JAAKKO PÖYRY
JAAKKO PÖYRY CONSULTING, INC.

Biodiversity

A Technical Paper for a Generic Environmental Impact Statement on Timber Harvesting and Forest Management in Minnesota

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Prepared for:

Minnesota Environmental Quality Board
658 Cedar Street
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November 20, 1992

Dr. Michael Kilgore
GEIS Project Manager
Minnesota Planning Office
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658 Cedar Street
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Dear Dr. Kilgore:

Pursuant to the State of Minnesota's GEIS contract (No. 30000-18408-01) with Jaakko Pöyry Consulting, Inc., as formally executed on May 15, 1991, and amended with Supplement No. 1 on July 10, 1991, and Supplement No. 2 on July 27, 1992, the sixth task included preparation of technical papers. One of these papers, Biodiversity, is hereby submitted for review and approval.

The material contained in this document is presented in accordance with the terms outlined in Attachment A to the base contract, Section III, Subsection F.

We look forward to a favorable review and approval of this work product in due course.

Respectfully yours,

James A. McNutt
Executive Vice President
and GEIS Project Manager

cc: Art Veverka
Bob Dunn
Doug Parsonson
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This technical paper consists of the following three parts:

1) *Technical Report.* The technical report was prepared by Jaakko Pöyry Consulting, Inc. under contract with the Minnesota Environmental Quality Board to develop a Generic Environmental Impact Statement on timber harvesting. This technical report was approved by the EQB and is one of nine such reports prepared by the contractor as part of the GEIS study development process.

2) *External Reviewer Comments and Contractor Responses.* Prior to finalizing the technical report, the contractor commissioned an independent technical assessment of the report from qualified reviewers. Comments on the technical report provided by these reviewers, along with responses by the contractor to substantive comments, issues or questions raised are included immediately following the red divider.

3) *Advisory Committee Comments and Contractor Responses.* A ten member advisory committee was established by the Minnesota Environmental Quality Board to provide direction to and oversight of the GEIS study. Comments on the completed technical report provided by individuals on this committee, along with responses by the contractor to substantive comments, issues or questions raised are included immediately following the green divider.

SUMMARY

This Technical Paper assesses the impact of timber harvesting and forest management on biodiversity, and complements the Forest Wildlife Technical Paper, which analyzes impacts of harvesting on all wildlife species. This paper looks at the following issues of concern identified by the GEIS Final Scoping Decision (FSD): (1) biological diversity in forests at genetic, species, and ecosystem levels; (2) forest-dependent federal and state species of special concern, threatened, or endangered species or habitats; and (3) old growth and old forests. Impacts were evaluated for the base, medium and high harvest scenarios, based on the second run data provided by the Maintaining Productivity and the Forest Resource Base study group.

Issues of concern from the FSD encompass specific issues analyzed by the Biodiversity and Wildlife study group. These include impacts of harvesting on major species at the edge of their range. Minnesota has an unusual number of these species, due to the following: its location at the junction of the boreal forest, deciduous forest and prairie biomes; rare communities depleted due to conversion to agriculture; overharvesting or fire suppression; and replacement of harvested old forest with younger forest of advancing age.

Throughout the Biodiversity Technical Paper, the major assumption is made that biodiversity is best preserved by the community approach: maintaining the natural plant communities upon which all species of plants and animals depend. There are four major reasons for this strategy to preserve biodiversity:

1. there are so many species in Minnesota (over 2,000 vascular plant species, about 380 moss species, 550 lichen species, 23 forest dependent mammals, 148 birds, 12 herps and numerous insects) that forest management guidelines to maintain each species individually would be hopelessly confusing;

2. knowledge of the habitat preferences and response to logging of most plant species is very rudimentary—there is insufficient information to construct habitat matrices relating plant populations to forest covertype and age;

3. biodiversity was maintained for thousands of years under natural disturbance regimes that created a pattern of plant communities on the landscape; and

4. management of forests to maintain all natural covertypes in reasonable proportions on the landscape will allow avoidance of future crisis-by-

crisis management which requires the implementation of recovery plans for a growing number of endangered species.

The best way to implement the community approach to saving biodiversity is to adapt spatial patterns and methods of harvest to more closely mimic natural spatial patterns and natural disturbances, on a large portion of the landscape. Without adjusting harvesting methods and spatial patterns, biodiversity could continue to be lost even without increased harvest. This is due to the long time lags between harvesting impacts such as fragmentation or reduction in area of natural cover types, and effects on biodiversity such as inbreeding or lack of regeneration of long-lived species.

Predicted significant impacts of harvesting on biodiversity include the following 12 items. However, note that numbers 3 and 9 are called *potential* impacts. Not enough is known at this time to make a firm prediction of harvesting impacts.

1. Predicted decline in area of old growth swamp conifer forest (medium and high harvest scenarios).
2. Predicted decline in populations of rare trees species: eastern hemlock, yellow oak, honeylocust, Kentucky coffeetree and sycamore (all scenarios), and rock elm (high scenario).
3. Potential decline in conifer component of mixed-species stands (all scenarios).
4. Decline of tree species in areas near the edge of their range (all three scenarios).
5. Accidental harvest of rare plant communities (all three scenarios).
6. Loss of genetic diversity of forest herbs due to fragmentation (all three scenarios).
7. Loss of genetic diversity for trees and plants during future climate changes (all three scenarios).
8. Loss of genetic diversity indirectly caused by harvesting through its effects on deer populations (all scenarios).
9. Potential displacement of native species by hybrids or exotics (all three scenarios).
10. Accidental physical damage to rare plant species (all three scenarios).
11. Decline of red-shouldered hawk populations, a state-listed special concern species (all three scenarios).
12. Decline in populations of pine marten, a state-listed special concern species (high scenario only).

The study group recommends the following combination of strategies as the most effective overall mitigation for harvesting impacts on biodiversity. First, a comprehensive inventory of biological features in Minnesota's forest lands should be undertaken, followed by development of harvesting methods consistent with maintaining rare species and communities identified in the inventory. Second, corridors of extended rotation forest should be distributed across the landscape in such a way as to connect major parks, wilderness areas and old growth areas. Third, an effort should be made to re-establish red and white pine and upland white cedar covertypes, and maintain or increase the conifer component of mixed-species aspen and birch stands. This combination of mitigation strategies helps to ameliorate nearly all of the significant negative impacts of harvesting on biodiversity, and requires that very little additional forest be reserved. The extended rotation forest would not impact timber harvest greatly in the state because no forest would be reserved from harvest. The GEIS harvesting scenarios show that 20 percent of state and federal forest lands can be managed under extended rotation guidelines and still meet demand for timber. The main difficulty with this combination is the physical difficulty of laying out a connected landscape.

Other mitigation alternatives, which may be useful in certain circumstances include: maintaining large blocks of mature conifer forest for the benefit of species/communities adapted to forest interior; prescribed burning to restore rare communities types such as oak or pine savannas; harvesting methods that will allow regeneration of trees near the edge of their range, and maintenance of rare communities; and careful use of hybrid and exotics to make sure native species are not displaced. Resolution of conflicting management goals such as the need to maintain both edge and interior species, generalist and specialist species on one area of land, will help avoid future problems that may arise from lack of planning.

