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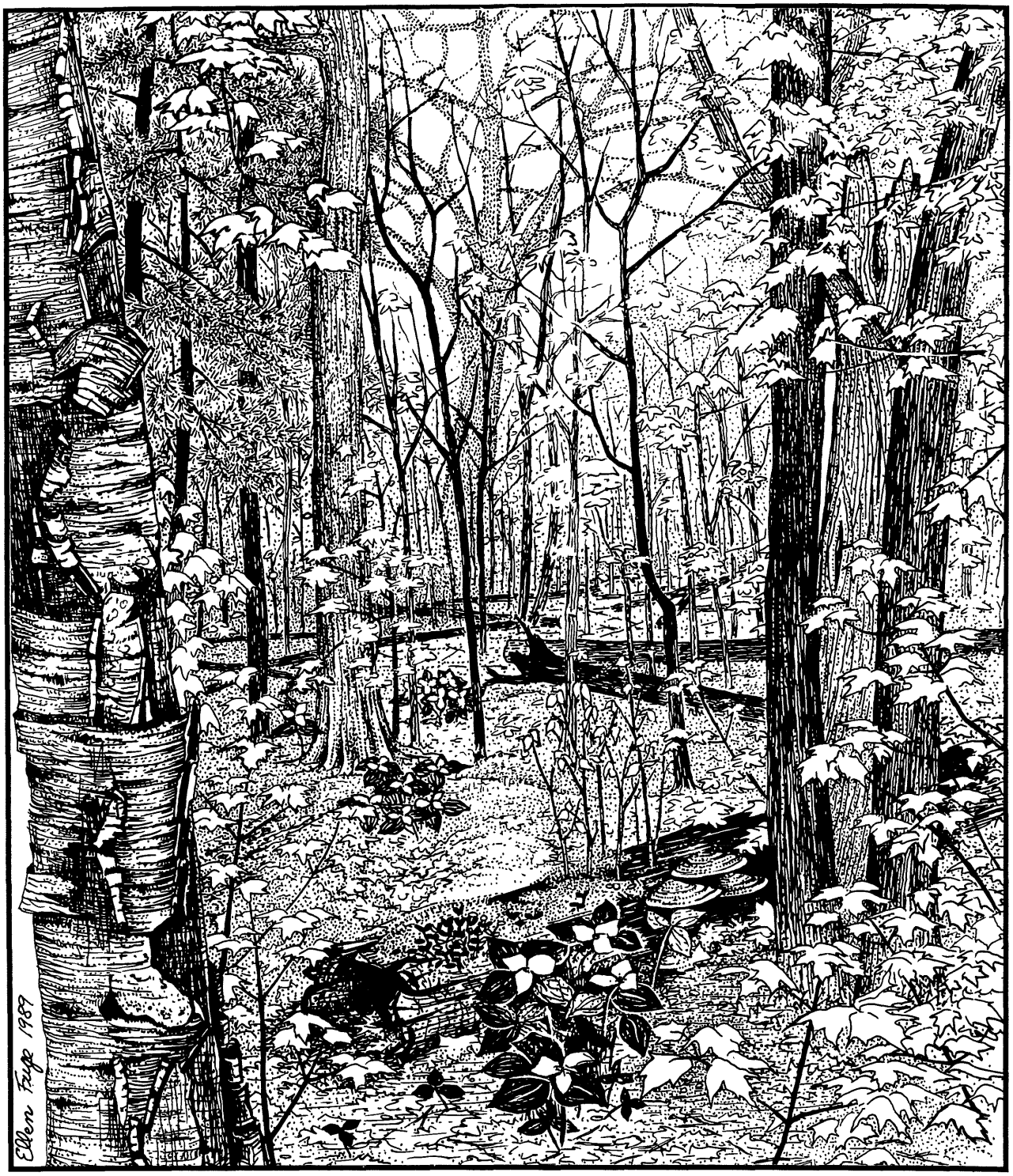

OLD-GROWTH FORESTS IN MINNESOTA

A Preliminary Report

Section of Wildlife - Natural Heritage Program
Minnesota Department of Natural Resources - Biological Report No. 5

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ABOUT THE COVER

The cover drawing by Ellen Fuge depicts an old-growth northern hardwood-conifer forest in Magney-Snively Park in Duluth. This drawing illustrates many key features of an old-growth northern hardwood-conifer forest as it appears in late spring.

Growing on the large, hollow log in the center foreground are mosses, bracket fungi, yellow birch seedlings, and, to the left, a clump of the rare flowering herb moschatel (Adoxa moschatellina), a species of special concern in Minnesota. In front of the hollow log is one of several clumps of large-flowered trillium (Trillium grandiflorum) that carpet the forest floor. Several highly shade-tolerant sugar maple seedlings and saplings are also apparent in the foreground.

