(86)[ab]	0(0)[a]	26(7)[b]
Beech	222(118)	182(99)	220(91)
Black cherry	515(193)	308(106)	304(107)
Choke cherry	158(76)	105(38)	61(27)
Common witch-hazel	0(0)	4(4)	2(2)
Currant	37(32)	0(0)	0(0)
Elm	37(31)	2(2)	41(41)
Ironwood	150(55)	239(111)	257(148)
Oak	5(5)	4(2)	2(2)
Red maple	158(63)	130(37)	132(37)
Striped maple	0(0)	5(5)	11(11)
Sugar maple	122(116)	65(65)	54(54)
White ash	30(20)	38(19)	33(15)
TOTAL	**2062(532)**	**1269(269)**	**1465(322)**

[a,b] Means with the same letters within the same row are not significantly different ($p > 0.10$).

Table 9. Mean densities (stems/ha) with standard errors of woody vegetation >1-m tall and <10.2-cm d.b.h. on red pine treatment plots compared over 1988 (Bender 1990), 1989, and 1990, Pigeon River Country State Forest, Mich.

	25.3 m^2/ha Plots			16.1 m^2/ha Plots		
Species	1988	1989	1990	1988	1989	1990
American white birch	25(12)[a]	0(0)[b]	0(0)[b]	0(0)	1(1)	1(1)
Balsam fir	14(7)	10(7)	12(9)	21(10)	14(8)	15(8)
Beaked hazelnut	458(348)[a]	3(2)[b]	42(28)[ab]	336(285)	226(201)	586(529)
Beech	211(54)	94(22)	124(40)	140(19)	126(13)	120(15)
Black cherry	509(106)[a]	139(41)[b]	406(84)[a]	305(91)[a]	117(44)[b]	327(104)[a]
Choke cherry	82(21)	53(18)	39(15)	82(29)	84(42)	51(12)
Common witch-hazel	33(21)	5(4)	56(38)	17(11)	39(26)	8(7)
Currant	38(15)[a]	0(0)[b]	0(0)[b]	8(3)	1(1)	0(0)
Elm	48(25)	48(21)	17(7)	15(5)	8(5)	9(2)
Ironwood	65(26)	353(239)	486(302)	36(7)[a]	205(96)[b]	181(81)[b]
Oak	19(11)	8(5)	12(6)	74(37)	35(13)	36(13)
Red maple	232(122)	93(39)	178(74)	576(244)	695(293)	993(368)
Striped maple	5(4)	6(6)	10(6)	4(4)	3(3)	0(0)
Sugar maple	54(30)	35(25)	16(9)	115(39)	151(105)	23(15)
White ash	111(67)	105(77)	128(92)	1095(137)	803(166)	905(189)
TOTAL	**2450(452)**	**3030(1261)**	**3669(1232)**	**3116(430)[a]**	**3321(359)[ab]**	**4790(722)[b]**

[a,b] Means with the same letters within the same row and plot-group are not significantly different ($p > 0.10$).

Horizontal Cover

In 1989, horizontal cover in the 0 - 0.5 m layer was significantly greater on HBAT and LBAT than on controls (Fig. 7). In 1990, horizontal cover in the 0 - 0.5 m and 0.5 - 1.0 m layers was significantly greater on both treatments than on controls (Fig. 8). Furthermore, horizontal cover in the 1.5 - 2.0 m layer was significantly greater on controls and on HBAT than on the LBAT in 1990 (Fig. 8).

Horizontal cover in the 1.0 - 1.5 m layer of the LBAT was significantly greater in 1990 than in 1989. On the HBAT, horizontal cover in the 1.5 - 2.0 m layer was significantly greater in 1990 than in 1989, and horizontal cover in the 0.5 - 1.0 m layer appeared to be greater ($p = 0.150$) in 1990 than in 1989. Horizontal cover on controls was not significantly different between 1989 and 1990.

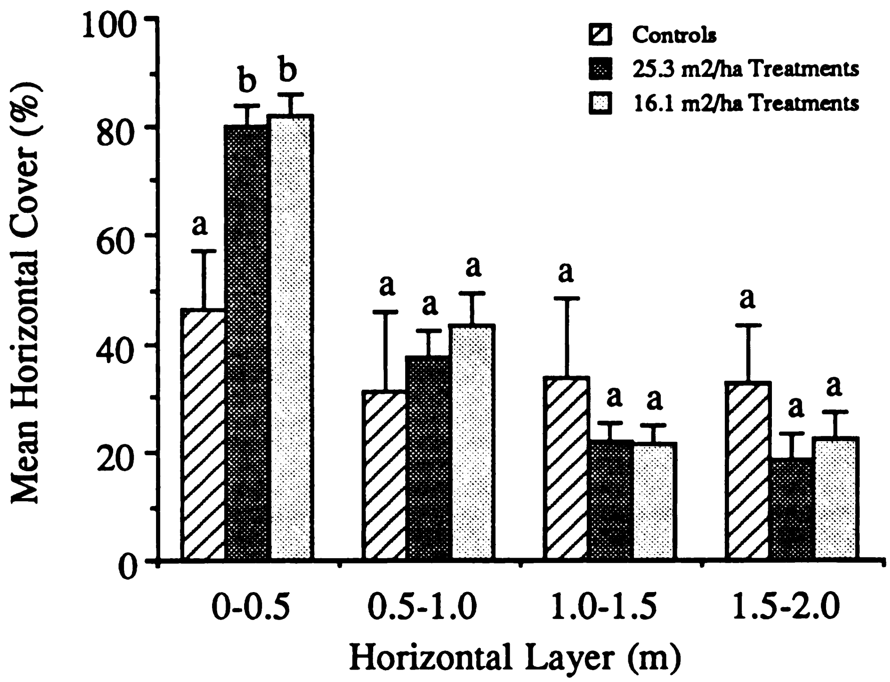


Figure 7. Mean horizontal cover (%) of red pine study plots, Pigeon River Country State Forest, Mich., summer 1989.

a,b Means with the same letters within the same horizontal layer are not significantly different (p > 0.10).

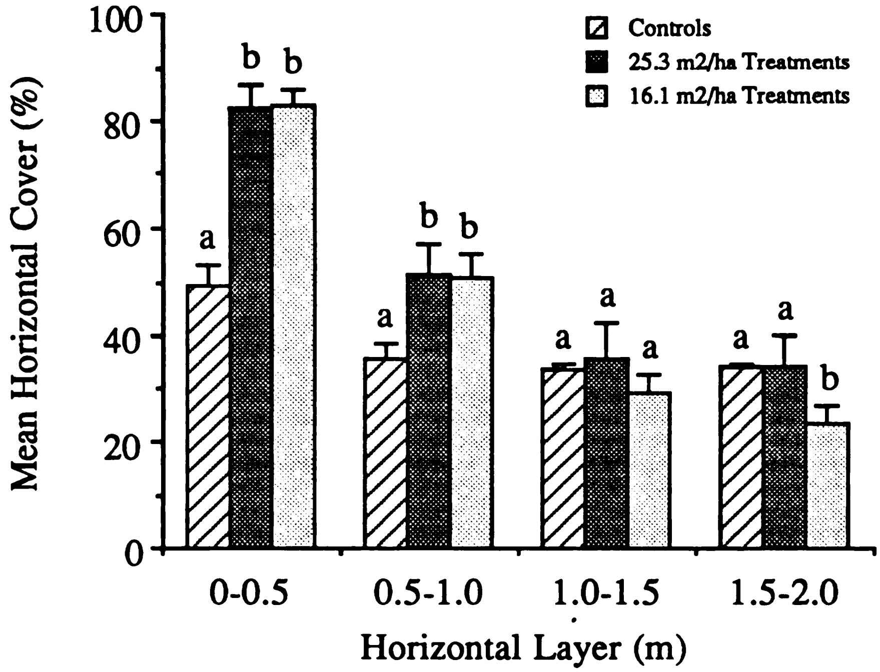


Figure 8. Mean horizontal cover (%) of red pine study plots, Pigeon River Country State Forest, Mich., summer 1990.

a,b Means with the same letters within the same horizontal layer are not significantly different ($p > 0.10$).

Vertical Cover

In 1989 and 1990, vertical cover in the <1 m stratum was significantly greater on HBAT and LBAT than on controls (Figs. 9, 10). In the >7 m stratum, vertical cover was significantly different in each plot-group in 1989 and 1990, with the controls being highest and the LBAT lowest (Figs. 9, 10). In 1990, vertical cover in the 2 - 7 m stratum was significantly greater on HBAT than on LBAT (Fig. 10). In 1990 the HBAT had nearly significantly more ($p = 0.121$) vertical cover in the 1 - 2 m stratum than did the controls, and the controls had nearly significantly more ($p = 0.116$) vertical cover in the 2 - 7 m stratum than did the LBAT (Fig. 10). Vertical cover in the >7 m stratum of the HBAT was significantly less in 1990 than in 1989.

Foliage height diversities were similar for the three plot-groups in 1989. In 1990, F.H.D. was significantly greater on the HBAT than on the LBAT and nearly significantly greater ($p = 0.121$) on the HBAT than on the controls. No significant differences were detected in F.H.D. on any plots-group between 1989 and 1990.

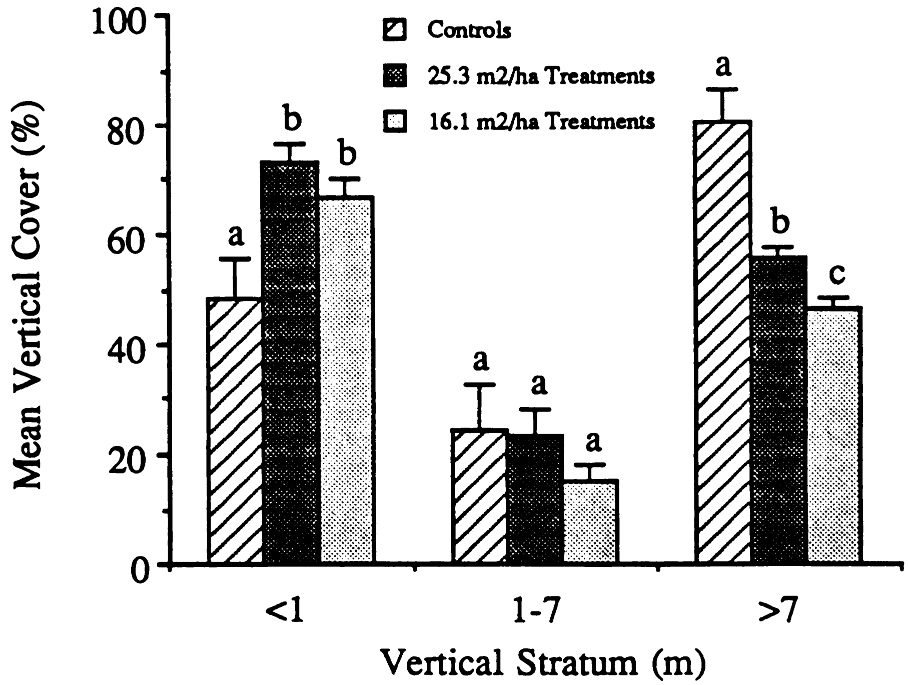


Figure 9. Mean vertical cover (%) of red pine study plots, Pigeon River Country State Forest, Mich., summer 1989.

a,b,c Means with the same letters within the same vertical stratum are not significantly different ($p > 0.10$).

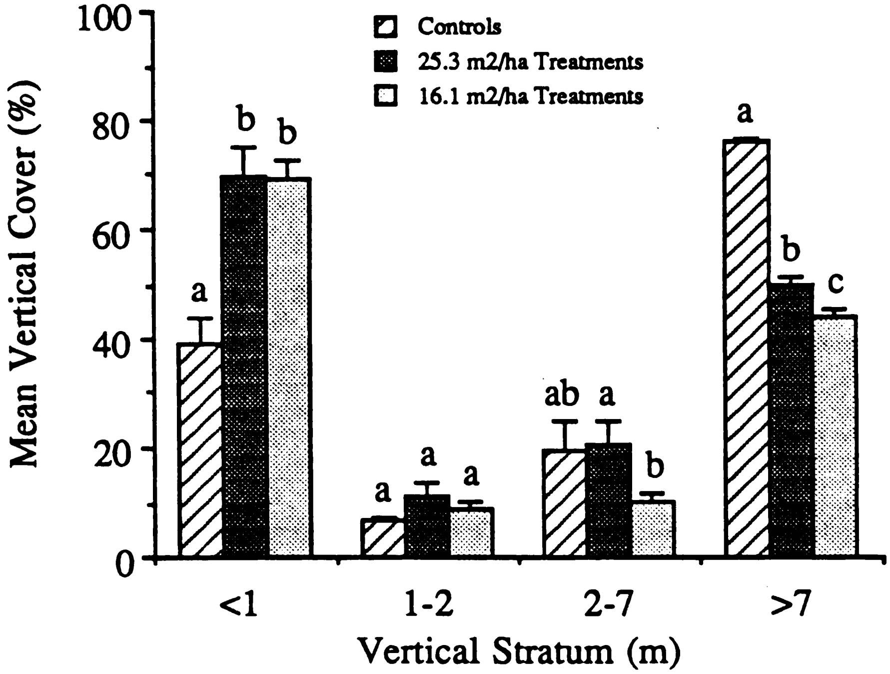


Figure 10. Mean vertical cover (%) of red pine study plots, Pigeon River Country State Forest, Mich., summer 1990.

a,b,c Means with the same letters within the same vertical stratum are not significantly different (p > 0.10).