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1
INTRODUCTION

1.1
Objectives

Plant Diversity in Forest Ecosystems. A diverse range of plants are associated with forest ecosystems. Considering previously specified timber harvesting levels and looking at timber harvesting and management activities statewide:

1. *What impact does timber harvesting and management have on the biological diversity of forests at the genetic, species and ecosystem levels? What spatial patterns of forest cover does timber harvesting create, and how do these patterns impact native plant communities (for example, fragmentation of forests)?*

2. *To what extent are federal and state-listed species of special concern, threatened, or endangered species or their habitats impacted by timber harvesting and management?*

3. *Based on the DNR's final definition of "old growth" forests and "old" forests, to what extent do these forests exist in Minnesota; how are they identified and managed; and how are they impacted by timber harvesting and management?*

1.2
Relationship to Forest Wildlife Paper

The Biodiversity and Wildlife Study Group is presenting its results in two papers; this paper and the technical paper on Forest Wildlife (Jaakko Pöyry Consulting, Inc. 1992b). Such organization reflects the structure of issues of concern given in the FSD, sections D and E. This paper examines all issues of impacts on plant species and types of plant communities, as well as upon the age structure and spatial patterning of plant communities, impacts on endangered species and on old and old growth forests, as listed in section D of the FSD issues of concern. The underlying strategy is to identify what, if any, changes may occur in overall biodiversity within all of Minnesota's forest lands as a result of increased levels of timber harvesting.

Inevitably, there is overlap between the present paper and Forest Wildlife Technical paper, which concentrates on section E of the issues of concern from the FSD. Just as every species of wildlife addressed comprises part of the region's biodiversity, so do the plants treated in this paper. The major variable treated in the Forest Wildlife Technical paper is habitat, which generally is defined in terms of types and structures of plant communities.

The reader will be referred to the Forest Wildlife technical paper at the appropriate points.

1.3 Background on Biodiversity

1.3.1 The Biodiversity Issue

The Biodiversity and Wildlife Study Group adopted the definition of biodiversity produced by the Society of American Foresters Task Force Report on Biological Diversity in Forest Ecosystems (1991):

> *Biological Diversity refers to the variety and abundance of species, their genetic composition, and the communities, ecosystems, and landscapes in which they occur. It also refers to the ecological structures, functions, and processes at all of these levels. Biological diversity occurs at spatial scales that range from local through regional to global.*

The earth's biological diversity is being depleted at an unprecedented rate. Wilson (1989) conservatively estimates that the annual number of species extinctions worldwide is 10,000 times greater than the *natural* rate in existence before the expansion of civilization during the past few thousand years. This rate is rapidly accelerating, so that extinctions today occur at a rate many times greater than just a century ago; the rate closely parallels the explosion in the world's human numbers. Most of the extinctions today are from forest communities—mainly tropical, where biodiversity is very high to begin with. If the current rate of extinction continues for the next century, the number of species on earth will be reduced to the lowest level since the catastrophic effects of a giant meteor strike upon this planet some 65 million years ago (Wilson 1989).

Through careful management, some level of forest harvest can be sustained even while the original biological diversity is protected. In general, the strategy requires first, identifying all of the elements to be protected, and then scheduling harvesting and other management actions so that adequate areas and variations of all the identified forest communities are maintained. These management practices also involve the use of harvest systems that minimize the disruption of fundamental biogeochemical processes: flow and filtration of water, recycling of nutrients by decomposition, protection of the soil surface layer, and retention of many microhabitats such as dead and decaying trees, which that provide habitats for a host of plants and animals.

Some might argue that protecting biodiversity can be handled far more easily by simply identifying individual species that appear to be in jeopardy, then mitigating through narrowly directed actions to prevent the species demise. This strategy does not always work for several reasons. First, when a species reaches a state of jeopardy, much of its genetic diversity may have already been lost; also, it may be too late and expensive by then to save regardless of the recovery strategy used. Second, many species can disappear before their status is discovered. And finally, and perhaps most importantly, the species is not the proper unit around which biological conservation should be organized. The proper unit for such activity is a region's array of natural biotic communities, each self-sufficient with its set of species and its set of ecosystem processes.

There certainly are instances where the single-species approach is necessary. For example, when a crisis takes us by surprise, a species such as the timber wolf ranges widely among many community types, or when a plant species is not associated with any one community type. In addition, even when the community approach to saving biodiversity is used, monitoring of individual species populations will always be necessary to make sure that the approach is working.

To preserve global biodiversity, it is necessary for citizens of each region of the globe to take stock of their local, unique biological wealth, and to assess the impacts of forest management on that diversity. In Minnesota, 287 species of plants and animals are listed by the Minnesota Department of Natural Resources (MNDNR) as endangered, threatened, or of special concern (Coffin and Pfannmuller 1988). An unknown number of insects, algae, and fungi may also be endangered, but there is simply insufficient information on such biota to know their status. Without management of the landscape for biological diversity, many more species may be threatened or extirpated before it is ever realized what has happened.

Within the state or region, the matrix of forest communities that comprises the baseline for biodiversity does not conform to any class of land jurisdiction. For this reason, if statewide biodiversity is to be preserved within our forests, it is imperative that all agencies, holders of industrial forests, and private land owners work together to maintain regional objectives. The boundaries of concern here are not political or ownership titles; rather they are features such as watersheds, soil types, species ranges, or existing stands of particular ages or covertypes. Management agreements between private landowners, such as those worked out by the Nature Conservancy, and between the MNDNR and national forests are just starting to develop in Minnesota.

It is fully recognized that concern for biodiversity cannot stop at Minnesota's borders. Neither can conservationists be naive about the reality of world markets and demand for forest products. If reasonable production of wood products from this state is not realized, then demand will lead to the products being taken elsewhere. If, for some economic and technological reasons, demands not met from Minnesota forests are met instead with products from poorly managed tropical areas, then the impact on global biodiversity will undoubtedly be far more severe.

Finally, the issue of protecting the planet's biodiversity in forests or in any other biome or ocean, cannot be properly addressed without some focus on the current worldwide trends. The earth's population has never been greater, and has never grown more rapidly, even while tremendous concern arises about the disappearance of species and whole ecosystems. The two processes are unalterably linked and no amount of planning can guarantee against the inevitable overwhelming overexploitation of resources, and consequential loss of species and ecosystems, if the population does not stabilize.

1.3.2 Biodiversity and Ecological Processes

Compositional Diversity

There are three main components to biodiversity (Society of American Foresters 1991). The first is *compositional diversity*. This refers to both the number of species present in an area, and the genetic variation within individual species. The number of species in one forest stand depends on the size of the stand, and the diversity of habitats and processes found within it.