At the left are a large yellow birch snag and a white pine. An American basswood snag is visible at the right, in the center of a clump of younger basswood stems. Dominating the center background is a huge, ghostlike, old-growth sugar maple; to its left is another large sugar maple. The center background also contains a number of down logs, perhaps the result of an unusually strong wind gust. The same localized disturbance created an opening in the canopy, and a number of small sugar maples and basswoods can be seen vying for their place in the sun.

PREFACE

This paper on old-growth forests was written out of my desire to share my evolving understanding of the ecological nature of old growth and its status in Minnesota. Old growth has become an important and often controversial issue throughout much of North America. In spite of this interest, there remains much confusion, even among land managers, about what constitutes old growth. I have attempted to address that confusion by adopting a definition of old growth consistent with that used by ecologists in other regions yet applicable to Minnesota forests.

In the Pacific Northwest, the old growth issue has pitted logging companies and the Forest Service against environmentalists and professional ecologists. In Minnesota, because we lack large areas of economically valuable old-growth timber and apparently have no ecological counterpart of the endangered spotted owl, old growth has been a less controversial issue. Nevertheless, old growth is an important conservation issue in Minnesota. In 1988, the Department of Natural Resources set up a task force to develop guidelines for the protection and management of old-growth forests on state land. Minnesota's two national forests, the Chippewa and the Superior, are also involved in protection and management of old growth.

There is much to learn about old growth in Minnesota. Two important questions are, "How much old growth existed prior to settlement?" and "How much old growth remains?". The former question can only be answered by analyzing the original land survey records from 1847 to 1907. We do know that even within what is now the Boundary Waters Canoe Area Wilderness where fire frequencies were relatively high, nearly 30% of the forest was at least 141 years old in 1868. In other words, there was probably more old growth prior to settlement than is commonly believed. The question of how much old growth remains in Minnesota can only be answered by a systematic survey guided by information in the forest inventory databases and leads from field personnel. Such a survey will be greatly facilitated by the development of quantitative structural and compositional descriptions of old growth for each important forest type. Research on these questions is a priority of the Minnesota Natural Heritage Program. Once old growth is identified, effective management strategies must be devised to assure that old growth remains part of the Minnesota landscape.

As in any scientific endeavor, research on old-growth forests leads to tentative conclusions that are subject to revision once we know more. This paper is clearly not the final word on old growth, but it is an important first step.

Kurt A. Rusterholz, Ph.D.
Plant Ecologist, Natural Heritage Program
Minnesota Department of Natural Resources
20 March 1989

OLD-GROWTH FORESTS IN MINNESOTA

Forests are never static. They change in form and composition from day to day and century to century. The predominant pattern of forest change is a progressive change in species composition and forest structure known as succession. Succession, if not interrupted by a disturbance such as fire, windstorm, or logging, will eventually culminate in a so-called "climax" forest. In many regions, however, catastrophic natural disturbances, which destroy most of the forest canopy, were part of the natural environment in which forests evolved. For example, the natural vegetation of the Lake States is, in large part, determined by patterns of catastrophic disturbances such as crown fires, windstorms, and disease and insect epidemics. In Minnesota, catastrophic disturbances, particularly forest fires, were considerably more frequent than in the forests of the northeastern United States or the coastal Pacific Northwest. Nevertheless, large areas of land escaped catastrophic disturbances for long periods. Forests on these sites survived because of their protected locations, lack of flammability, or simply by chance. It was here that old-growth forests developed.

Under natural conditions, a new forest is usually initiated as the result of a catastrophic disturbance. It then progresses through a series of successional stages, until at some point the forest is destroyed by a natural catastrophe. It is convenient to recognize five stages in the natural development of a forest:

1) herb and shrub stage,
2) young forest,
3) mature forest,
4) subclimax old-growth forest,

and 5) climax old-growth forest.

Old-growth includes the last two stages in the development of a natural forest. Therefore, old growth represents successional stages that occur only after a relatively long period of time without a catastrophic disturbance. In Minnesota, old-growth forests probably develop after 125-150 years without a catastrophic disturbance.