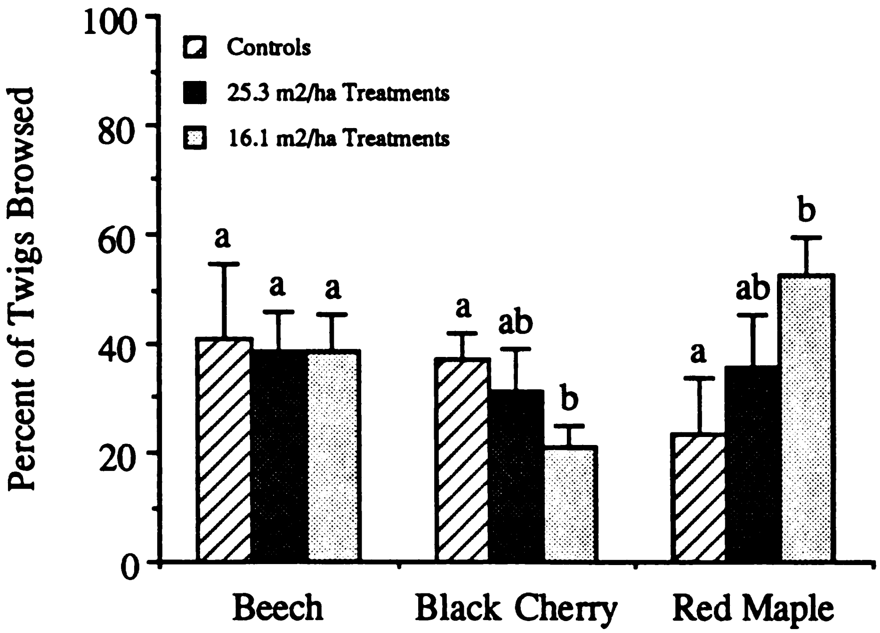
Browse Utilization

In 1990, utilization of black cherry was significantly higher on controls than on LBAT, whereas utilization of red maple was significantly higher on LBAT than on controls (Fig. 11). Utilization of beech on the LBAT and HBAT was significantly higher in 1990 than on those plots in 1988. Although not significant at $p = 0.10$, utilization of black cherry was nearly significantly higher ($p = 0.116$) in 1990 than in 1988 on controls, whereas utilization of red maple was nearly significantly lower ($p = 0.116$) in 1990 than in 1988 on controls.

Figure 11. Percent of twigs browsed and relative browsing of beech, black cherry, and red maple stems >1-m tall and <10.2-cm d.b.h. on red pine study plots, Pigeon River Country State Forest, Mich.

*Relative browsing computed as percent of twigs browsed per species multiplied by mean density of the species (i.e. 1989 stems/ha).

[a,b] Means with the same letters within the same species are not significantly different ($p > 0.10$).


100
80
60
40
20
0
Percent of Twigs Browsed
Controls
25.3 m2/ha Treatments
16.1 m2/ha Treatments
a
a
a
a
ab
b
a
ab
b
Beech
Black Cherry
Red Maple

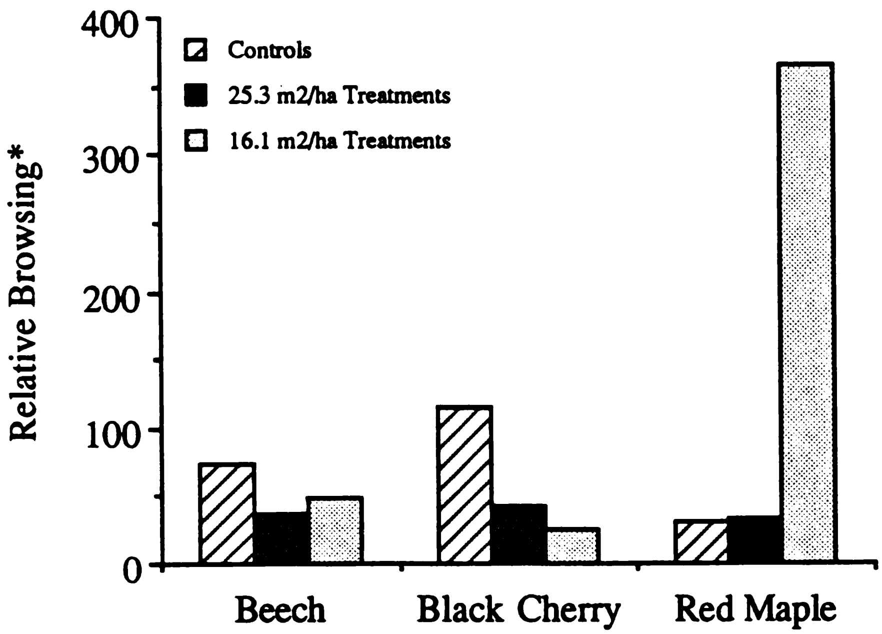

400
300
200
100
0
Relative Browsing*
Controls
25.3 m2/ha Treatments
16.1 m2/ha Treatments
Beech
Black Cherry
Red Maple

Figure 11

Pellet-Group Survey

Significantly more white-tailed deer pellet groups and total deer and elk pellet groups were found on the LBAT than on controls in 1990 (Fig. 12). Pellet-group data for 1988 and 1989 were taken from Bender (1990). In 1988, deer pellet groups were significantly fewer on LBAT than in 1989 or 1990. Similarly, total pellet groups were significantly fewer on LBAT in 1988 than in 1989 and nearly significantly fewer ($p = 0.102$) on LBAT in 1988 than in 1990.

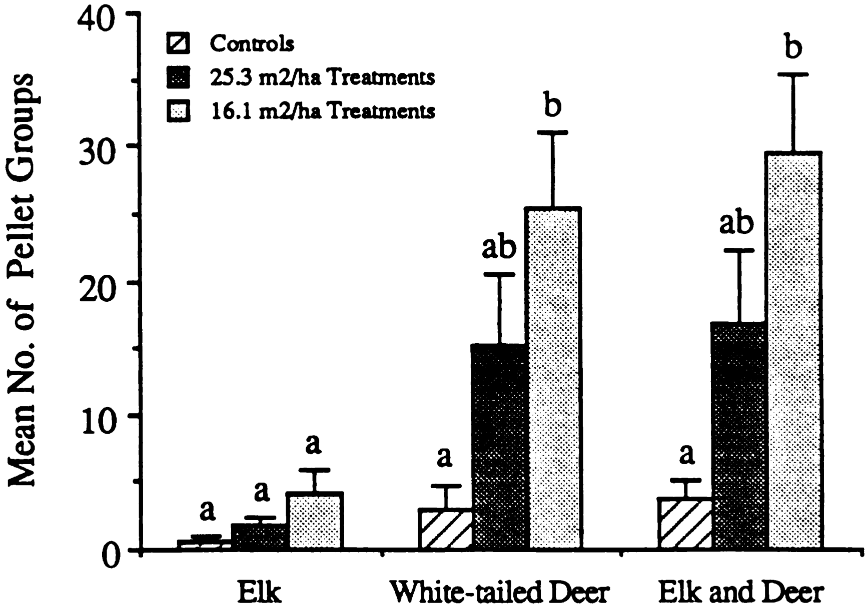


Figure 12. Elk and white-tailed deer pellet-group findings on red pine study plots, Pigeon River Country State Forest, Mich., April 1990.

[a,b] Means with the same letters within the same ungulate group are not significantly different ($p > 0.10$).

Small Mammals

Small mammal capture and diversity information is presented in Table 10. A total of 12 identified small mammal species were captured on the red pine study plots during 1989 and 1990. Jumping mice, masked shrews, red squirrels, and white-footed mice were found on each of the three plot-groups during 1989 and 1990. Eastern chipmunks and southern red-backed voles were caught on LBAT and on HBAT but not on controls in both years. Meadow voles were caught on both treatments in 1989 and on all three plot-groups in 1990. Short-tailed shrews were found on all three plot-groups in 1989 but were caught only on the two treatment plot-groups in August of 1990. Three species, ermine, flying squirrel, and pygmy shrew, each had only one individual captured and only on the LBAT.

Eastern moles were caught on each of the plot-groups in 1988 but were not caught in 1989 or 1990. Ermine, flying squirrels, meadow voles, pygmy shrews, red squirrels, and short-tailed shrews were caught in 1989 or 1990 but not in 1988. Three of these species, flying squirrel, red squirrel, and short-tailed shrew, were caught on pretreatment HBAT plots in 1987 (Bender 1990). From 1988 to 1990, the controls and HBAT plots each had a total of nine small mammal species, whereas the LBAT had a total of 12 small mammal species.

In July and August of 1989, the diversity indices of the LBAT and HBAT, which did not significantly differ, were significantly higher than the diversity index of the control plots. In August 1989, the average number of species caught was significantly higher on LBAT and on HBAT, which did not significantly differ, than on controls. In July 1990, the average number of individuals caught was significantly higher on LBAT and on HBAT, which did not significantly differ, than on controls. In August 1990, the average number of individuals caught was significantly higher on HBAT than on either LBAT or controls, which did not significantly differ. In 1990, the mean number of species caught in August was significantly higher on HBAT than on controls, and no significant differences were detected among diversity indices in either month.

Table 10. Minimum population size, number of individuals of all species captured, number of species captured, and diversity index for 5-day trapping periods on red pine study plots compared within and over 1988 (Bender 1990), 1989, and 1990, Pigeon River Country State Forest, Mich.

	Jul 88 Mean(SE)	Aug 88 Mean(SE)	Jul 89 Mean(SE)	Aug 89 Mean(SE)	Jul 90 Mean(SE)	Aug 90 Mean(SE)
Control Plots						
Eastern chipmunk	0.3(0.3)	0.0(0.0)	0.0(0.0)^{x}	0.0(0.0)^{x}	0.0(0.0)	0.0(0.0)
Eastern mole	0.3(0.3)	1.0(0.6)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)
Jumping mouse	1.7(0.3)	2.3(1.2)	0.7(0.3)	1.3(1.3)	0.0(0.0)^{x}	1.3(0.9)
Masked shrew	0.3(0.3)	0.3(0.3)	0.0(0.0)	0.3(0.3)^{x}	0.0(0.0)	0.3(0.3)
Meadow vole	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.7(0.7)	0.0(0.0)
Red squirrel	0.0(0.0)	0.0(0.0)	1.7(1.7)	0.3(0.3)	1.0(0.6)	1.3(0.9)
Short-tailed shrew	0.0(0.0)	0.0(0.0)^{a}	0.7(0.3)	4.3(1.8)^{b}	0.0(0.0)	0.0(0.0)^{a}
So. red-backed vole	0.3(0.3)^{x}	1.3(0.7)	0.0(0.0)^{x}	0.0(0.0)^{x}	0.0(0.0)	0.0(0.0)^{x}
White-footed mouse	0.7(0.7)	0.7(0.7)^{a}	4.0(1.0)	6.3(0.9)^{b,x}	3.7(0.9)	4.3(1.2)^{b}
Number of Individuals	**3.7(0.3)^{a,x}**	**5.7(1.5)**	**7.0(1.0)^{b}**	**12.7(3.8)**	**5.3(0.7)^{ab,x}**	**7.3(2.2)^{x}**
Number of Species	**2.7(0.3)^{x}**	**2.7(0.7)**	**2.7(0.7)**	**3.0(1.0)^{x}**	**2.0(0.0)**	**2.7(0.3)^{x}**
Diversity Index	**2.6(0.3)^{a}**	**2.3(0.7)^{a}**	**0.7(0.2)^{b,x}**	**0.8(0.3)^{ab,x}**	**0.6(0.1)^{b}**	**0.8(0.1)^{b}**
25.3 m^{2}/ha Plots						
Eastern chipmunk	1.0(0.3)	1.8(0.7)^{a}	1.5(0.6)^{xy}	1.7(0.8)^{a,xy}	0.5(0.2)	0.0(0.0)^{b,x}
Eastern mole	0.3(0.3)	1.2(0.6)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)
Jumping mouse	0.3(0.2)^{a}	0.7(0.3)	0.3(0.2)^{a}	2.2(1.0)	1.8(0.5)^{b,y}	2.7(1.1)
Masked shrew	0.2(0.2)	1.0(0.6)	0.2(0.2)	0.8(0.3)^{xy}	0.2(0.2)	0.2(0.2)
Meadow vole	0.0(0.0)	0.0(0.0)	0.2(0.2)	0.5(0.5)	1.2(0.8)	1.3(1.0)
Red squirrel	0.0(0.0)	0.0(0.0)	0.2(0.2)	0.3(0.2)	0.5(0.3)	0.7(0.5)
Short-tailed shrew	0.0(0.0)^{a}	0.0(0.0)^{a}	1.2(0.6)^{b}	3.2(0.7)^{b}	0.0(0.0)^{a}	0.5(0.3)^{a}
So. red-backed vole	0.5(0.2)^{a,x}	2.0(0.7)	3.2(1.3)^{b,y}	2.0(0.5)^{y}	1.0(0.5)^{ab}	2.2(0.7)^{y}
White-footed mouse	0.3(0.2)^{a}	0.8(0.5)^{a}	4.8(0.8)^{b}	6.0(1.3)^{b,xy}	5.7(1.6)^{b}	6.8(1.6)^{b}
Number of Individuals	**4.2(0.6)^{a,x}**	**7.5(2.0)^{a}**	**11.5(1.9)^{b}**	**16.7(1.0)^{b}**	**10.8(2.1)^{b,y}**	**14.3(1.5)^{b,y}**
Number of Species	**2.7(0.3)^{a,x}**	**3.3(0.6)^{a}**	**4.2(0.5)^{b}**	**5.7(0.7)^{b,y}**	**4.0(0.6)^{b}**	**4.2(0.5)^{ab,y}**
Diversity Index	**2.4(0.3)^{a}**	**2.9(0.5)^{a}**	**1.2(0.1)^{b,y}**	**1.5(0.1)^{b,y}**	**1.1(0.2)^{b}**	**1.1(0.2)^{b}**
16.1 m^{2}/ha Plots						
Eastern chipmunk	3.6(1.6)	2.0(0.6)	3.9(1.7)^{y}	2.2(0.4)^{y}	1.8(0.8)	1.0(0.3)^{y}
Eastern mole	0.1(0.1)	0.3(0.2)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)
Ermine	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.1(0.1)	0.0(0.0)	0.0(0.0)
Flying squirrel	0.0(0.0)	0.0(0.0)	0.1(0.1)	0.0(0.0)	0.0(0.0)	0.0(0.0)
Jumping mouse	2.1(0.5)	0.2(0.2)^{a}	0.3(0.2)	1.7(0.6)^{b}	1.7(0.9)^{xy}	2.3(1.3)^{ab}
Masked shrew	0.3(0.2)	1.1(0.4)^{a}	0.2(0.2)	1.3(0.3)^{a,y}	0.0(0.0)	0.1(0.1)^{b}
Meadow vole	0.0(0.0)	0.0(0.0)^{a}	0.0(0.0)	1.0(0.5)^{b}	0.1(0.1)	0.0(0.0)^{a}
Pygmy shrew	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.1(0.1)	0.0(0.0)
Red squirrel	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.1(0.1)	0.3(0.2)	0.4(0.2)
Short-tailed shrew	0.0(0.0)^{a}	0.0(0.0)^{a}	2.2(0.7)^{b}	3.0(0.4)^{b}	0.0(0.0)^{a}	0.4(0.2)^{a}
So. red-backed vole	3.9(0.7)^{a,y}	4.4(1.0)^{a}	3.1(0.6)^{a,y}	2.6(0.6)^{ab,y}	0.8(0.3)^{b}	1.8(0.4)^{b,y}
White-footed mouse	0.3(0.3)^{a}	1.9(0.6)^{a}	3.6(0.6)^{ab}	4.2(0.6)^{b,y}	4.9(0.6)^{b}	3.9(0.5)^{b}
Number of Individuals	**10.3(2.0)^{y}**	**9.0(0.9)^{a}**	**13.4(2.6)**	**16.2(1.5)^{b}**	**9.7(1.6)^{y}**	**10.0(1.8)^{a,x}**
Number of Species	**3.6(0.3)^{y}**	**3.7(0.4)^{a}**	**4.0(0.5)**	**6.2(0.4)^{b,y}**	**3.1(0.4)**	**3.7(0.4)^{a,xy}**
Diversity Index	**2.6(0.3)^{a}**	**2.6(0.3)^{a}**	**1.2(0.1)^{b,y}**	**1.7(0.1)^{b,y}**	**0.9(0.1)^{c}**	**1.1(0.1)^{c}**