A *community* is a combination of organisms occupying one location or stand. Communities are sometimes synonymous with forest types, or covertypes; for example, maple-basswood forest or upland white cedar forest. As a general rule, within one stand, or one community in Minnesota, about 5 to 10 vascular plant species are very common. This means they are found in large numbers, and can be seen by an observer at nearly every point within the stand or forest type. The vast majority of species, ranging from 20 or 30 to over 100, are uncommon. That is, they occur in very low numbers and/or at only a few points. Few species of plants are absolutely dependent on one forest type or age class for survival. However, most species reach a peak abundance in one community type, which has a set of species, and species interactions, that is uniquely favorable. The same species that are very abundant in one community may be uncommon in other communities. The definition of biodiversity adopted above recognizes that these unique combinations of species are part of biodiversity. Thus, compositional diversity includes more than simply saving a population of each species. Different mixtures of species with different interactions are considered important to overall diversity.

There are two types of genetic variability within a species (1) *within population* variability—genetic differences (genotypes) among individuals in one stand, and (2) *among population* variability—genetic differences between stands over a region. Native species are composed of populations with many different adaptations that have accumulated over thousands of years. Temperate forest trees typically have high within population diversity, although ecotypes (see below) certainly exist (Millar and Libby 1991), while herbaceous plants have high between population diversity (Bradshaw 1984). This difference in genetic architecture suggests that genetic diversity in temperate forest trees is best protected by maintaining a few large populations, while smaller plants may require protection of many small populations.

Ecotypes are major geographically and genetically distinct metapopulations, or groups of populations, which, through the process of natural selection, are adapted to the particular soils, water and nutrient supply, diseases, and climate where they are found. They are a type of among population variability and occur at the scale of the ecoregion or larger. One species may be facing selection pressure to better adapt to drought along the southwestern edge of its range, while simultaneously undergoing selection to better adapt to cold, wet summers at the northern edge of its range. Plant breeders take advantage of such natural variability in crop plants to develop short- and long-season varieties for use by farmers in different regions.

Structural Diversity

Structural diversity, the second component of biodiversity, refers to the spatial arrangement and mixture of species within a stand and over the landscape. Structural diversity occurs at different spatial scales.

1. *Within stand* (an area of homogeneous vegetation one to several acres in size) diversity is influenced by factors such as availability of rotten logs, snags, treefall gaps, boulders, small wet spots, and other relatively small variations in habitat. There are plant species (yellow birch, berry-producing shrubs) which reproduce best in gaps formed by the death of canopy trees within an old forest (Bormann and Likens 1979). If all forests are cut before reaching the stage where canopy gaps occur, then structural diversity is lost, and habitats for certain species are also lost.

2. *Between stand* diversity (within one forest management unit, park, or county) depends on the local mix of age classes and forest types. In northern Minnesota, wildlife species such as white-tailed deer are dependent on the juxtaposition of mature conifer stands with young aspen stands. The former are often used for winter cover, while the latter have plants eaten by the deer.

3. *Regional* diversity (an area ranging from the size of ecoregions up to the state of Minnesota) is influenced by the placement of lakes, wetlands, outcrops of rocks, climate, and other natural geographic features. Natural disturbances, such as windstorms, fires and insect epidemics also

create a complicated mosaic of patches on the landscape (Heinselmann 1973, Lorimer 1977, Canham and Loucks 1984). This creates a large variety of habitats for species which live in forests of many different ages, with different patch sizes and shapes, as well as different juxtapositions to lakes, wetlands, and forest stands of different ages. To maintain a landscape with all of the patch types representing all successional stages and functional types under natural conditions, the area must be much larger than the disturbance patches. A landscape unit large enough to have a stable composition of patch types over time is known as the *minimum dynamic area* (or quasi-equilibrium landscape). Shugart (1984) suggests that a landscape must be about 50 times the size of an average patch to be stable in the statistical sense.

Functional Diversity

The third major component of biodiversity is *functional diversity,* which refers to the variety of natural processes occurring in a region. Some forests may absorb rainfall during heavy downpours, and then release the water slowly, so that floods and siltation do not occur downstream. In other areas with bare rock, water may flow off in cascades and form ephemeral pools in depressions of the rock surface. There are species which are adapted to both the clearwater streams (trout), and the ephemeral pools in this example of contrasting natural functions. Another contrasting functional pair is the recycling of nutrients within black spruce bog forests, compared to the same in a northern hardwood forest. In the black spruce forest, decomposition is very slow, and moss accumulates for thousands of years. Because decomposition is slow, nutrients such as nitrogen are not released into the soil very rapidly. In the northern hardwood forest dominated by sugar maple, decomposition of leaf fall each year is rapid, and the nutrients from the leaves are returned to the soil within a few years. There is a completely separate suite of species adapted to the low and high nutrient status of the soil in these two forest types. Thus, functional diversity contributes to compositional diversity.

1.3.3
Old Growth Forest, Old Forest and Biodiversity

Both old growth forests (defined by MNDNR as being greater than 120 years old and of natural origin) and old forests (forests as old as old growth, but are not of natural origin or have had significant management activity) are unique in their structural and functional components of biodiversity. Large coniferous logs on the forest floor may take 200 years to decompose (Tyrell 1991). These logs provide a substrate for a unique small-scale community, including many mosses, and as yet unstudied invertebrates. Invertebrates living in the logs are important food sources for a variety of vertebrates including salamanders and bears. Rotten wood is the site of successful seedling establishment for several tree species in Minnesota, including yellow birch, white cedar, and hemlock, which is state-listed as of special concern. The large logs probably also play an important role in nutrient dynamics, because they are sites where nitrogen fixation occurs. During this process bacteria convert inert nitrogen present in the air into ammonium—a form of nitrogen available to plants (Harmon et al. 1986). Old growth forests also store large amounts of carbon in above ground tree biomass—several times as much on a per acre basis as young forests. For example, the mixed-species red pine covertype at age 100 in Minnesota is estimated to have 59 tons of carbon/acre in tree biomass, compared with 16 tons at age 20 (MNDNR 1991). Although old growth may not have net accumulation of carbon (decay=new growth), the release of carbon to the atmosphere can be large if they are converted to younger forest, even if much of the wood is used for building material (Harmon et al. 1990).

Old growth provides habitat for unique arboreal lichen communities (Coffin and Pfannmuller 1988, Lesica et al. 1991, Thomson unpublished). Some of the species in hardwood forests do not grow in stands less than approximately 200 years old, including the state threatened *Lobaria quercizans*. The state endangered *Pseudocyphellaria crocata* occurs in old hardwood and conifer forests in northern Minnesota. Two species of special concern occur only on tree bark in old cedar forests—*Cetraria aurescens*, and *Sticta fuliginosa*.

In addition, old and old growth forests often have a greater abundance of all forest floor plant species—including herbs and shrubs—because the forests have many gaps. Even-aged forests up to rotation age are often in stem exclusion stage of development during which there are no canopy gaps large enough for recruitment of new canopy trees. These stands have comparatively little light at the forest floor compared to old forests.