The different successional stages of a forest are characterized by distinct groups of tree species: **pioneer species**, **gap phase species**, and **climax species**. Each of these species groups is favored by a different pattern of disturbance, and each group requires a different set of environmental conditions for optimal reproduction and persistence. **Pioneer species** usually become established following a catastrophic disturbance and dominate the early stages of succession. In the Lake States, pioneer species include jack pine, red pine, aspen, bur oak, and white birch. White pine is sometime considered a pioneer species because white pine stands most often originated following forest fires. White pines do reproduce in existing forests but these seedlings are often outcompeted by more shade-tolerant species. Because red pines and white pines are quite long-lived, these species often survive to dominate subclimax old-growth forests. **Gap phase species** are more shade tolerant than pioneer species but only enter the canopy when a gap appears, usually as the result of the death of an individual canopy tree. Gap phase species in the Lake States include red oak, red maple, yellow birch, basswood, white spruce, and, under appropriate conditions, white pine. Gap phase species may dominate subclimax old-growth forests and

persist in climax old-growth forests. **Climax species** reproduce and persist under low light conditions beneath the forest canopy and therefore dominate climax old-growth forests. Like gap-phase species, climax species enter the canopy when small canopy gaps occur. Climax species, however, can tolerate lower light intensities, are more sensitive than gap phase species to moisture stress, and are less resilient following fire and animal damage. Climax species in the Great Lakes region include white cedar and white spruce and especially sugar maple and balsam fir.

Development of old-growth forests

The old-growth red pine and white pine forests of the Lake States and the classic old-growth Douglas-fir forests of the Pacific Northwest are dominated by pioneer species that became established following a catastrophic disturbance, usually a forest fire. These species, which typically do not reproduce successfully in the shade of their own canopy, dominate the old-growth forest for many decades because of their large size and great longevity. Eventually, these species die and, in the absence of catastrophic disturbance, are replaced by gap phase and climax tree species as a climax forest develops. As an example, old-growth subclimax forests in the Boundary Waters Canoe Area Wilderness (BWCAW) are often dominated by white pines. These trees may reach nearly 400 years of age. At some locations these old-growth pines are rapidly dying and have been replaced as dominants by northern white cedar and white spruce. These more shade-tolerant species, themselves well over 200 years old, will continue to dominate the old-growth forest until it is destroyed by a catastrophic disturbance. In other parts of Minnesota, old-growth northern hardwood forests and maple-basswood forests are now approaching climax conditions on the relatively few sites that have been well-protected from catastrophic disturbances, both natural and human.

RECOGNITION OF OLD GROWTH FORESTS

Old growth is recognized by several key structural characteristics that develop in a forest as it progresses from mature forest to old-growth forest:

1. The presence of old, usually large, trees. This feature is the best single indicator of old growth. Old-growth forests, however, are seldom composed solely of large old trees.

Many old-growth forests contain many small and medium-sized individuals of climax and gap-phase tree species, which may enter the canopy as tree-fall gaps appear. The increased light and soil disturbance caused by tree fall gaps also provides optimal conditions for seedling establishment of gap-phase species.

Another reason that old growth is not always dominated by large trees is that the relationship between tree age and tree size is quite variable and depends on tree species, climate, and site conditions. Thus, old growth on sites where conditions are harsh will not contain particularly large trees.

2. The presence of large snags, which are often abundant. When standing trees die they become snags. Not all old-growth forests, however, contain abundant snags. For example, old-growth red pine forests generally experience little tree mortality until they are over 150 years old, and hence these forests have few snags.

3. The presence of frequent down logs. Like snags, down logs are not always abundant in the earlier stages of old growth. In general, however, both frequent down logs and frequent snags (collectively known as coarse woody debris) are good indicators of old growth. Coarse woody debris, however, is often common in young forests, because snags and down logs are often produced by the catastrophic disturbance that initiated the development of the new forest. By the time a mature forest develops this coarse woody debris is usually well-decayed. Thus, mature forests typically contain little coarse woody debris.

4. Structural complexity. Forests often become structurally more complex with age. As individual trees of pioneer species die, long-lived canopy gaps are produced. These gaps provide appropriate conditions for gap phase tree seedlings and understory species that require high light availability and the moderate soil disturbance resulting from tip-up mounds. Heavily shaded areas also develop in which only the most shade-tolerant understory species can survive. Because of the diversity of microhabitats across the forest floor, a patchy distribution of understory plants often develops. Horizontal complexity of the forest increases as well, as both existing but suppressed saplings and newly germinated seedlings grow rapidly in response to increased light availability in gaps.

The forest floor in an old-growth forest is also topographically complex. This diversity is caused by fallen tree boles, their uprooted butts, and pits and mounds produced when trees are uprooted. The structural diversity of the forest floor provides optimal habitat for many plants and small animals. Pit-and-mound topography is an important factor in maintaining the diversity of the herb layer and promoting tree regeneration; it is also a major cause of soil mixing.