^{a,b,c} Means with the same letters within the same row and month are not significantly different ($p > 0.10$).

^{x,y} Means with the same letters within the same column and row-title are not significantly different ($p > 0.10$).

Comparison of Different-aged 16.1 m^2/ha Plots

Herbaceous annual productivity was 508.3(52.2) kg/ha on LBAT86 and 547.8(65.3) kg/ha on LBAT87 in 1990, and no significant differences were detected in herbaceous or black cherry annual productivity between the different-aged LBAT. However, red maple annual productivity in 1990 was significantly greater on LBAT86 than on LBAT87 (Fig. 13). Absolute and relative frequencies for the LBAT86 and LBAT87 in 1990 are presented in Table 11. No significant difference was detected in the average number of identified herbaceous species, but the total number of species identified was higher on the LBAT87 than on the LBAT86.

Densities and relative densities of woody vegetation in 1989 for LBAT86 and LBAT87 are presented in Table 12. Total density and the average number of species were significantly higher on LBAT86 than on LBAT87. However, more species were found on LBAT87 than on LBAT86. Densities and relative densities of woody vegetation in 1990 for LBAT86 and LBAT87 are presented in Table 13. The average number of species was significantly higher on LBAT86 than on LBAT87, and the total density was nearly significantly higher ($p = 0.121$) on LBAT86 than LBAT87. However, more woody species were found on LBAT87 than on LBAT86, as was the case for these two plots in 1989.

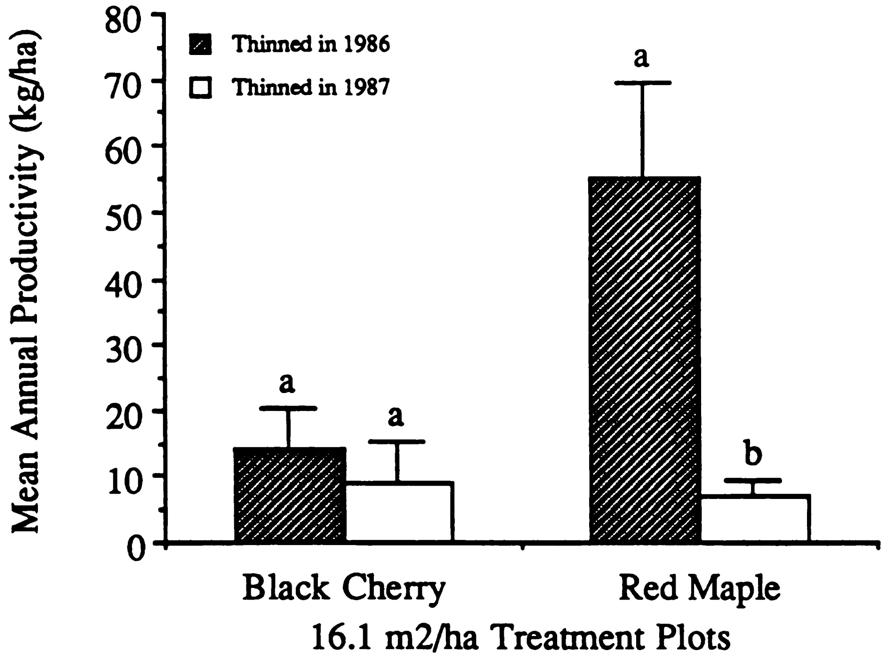


Figure 13. Mean annual productivity (kg/ha) of black cherry and red maple on red pine 16.1 m^2/ha treatment plots thinned about 1 year apart, Pigeon River Country State Forest, Mich., 1990.

[a,b] Means with the same letters within the same species are not significantly different ($p > 0.10$).

Table 11. Mean absolute frequencies (AF) (%) and mean relative frequencies (RF) (%) with standard errors of herbaceous vegetation and brambles found on red pine 16.1 m^2/ha treatment plots thinned about 1 year apart, Pigeon River Country State Forest, Mich., summer 1990.

16.1 m^2/ha Plots:	Thinned in 1986		Thinned in 1987	
Species	AF	RF	AF	RF
Anemone	2.2(1.1)	0.2(0.1)	3.3(0.9)	0.4(0.1)
Aniseroot	0.0(0.0)	0.0(0.0)	4.4(2.0)	0.5(0.2)
Arrow-leaved aster	45.6(7.3)^a	4.8(1.0)^A	27.2(5.9)^b	3.2(0.6)^B
Aster	11.1(2.9)^a	1.1(0.2)	3.9(2.2)^b	0.5(0.3)
Bedstraw	22.2(8.7)	2.3(0.8)^A	40.6(8.9)	4.6(0.7)^B
Blueberry	0.0(0.0)	0.0(0.0)	0.6(0.6)	0.1(0.1)
Bracken fern	58.9(14.4)	6.1(1.3)	42.2(9.0)	5.0(0.9)
Bramble	82.2(5.9)	8.6(0.2)	81.7(3.2)	10.3(1.4)
Bristly sarsaparilla	0.0(0.0)	0.0(0.0)	0.6(0.6)	0.1(0.1)
Bunchberry	23.3(1.9)^a	2.5(0.3)^A	0.0(0.0)^b	0.0(0.0)^B
Burdock	0.0(0.0)	0.0(0.0)	0.6(0.6)	0.1(0.1)
Canada mayflower	71.1(6.2)^a	7.5(1.0)^A	40.6(9.4)^b	4.7(0.9)^B
Clover	0.0(0.0)	0.0(0.0)	7.2(3.6)	0.8(0.4)
Columbine	2.2(2.2)	0.2(0.2)	0.6(0.6)	0.1(0.1)
Common chickweed	0.0(0.0)	0.0(0.0)	0.6(0.6)	0.1(0.1)
Cowwheat	5.6(4.0)	0.6(0.4)	0.6(0.6)	0.1(0.1)
Cranesbill	0.0(0.0)	0.0(0.0)	1.1(1.1)	0.1(0.1)
Daisy	1.1(1.1)	0.1(0.1)	0.0(0.0)	0.0(0.0)
Daisy fleabane	3.3(1.9)	0.3(0.2)	0.6(0.6)	0.1(0.1)
Dandelion	3.3(0.0)^a	0.4(0.0)^A	13.3(2.4)^b	1.7(0.4)^B
Evening primrose	0.0(0.0)	0.0(0.0)	0.6(0.6)	0.1(0.1)
Fern	0.0(0.0)	0.0(0.0)	1.1(0.7)	0.2(0.1)
Field hawkweed	0.0(0.0)	0.0(0.0)	2.2(0.7)	0.3(0.1)
Field sorrel	8.9(4.0)	0.9(0.4)	8.3(2.5)	1.1(0.4)
Goldenrod	11.1(4.0)	1.2(0.4)	6.7(2.9)	0.8(0.3)
Goldthread	0.0(0.0)	0.0(0.0)	1.1(1.1)	0.1(0.1)
Grass/Grasslike	94.4(2.9)	10.0(0.7)	95.0(1.9)	11.8(0.9)
Hairy hawkweed	0.0(0.0)	0.0(0.0)	5.0(3.8)	0.6(0.5)
Hawkweed	0.0(0.0)	0.0(0.0)	5.6(5.6)	1.0(1.0)
Horsetail	0.0(0.0)	0.0(0.0)	0.6(0.6)	0.1(0.1)
Indian pipe	0.0(0.0)	0.0(0.0)	0.6(0.6)	0.1(0.1)
Ladies' tresses	0.0(0.0)	0.0(0.0)	1.1(0.7)	0.1(0.1)
Leathery grape-fern	2.2(2.2)	0.3(0.3)	1.7(0.7)	0.2(0.1)
Lily/Orchis	4.4(1.1)	0.5(0.1)	2.8(1.6)	0.4(0.2)
Milkweed	17.8(12.8)	1.7(1.2)	12.8(4.7)	1.6(0.5)
Mint	3.3(1.9)	0.3(0.2)	6.1(2.0)	0.7(0.2)
Moneywort	14.4(1.1)^a	1.5(0.2)^A	0.6(0.6)^b	0.1(0.1)^B
Moss/Lichen	100.0(0.0)	10.5(0.6)	97.2(1.8)	12.1(1.0)
Mullein	3.3(0.0)	0.4(0.0)^A	10.6(3.7)	1.3(0.4)^B
Narrow-leaved pinweed	0.0(0.0)	0.0(0.0)	0.6(0.6)	0.1(0.1)
Orange hawkweed	71.1(6.2)	7.5(0.8)	52.2(10.8)	5.9(1.2)
Oxeye daisy	3.3(1.9)	0.3(0.2)	0.0(0.0)	0.0(0.0)
Pearly everlasting	2.2(1.1)^a	0.2(0.1)^A	14.4(4.7)^b	1.7(0.5)^B

Table 11 (cont'd).

16.1 m^2/ha Plots:	Thinned in 1986		Thinned in 1987	
Species	AF	RF	AF	RF
Poison ivy	2.2(1.1)	0.2(0.1)	0.0(0.0)	0.0(0.0)
Pussytoes	3.3(1.9)	0.4(0.2)	3.9(1.0)	0.4(0.1)
Pyrola	5.6(2.9)	0.6(0.3)	3.9(1.6)	0.5(0.2)
Rattlesnake fern	6.7(1.9)	0.7(0.2)	8.9(4.0)	0.9(0.4)
Sanicle	0.0(0.0)	0.0(0.0)	0.6(0.6)	0.0(0.0)
Shinleaf	27.8(9.1)	2.8(0.9)	25.0(5.9)	2.9(0.6)
Solomon's seal	0.0(0.0)	0.0(0.0)	4.4(1.6)	0.6(0.3)
Spreading dogbane	15.6(6.2)[a]	1.7(0.7)[A]	36.7(4.7)[b]	4.5(0.6)[B]
St. johnswort	14.4(14.4)	1.4(1.4)	0.0(0.0)	0.0(0.0)
Starflower	37.8(17.9)	4.2(2.0)	23.9(5.6)	2.8(0.6)
Strawberry	70.0(10.2)[a]	7.3(0.7)[A]	16.7(4.6)[b]	1.8(0.4)[B]
Sumac	0.0(0.0)	0.0(0.0)	0.6(0.6)	0.1(0.1)
Sweet clover	0.0(0.0)	0.0(0.0)	0.6(0.6)	0.1(0.1)
Thimbleweed	1.1(1.1)	0.1(0.1)	0.6(0.6)	0.1(0.1)
Thistle	1.1(1.1)	0.1(0.1)	2.2(0.7)	0.3(0.1)
Touch-me-not	0.0(0.0)	0.0(0.0)	0.6(0.6)	0.1(0.1)
Trillium	0.0(0.0)	0.0(0.0)	1.1(1.1)	0.2(0.2)
Violet	34.4(6.8)	3.6(0.6)	27.2(4.3)	3.1(0.3)
Wild basil	6.7(5.1)	0.6(0.5)[A]	19.4(3.0)	2.4(0.3)[B]
Wild geranium	0.0(0.0)	0.0(0.0)	0.6(0.6)	0.1(0.1)
Wild lettuce	3.3(0.0)[a]	0.4(0.0)[A]	18.9(4.3)[b]	2.1(0.4)[B]
Wild sarsaparilla	45.6(14.4)	4.7(1.4)	23.9(8.0)	2.6(0.7)
Wood anemone	1.1(1.1)	0.1(0.1)	0.0(0.0)	0.0(0.0)
Yarrow	0.0(0.0)	0.0(0.0)	0.6(0.6)	0.1(0.1)
Other	8.9(5.9)	1.0(0.6)	19.4(5.4)	2.1(0.5)
Mean No.(SE) of Identified Species	**34.0(1.0)**		**34.8(4.7)**	
Total No. of Identified Species	**42**		**61**	

a,b Mean absolute frequencies with the same letters within the same row are not significantly different ($p > 0.10$).