There is potential for some conflict from a biodiversity viewpoint concerning relationships between forest age-class structure and disease vulnerability. Apparently disease outbreaks are generally minimized by maintaining stands at a relatively young age, not permitting accumulations of older or *unhealthy* trees or of dead material standing or downed. However, it is some of these characteristics of older forests that generate habitat characteristics for a wide variety of vertebrates, the absence of which would seriously reduce biodiversity in Minnesota forests.

1.3.4
Forest Management and Biodiversity

Direct Physical Effects

The direct long-term effect of logging on plant communities is relatively minor. The exceptions, of course, are small populations of rare species that may be physically destroyed; logging of vulnerable sites such as steep slopes that may erode after harvest; and soil compaction, which causes loss of area of suitable soil for herbaceous plants within harvested forests. Most of the effects of harvesting are indirect, such as through altering the frequency of stands with different age classes on the landscape or changes in the frequency of some natural disturbance forces, especially fire.

Short-term effects (within 1 to 5 years) of clearcutting usually involve a peak in local plant diversity, as both forest herbs and invading plants usually found in more open habitats coexist (Bormann and Likens 1979, Outcalt and White 1981, Metzger and Schultz 1984). Within several decades after clearcutting in northern hardwood forests, the mixture of common understory herbs approaches that of the preharvest forest (Metzger and Schultz 1981, 1984). In a northern hardwood forest subjected to periodic selection cutting, the understory vegetation was more diverse than in a stand clearcut 50 years previously (Metzger and Schultz 1981). Although nutrient cycling and carbon storage are affected differently by cutting and windthrow, clearcutting has physical similarities to catastrophic windthrow, and group selection cutting has similarities to periodic gap formation in old growth forests. Thus, it is not surprising that the species making up the forest plant communities are adapted to some harvesting activities.

Similar recovery occurs in aspen-birch-fir-spruce forests common in Minnesota. For example, Kurmis et al. (1986) were able to recognize the same plant communities in Voyageurs National Park—much of which had been logged since 1900—as Ohmann and Ream (1971) found in unlogged forests of the nearby Boundary Waters Canoe Area Wilderness (BWCAW). The plants communities in Voyageurs National Park were at an earlier successional stage than the unlogged BWCAW communities, but successional trends towards the presettlement type communities was evident from understory species composition (Kurmis et al. 1986).

In general, understory species composition is affected less by dormant season harvest. Outcalt and White (1981) found that understory composition in fir-birch forests was altered less if deep snow was on the ground during harvest.

Indirect Effects

Habitat loss and forest type conversion is the major reason for loss of biodiversity worldwide as well as in Minnesota. Minnesota currently has only about half as much forest acreage as in pre-European settlement times. Even if the forest acreage of a region stays constant, there can still be habitat loss for some species if there is conversion of one forest type to another. In any forest type conversion, some species lose habitat and others gain. The overall consequences of forest type conversion for regional diversity depend on whether the species that lose habitat are already rare or declining. Elimination of fire in managed forests leads to the loss of certain community types, such as pine or oak savannas.

Fragmentation of forests changes the structural diversity of forested landscapes, but can affect all three components of biodiversity. The number of species within an isolated block of forest is roughly a function of the logarithm of land area and its distance to other blocks of forest (Scanlan 1981). One effect of fragmentation involves a change in the *environment* within isolated forest stands. Small fragments of forest landscape tend to favor a different suite of species adapted to *edge* habitat, which receives more light, and more wind—hence lower humidity and drier conditions (Levenson 1981). Therefore, a landscape with many small isolated forest stands may ultimately exclude forest interior species.

A second effect of fragmentation is changing *competitive relationships* among species. An example is the relationship between plants such as grasses, and interior forest plants such as woodfern and maidenhair fern. The ferns will grow better with more light at the edge of the forest, but they cannot compete with the grasses, which grow even better in high light.

A third potential effect of fragmentation is loss of local genotypes or ecotypes, because *inbreeding* may result if seeds and pollen, or individual animals cannot travel between woodlots. Inbreeding results in a decreased reproductive rate among many plants and animals (Wright 1977, Soule 1980). Islands of habitat that are isolated genetically must be large enough to maintain a minimum viable population, within which inbreeding will not become significant.

There is an unknown *time lag* between the isolation of a block of forest, and a decline in species richness that may later occur. This is because many forest species are perennials, such as trilliums, violets, ferns, shrubs and trees, which live for many decades. If the structure or natural functions within a woodlot change so that some species can no longer reproduce, the species may not disappear for a century or more. During this time, it may not be clear to foresters whether or not a genuine failure of reproduction is occurring. By the time the failure of reproduction is noticed, it may be too late to save the population.

A fourth effect of fragmentation is *disruption of structure and function* of the landscape. Reducing a forested landscape to scattered fragments (e.g., Twin Cities metro area) changes the climate of a region, so that it is no longer cooled during summer by evapotranspiration. This can lead to a regional increase in mean summer temperature of several degrees F (Akbari et al. 1988). The change in temperature then leads to further changes in species composition of forest remnants. Fragmentation can also lead to changes in water flow, soil building processes, and cycling of nutrients that affect the function of future forests.

If the natural structure of the landscape is disrupted, it is difficult for species to respond to disturbance. Local catastrophes (windstorms or disease, etc.) may eliminate a species from a forest isolated by surrounding farmlands, or by other types of forest. Under natural conditions, migration of new individuals from adjacent stands would have allowed recovery of the locally lost species (Curtis 1956).

In Minnesota, two types of forest fragmentation occur. First, there is conversion to uses such as field crops, leaving islands of forest surrounded by open habitat. Fragmentation of this type is highly significant in ecoregions 5, 6, 7, and parts of southern ecoregion 4. The second type of fragmentation—more relevant to future harvesting within densely forested northern Minnesota—is within-forest fragmentation. This concept deals with the juxtaposition of forests of different types and ages on the landscape. Fragmentation exists where small conifer stands are surrounded by large areas of aspen, or old growth is embedded within a large area of young forest. This is the case with pine forests in Minnesota, because much of the original pine has been converted to aspen (Frelich, in prep.). No detailed studies of within-forest fragmentation have been found for Minnesota. However, Mladenoff et al. (1992), found that conifer patches in a hemlock-sugar maple patchwork in Upper Michigan were larger and had a more complex shape in primary forest than second growth. The result was that the landscape was better *connected*, in that plants and animals could disperse seeds or move relatively long distances while still being within a certain type of habitat.

It is important to realize that the landscape was fragmented prior to settlement. In Minnesota, the large number of lakes, and frequent fires and windthrow contributed to a natural pattern of fragmentation on the landscape. However, forest management can change the degree and type of fragmentation, as has happened in ecoregions 5 and 6. It is generally agreed among ecologists that managed forest landscapes are more fragmented than natural landscapes (Burgess and Sharpe 1981).