As should be apparent from the preceding discussion, old growth as an ecological condition is highly variable. Not all old-growth forests fit the widespread conception of aesthetically pleasing forests dominated by huge trees with an open, parklike understory. In fact, old-growth forests can be quite messy. Although the presence of large trees and decadence are the two best structural indicators of old-growth, the use of a multi-factored scorecard is perhaps the best way to evaluate and rank old growth. Such a scorecard has been developed by the U.S. Forest Service and is based on 12 old-growth characteristics, each of which is given a rank from one to five (Old Growth Habitat Scorecard. Medicine Bow National Forest. USDA Forest Service, 1983). Modification of this procedure for each old-growth forest community type in Minnesota will provide a reasonably objective means of assessing old growth.

In short, old-growth forests have developed for a relatively long period of time without experiencing a catastrophic disturbance and as a result contain old trees. In Minnesota the absence of short-lived, pioneer species such as aspen in a forest may be indicative of old growth.

THE VALUE OF OLD-GROWTH FORESTS

Old-growth forests are intrinsically valuable to society for several important reasons.

1) Old-growth forests provide essential ecosystem services. As ecosystems that have experienced little significant human disturbance, old-growth forests still function in a manner that maintains naturally high soil fertility and high water quality.

The mycorrhizal fungi that live symbiotically with the billions of fine rootlets of forest trees and other plants are, in large part, responsible for the ability of plants to absorb essential nutrients from the soil. At least on dry sites, decaying wood (common in the soil of old-growth forests) is correlated with the presence of mycorrhizal fungi and increased conifer seedling establishment.

Old-growth forests retain soil nutrients very tightly, i.e. nutrients are cycled in a nearly closed system between the soil and living organisms, with few nutrients being lost by run-off. The decomposition of fallen logs plays an important role in nutrient cycling. The decaying wood provides a substrate for long-lived decomposer and myccorhizal fungi that capture nutrients such as nitrogen. The nitrogen is then slowly released in a form more readily available for plant growth. Down logs also retain other essential nutrients (because of their high cation exchange capacity) and have a high water holding capacity. As a consequence of the tight nutrient cycling in old-growth forests, water quality of associated lakes and streams is usually very high. In addition, the presence of coarse woody debris from old-growth forests in streams of the Pacific Northwest maintains high game fish species diversity.

Old-growth forests also provide abundant substrates for the growth of lower plants such as lichens that convert atmospheric nitrogen into a form that can be used by trees. For example, the lichen Lobaria oregana, which grows in tree canopies, plays an important ecological role by fixing atmospheric nitrogen (8-10 kg/ha/yr) in old-growth forests of the Pacific Northwest. The closely related, Lobaria quercizans, which grows on the trunks of old trees, is a threatened species in Minnesota as the result of logging of old-growth yellow birch.

2) Old-growth forests provide important habitat for a number of rare and several endangered species of plants and animals.

Although no vertebrate animals are limited solely to old-growth forests in Minnesota, a variety of uncommon to rare bird species are most common in old growth, and several rare mammal species may require old-growth forest conditions as part of their habitat requirements.

In general, old-growth forests support higher densities of a number of uncommon bird species than young, disturbed forests. Within northern hardwood forests of the northeastern United States most species of fly-catchers and woodpeckers have shown significant declines in abundance following large scale forest disturbance. Other species exhibiting

significant population reductions in disturbed and early successional forests include the scarlet tanager, wood thrush, yellow-throated vireo, and Louisiana waterthrush. The Louisiana waterthrush is particularly rare in Minnesota where it is officially listed as a Species of Special Concern. The four species listed above, along with most flycatchers, winter in the tropics where their wintering habitats have been subjected to extensive deforestation. Several of these species have experienced serious population declines in the northeast. Although habitat destruction in the tropics will, no doubt, eventually affect breeding populations of temperate forest birds, most documented population declines appear to be caused by the destruction of their breeding habitats in the northeastern United States. Similar bird population declines may occur in Minnesota if current projections for increased timber harvest materialize. For many bird species, population size is limited by the availability of potential nest sites. All of the woodpeckers, for example, are hole-nesters. Snags are the best potential nest sites for these species. For one species, the chimney swift, virtually the only remaining natural nesting sites are large hollow trees found in old-growth forests. Chimney swifts have now adopted chimneys as nesting sites, but areas away from cities seldom have chimney swifts unless they are near old-growth forests.

Old-growth forests provide optimal habitat for flying squirrels and pine martens. The northern flying squirrel is a hole-nester that, at least in the Pacific Northwest, feeds heavily on certain fungi that grow on the floor of old-growth forests. Pine martens require large areas of relatively undisturbed forest as part of their habitat requirements. Old-growth boreal forest communities may also be important if woodland caribou are to be successfully reintroduced into Minnesota. Old-growth boreal forest communities are important to the survival of caribou because they support abundant growth of lichens, the caribou's major food. Lichens are notoriously slow growing and take a long time to re-establish after a catastrophic disturbance. Old-growth forests also support very few white-tailed deer, the intermediate host of the parasitic brain-worm (Paralopostrongylus tenius), which is thought to be partly responsible for the extirpation of caribou from Minnesota.