A,B Mean relative frequencies with the same letters within the same row are not significantly different ($p > 0.10$).

Table 12. Mean densities (stems/ha) and mean relative densities (RD) (%) with standard errors of woody vegetation >1-m tall and <10.2-cm d.b.h. on red pine- 16.1 m^2/ha treatment plots thinned about 1 year apart, Pigeon River Country State Forest, Mich., summer 1989.

16.1 m^2/ha Plots:	Thinned in 1986		Thinned in 1987	
Species	Density	RD	Density	RD
American elm	20.4(12.0)^a	0.5(0.2)^A	1.4(1.4)^b	0.1(0.0)^B
American white birch	0.0(0.0)	0.0(0.0)	0.9(0.9)	0.0(0.0)
Balsam fir	38.0(18.6)^a	0.9(0.3)^A	1.6(1.6)^b	0.0(0.0)^B
Balsam poplar	41.7(41.7)	0.9(0.5)	127.8(90.6)	5.2(1.4)
Beaked hazelnut	677.8(574.7)^a	14.3(6.7)^A	0.0(0.0)^b	0.0(0.0)^B
Beech	99.1(21.9)	2.3(0.2)^A	139.1(13.3)	5.5(0.4)^B
Black cherry	200.9(89.2)^a	5.2(1.5)	74.6(43.4)^b	3.7(1.1)
Bramble	58.3(39.4)^a	1.2(0.5)^A	280.9(57.0)^b	11.9(1.4)^B
Choke cherry	216.7(89.1)^a	5.1(1.2)^A	17.1(5.9)^b	0.6(0.1)^B
Common witch-hazel	66.7(66.7)	1.4(0.8)	25.5(23.8)	0.8(0.3)
Currant	0.0(0.0)	0.0(0.0)	0.9(0.9)	0.0(0.0)
Gooseberry	0.0(0.0)	0.0(0.0)	4.2(4.2)	0.2(0.1)
Highbush cranberry	20.4(15.2)	0.4(0.2)	0.0(0.0)	0.0(0.0)
Ironwood	438.9(243.1)^a	9.7(2.7)^A	87.6(44.5)^b	4.3(1.1)^B
Mapleleaf viburnum	44.4(32.8)	1.0(0.5)	1.4(1.4)	0.1(0.0)
Quaking aspen	148.2(17.7)	3.6(0.4)	623.2(194.5)	19.0(2.3)
Red maple	1668.5(550.2)^a	42.0(9.0)^A	208.7(60.4)^b	8.1(1.0)^B
Red oak	40.7(21.4)^a	1.0(0.3)^A	4.6(3.0)^b	0.1(0.0)^B
Red pine	2.8(2.8)	0.1(0.0)	0.0(0.0)	0.0(0.0)
Striped maple	0.0(0.0)	0.0(0.0)	3.7(3.7)	0.2(0.1)
Sugar maple	0.0(0.0)^a	0.0(0.0)^A	227.0(152.4)^b	6.3(1.5)^B
White ash	429.6(171.9)	9.9(2.3)^A	989.4(198.2)	33.3(1.7)^B
White oak	27.8(14.7)	0.6(0.2)	13.9(6.1)	0.5(0.1)
TOTAL	**4240.7(369.4)^a**		**2833.6(387.7)^b**	
Mean No. (SE) of Species	**14.7(2.5)^a**		**11.3(2.0)^b**	
Total No. of Species	**18**		**20**	

^{a,b} Means with the same letters within the same row are not significantly different ($p > 0.10$).

^{A,B} Mean relative densities with the same letters within the same row are not significantly different ($p > 0.10$).

Table 13. Mean densities (stems/ha) and mean relative densities (RD) (%) with standard errors of woody vegetation >1-m tall and <10.2-cm d.b.h. on red pine 16.1 m^2/ha treatment plots thinned about 1 year apart, Pigeon River Country State Forest, Mich., summer 1990.

16.1 m^2/ha Plots:	Thinned in 1986		Thinned in 1987	
Species	Density	RD	Density	RD
American basswood	1.9(1.9)	0.0(0.0)	0.9(0.9)	0.0(0.0)
American elm	0.0(0.0)	0.0(0.0)	6.5(2.2)	0.1(0.0)
American white birch	1.9(1.9)	0.0(0.0)	0.0(0.0)	0.0(0.0)
Balsam fir	46.3(10.3)[a]	0.8(0.2)[A]	0.0(0.0)[b]	0.0(0.0)[B]
Balsam poplar	0.0(0.0)	0.0(0.0)	51.9(23.5)	1.5(0.3)
Beaked hazelnut	1727.8(1541.9)[a]	20.5(9.8)[A]	14.8(8.9)[b]	0.5(0.2)[B]
Beech	151.9(41.7)	2.4(0.3)	103.7(7.4)	2.9(0.1)
Black cherry	498.2(188.4)[a]	9.5(2.6)	241.7(121.0)[b]	8.6(2.3)
Black oak	9.3(1.9)	0.2(0.0)	6.5(2.7)	0.2(0.0)
Bramble	329.6(115.5)	5.3(1.2)[A]	1113.0(579.6)	24.5(3.3)[B]
Choke cherry	81.5(22.5)[a]	1.3(0.1)	36.1(10.6)[b]	1.2(0.2)
Common witch-hazel	1.9(1.9)	0.0(0.0)	11.1(11.1)	0.3(0.1)
Gooseberry	0.0(0.0)	0.0(0.0)	4.6(2.7)	0.2(0.0)
Hawthorn	3.7(3.7)	0.1(0.0)	0.0(0.0)	0.0(0.0)
Honeysuckle	0.0(0.0)	0.0(0.0)	1.9(1.9)	0.1(0.0)
Ironwood	451.9(152.8)[a]	7.0(1.3)[A]	45.4(11.4)[b]	1.5(0.2)[B]
Juneberry	14.8(9.8)	0.3(0.1)	0.9(0.9)	0.0(0.0)
Mapleleaf viburnum	74.1(24.3)[a]	1.1(0.1)	12.0(4.9)[b]	0.4(0.1)
Quaking aspen	37.0(12.1)	0.7(0.2)	884.3(366.2)	21.4(3.5)
Red maple	2292.6(564.2)[a]	41.5(8.1)[A]	343.5(91.7)[b]	8.3(0.6)[B]
Red oak	22.2(0.0)[a]	0.4(0.0)[A]	4.6(1.7)[b]	0.1(0.0)[B]
Red pine	5.6(3.2)	0.1(0.0)	0.9(0.9)	0.0(0.0)
Slippery elm	1.9(1.9)	0.0(0.0)	5.6(3.5)	0.2(0.1)
Spruce	0.0(0.0)	0.0(0.0)	0.9(0.9)	0.0(0.0)
Sugar maple	0.0(0.0)	0.0(0.0)	34.3(21.4)	1.0(0.2)
Swamp oak	16.7(9.6)	0.3(0.1)	4.6(3.0)	0.1(0.0)
White ash	501.9(213.2)	7.9(1.9)[A]	1106.5(228.1)	26.8(0.7)[B]
White oak	24.1(21.4)	0.5(0.3)	0.9(0.9)	0.0(0.0)
TOTAL	**6296.3(1300.4)**		**4037.0(756.9)**	
Mean No. (SE) of Species	**17.3(1.2)[a]**		**14.8(1.3)[b]**	
Total No. of Species	**22**		**25**	

[a,b] Mean absolute densities with the same letters within the same row are not significantly different
($p > 0.10$).

[A,B] Mean relative densities with the same letters within the same row are not significantly different
($p > 0.10$).

In 1989 and 1990, horizontal cover in the 1.0 - 1.5 m layer was significantly greater on LBAT86 than on LBAT87 (Figs. 14, 15). In 1990, horizontal cover in the 1.5 - 2.0 m layer was significantly greater on LBAT86 than on LBAT87 (Fig. 15), and in the same layer in 1989 there appeared to be a similar difference between the LBAT86 and LBAT87, although it was not significant ($p = 0.121$). Also nearly significantly higher ($p = 0.121$) on the LBAT86 than on LBAT87 is the horizontal cover in the 0.5 - 1.0 m layer in 1990 (Fig.15).

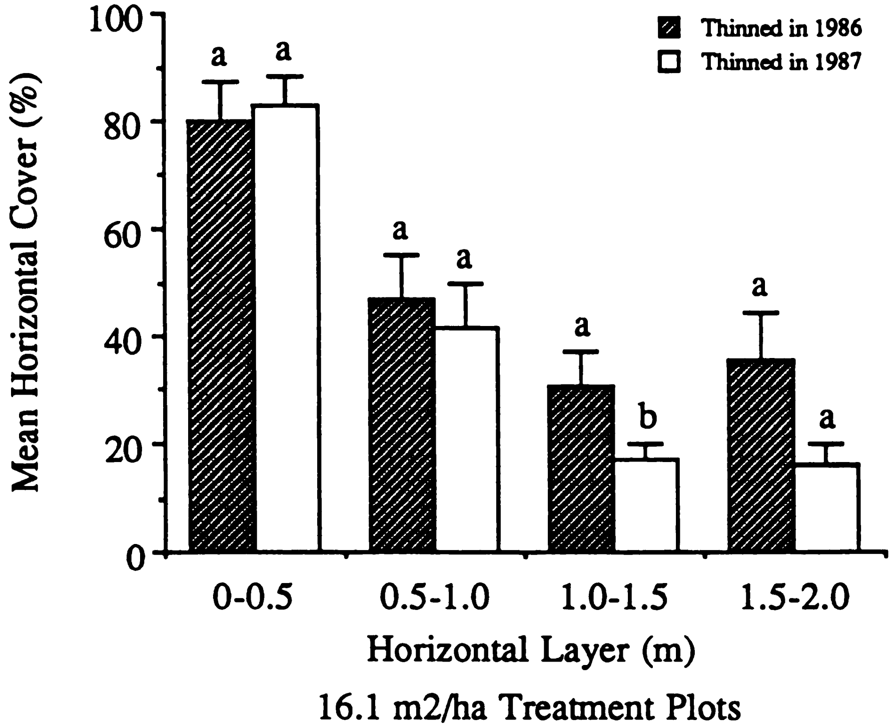


Figure 14. Mean horizontal cover (%) of red pine 16.1 m^2/ha treatment plots thinned about 1 year apart, Pigeon River Country State Forest, Mich., summer 1989.

[a,b] Means with the same letters within the same horizontal layer are not significantly different ($p > 0.10$).

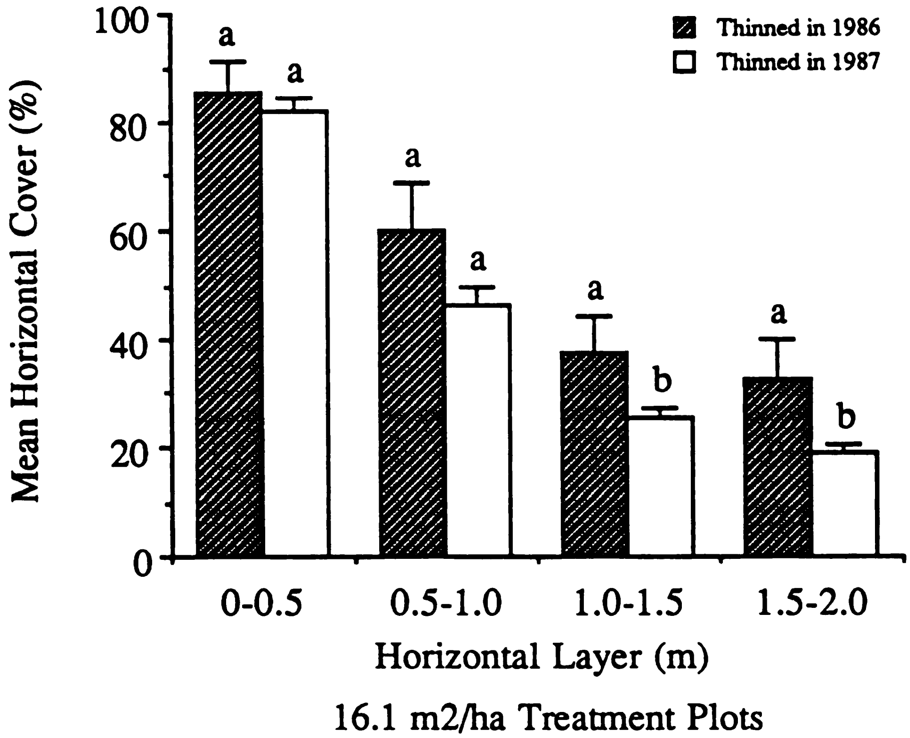


Figure 15. Mean horizontal cover (%) of red pine 16.1 m^2/ha treatment plots thinned about 1 year apart, Pigeon River Country State Forest, Mich., summer 1990.

a,b Means with the same letters within the same horizontal layer are not significantly different ($p > 0.10$).

No significant differences were found in vertical cover between LBAT86 and LBAT87 in either 1989 or 1990, but in 1990 vertical cover in the 1 - 2 m stratum was nearly significantly greater ($p = 0.121$) on LBAT86 than on LBAT87. No significant difference in F.H.D. was detected between different-aged LBAT in 1989, but in 1990 F.H.D. was significantly greater on LBAT86 than on LBAT87.

In 1990, utilization of beech, black cherry, and red maple was significantly higher on LBAT86 than on LBAT87 (Fig. 16). Significantly more deer pellet groups and total deer and elk pellet groups were found on LBAT86 than on LBAT87 in 1990 (Fig. 17).

Figure 16. Percent of twigs browsed and relative browsing of beech, black cherry, and red maple stems >1-m tall and <10.2-cm d.b.h. on red pine 16.1 m^2/ha treatment plots thinned about 1 year apart, Pigeon River Country State Forest, Mich.