Management to maximize within-stand diversity may be detrimental to biodiversity at the regional level. For example, within the unlogged forests of the BWCAW, aspen stands have the highest number of plant species of any forest type (Ohmann and Ream 1971). However, there are many forest species that are either rare, or do not occur at all within aspen stands. If forests in the region were managed exclusively for maximum within-stand diversity (aspen), between-stand and regional diversity would decline. Management for maximum local species richness usually favors *generalist* species, like large-leaved aster and white tailed deer, over specialist species, such as the showy lady slipper, which occurs in only a few forest types, and pine marten, which reaches maximum abundance in mature conifer forests.

Invasion by exotic species can displace native species and cause loss of biodiversity. Such invasions are small and limited in northern Minnesota. However, oak forests in southeastern Minnesota have been invaded by European buckthorn and tartarian honeysuckle—two non-native species which displace native shrubs, and shade the forest floor so densely that neither native tree seedlings nor native herbaceous plants can survive (Converse 1988, 1989). There is also some concern that hybrid trees, developed for fast growth rates, may invade natural forests in the future.

Introduced forest pests present an entirely different challenge to conservation of diversity. Most notable in Minnesota are white pine blister rust, and Dutch elm disease, which are not native to our region. Both have major impacts on individual forest species so as to unnaturally reduce tree diversity. Therefore the cause of biodiversity is served through full cooperation with forest pathologists and geneticists seeking to control spread of exotic pathogens.

Grazing and browsing by cattle and by high numbers of white-tailed deer in some areas of Minnesota have caused local loss of populations of native herbaceous plants. In addition, deer eat tree seedlings, and can inhibit regeneration of red and white pine, white cedar, oaks, yellow birch, and the state-listed eastern hemlock (Graham 1954, Ross et al. 1970, Krefting 1975, Rogers 1978, Frelich and Lorimer 1985). The local loss of tree species then is accompanied by the loss of smaller plants, insects and birds that depended on those tree species. Moose, where they occur in high numbers, have a negative impact on populations of mountain ash, red maple, red oak, paper birch, and quaking aspen.

Overharvesting has been a factor in the reduction of ginseng (*Panax quinquefolium*) and goldenseal (*Hydrastis canadensis*), two herbaceous plant species now listed as threatened in Minnesota and the other lake states. Harvesting could potentially alter local populations of minor tree species in Minnesota, such as mountain ash, yellow birch, and Kentucky coffeetree.

Global warming, if it occurs, will significantly affect Minnesota biodiversity because it will be difficult for many forest plant species to shift their range northward by natural processes in a fragmented landscape that would force them to jump from woodlot to woodlot. The degree to which plant species will be able to respond to global warming depends on timber harvesting practices that do not further fragment the landscape and disrupt potential north-south migration routes for plants.

1.3.5 Value of Biodiversity

The maintenance of biological diversity is of immense ecological, social, and economic importance to all regions of the world, for many reasons. Ultimately, the sustainability of forest resources, both economically and ecologically, depends on the maintenance of biodiversity. The Biodiversity and Wildlife study group highlights six values of biodiversity that are important to Minnesota.

1. *Conservation of genetic strains of forest trees and other plants which are adapted to local climate and site conditions.* Minnesota has many species which reach either the northern or southwestern edge of their geographic range in the state. Currently, these species may be rare at the edge of their range, but they may become dominant in the future. If global warming occurs as predicted, local genotypes of trees from near the edge of the species range that are adapted to climatic extremes may help maintain forest productivity. For example, sugar maple has several isolated outlying populations along the North Shore of Lake Superior (ecoregion 3). If the climate of northeastern Minnesota becomes warmer, these isolated sugar maple stands would serve as nuclei for new northern hardwood forests that would be more productive than the current birch-spruce-fir forests, which would be under heat and drought stress. Another example is white pine, which reaches the southwestern edge of its geographic range in ecoregion 5. If the climate of ecoregion 4 becomes warmer and more droughty, genetic stock from populations along the current southwestern border of the species range could be used to reforest ecoregion 4. Although the degree of local genetic variability of most forest trees is not currently known, it is wise to follow a conservative approach and maintain local populations.

2. *Conservation of local populations with natural resistance to disease.* Scientists who develop disease resistant varieties of crops and forest trees often search wild populations for individuals which appear to have genetically-conferred disease resistance. The disease resistance can often be transferred through breeding to other populations which may have superior growth rates or form. Using this technique, varieties of white pine resistant to blister rust and varieties of American elm resistant to Dutch Elm Disease have been developed.

3. *Conservation of species which may produce new economically valuable products.* It is impossible to predict when an apparently unusable plant may, at some future date, produce a necessary product or allow a new local industry to develop. Two recent examples illustrate the potential. Pacific yew (*Taxus brevifolia*), which grows in Oregon and Washington, is a small tree that produces a chemical called taxol, which has been

found to cure certain types of cancer, and cannot be made synthetically. Until recently, pacific yew was considered a nuisance species by the USDA Forest Service. Little was done to protect this understory tree in old growth forests, and there is little information available on how to cultivate and manage pacific yew. A second example of an unexpected product is ginseng (*Panax quinqefolium*), a small herb of old growth sugar maple forests, now listed as of special concern in Minnesota. Ginseng is in demand for medicinal use in oriental countries. Farmers in north central Wisconsin, a region where ginseng was once abundant in the wild, used local wild stocks to start up ginseng farms, and these expanded rapidly in the 1970s and 1980s. Today, ginseng farming is a significant portion of the agricultural economy of north central Wisconsin.

4. *Conservation of rare species that may play critical but currently unknown roles in ecosystem function.* Some species may provide critical links in nutrient or energy flow in ecosystems and people will not know whether there are other species that can replace these functional links until after local extirpation occurs.

5. *Conservation of aesthetic and recreational values*. Landscapes managed to enhance biodiversity include a large variety of forest types. This has important implications for tourism, which is a major industry in Minnesota. Many people visit Minnesota to see forest wildlife such as bald eagles, owls, hawks, gray wolf, white-tailed deer and black bear. These species range widely and use a variety of special habitats, such as isolated stands of oaks or large pines. Many songbirds and wildflowers occur mainly in mature or old growth forests. Patches of oaks and maples provide fall colors. Management of Minnesota's forest landscape to enhance biodiversity will maintain all of these recreational resources into the future.

   An important aspect of Minnesota's 19th century history was the cutting of the great forests of white and red pine. Assuring that stands of these species are able to re-establish in representative sites throughout their original ranges is as much a cultural responsibility as it is an environmental one.

6. *Knowledge of ecological processes is useful for management and educational purposes*. It is known that many original vegetation types were maintained in a sustainable, productive state on the landscape by natural disturbances, and that soils developed slowly over thousands of years. By comparing the natural rate at which nutrients are added to and removed from the soil by disturbances and successional processes, to similar rates for managed forests, the sustainability of current forest management practices can be assessed. Natural disturbances of various

types can hold forests at one successional stage, or speed the development of a desired late successional stage. However, disturbance must be studied in its natural context before it can be applied to forest management. Ultimately, forest management will be sustainable if natural processes are used as guidelines.