Down logs provide essential habitat for salamanders and an almost incomprehensible array of invertebrates. Down logs, however, are usually rare in mature and managed forests. The overall importance of coarse woody debris in maintaining biological diversity is illustrated by a statement by the eminent ecologist, Charles Elton, who noted that removal of dead and dying material from a forest impoverishes its flora and fauna by 20%.

A number of rare and endangered plants are limited to old-growth forests including the State Endangered species Chilean sweet cicely (Osmorhiza chilensis) and gold-seal (Hydrastis canadensis). Most lichen species have been eliminated from regions near urban areas because they are extremely sensitive to air pollution. In Minnesota, five species of lichens that grow on tree trunks are now extremely rare, primarily as the result of logging and the destruction of old-growth forests. Of these species two are listed as State Endangered, one is listed as State Threatened, and two are Species of Special Concern.

3) Old-growth forest have esthetic and cultural values to society.

Like the great European cathedrals and the Washington Monument, old-growth forests are part of our human heritage. The old-growth forests of the eastern United States provided the first frontier environment that helped shape the American character. The preservation of old-growth forests will allow Minnesotans to experience the natural environment that shaped their forebears' lives.

4) Old-growth forests are valuable in and for themselves.

Old-growth forests are one of the few remaining natural ecosystems that function in a manner that evolved over many millennia. These forests are places where scientists can study and laymen can observe interactions between plants, animals, and their environment in some of the most natural situations remaining in Minnesota. Furthermore, a more complete understanding of forest ecology, particularly the processes of natural reproduction of trees, nutrient cycling, and succession, can only be gained by studying old-growth forests.

5) Old-growth forests contain a storehouse of knowledge that can be used to improve forest management of commercial forests and multiple use forest lands. Old-growth forests, therefore, have a direct economic value to the forest products industry.

State, federal, and private forest managers have shown a strong interest in developing an Ecological Classification System (ECS) for Minnesota forests. A well-designed ECS will allow forest managers to determine the potential vegetation of a site from easily measurable site characteristics and from the presence and abundance of certain plant indicator species. The significance of an ECS is that it allows a forester to predict the potential of a site to produce high volumes of wood from tree species that may currently not occur on the site.

Ecological Classification relies heavily on sampling late successional and old-growth stands in order to document successional pathways and to produce reliable growth curves that extend beyond normal rotation age. Because all species, including groundlayer plants, are weighted equally in the analysis of ECS plots it is important to distinguish plant distributions that result from human-induced disturbances from those that occur on a site because of natural environmental factors (e.g. soils, topography, parent material). Old-growth stands serve as examples of forests that have experienced little human disturbance and therefore provide the only objective means of eliminating "disturbance" species from the list of potential site indicator species.

The continued loss of late-successional and old-growth stands as ECS sample sites will seriously inhibit ECS efforts in Minnesota. The loss of old-growth northern hardwoods will diminish the ability of an ECS to predict the potential for expansion of the hardwood industry in northern Minnesota given the scenario of rapid global warming induced by greenhouse gases. The loss of late successional stands of pine, spruce, white cedar, and balsam fir will reduce the accuracy of ECS predictions of differential productivity among these softwoods and preclude any evaluation of softwood sites for hardwood conversion.

Evidence from European forests indicates that old-growth forests are considerably less affected by forest decline than nearby managed forests. Forest decline is a general term applied to the widespread death of European forests, apparently due to air pollution. The apparent immunity of old-growth forest to this environmental disaster provides hope that information on how old-growth forests escape damage from forest decline can be applied to managed forests. In a recent policy statement, the Society of American Foresters (1984) stated its concern about the general lack of knowledge about complex forest ecosystems such as old-growth forests: "In the face of mounting evidence that forest productivity is declining worldwide, researchers know too little about complex ecosystems and the cumulative effect of subtle stresses from atmospheric pollutants."

HOW MUCH OLD GROWTH REMAINS IN MINNESOTA?

The amount of old-growth forest remaining in Minnesota is very difficult to determine accurately from the data currently available. Previous forest inventory methods have not been directed towards identifying old-growth, and it remains to be seen how useful traditional forest inventories will be in identifying old growth and determining how much remains. The Old Growth Forest Task Force of the Minnesota Department of Natural Resources has begun to assess the value of such data to identify potential old growth.