*Relative browsing computed as percent of twigs browsed per species multiplied by mean density of the species (i.e. 1989 stems/ha).

[a,b] Means with the same letters within the same species are not significantly different ($p > 0.10$).

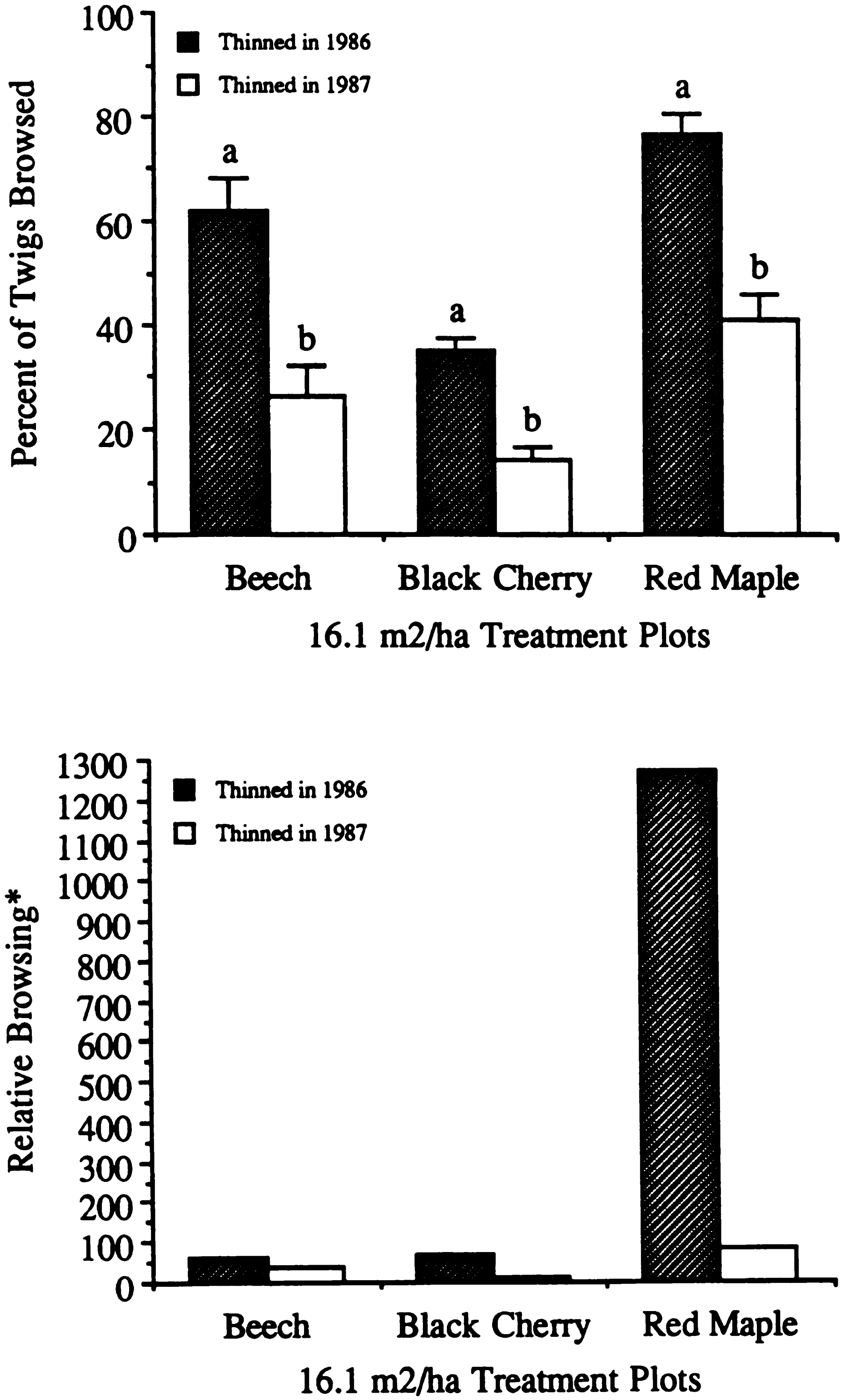

Percent of Twigs Browsed
100
80
60
40
20
0
Thinned in 1986
Thinned in 1987
a
b
a
b
a
b
Beech
Black Cherry
Red Maple
16.1 m2/ha Treatment Plots
Relative Browsing*
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
Thinned in 1986
Thinned in 1987
Beech
Black Cherry
Red Maple
16.1 m2/ha Treatment Plots

Figure 16

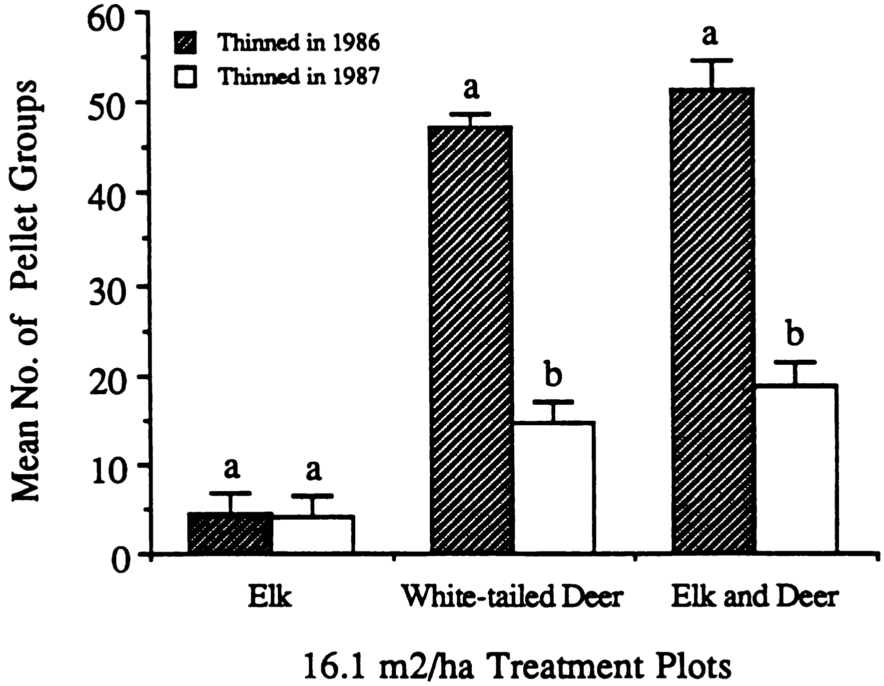


Figure 17. Elk and white-tailed deer pellet-group findings on red pine 16.1 m^2/ha treatment plots thinned about 1 year apart, Pigeon River Country State Forest, Mich., April 1990.

[a,b] Means with the same letters within the same ungulate group are not significantly different ($p > 0.10$).

Small mammal capture and diversity information of LBAT86 and LBAT87 plots for 1989 and 1990 is presented in Table 14. The average number of individuals caught in July of both 1989 and 1990 was significantly higher on the LBAT86 than the LBAT87, and no significant differences in the mean number of species caught or diversity indices were detected for either trapping period on these plots.

Table 14. Minimum population size, number of individuals of all species captured, number of species captured, and diversity index for 5-day trapping periods in 1989 and 1990 on red pine 16.1 m^2/ha treatment plots thinned about 1 year apart, Pigeon River Country State Forest, Mich.

	1989		1990	
Year Thinned:	1986	1987	1986	1987
	Mean(SE)	Mean(SE)	Mean(SE)	Mean(SE)
JULY				
Eastern chipmunk	8.7(3.5)[a]	1.5(0.8)[b]	4.3(1.5)[a]	0.5(0.3)[b]
Flying squirrel	0.0(0.0)	0.2(0.2)	0.0(0.0)	0.0(0.0)
Jumping mouse	1.0(0.6)	0.0(0.0)	4.7(1.3)[a]	0.2(0.2)[b]
Masked shrew	0.3(0.3)	0.2(0.2)	0.0(0.0)	0.0(0.0)
Meadow vole	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.2(0.2)
Pygmy shrew	0.0(0.0)	0.0(0.0)	0.3(0.3)	0.0(0.0)
Red squirrel	0.0(0.0)	0.0(0.0)	0.3(0.3)	0.3(0.2)
Short-tailed shrew	4.0(1.7)	1.3(0.4)	0.0(0.0)	0.0(0.0)
So. red-backed vole	3.7(0.9)	2.8(0.8)	0.3(0.3)	1.0(0.5)
White-footed mouse	2.3(0.3)	4.2(0.8)	5.0(0.6)	4.8(0.9)
Number of Individuals	**20.0(3.8)[a]**	**10.2(2.6)[b]**	**15.0(2.5)[a]**	**7.0(1.0)[b]**
Number of Species	**5.0(0.0)**	**3.5(0.6)**	**4.0(0.6)**	**2.7(0.5)**
Diversity Index	**1.3(0.1)**	**1.1(0.2)**	**1.2(0.1)**	**0.7(0.2)**
AUGUST				
Eastern chipmunk	3.0(0.6)	1.8(0.5)	2.0(0.0)[a]	0.5(0.3)[b]
Ermine	0.0(0.0)	0.2(0.2)	0.0(0.0)	0.0(0.0)
Jumping mouse	3.7(0.9)[a]	0.7(0.2)[b]	6.0(3.1)	0.5(0.2)
Masked shrew	1.3(0.3)	1.3(0.4)	0.0(0.0)	0.2(0.2)
Meadow vole	0.0(0.0)[a]	1.5(0.7)[b]	0.0(0.0)	0.0(0.0)
Red squirrel	0.0(0.0)	0.2(0.2)	0.3(0.3)	0.5(0.3)
Short-tailed shrew	2.3(0.3)	3.3(0.5)	1.0(0.6)	0.2(0.2)
So. red-backed vole	3.0(1.7)	2.3(0.3)	2.0(1.0)	1.7(0.4)
White-footed mouse	3.7(0.9)	4.5(0.8)	3.3(0.3)	4.2(0.7)
Number of Individuals	**17.0(2.0)**	**15.8(2.1)**	**14.7(3.5)**	**7.7(1.3)**
Number of Species	**5.7(0.3)**	**6.5(0.6)**	**4.3(0.9)**	**3.3(0.4)**
Diversity Index	**1.6(0.1)**	**1.7(0.1)**	**1.2(0.1)**	**1.0(0.1)**

[a,b] Means with the same letters within the same row and year are not significantly different ($p > 0.10$).

DISCUSSION

Understory Vegetation Responses

Production of herbaceous vegetation was significantly greater on each treatment group than on the control group, and correspondingly, horizontal cover in the 0 - 0.5 m layer and vertical cover in the <1 m stratum were significantly greater on treatments than on controls. Similarly, Dickmann et al. (1987) found that more-open red pine overstories had more vegetation growing below them than did heavier overstories. Red maple productivity was significantly greater on LBAT than on controls, yet black cherry annual productivity did not significantly differ among plot-groups. This may reflect red maple's shade tolerance and vigor of response to release and black cherry's shade intolerance and slower response to release.

Understory production has been found to be inversely related to canopy closure, stand basal areas (Conroy et al. 1982), and timber density (Halls 1970), and the relationship between increased understory production and overstory reduction has been widely reported (e.g. Cook 1939, Westell 1954, Halls and Schuster 1965, Ffolliott and Clary 1982, Bartlett and Betters 1983). Haynes (1990) stated that any type of timber removal will have an effect on the understory vegetation, and changes in vegetation will inevitably affect the kind and amount of habitat available for wildlife.

Several studies of stands of other pine species show similar findings. Anderson et al. (1969) found that understory herbaceous cover responded inversely with the density of pine canopy. In a comparison of thinned and unthinned ponderosa pine stands, Clary and Ffolliott (1966) reported significantly greater understory production in thinned stands for basal area levels of less than 16.1 m^2/ha. Similarly, ponderosa pine thinning caused highly significant increases in understory vegetation as reported by McConnell and Smith (1970). Crouch (1986) reported that thinning pole-sized lodgepole pine to relatively wide spacing increased forage production, quality, and availability, and several other studies report on the value of thinning lodgepole pine in terms of wildlife habitat produced (e.g. Dealy 1975, Austin and Urness 1982).

Forage production has been reported as being closely associated with timber density (Grelen et al. 1972, Hurst and Warren 1980) and basal area (Gaines et al. 1954, Halls 1955, 1973a; Wolters 1973, 1982; Wolters and Schmidtling 1975, Conroy et al 1982, Wolters et al. 1982) in southern pine plantations as well. A loblolly pine plantation was thinned every 5 years beginning at age 20 to residual basal areas of approximately 16.1 m^2/ha, 19.5 m^2/ha, and 23.0 m^2/ha, and herbage production was found to be directly related to the intensity of thinning (Blair 1960, Blair 1967, Blair and Enghardt 1976).

Decreases in canopy cover allow more light and water to reach the understory, stimulating growth of understory herbaceous vegetation and suppressed hardwoods (Anderson et al. 1969). For example, Cheo (1946) found that the mean maximum air temperature, precipitation reaching the ground, light available for tree growth, soil temperature, and the average soil moisture content increased with the degree of thinning of a young red pine stand. Thus, favorable conditions for understory growth exist for several years after thinning, which in turn creates a more diversified habitat for wildlife (Patton 1969, Clary and Larson 1971, Blair and Enghardt 1976). The potential for increasing forage production by thinning appears to be highest on intrinsically good (moist) sites (Conroy et al. 1982).

Factors such as soils, site quality, and physiographic features also influence forage production (Schuster and Halls 1963, Schuster 1967, Cromer and Smith 1968, Wolters et al. 1982). Deficiencies in nitrogen and phosphorus are not uncommon in coniferous forests (Miller et al. 1979). Original forest stands in the Great Lakes states were subject to frequent stand-initiating fires (Heinselman 1981), and the low overall nutrient concentrations in pines may be an adaptation to the post-fire environment of low nutrient status (Hendrickson et al. 1987). Decomposition of litter from herbaceous vegetation and deciduous trees in the understory may result in increased nutrient availability. So, as an indirect result of opening the canopy, nutrient cycling may be enhanced, contributing to further understory production. In addition to basal area, crown cover, tree density, site characteristics, and physiography, forage production has also been related to needle litter in pine stands (Pase and Hurd 1957).