1.4 Definition of Terms Including Biotic Groupings

Forests: As used in this document, forests means the sum of all timberland, woodland, reserved timberland and reserved woodland. Any exceptions to this will be clearly explained at the point where they occur in the text. The USDA Forest Service defines timberland as "forest land producing or capable of producing crops of industrial wood and not withdrawn from timber utilization," and woodland is defined as "Forest land not capable of producing 20 cubic feet per acre of annual growth under natural conditions because of adverse site conditions."

Old Growth Forests: The definition used here is that of the MNDNR:

"Old-growth forests have developed over a long period of time essentially free from catastrophic disturbances. They contain large, old trees of long-lived species that are beyond rotation age. Typical old-growth forest stands experience frequent ongoing mortality, including some mortality of canopy trees. Such stands contain a relatively high frequency of large snags and large-diameter, downed logs in various stages of decay."

Old growth can develop in the following forest types: black ash, lowland hardwoods, northern hardwoods, oak/central hardwoods, red and white pine, white spruce, upland white cedar, and lowland conifers. MNDNR guidelines state that stands should generally be greater than 20 acres in size, older than 120 years (90 years for white spruce), have had negligible human disturbance (natural origin), and have average tree diameter of at least 20 inches in red and white pine, 15 inches in other forest types in southern Minnesota and 10 inches in other forest types in northern Minnesota.

Old Forests, are forests that meet old growth criteria for age, stand and tree size, but that may have had some selective harvest or other management activities, or stands with any origin, including natural, logging or planted. Currently, there is no official MNDNR definition of old forest. Old forest, as used in this report, may include both old growth and other old forests.

Extended Rotation Forests, as defined by draft guidelines of the MNDNR, are composed of stands, groups of stands, or particular areas that have been identified through a planning process and assigned an extended rotation management prescription that lengthens the time to the planned final harvest, compared to the standard rotation, of the designated stand or stands.

Extended rotations will be about 30 to 50 percent longer than average recommended rotations for a given forest type. The goals are to: (1) produce larger wood products such as sawlogs, (2) provide older forests with structural diversity, such as downed logs, and uneven-aged trees that will be important to wildlife and biodiversity in general, (3) provide scenic and recreational diversity, and (4) reduce the frequency of management activities on highly erodible or compactable soils and wetlands. Current draft guidelines suggest that at least 10 to 25 percent of MNDNR forest land be managed under extended rotation prescriptions.

Ecosystem and Community. The FSD indicates concern about impacts at the ecosystem level. It is appropriate to ensure that all parties are clear on the technical meaning of this term, particularly since current semipopular writings use the term quite loosely, hence in a misleading manner. Most ecologists recognize a distinction between the terms *community* on the one hand and *ecosystem* on the other, even though both can refer to the same entity. The former has a species complex connotation: most simply, it defines the mix of species that occurs in a particular region or physical setting. Ecosystem, on the other hand, focuses on the dynamic processes that interconnect among the species and between the biota and the physical surroundings. For example, a watershed is an ecosystem. Water and nutrients enter the ecosystem through precipitation, which is used and modified by plants and animals as it moves through the soil and into streams or lakes. Water and nutrients leave the ecosystem through outflow in rivers or through evaporation and conversion to gases.

Endangered, Threatened and Special Concern Species. Under Minnesota Statute 84.0895, a species is designated as:

(1) *endangered*, upon showing that such species is threatened with extinction throughout all or a significant portion of its range;or
(2) *threatened*, upon showing that such species is likely to become endangered within the foreseeable future throughout all or a significant portion of its range; or
(3) *species of special concern*, upon showing that while a species is not endangered or threatened, it is extremely uncommon in Minnesota, or has a unique or highly specific habitat requirements and deserves careful monitoring of its status. Species on the

periphery of their range which are not listed as threatened may be included in this category along with those species which were once threatened or endangered but now have increasing or protected, stable populations.

Exotic species: Any species not native to a given geographical region, such as an ecoregion.

Hybrid: Any cross between two species or varieties.

1.5 Geographic Focus

Although the normal focus upon timber harvest is concentrated in regions where the timber industry is prominent, impacts of timber harvesting and forest management activities upon biodiversity and wildlife uses are not necessarily distributed similarly. The majority of timber harvesting occurs in the northern third of the state and on upland sites. However, significant impacts on native plants and animals and upon public use of wildlife can occur more widely, e.g., in riparian corridors and woodlots of the southwest and western farmlands, in the oak-dominated woodlands of the southeast, in the suburban margins of the metropolitan zone, or in lowland-wet communities throughout the state. To properly meet the challenge presented by the EQB, this study group has focused attention over Minnesota as a whole in order to identify perturbations wherever increased timber harvesting and forest management activities may take place.

When sufficient data are available, the analyses in this paper have looked for significant impacts within ecoregions of Minnesota, in recognition that biodiversity may not be similarly affected in all parts of the state. A map of geographic regions with similar physical and biophysical characteristics (ecoregions) in Minnesota, Wisconsin, and Michigan was commissioned by the Upper Great Lakes Biodiversity Committee (UGLBC), which is an interdisciplinary group including scientists representing the natural resources agencies and conservation organizations in the Great Lakes area. The UGLBC map prepared by Dennis Albert (1993) for Minnesota shows 16 major ecoregions differentiated by: (1) the range limits of plants (Ownbey and Morley 1991), (2) physiography (Wright 1972), especially where physiography controlled the prairie/forest border (Grimm 1984, McAndrews 1966), (3) surficial geology (Hobbs and Goebel 1982), (4) soils (Cummings and Grigal 1987, Minnesota soil atlas 1971–81), and (5) modern natural vegetation (Minnesota County Biological Survey 1987–present). These ecoregions are similar to the landscape regions proposed by Kratz and Jensen (1983), who synthesized much of the same information that was available prior to 1983.

For the purpose of data summary and reporting, the UGLBC ecoregion map is unnecessarily fine, because many of the units are distinguished by plant communities or the range of species that are components of prairies, prairie/forest mosaic communities, or wetlands. Units so defined were combined for this study when the forest communities were similar. This combination of regions resulted in the seven ecoregions (figure 1.1) that will be used in this study. However, in many aspects of analysis, it is expected that uplands and lowlands of each ecoregion will be considered separately. Much of the analysis undertaken for this study will be performed using considerably smaller units than the ecoregions. Results from these small-scale analyses will be aggregated and reported at the ecoregion scale.