A crude estimate of existing old growth in Minnesota is provided by a U.S. Forest Service inventory update for 1987. This inventory update lists the acreage by age class of each commercial forest type on unreserved forest lands. Overall there are over 13 million acres of timber land in Minnesota, but only 195 thousand acres of forest greater than 120 years of age, which might qualify as old-growth. Thus, only 1.4 % of unreserved timberland in the state is potentially old growth. Of this 1.4%, well over half is lowland northern white cedar. Of the upland forest types, potential old growth is limited to about 1300 acres of white pine, 8300 acres of red pine, and 36,600 acres of northern hardwood and maple-basswood forests combined. The later figure includes five distinct natural community types as defined by the Minnesota Natural Heritage Program. Since age alone is not an adequate indicator of old growth, only a fraction of these acreages are truly old-growth forest communities.

Somewhat less than 1.2 million acres of forest land in Minnesota are reserved. This land occurs primarily within the Boundary Waters Canoe Area Wilderness (BWCAW) and Voyageurs National Park. Little, if any, old growth exists in Voyageurs National Park. As of 1973, 71,296 acres of virgin forest within the BWCAW (9.5 % of the land area) was greater than 125 years of age. Much of this older forest is dominated by short-lived, pioneer species and is not old growth. Old growth community types such as red pine forest and upland white cedar forest each comprise only 3.9% of the virgin forest in the BWCAW. Furthermore, the old growth in the BWCAW and that protected in Itasca State Park represent only a few forest community types in only two of the 13 ecological regions of the state that may support old growth.

ALTERNATIVE USES OF OLD GROWTH

Much of the remaining old growth in Minnesota exist today because either the forest was inaccessible or there was little market for the timber. Many such stands are still rather inaccessible and could only be harvested by building costly logging roads. Much of the remaining northern-hardwood conifer forests in northeastern Minnesota exists today because there has been little commercial market for maple in Minnesota. Most of these forests, however, have been "high graded" with white pine and some yellow birch removed. The lack of commercial value of sugar maple has also been detrimental to the survival of northern hardwood forests in northeastern Minnesota because of the practice of clear-cutting these forests and converting them to conifer plantations. Many old-growth forests have little value as timber sources because the old-growth trees are often hollow and "poorly formed". Harvesting the few remaining old-growth forests with merchantable timber will provide only a limited, short-term economic benefit; a benefit that is greatly outweighed by the economic and social benefits accrued by preserving Minnesota's old growth.

PRESERVATION OF OLD GROWTH

Because little old growth remains in Minnesota representative old-growth forests need to be quickly identified and protected before they are lost forever. Sites identified for protection should not be limited to the to the oldest and most pristine stands. Once identified and protected, some old-growth forests will require active management.

APPENDIX. MINNESOTA FOREST COMMUNITIES WITH OLD-GROWTH CHARACTERISTICS

The Minnesota Heritage Program has stratified Minnesota forests into 17 natural community types. Fourteen of these types have the potential to exhibit old-growth forest characteristics:

1. Northern Hardwood-Conifer Forest*
2. Maple-Basswood Forest (Big Woods Section)*
3. Maple-Basswood Forest (Driftless Section)*
4. Maple-Basswood Forest (West Central Section)*
5. Maple-Basswood Forest (East Central Section)*
6. Spruce-Fir Forest
7. Upland White Cedar Forest
8. Great Lakes Pine Forest: Red Pine-White Pine Forest *
9. Great Lakes Pine Forest: White Pine Forest *
10. Mixed Oak Forest
11. Floodplain Forest
12. Hardwood Swamp
13. Conifer Swamp
14. Forested Bog

A detailed description of seven of these forest community types (those marked with an asterisk) along with a list of their old-growth characteristics is presented below.

Northern Hardwood-Conifer Forest

This community type is dominated at most sites by sugar maple, usually associated with yellow birch and/or American basswood. Frequent conifer associates include white spruce, balsam fir, white cedar, and white pine. On wetter sites northern hardwood-conifer forests may include American elm and black ash as dominant species, whereas on drier sites red oak and even bur oak may be important. Most northern hardwood-conifer forests occur on mesic, loamy sites. On sites particularly well-protected from fire, however, such communities may develop on other soils. Northern hardwood-conifer forests are found primarily in a narrow belt in the highlands along Lake Superior and in scattered pockets across north central and east central Minnesota. Northern hardwood-conifer forest merges into maple-basswood forest to the west and south.