In concurrence with increased herbaceous productivity, the total number of herbaceous species increased with decreasing basal area. The average number of herbaceous species was significantly higher on the HBAT than on either the controls or the LBAT. The total number of herbaceous species recorded nearly doubled from 1988 to 1990, and each significant difference detected between 1988 to 1990 was an increase in frequency. Drought conditions may have been responsible for decreased herbaceous species richness in 1988 (Bender 1990). Only brambles significantly increased with each decreasing basal area in 1990, likely reflecting their vigorous response to sunny conditions.

A persistent shrub layer is very important to the suitability of conifer plantations as wildlife habitat (Ohmann 1982). The total density of woody stems >1-m tall and <10.2-cm d.b.h. significantly increased only on the LBAT plots from 1988 to 1990, and only the LBAT significantly increased in mean number of woody species from 1989 to 1990. The overall total number of woody species recorded for all three plot-groups increased from 1988 to 1990, and the LBAT had a significantly higher total density than the controls in 1989 and 1990. Thus, it appears that the LBAT plots have a shrub layer that is not only persisting but also is increasing in woody species richness as compared to the controls. Drought conditions may have affected response or growth of woody species in 1988.

As a dense pine canopy is opened by thinnings, woody species respond in direct proportion to the degree of pine removal (Blair 1967). Both the midstory species richness and the number of stems of a species have been shown to increase with increased thinning intensity in pine (Blair and Enghardt 1976). Overstory thinning will inevitably allow hardwoods to develop under pure stands of pine (Blair and Enghardt 1976). Typically, browse responds to thinning at a slower rate than herbage (Halls 1973b).

In 1990, the LBAT had significantly lower horizontal cover in the 1.5 - 2.0 m layer than did the other two plot-groups, possibly due to lower trunk areas providing less obstruction of the profile board at that height. In both 1989 and 1990, cover in the >7 m stratum significantly increased from the LBAT to the HBAT to the controls, reflecting the canopy coverage specified by the study design. The significant decrease in cover in the >7 m stratum from 1989 to 1990 on the HBAT was likely due to thinning that occurred during the summer of 1990.

Although bird use was not assessed, as a side light to this study, foliage height diversities were determined as an indication of bird species diversity. Closed-canopy plantations often lack vertical structure and thus have relatively low species diversity (Hunter 1990). Thinning should be expected to increase the F.H.D. and subsequently increase the diversity of bird species on the site (MacArthur and MacArthur 1961). Foliage height diversities were similar for the three plot-groups in 1989, but in 1990, F.H.D. was significantly greater on the HBAT than on the LBAT. Since the number of strata sampled was the same on both treatments in 1990, the difference in F.H.D. was apparently due to the more even distribution of vertical cover among strata on the HBAT than on the LBAT.

Early and repeated crown thinnings are often the most practical way to maintain species richness and vertical diversity in plantations. However, thorough low or dominant thinnings can reduce vertical structure and species richness (Hunter 1990). In addition, thinnings may build vertical structure that may benefit songbirds but that may be detrimental to terrestrial herbivores (Dickson 1981).

Deer and Elk Responses

Deer and Elk Use Indices

To minimize bias that may result from sampling use of one highly preferred woody species, three woody species that reportedly vary in their attractiveness.to deer as forage were sampled. Use was presented as percent utilization per woody species rather than percent utilization per area since the latter may merely reflect the relative abundance of a woody species rather than the comparable degree of use of that species (Bender 1990). However, use paralleled relative abundance of the woody species. That is, use of red maple was significantly higher on the LBAT than on controls, and red maple was one of the most abundant understory trees on LBAT. Similarly, use of black cherry was significantly higher on the controls than on the treatments, and black cherry was the most abundant understory tree species on the controls. Beech utilization was similar for all plots possibly reflecting the relatively low preference of ungulates for beech and/or the low abundance of beech on each plot-group. Collins et al. (1978) found that highly abundant but non-preferred forage species took on principal dietary status, whereas some preferred species, scarce in the vegetation, comprised relatively little of elk diets in lodgepole pine stands. Because of the many possible confounding factors, evaluating wildlife use based solely on browse utilization results should be avoided.

Researchers have also cautioned against inferring habitat use from pellet-group counts (Neff 1968, Collins and Urness 1981,1984). However, some studies indicate that the relative magnitude of deer densities determined from pellet-group counts can provide a reliable index of use (e.g. Leopold et al. 1984, Etchberger et al. 1988). In this study, pellet-group counts were used as indices of relative use of the plot-groups, so the problems associated with determining absolute use from pellet groups should be circumvented.

Assumptions of pellet-group analysis include no observer bias in seeing groups, accuracy in aging or identifying pellet groups, and no loss of groups (Neff 1968). In this study, in a single year the same individual sampled each quadrat thereby minimizing or eliminating the pellet-group sighting bias. However, comparisons of pellet-group findings between 1988 or 1989 and 1990 should be done with hesitancy because a different observer was used in 1990 than in 1988 and 1989. Each quadrat was permanent and cleared after sampling, so no aging of pellet groups was necessary. However, the exact boundaries of the permanent quadrats were not marked, so the quadrats may not have been precisely the same from 1988 to 1990, possibly increasing the variability in results (Robinette et al. 1958). In a single year, identification of pellets was consistent among plots (i.e. the same observer made each count), but a cumulative pellet-group count for both deer and elk is provided to account for any misidentification of pellet-groups. Assuming that pellet-groups were lost at a constant rate among plot-groups should account for the assumption of no lost groups, since counts were used as a relative rather than absolute comparison measure.

Results from red maple utilization in conjunction with results from pellet-group counts suggest that ungulate use increases with decreased basal area. Pellet-group counts indicate that deer were responsible for the majority of the difference in browse use among or between plot-groups. Incidence of browsing and numbers of fecal groups also have been used as indices of ungulate activity in lodgepole pine stands (Crouch 1986). Crouch (1986) reported that the incidence of browsing increased among all vegetative species and treatments as basal area decreased. Furthermore, fecal group results indicated that mule deer showed preference for more heavily thinned blocks, whereas elk showed no preference among differently-thinned blocks (Crouch 1986). Pearson (1968) found that deer use measured by pellet-group counts was not significantly different among four thinning densities, 4.6, 9.2, 13.8, and 18.4 m^2/ha (20, 40, 60, 80 ft^2/ac, respectively) of basal area in ponderosa pine stands, but elk use was lower in the 18.4 m^2/ha stand than in the other three thinned stands.

Thinning can affect the quality and availability of foraging areas, hiding cover, and thermal cover (Thill et al. 1983). Thus, it is likely that the red pine treatment plots were used more than the control plots by deer or elk due to more favorable quality and quantity of forage and cover.

Forage

Thinnings temporarily increase variety, quantity, availability, palatability, and nutritive value of understory plants (Harlow and Van Lear 1987). Clary and Larson (1971) conducted pellet-group surveys and found that elk use of a stand that was 85% ponderosa pine at an average of 25.3 m^2/ha basal area was directly related to total herbage production and to forb production but not to browse production, which was noted as being consistent with the grazing habits of elk. Elk use was inversely related to ponderosa pine basal area, possibly indicating a combination of a preference for lower forest densities and of greater forage availability allowed by lower tree density (Clary and Larson 1971). However, in that same study, no significant relationships were found between deer use and herbage production, browse production, or ponderosa pine basal area. It has been noted that use by more than one herbivore can confound utilization results (Cook and Stoddart 1953).

Forage in the form of grass, forbs, and browse probably contributes more than other factors to the reproduction and maintenance of wild ungulate populations (Thill et al. 1983), and estimates of vegetative biomass are important in assessing the forage supply for wildlife (Joyce and Mitchell 1989). As aforementioned, annual productivity of herbaceous vegetation was significantly higher on both treatments than on controls, and red maple, a reportedly highly preferred browse species (Rogers et al. 1981), had significantly higher annual productivity on the LBAT than on the HBAT or controls. The absolute frequency of grasses and grasslike vegetation was high on all three plot-groups. Grasses were found to be the main herbage producers in thinned loblolly stands, and grass yields under moderately and heavily thinned stands were almost twice as great as under lightly thinned stands (Blair 1967). Similarly, McConnell and Smith (1970) noted that grasses became progressively more predominant as a ponderosa pine canopy was opened. Forbs are a highly desirable deer food, but most species are intolerant of low light levels (Blair and

Enghardt 1976). Several forbs including clover, field sorrel, and strawberry were found to be more frequent on treatments than on controls. Increases in productivity of these important forages likely contributed to increased ungulate use of the thinned plots.

Browse is an important food source of white-tailed deer in the northern Great Lakes states (Blouch 1984), and Spiegel et al. (1963) found that woody plants comprised the majority of the diet of elk in winter in the P.R.C.S.F. In 1989 and 1990, red maple and white ash were the two most abundant understory trees on the LBAT, quaking aspen was the most abundant understory tree on HBAT, and black cherry was the most abundant understory tree on the controls. Similarly, Dickmann et al. (1987) found that red maple and white ash tended to be more abundant where overstory stocking was the lightest, quaking aspen was more common on the moderately stocked areas, and black cherry was the most important tree on the heaviest stocked areas. The increase in total woody density in conjunction with the increase in densities of preferred deer browse species such as red maple, quaking aspen, and white ash on the LBAT as compared to the controls probably greatly contributed to the higher use of the LBAT than controls by deer. However, too great a density of trees may decrease wildlife use of the stands. For example, elk avoided dense pole stands of trees, and as stand density per acre approached 1,000 trees of >2.5 cm in d.b.h., elk sign disappeared (Spiegel et al. 1963).

Although not investigated in this study, thinning may have produced changes in nutritional quality of understory vegetation. The protein, phosphorous, and calcium content of forage can be greater in forage grown under heavy shade than under full sunlight; However, shade can also reduce the digestibility of forage by causing a high cellulose content, and the reduced digestibility can more than negate the advantage (Blair et al. 1983, Hunter 1990). Forage will tend to have increased levels of soluble carbohydrates, digestible energy, and digestible dry matter as well as more leaf biomass when light is increased from 8% to 45% of full sunlight (Hunter 1990). Bender (1990) found little change in understory nutritional quality soon after thinning of red pine overstory except for an increase in moisture content.

Cover

Even-aged management tends to concentrate all of a forest's resources into a single stratum (Peterken 1981). The physical structure of an area is important in determining bedding and feeding sites used by deer (Webb 1948) as well as playing a role in heat loss from an animal (Stevens and Moen 1970). Horizontal cover was evaluated as an indicator of hiding cover, whereas vertical cover in the overstory layer (i.e. >7 m in height) of the red pine plots was evaluated as an indicator of thermal cover for deer and elk.

The significantly higher horizontal cover on both treatments as compared to controls in the 0 - 0.5 m layer in 1989 and in 1990 and the 0.5 - 1.0 m layer in 1990 can be attributed to increased herbaceous and bramble production resulting from thinning. From 1989 to 1990, horizontal cover in certain layers increased significantly on the treatments but not on the controls. These increases in horizontal cover likely enhanced the hiding cover of an area, possibly increasing the suitability of the area for wild cervids.

The density of understory vegetation at different heights (i.e. its vertical structure) may be an important determinant of habitat selection by white-tailed deer (Nudds 1977) possibly because of its value as shelter (Guilkey 1958). Thermal regimes vary beneath different canopy types, and conifer stands can provide crucial winter cover in which wind and radiant heat loss are minimized (Moen 1968). Abilities of different canopy types to intercept and prevent ground accumulation of snow vary, and conifer stands generally allow less snow accumulation than do deciduous stands, so ungulate mobility is less restricted (Ozoga and Gysel 1972). The quality of thermal cover for deer and elk is considered optimal at 75% conifer crown closure (Thomas et al. 1979) and is believed to decrease as the crown closure decreases (L. C. Bender, White-tailed deer HSI for the Upper Great Lakes Region, Michigan State University, East Lansing, 1991).

Heavy thinnings may create a broken canopy that affords little thermal protection and allows snowpacks deep enough to severely stress deer or elk (Hunter 1990). Cover in the >7 m stratum, not surprisingly, significantly decreased with increased thinning intensity. Likewise, thinning of small-stem lodgepole pine was shown to reduce hiding cover and thermal cover in that stand, but, unlike the study presented here, slash had been removed and may have been a factor in the loss of hiding cover (Lyon 1987). Since dense patches of conifers are important for seasonal use by ungulates, thinning may render red pine stands unsuitable to ungulates in terms of thermal cover. However, Beyer (1987) found that elk and deer in the P.R.C.S.F. tended to select well-stocked mixed conifer or cedar swamps for thermal cover during harsh winters, so elk and deer use of pure red pine stands is probably not significantly determined by quality of thermal cover.

The availability of browse on ungulate winter ranges may be significantly influenced by silvicultural practices that alter snow accumulation and browse burial rates, suggesting that in winter a stand with greater canopy coverage may provide more available browse than a more open stand, even though the more open stand produces more total browse (Schwab et al. 1987). It has been noted that the influence of forest overstory on ungulate use may depend in part on snow conditions (Hanley and Rose 1987), since snow can render forage unavailable to deer or elk in the critical winter months (Hanley and Rose 1987). So, deer and elk use of the thinned red pine stands may vary among years depending on the snow fall and accumulation within a year, but this point warrants further investigation.

Slash

Deer and elk use of thinned areas is influenced not only by enhanced forage and cover but also by the availability of water, the design of roads as they influence disturbance from humans, and the manner in which logging slash is treated on the site (Reynolds 1962, Thill et al. 1983). It should be noted that slash was left on the red pine study sites and possibly affected the expected direction of changes or degree of changes in herbage production and ungulate use. Accumulation of slash from cuttings may be an asset or liability to ungulates depending on the volume of material, how it is treated, and the species of ungulate present (McAninch et al. 1984).