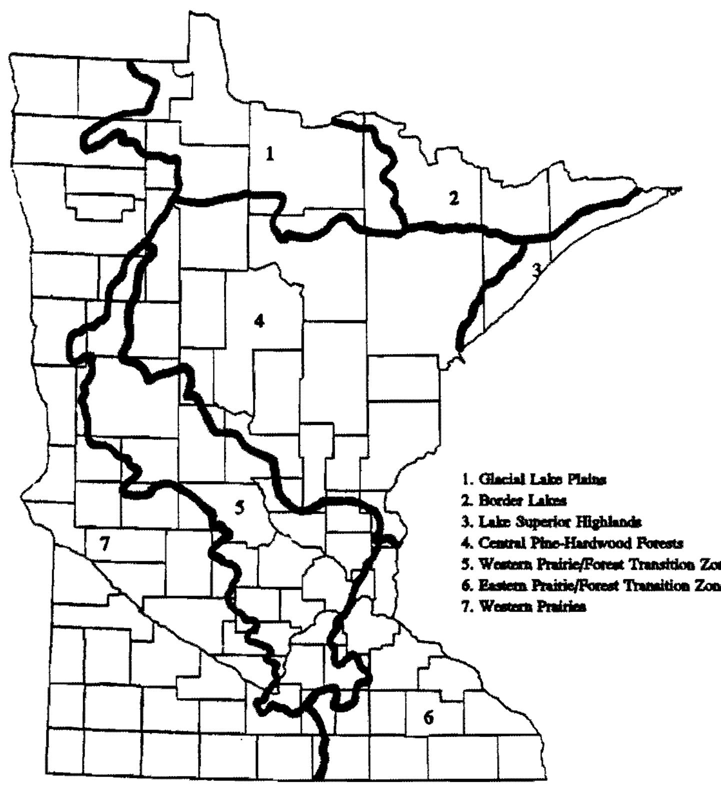


Figure 1.1. Ecoregions of Minnesota.

2
DESCRIPTION OF MINNESOTA PLANT COMMUNITIES

2.1
Natural History

2.1.1
Post-Glacial Synopsis

Sixteen thousand years before present (ybp), glacial ice covered nearly all of Minnesota. The only area escaping glaciation was the southeast corner of the state (eastern two-thirds of ecoregion 6), which is part of the never-glaciated driftless area. By 12,000 ybp, the ice had receded northward to the extent that Minnesota was nearly ice free. The sequence of events and establishment of vegetation as the ice left was very different in different parts of the state. For contrast, the successional sequence during the Holocene (period of time since the peak of the last glaciation in eastern North America) is examined at three points in Minnesota; changes since the last glaciation for the whole state are summarized in figure 2.1.

1. Southwestern Minnesota (ecoregion 7, southern half). The ice left this region approximately 14,000 ybp, and was closely followed by spruce-fir forests, which lasted until nearly 12,000 ybp. As the climate warmed rapidly, spruce forest gave way to forests of birch and alder. The birch-alder forest was transitional, lasting only several hundred years before being replaced by forests of oak and elm. After 2,000 years (11,000 ybp to 9,000 ybp), the oak-elm forest gradually gave way to prairie, which persisted until European settlement in the 1880s (Webb, Cushing and Wright 1983). The interglacial warm period peaked in the upper midwest from about 9,000 to 3,000 ybp. Since 3,000 years ago, the climate has steadily cooled, but not enough to allow reinvasion of forests in southwestern Minnesota. However, some oaks formed small savannas in areas sheltered from prairie fires.

2. The sequence of events during the Holocene was more complicated in east central Minnesota (northern tip of ecoregion 6, southern part of ecoregion 4, eastern ecoregion 5). Glacial ice left the area about 14,000 ybp, to be succeeded by spruce forests for 4,000 years. A transitional oak-elm forest from 10,000 to 8,000 ybp yielded to prairie, as the prairie-forest border moved east of the Twin Cities, into Wisconsin. About 5,000 ybp, the prairie-forest border began to move back to the west, once again placing the Twin Cities in the oak savanna and oak forest zone. Finally, about 500 ybp, sugar maple and basswood became abundant in the area, possibly in response to the relatively cool and moist climate during the little ice age, which lasted from about 1500 to 1850. Thus, 500 ybp marked the establishment of the *Bigwoods* of Minnesota,

which occupied much of ecoregions 5 and 6 at the time of European settlement (Grimm 1983, 1984).

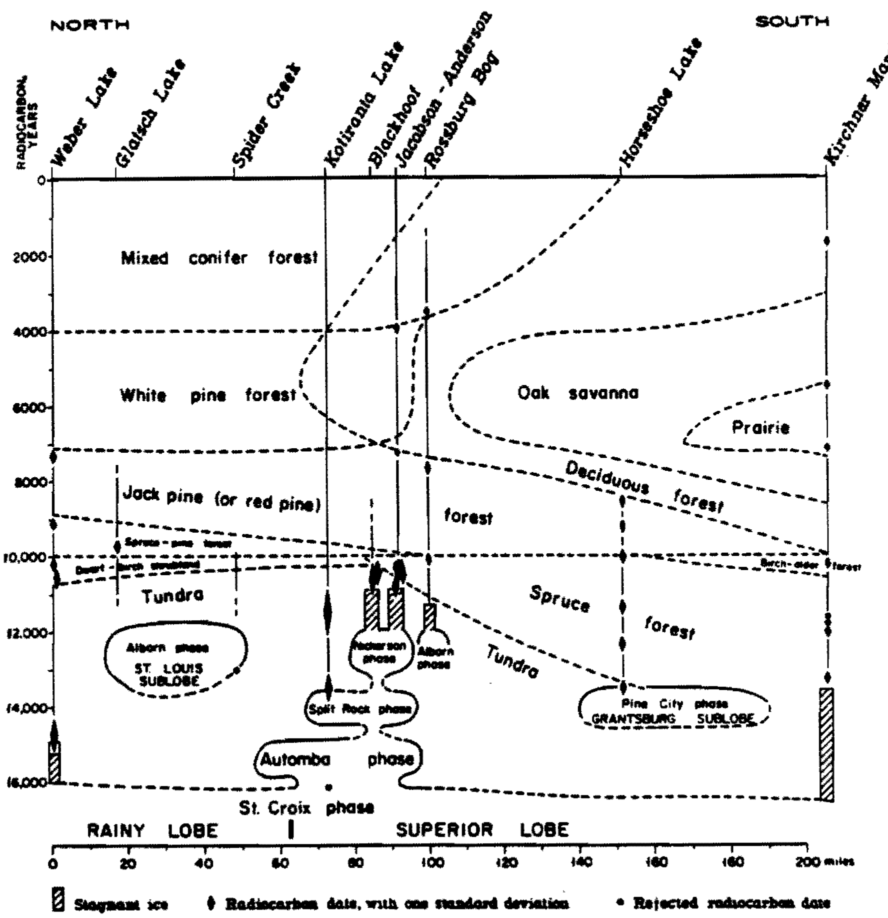


Figure 2.1. Diagrammatic representation of late glacial and postglacial shifts in vegetation of eastern Minnesota. A north-south transect extends from the present conifer forests of northeastern Minnesota (Weber Lake) to the prairie border (Kircher Marsh south of Minneapolis). Bulbous patterns in lower portion of figure indicate areas and times of advance and retreat of ice during the main Wisconsin glaciation (from Wright 1972).