The classic northern hardwoods community type is most widespread to the east of Minnesota in the Great Lakes and New England regions. Even before European settlement, northern hardwood-conifer forests in Minnesota were limited to isolated pockets where appropriate soils, protection from fire, and protection from late spring frosts allowed their development. Selective removal of yellow birch and conifers has changed the species composition of most stands not destroyed by clear cutting. As a result, mesic stands containing yellow birch and conifers as conspicuous components are rare. Very few intact old-growth stands larger than 15 acres are known to exist today. These stands continue to be threatened by logging and conversion to conifer plantations and are often selected for firewood cutting. Thus, northern hardwood-conifer forests that still maintain their original species composition and old-growth characteristics are listed by the Minnesota Natural Heritage Program as endangered. Currently, only 125 acres of high quality old-growth northern hardwood-conifer forests are completely protected at five sites in Minnesota; 390 acres at seven sites are under partial

protection (e.g. State Parks). Another 1970 acres of old growth are not formally protected.

Small tracts of northern hardwood-conifer forest of the highest quality have the following old-growth characteristics:

1. Canopy dominated by large trees (125-250 years old), usually with clear straight boles. Canopy is usually closed except for gaps where individual trees have fallen.

2. Frequent large snags and down logs in various stages of decay; tip-up mounds present.

3. Heterogeneous understory with patchily distributed herb layer.

4. Understory dominated by shade-tolerant tree species, especially sugar maple, which are represented by a variety of age classes.

5. Abundant spring ephemerals and spring-blooming herbs.

6. No evidence of logging or evidence of logging limited to selective harvesting of species such as yellow birch and white pine.

Maple-Basswood Forests (Four geographic sections).
Maple-basswood forests are dominated by sugar maple, American basswood, elms, and/or red oak. Sugar maples are most important on well-drained sites with very good fire protection; whereas elms are most important on wetter soils and may dominate such sites. Oaks, particularly red oak, are most important on more xeric sites. At the dry end of the soil moisture gradient maple-basswood forests grade into mixed oak forests; on wetter sites maple-basswood forests grade into floodplain forests and hardwood swamps.

Maple-basswood forests occur at the western edge of the deciduous forest formation in North America. In Minnesota, maple-basswood forests were originally widespread in a broad belt extending from the southeast corner into the west-central section of the state. The boundaries of the presettlement maple-basswood forests were largely controlled by fire frequency. Sites where lakes, rivers, and rough topography formed natural firebreaks supported maple-basswood forests, whereas less protected sites supported prairie, savanna, or mixed oak forest.

Maple-Basswood Forest (Big Woods Section)
Prior to European settlement, a nearly contiguous area of maple-basswood forest known as the "Big Woods" covered over 3,000 square miles in south central Minnesota. Today all that remains of the Big Woods are remnant maple-basswood woodlots ranging in size from five to 600 acres. These remnant stands are completely isolated from one another by agricultural fields and other non-forest lands. Most of these stands have experienced a long history of selective logging and grazing, both of which have altered their original species composition and structure. Maple-basswood forests of the Big Woods that exhibit old-growth characteris-

tics are listed as endangered in Minnesota. Only about 800 acres of high quality old-growth Big Woods maple-basswood forest are known to exist today. Of this acreage, only three sites totaling about 200 acres are completely protected, whereas about 530 acres at seven sites receive limited protection. About 70 acres of old-growth Big Woods maple-basswood forest receive no formal protection. Due to the location of Big Woods forests in a primarily agricultural region and a long interest in their preservation, it is unlikely that much old-growth of this type remains unreported.

Maple-Basswood Forest (Driftless Section)
Maple-basswood forests in southeastern Minnesota are found on rugged, stream-dissected lands of the Driftless Area. Here, maple-basswood forests occur in small patches on moist, protected sites on steep, north- and east-facing slopes. In these forests, white oak is often a dominant species along with sugar maple and American basswood. Although many of the steep slopes of the Driftless Area are forested today, past farming, grazing, and continued logging have altered most of the original forest. Today, examples of relatively undisturbed maple-basswood forest are quite rare in the Driftless Area. Only one high quality maple-basswood forest with old-growth characteristics is known from the Driftless Area; this forest is owned by many small landowners and is still largely unprotected. A few other old-growth maple-basswood forests may still exist in the Driftless Area but a systematic search of the area has yet to be conducted. Whatever remains is most likely threatened by increased selective logging activities, particularly on private land.

Maple-Basswood Forest (West Central Section)
Maple-basswood forests in west central Minnesota occur primarily in a narrow band between the coniferous forest and prairie formations. These forests, which extend as isolated stands into northwestern Minnesota, represent the northwest limit of maple-basswood forest in North America. These forests are characterized by reduced tree species diversity as compared to more southerly forests. There is a general decrease in height and size of dominant trees to the northwest as conditions for tree growth become less favorable. Unlike the Big Woods, the west central section still maintains a relatively high percentage of forest cover. Undisturbed, old-growth stands, however, have nearly been eliminated by selective logging and grazing. Only a handful of potentially high quality old-growth maple-basswood forests of this type are known to remain in Minnesota.