When slash is not removed or treated, it may result in substantial reductions in expected production by understory plants and can become an obstruction to deer and elk use of thinned stands (Lyon 1987). Dealy (1975) reported that slash accumulation from thinning lodgepole pine stands was so great that it completely precluded deer use immediately after thinning. Lyon and Jensen (1980) showed that elk and deer preferred openings in which logging slash was not a barrier to movement. Reynolds (1966, 1969) showed that deer preferred cut-over areas where slash was not treated to those sites where slash was cleaned up. Deer and elk preferred openings in ponderosa pine forests where slash had been piled and burned as compared to just piled (Ffolliott et al. 1977). Slash cleanup after thinning has been shown to decrease deer but not elk use of the thinned pine stands (Pearson 1968, Clary and Larson 1971).

Slash removal may reduce hiding or security cover for deer and elk (McAninch et al. 1984). If the amount of slash is not too great, scattering or no treatment may be the best practice on ungulate ranges (McAninch et al. 1984). For instance, slash can be piled or windrowed to obstruct long sight distances for deer and elk (McAninch et al. 1984).

Small Mammal Responses

In general, thinnings in pine plantations are beneficial for most small mammals because of increased food supplies and protective cover (Harlow and Van Lear 1987).

This is reflected in the tendency for increased mean number of individuals, number of species, and diversity on treatments as compared to controls. In August of 1989 and 1990, the average number of species caught was significantly greater on HBAT than on controls, and in August of 1989 LBAT also had a higher average number of species than did the controls. In July of 1990, the mean number of individuals caught was significantly higher on each treatment than on controls, but in August, the HBAT had a significantly higher mean number of individuals caught than either the controls or LBAT. Baseline data (i.e. before treatment was imposed) showed that HBAT plots had a significantly higher mean number of eastern chipmunks, individuals, and number of species in August than did the controls (Bender 1990), indicating that the HBAT plots and control plots may be inherently different in terms of small mammal use.

Within year differences in small mammal diversity indices were not consistent over years. In July and August, the small mammal diversity index was significantly higher on each treatment than on controls in 1989, but no significant differences in diversity indices among plot-groups were detected in 1990. The number of species caught on each plot-group in each sampling period in 1989 was similar to the number of species caught on the corresponding plot-group and sampling period in 1990. So, it appears that the significant difference in diversity index between treatments and controls in 1989 may be due to the more even distribution of small mammal individuals among species on the treatments as compared to the controls

The small mammal diversity index for controls and for HBAT was significantly higher in 1988 than in either 1989 or 1990. The mean number of species caught in each trapping period on the controls did not seem to vary among years, so the significant increase in abundance of white-footed mice over years likely caused a decrease in evenness, resulting in a lower diversity index. The mean number of species was significantly greater in 1989 and 1990 than in 1988 on the HBAT. However, despite the increase in number of species, a disproportionate increase in white-footed mice abundance appeared to caused a decrease in diversity index with time from thinning on the HBAT.

The small mammal diversity index of LBAT significantly decreased each year from 1988 to 1990. As the number of species caught in each trapping period on the LBAT was similar over years, it appears that small mammal evenness decreased with time from thinning. Particularly, it appears that white-footed mice increased in abundance, whereas southern red-backed voles and masked shrews decreased in abundance from 1988 to 1990 on the LBAT. Short-tailed shrews were significantly more abundant in 1989 than in either 1988 or 1990 on each plot-group, which is interesting to note but not explainable.

The abundance and diversity of small mammals generally follow the same pattern as plant species diversity of regenerating plantations, except that some older stands with greater foliage height diversity and more open canopies can provide more niches than young plantations (Atkeson and Johnson 1979, Hunter 1990). Furthermore, 1988 and 1989 had noticeably lower precipitation than the long-term norm, and drought conditions may have contributed to small mammal declines in those years (Bender 1990). Reproductive recruitment has been shown to be especially vulnerable to resource limitations (Ricklefs 1979). Trapping success for small mammals also has been found to depend on site characteristics. For example, trapping success on slash pine stands was primarily related to local site variation (i.e. soil drainage) (Landers unpubl. data as in Johnson 1987).

Eastern chipmunks and southern red-backed voles were significantly higher on LBAT plots than on controls in 1989 but not in 1990. However, some discussion of chipmunk and red-backed vole use seems warranted, since they were the only species caught on treatments but not on controls in both years. Southern red-backed voles prefer densely forested areas, especially where there is shrub and ground cover shade, leaf litter, and damp soil (Krefting and Ahlgren 1974), and they primarily eat green vegetation (DeGraaf and Rudis 1986). Eastern chipmunks inhabit edges or interiors of deciduous woodlands with abundant cover of undergrowth, old logs or semi-open brushlands with ample cover (DeGraaf and Rudis 1986) and are granivore-omnivores (Kirkland 1977).

Thinning produced conspicuous changes in the physical and biotic environments of resident small mammals (Kirkland 1977). For example, ground cover (i.e. cover in the <1 m stratum) was significantly greater on treatments than on controls. Vertical cover in the ground layer may serve to conceal small mammals from aerial predators, and it is likely that increased grass on the thinned plots provided increased forage for southern red-backed voles. Thus, it appears that thinning favored southern red-backed voles and eastern chipmunks by allowing an increased food supply and hiding cover in the understory (DeGraaf and Rudis 1986).

Some small mammal species may be deleteriously affected by overstory thinning. Red squirrels and flying squirrels depend upon mature or old-growth forests that provide cone-producing trees and nesting cavities (Gruell et al. 1982). No significant differences in red squirrel abundance among the plot-groups were found, and the only flying squirrel captured was caught on the lowest basal area treatment. This indicates that thinning to about 16.1 m^2/ha of basal area may not significantly alter squirrel use of red pine stands.

Leaving slash on a site can affect small mammal use depending on the habitat requirements of the species. White-footed mice have been found to be negatively correlated with percent cover of slash, whereas red-backed voles and masked shrews have been found to be positively correlated with the percent cover of slash (Eaton 1986). The presence of slash may decrease use by jumping mice (Eaton 1986). Slash may increase the abundance of insects and consequently increase the food supply for insectivorous small mammals

Summary of Wildlife Responses

Deer and elk use of the red pine stands increased with decreasing basal area apparently due to increases in food and/or cover. In both 1989 and 1990, horizontal cover below 1 m and vertical cover below 1 m were significantly greater on both treatments than on controls; this low vegetation was probably more valuable to deer and elk as forage than as hiding or thermal cover. The presence of heavy ground cover and high stem densities in conjunction with limited midstory and overstory cover of the LBAT leads to the conclusion that the LBAT were more heavily used by deer because of the enhanced food availability rather than because of enhanced cover attributes.

Few significant differences in small mammal use among the plot-groups within years were found. However, the mean number of individuals captured in each trapping period did tend to be higher on treatments than on controls in all 3 years. In addition, eastern chipmunks and southern red-backed voles were the only species to be found on the treatments but not on the controls in 1989 and 1990. Since chipmunks are omnivores it is possible that increases in cover were responsible for their increased use of thinned plots. It is likely that both the increased cover and increased food supply, especially grass, were responsible for increased southern red-backed vole use of the thinned plots as compared to the control plots.

Overall, results indicated that deer and elk habitat quality was highest on the 16.1 m^2/ha treatment plots and lowest on the control plots. Trends in vegetation and pellet-group data indicated that stands of 16.1 m^2/ha of basal area provide better deer and elk habitat than do stands of 25.3 m^2/ha of basal area. Thus, given that understory vegetation is maintained, it appears that the quality of mature red pine stands as habitat for elk, white-tailed deer, and certain small mammal species increases with increased thinning, at least to 16.1 m^2/ha of basal area.

Maintaining Wildlife Habitat in Red Pine Stands

Productivity of herbaceous vegetation and red maple was significantly greater on the LBAT than on the controls at 3 to 4 years after thinning. However, in even-aged forests, undergrowth may subside and then increase with the growth and thinning of overstory trees (Tappeiner and Alm 1975). Herbage yields have been shown to generally peak in 2 to 3 years after thinning and then gradually decline in a slightly curvilinear pattern as a timber stand becomes progressively denser (Halls and Schuster 1965, Halls 1970, 1973b; Blair and Enghardt 1976). Browse yields also decline but at a slower rate, with production peaking about 5 to 8 years after thinning (Halls 1973b). Annual productivity on the thinned red pine plots thus should be expected to gradually decrease with increased time from thinning.

Browse not only eventually decreases in production as a canopy closes, it also becomes inaccessible to ungulates. For instance, it has been found that within 10 years after a pine stand is first opened, much of the woody understory grows beyond the reach of deer to form a midstory cover of hardwoods and large shrubs (Blair 1967). In 1990, LBAT had significantly less vertical cover in the 2 - 7 m stratum than did HBAT, and, although not significant at $p = 0.10$, LBAT appeared to have less 2 - 7 m vertical cover than did controls ($p = 0.116$). No significant difference in vertical cover up to 7 m occurred on either treatment from 1989 to 1990, indicating no significant increase in the midstory layer. This is not surprising due to the short time from thinning, but an increase in midstory coverage should be expected with time from thinning. Gruell et al. (1982) reported that the quality of mule deer habitat varied with time since logging of a ponderosa pine forest, with browse conditions most favorable soon after logging and deteriorating where stand densities increased and tree canopies closed.

Thinnings can result in the development of a midstory of shade-tolerant species that may intercept even more light than the original canopy, and a reduction in forage production beyond that caused by overstory closure alone may result (Blair and Feduccia 1977, Hunter 1990). So, the sparse midstory of the LBAT not only can be expected to increase but also to contribute to decreases in herbaceous productivity. Blair and Feduccia (1977) reported that the presence of a hardwood midstory offset the benefits of greater forage yields achieved from managing loblolly pine at a lower basal area level.

As a result, it is important to take measures to maintain the production and accessibility of wildlife forage in order to maintain wildlife use of thinned red pine stands.

Productivity of herbage and browse can be restored by recurrent intensive thinning of pine stands (Wolters 1982). For example, to maintain deer habitat, Hurst and Warren (1980) noted that decreases in deer forage abundance coincided with the need for silvicultural practices. Blair (1968) recommended 4- or 5-year cutting intervals, and it was noted that a shorter cutting interval would likely be economically unacceptable to the timber producer (Halls 1970). In concurrence, Blair and Enghardt (1976) projected that a loblolly plantation thinned to about 16 m^2/ha every 5 years after age 20 could provide adequate forage for deer when the midstory is limited to desirable fruiting trees and shrubs. Conroy et al. (1982) suggested thinning at intervals of 5 years or less to increase forage production without allowing the tree crowns to expand and fully shade the site between thinnings. Intermediate thinnings coordinated with management practices aimed at keeping the undergrowth within reach of deer (e.g. carefully scheduled prescribed burning [Lay 1967, Grano 1970]) would be of optimum value to deer (Blair 1967). Longer cutting cycles of 8 to 10 years with prescribed burning at 3- to 5-year intervals have been suggested for stands managed primarily for timber products (Halls 1973b, Halls and Boyd 1982).

Managing for Multiple Benefits

When dense pine overstories are thinned, understory vegetation increases which in turn provides wildlife habitat. However, wide-spacing may be considered as wasting growing space, minimizing eventual yield, and preventing full utilization of available nutrients (Sarigumba and Anderson 1979). For example, tall shrubs are known to compete with the overstory for growth and reproduction (Balogh and Grigal 1988). Anticipated growth increments may be adversely affected by increases in understory vegetation, and substantial increases in wood fiber production may occur when understory vegetation is greatly reduced (Barrett 1965, Barrett and Youngberg 1965). Plantations of extremely low densities expend much energy in the production of branches, thereby decreasing the volume and value of merchantable timber (Wilde 1967). For the above reasons, foresters may question the use of low stocking levels or wide spacings that result from thinnings of pine plantations.

It is true that reduction in timber stocking often immediately decreases timber growth per acre, but individual tree growth may increase so that eventually timber growth per acre may increase (Ffolliott and Worley 1965). Thinning can increase net volume yield and financial returns of red pine by enabling harvest of suppressed trees that might be lost to mortality and concentrating growth on the better trees (Schone et al. 1984). Dickmann et al. (1987) reported that per acre volumes of red pine were positively related to stocking levels, illustrating the potential for a loss in timber volume at lower basal areas. However, these authors found that more usable cordwood volume was removed from lower stocked areas than from higher stocked areas (Dickmann et al. 1987).

From a "dollar-sign forestry" point of view, wild cervid habitat and habits may be detrimental to the realization of maximum yield of sawlogs or pulpwood (Spiegel et al. 1963:72). However, from the standpoint of multiple use, creating habitat for wild cervids creates habitat for other wildlife, the presence of wild cervids provides recreation for people, and maintaining a minimum basal area should allow an acceptable level of timber production. Dickmann et al. (1987) asserted that wide-spaced red pine stands can be managed for the production of forage and cover for wildlife as well as for timber production. Similarly, Halls (1970) stated that when trees reach harvestable size, a stand can be thinned to provide growing space for deer browse without detracting from the stand's wood-producing potential.

McConnell and Smith (1970) discussed some of the silvicultural advantages of having understory vegetation present, such as improved soil fertility due to nitrogen fixation by some understory plants, mechanical protection of pine seedlings from grazing and trampling, and more favorable soil moisture and temperature for pine seedlings under shrubs than under grasses or on open ground. McKee (1987) discussed a potential benefit to the timber producer from big game, showing that net revenues from the joint production of timber and wildlife under fee hunting situations in the South were greater than revenues generated from maximizing timber production (Flather and Hoekstra 1989). Von Althen et al. (1978) presented a study illustrating not only the physical response of a red pine plantation to a thinning program but also the economic results calculated on the basis of historical and assumed costs and revenues.

Several valid concerns exist about encouraging undergrowth in red pine plantations. For example, understory vegetation can contribute to the development of insect and disease problems in red pine plantations (Schone et al. 1984). The Saratoga spittlebug is notorious for killing red pine in Michigan and Wisconsin, and its nymphs require the sap of understory herbs and/or woody plants for food (Kennedy and Wilson 1971). Brambles, strawberry, orange hawkweed, and bracken fern are considered important spittlebug hosts (Ewan 1961), and these vegetative species occurred on each of the plot-groups. But, only brambles was found to be significantly greater on the treatments than on controls, and it has been noted that these plants must be extremely abundant to sustain a spittlebug outbreak (Kennedy and Wilson 1971). Finally, red pine is troubled by needle blight (*Coleosporium solidaginis*) whose alternate hosts are goldenrod and aster (Cook 1941). However, frequencies of goldenrod and aster did not significantly differ among the three plot-groups, indicating that thinning to about 16.1 m^2/ha of basal area may not increase the likelihood of a needle blight outbreak.

As another example, small mammals may be considered detrimental to red pine plantations because of consumption of red pine seeds or bark. Since regeneration of red pine typically involves planting, small mammal consumption of red pine seeds should not be viewed as a problem. Girdling of overstory trees by consumption of inner bark presents a possible threat from small mammals, but very little information was found on the effects of small mammals on mature red pine trees. It should be noted that small mammals have a useful place in forest ecology, such as reducing some insect pests and loosening the soil and duff layers allowing better air and water penetration (Harris 1968). Management for wildlife should recognize "the practical ecology of all vertebrates and their plant and animal associates. While emphasis may often be placed on species of special economic importance, wildlife management along sound biological lines is also part of the greater movement for conservation of our entire native fauna and flora" (Bennitt et al. 1937:1).

Several planning aids for multiple use have been offered. Boyce (1982, 1985) proposed an approach to multiple-use decision making and control that limits complexity and provides clear channels of communication. Joyce et al. (1990) described a conceptual framework that integrates timber projections with forage, wildlife, water, and fish projections at the regional level. Ffolliott and Worley (1965) described a basal area factor inventory system to determine if it is feasible to manage a tract of land as proposed, to determine what changes in multiple use production can be expected, and to estimate the immediate direct costs and returns associated with change in management. The Wildlife Habitat Association data base, developed for the Chippewa National Forest, Minnesota, offers an objective and organized way of dealing with wildlife habitat values and the consequences of silvicultural and other land use proposals (Mathisen 1988). Finally, many guidelines for coordination of wildlife and timber management have been developed for southern forests (Johnson et al. 1974, Harris et al. 1979, Buckner and Landers 1980, Harris and Marion 1982, Landers 1985).

Concerns and Recommendations

I have several concerns to mention. First, basal area was used as the treatment factor, but basal area may not always be the best measure of the influence of the tree layer upon the species existing below (Buell and Cantlon 1950). Specifically, a given basal area per unit area may represent an open stand of older and larger trunks as in this study, or it may represent a closed canopy formed by a dense growth of young individuals. So, basal area should be viewed in conjunction with average d.b.h. or percent crown cover to evaluate the effects of thinning on wildlife habitat in the understory. Second, this study was of responses of wildlife and vegetation at only 3 years after thinning, which may be too short a time frame for responses to fully manifest. Third, thinning and timber removal occurred on several of the treatment plots during the field season of 1990. This may have confounded results, since physical disturbances caused by logging, such as forest floor alterations or reduction in competing shrub cover, may have contributed to understory vegetative differences among plots (Thill et al. 1983). Finally, low rainfall in two of the study years was likely partly responsible for changes detected over years.

Comparisons between LBAT that were thinned in different years were made to evaluate if parameters changed with increased time since overstory thinning. Unfortunately, baseline data for these plots were not gathered, so it is not possible to determine if initial floral and faunal compositions were similar. Yet, if the plots were inherently similar, one would expect the 1989 results from the LBAT86 plots to be similar to 1990 results from the LBAT87 plots because they would both be 3-year-old thins. However, total woody density, densities of several woody species (eg. red maple and choke cherry), small mammal abundance and diversity, and total deer and elk use were quite different between the LBAT at 3 years after thinning.

Several possible reasons exist for these differences between LBAT86 and LBAT87. First, the six LBAT87 plots were located very close to one another, the three LBAT86 plots were also close to each other, but the two groups of different-aged plots were about 1.6 km away from each other. In addition to the proximity difference, the LBAT87 plots had a higher site index than the LBAT86. Thus, the validity of assuming that all factors other than age since thinning were constant for these plots is questionable, so no attempt to explain effects of time since thinning was made.

I have several recommendations for future research on red pine. First, use of thinned red pine stands by wildlife species besides those studied in this project should be determined. Particularly, with the popularity of bird watching on the rise nationwide (Flather and Hoekstra 1989), the response of birds to different thinning intensities of red pine would be important to evaluate. Second, mature red pine is adapted for the use of fire in the understory, so the effects of prescribed burning on wildlife habitat and wildlife use under different thinning regimes in red pine plantations needs to be fully investigated and documented. Fire can be a valuable management tool because it creates a mosaic of vegetation, releases nutrients, can be cost effective when used correctly, and is a natural disturbance factor. Finally, studies on red pine need to span several years to enable evaluation of trends within the stands.

CONCLUSION

The extent of understory vegetative growth and, in turn, the quality of wildlife habitat in a mature red pine plantation are determined largely by the degree of overstory cover. The results of this study provide quantitative evidence that red pine stands can be improved as wildlife habitat by thinning to a relatively low basal area. Research over a longer time period is needed to determine the optimum level of thinning for maintaining satisfactory levels of both red pine timber and wildlife.

Vegetation and wildlife responses to silvicultural practices may differ drastically at different places and different times depending upon site characteristics, previous land uses, and weather conditions. However, thinning mature red pine plantations on high quality sites located throughout the Great Lakes region will likely increase the quality of wildlife habitat within those stands. Red pine plantations grown on a long-term rotation can provide sustained habitat for wildlife only if they are intentionally managed for wildlife forage and cover in the understory. Thus, close coordination between sometimes divergent interests is important in maintaining a responsible integration of forest uses.

APPENDIX

APPENDIX

Table 15. Common and scientific names of fauna mentioned in thesis.

Common Name	Scientific Name
Bald eagle	*Haliaeetus leucocephalus*
Blackburnian warbler	*Dendroica fusca*
Chipping sparrow	*Spizella passerina*
Deer	*Odocoileus* spp.
Dung beetle	Scarabaeidae
Eastern chipmunk	*Tamias striatus*
Eastern mole	*Scalopus aquaticus*
Elk	*Cervus elaphus*
Ermine	*Mustela erminea*
Flying squirrel	*Glaucomys* spp.
Jumping mouse	Zapodidae
Marten	*Martes americana*
Masked shrew	*Sorex cinereus*
Meadow vole	*Microtus pennsylvanicus*
Mule deer	*Odocoileus hemionus*
Pileated woodpecker	*Dryocopus pileatus*
Pine warbler	*Dendroica pinus*
Porcupine	*Erethizon dorsatum*
Pygmy shrew	*Microsorex hoyi*
Red-backed vole	*Clethrionomys* spp.
Red-breasted nuthatch	*Sitta canadensis*
Red squirrel	*Tamiasciurus hudsonicus*
Saratoga spittlebug	*Aphrophora saratogensis*
Short-tailed shrew	*Blarina brevicauda*
Snowshoe hare	*Lepus americanus*
Southern red-backed vole	*Clethrionomys gapperi*
Starling	*Sturnus vulgaris*
White-footed mouse	*Peromyscus* spp.
White-tailed deer	*Odocoileus virginianus*

Table 16. Common and scientific names of flora mentioned in thesis.

Common Name	Scientific Name
American basswood	*Tilia americana*
American elm	*Ulmus americana*
American hazelnut	*Corylus americana*
American white birch	*Betula papyrifera*
Anemone	*Anemone* spp.
Aniseroot	*Osmorhiza* spp.
Arrow-leaved aster	*Aster sagittifolius*
Aspen	*Populus* spp.
Aster	*Aster* spp.
Balsam fir	*Abies balsamea*
Balsam poplar	*Populus balsamifera*
Beaked hazelnut	*Corylus cornuta*
Bedstraw	*Galium* spp.
Beech	*Fagus grandifolia*
Bigtooth aspen	*Populus grandidentata*
Bitter dock	*Rumex obtusifolius*
Black cherry	*Prunus serotina*
Black oak	*Quercus velutina*
Black spruce	*Picea mariana*
Blueberry	*Vaccinium* spp.
Bracken fern	*Pteridium aquilinum*
Bramble	*Rubus* spp.
Bristly sarsaparilla	*Aralia hispida*
Bunchberry	*Cornus canadensis*
Burdock	*Arctium* spp.
Canada anemone	*Anemone canadensis*
Canada mayflower	*Maianthemum canadense*
Cedar	*Thuja* spp.
Choke cherry	*Prunus virginiana*
Cinquefoil	*Potentilla* spp.
Clover	*Trifolium* spp.
Columbine	*Aquilegia* spp.
Common chickweed	*Stellaria media*
Common cinquefoil	*Potentilla simplex*
Common mullein	*Verbascum thapsus*
Common plantain	*Plantago major*
Common witch-hazel	*Hamamelis virginiana*
Cowwheat	*Melampyrum lineare*
Crabapple	*Pyrus* spp.
Cranesbill	*Geranium* spp.
Currant	*Ribes* spp.
Daisy	*Chrysanthemum* spp.
Daisy fleabane	*Erigeron annuus*
Dandelion	*Taraxacum* spp.
Dwarf bush-honeysuckle	*Diervilla lonicera*

Table 16 (cont'd).

Common Name	Scientific Name
Evening primrose	*Oenothera* spp.
Field bindweed	*Convolvulus arvensis*
Field hawkweed	*Hieracium pratense*
Field sorrel	*Rumex acetosella*
Goldenrod	*Solidago* spp.
Goldthread	*Coptis groenlandica*
Gooseberry	*Ribes* spp.
Grass/Grasslike	Poaceae/Cyperaceae,Juncaceae
Hairy hawkweed	*Hieracium gronovii*
Hawkweed	*Hieracium* spp.
Hawthorn	*Crataegus* spp.
Highbush cranberry	*Viburnum trilobum*
Honeysuckle	*Lonicera* spp.
Hooked crowsfoot	*Ranunculus recurvatus*
Horsetail	*Equisetum* spp.
Indian pipe	*Monotropa uniflora*
Ironwood	*Carpinus caroliniana*
Jack pine	*Pinus banksiana*
Juneberry	*Amelanchier* spp.
Ladies' tresses	*Spiranthes* spp.
Leathery grape-fern	*Botrychium silaifolium*
Lily/Orchis	Liliaceae
Loblolly pine	*Pinus taeda*
Lodgepole pine	*Pinus contorta*
Mapleleaf viburnum	*Viburnum acerifolium*
Milkweed	*Asclepias* spp.
Mint	Labiatae
Moneywort	*Lysimachia nummularia*
Moss/Lichen	Bryophyta/Various
Mossycup oak	*Quercus macrocarpa*
Mulberry	*Morus* spp.
Narrow-leaved pinweed	*Lechea tenuifolia*
New Jersey tea	*Ceanothus americanus*
Ninebark	*Physocarpus opulifolius*
Orange hawkweed	*Hieracium aurantiacum*
Oxeye daisy	*Chrysanthemum leucanthemum*
Pearly everlasting	*Anaphalis margaritacea*
Pine	*Pinus* spp.
Pinesap	*Monotropa hypopithys*
Plantain	*Plantago* spp.
Plum	*Prunus* spp.
Poison ivy	*Rhus toxicodendron*
Ponderosa pine	*Pinus ponderosa*
Prairie willow	*Salix humilus*
Pussytoes	*Antennaria* spp.
Pyrola	*Pyrola* spp.

Table 16 (cont'd).

Common Name	Scientific Name
Quaking aspen	*Populus tremuloides*
Raspberry	*Rubus* spp.
Rattlesnake fern	*Botrychium virginianum*
Red maple	*Acer rubrum*
Red oak	*Quercus rubra*
Red pine	*Pinus resinosa*
Sanicle	*Sanicula* spp.
Scrub oaks	*Quercus* spp.
Shinleaf	*Pyrola elliptica*
Siberian crabapple	*Pyrus baccata*
Slash pine	*Pinus elliottii*
Slippery elm	*Ulmus rubra*
Solomon's seal	*Polygonatum* spp.
Spirea	*Spiraea* spp.
Spreading dogbane	*Apocynum androsaemifolium*
Spruce	*Picea* spp.
St. johnswort	*Hypericum* spp.
Starflower	*Trientalis borealis*
Strawberry	*Fragaria* spp.
Striped maple	*Acer pensylvanicum*
Sugar maple	*Acer saccharum*
Sumac	*Rhus* spp.
Swamp oak	*Quercus bicolor*
Sweetfern	*Comptonia peregrina*
Sweet clover	*Melilotus* spp.
Tamarack	*Larix laricina*
Thimbleweed	*Anemone virginiana*
Thistle	*Cirsium* spp.
Touch-me-not	*Impatiens* spp.
Trailing arbutus	*Epigaea repens*
Trillium	*Trillium* spp.
Twisted stalk	*Streptopus amplexifolius*
Upright bindweed	*Convolvulus spithamaeus*
Violet	*Viola* spp.
Virgin's bower	*Clematis* spp.
White ash	*Fraxinus americana*
White oak	*Quercus alba*
White pine	*Pinus strobus*
White spruce	*Picea glauca*
Wild basil	*Satureja vulgaris*
Wild geranium	*Geranium maculatum*
Wild lettuce	*Lactuca canadensis*
Wild sarsaparilla	*Aralia nudicaulis*
Willow	*Salix* spp.
Wood anemone	*Anemone quinquefolia*
Yarrow	*Achillea millefolium*

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