Maple-Basswood Forest (East Central Section)
Presettlement examples of this community type differed from other maple-basswood forests by the presence of frequent, large white pines along with a number of understory species with more northerly ranges. These maple-basswood forests are located in a band from southeastern Benton County to southwestern Pine and eastern Chisago counties; they grade into northern hardwood-conifer forest to the north. Today, most of the these maple-basswood forests have been cleared for agriculture or replaced by successional aspen-white birch forests. Furthermore, most existing forests are quite different from presettlement forests, having been greatly altered by logging and grazing. Undisturbed, old-growth maple-basswood forests (east central section) are very rare. Currently,

no examples of old-growth maple-basswood forest have been documented from east central Minnesota.

In all regions, small tracts of maple-basswood forest of the highest quality have the following old-growth characteristics:

1. Canopy dominated by large trees (125-250 years old), usually with clear, straight boles. In the Big Woods sugar maples, American basswoods, and red oak reach 30" dbh; elms are commonly larger than 40" dbh. Old-growth trees in the west central section are generally smaller than in other sections. Canopy is usually closed except for gaps where individual trees have fallen.

2. Frequent snags and down boles in various stages of decay.

3. Heterogeneous understory with patchily distributed herb layer.

4. Understory dominated by shade-tolerant tree species such as sugar maple, which are represented by a variety of age classes.

5. Spring ephemerals and spring-blooming herbs are both abundant and rich in species; species richness is generally highest in the Driftless section and lowest in the west central section.

6. No evidence of logging or limited selective logging only.

Great Lakes Pine Forests

Prior to European settlement, two types of Great Lakes pine forest, each the product of a different fire regime, exhibited old growth characteristics in Minnesota. **Red Pine-White Pine Forests** were dominated by red pine with lesser amounts of white pine and exhibited little, if any, understory development. These forests generally grew on more xeric or fire prone sites and experienced periodic light surface fires at 5-50 year intervals. More severe fires, occurring at longer intervals, established new age classes of pines. **White Pine Forests** (sometimes with a lesser amount of red pine) contained large components of shade-tolerant tree species such as red maple, white spruce, white cedar, balsam fir and sugar maple. white pine forest occurred on more mesic or fire-protected sites where fires were less frequent, with severe fires occurring at 150-300 year intervals. These fires generally destroyed most of the pines and initiated the development of a new forest. In short, fire both initiated and maintained Great Lakes pine forests. Old-growth Great Lakes pine forests developed on sites than had not experienced a catastrophic fire for 125-175 years.

The natural pine forests of Minnesota were decimated by the logging of most old-growth stands, followed be recurrent fires that favored the development of aspen-white birch forests. With onset of widespread fire suppression in the twentieth century, the initiation of new pine forests (the old growth of the future) was further curtailed and the maintenance of the existing subclimax old-growth pine forests was disrupted. As a result of human disturbance very few high quality old-growth Great Lakes

pine forest stands exist today.

The Natural Heritage Program has data on nine examples of old-growth Great Lakes pine forest. Five old-growth red pine-white pines stands (about 1400 acres) and four old-growth white pine stands (about 530 acres) are protected in Minnesota. Additional protected old-growth pine stands occur in the BWCAW, but these stands and a few small stands located elsewhere in the state have not been surveyed by the Natural Heritage Program. In the absence of fire, some of the old-growth red pine-white pine stands have developed understories of shade-tolerant species that were uncharacteristic of presettlement pine forests. Of even greater concern is the fact that, in most parts of the state, few younger natural pine stands are now present. Younger stands are particularly scarce in northeastern Minnesota. Here climatic conditions make young white pines especially susceptible to white pine blister rust, an introduced fungal disease. These younger stands are necessary if old-growth pine forests are going to continue as part of Minnesota's natural heritage. Clearly, the continued existence of old-growth Great Lakes pine forest requires not only identification and protection of existing old growth but also management to allow development of future old growth and management of existing old growth.

Tracts of Great Lakes pine forest of the highest quality have the following old-growth characteristics:

1. Canopy dominated by large red pines and/or white pines (greater than 125 years of age). Canopy trees, especially red pines, with fire scars.

2. Large snags and down logs present. (The abundance of coarse woody debris is highly variable, generally increasing in the later stages of old growth.) Huge snags and down logs in various stages of decay are abundant in the oldest white pine forests.

3. Poorly developed open understory with some pine reproduction (red pine-white pine forest) **or** understory dominated by shade-tolerant tree species (white pine forest).

4. No evidence of logging or logging limited to selective logging of a few trees.

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