3. In northern Minnesota's border lakes (ecoregion 2), glacial ice left between 13,000 and 12,000 ybp. The area was then occupied by arctic tundra (rather than spruce forest) until 10,000 ybp. A transitional spruce forest existed briefly (several hundred years), before jack and red pine forests became dominant. Between 7,000 and 6,000 ybp, white pine

entered the area (Davis 1981), and the mixture of jack, red and white pine stands familiar in the BWCAW today probably developed at that time. About 3,000 ybp, spruce and cedar, responding to gradual cooling of the climate, began to increase in abundance within the ecoregion 2, but the pine forest types remained dominant on the landscape.

2.1.2 Presettlement Forests

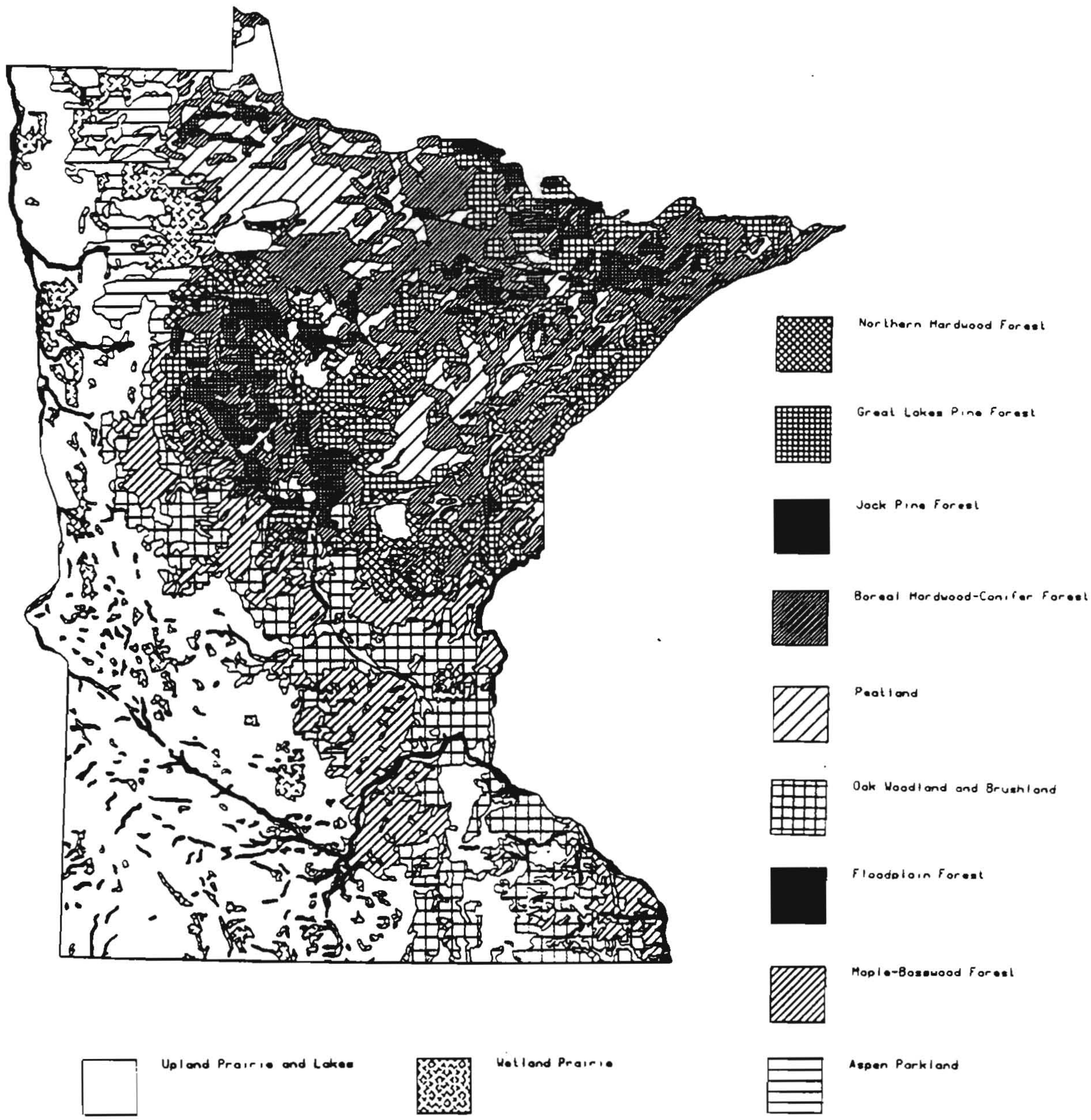
General. Much of the natural history of forests deals with the frequency, and types of disturbances (disturbance regimes) that perpetuated the original forests of Minnesota. Natural disturbances interacted with topographical features and climate to create, and maintain for thousands of years, the diversity of forests found in the state at the time of settlement. Thus, knowledge of presettlement forests and disturbance regimes provides guidelines for sustainable management of present-day forests. It is important that forest management continue to maintain the unusual biological diversity found in Minnesota forests. Few areas of comparable size approach Minnesota in the diversity of forest types. The state sits at the intersection of two very steep climatic gradients; a north-south temperature gradient and an east-west precipitation gradient. As a result, Minnesota has examples of nearly all major forest types found in the earth's temperate zone.

Natural disturbance regimes that affect Minnesota forests can be broken into two general categories. One type is fire dependent and has a short-rotation period between catastrophic disturbances. Fire-dependent forests are typically dominated by pioneer species with low to medium shade tolerance. The cyclic successional sequence is reset by catastrophic fire every 50 to 200 years, although surface fires may occur at intervals of a few decades between the major catastrophes. These forests are one generational, so that some of the first trees to invade after the stand-originating fire live until the next catastrophic fire. Old growth is a temporary phenomenon, if it is attained at all, so that nearly all stands are constantly in a state of recovery from heavy disturbance. In contrast, long-rotation disturbance regimes are usually dominated by heavy windstorms and tornados that occur at >1000 year intervals. These forests occur on sites sheltered from fire and are dominated by shade-tolerant species, such as sugar maple, that can reproduce without large canopy openings, and mid-tolerant species, such as yellow birch, that reproduce in gaps caused by the death of one to several canopy trees. Such forests are multigenerational, and old growth conditions may last centuries, with temporary interruptions caused by disturbance.

Much of Minnesota was originally occupied by the fire dependent short-rotation types of forest. Because the frequency of dry lightning is fairly low in Minnesota, many of the fires in presettlement times were probably set by Native Americans. These fires are widely believed to have been responsible for maintaining oak savannas in the open state (Curtis 1959). Most of the area burned by fires was burned by the few largest fires, which occurred during major droughts. It is often said that the 10 percent of fires with the largest area burn 90 percent of the landscape. In Minnesota these large *ecologically significant* fires were probably greater than 10,000 acres in size (Heinselman 1981), and fires in the border lakes up to 400,000+ acres have been documented (Heinselman 1973). The mean size of fires listed by Heinselman for the BWCAW was 47,000 acres. In contrast, catastrophic windstorms had a mean area of 230 acres and a likely maximum size of about 6,000 acres (Canham and Loucks 1984). Using Shugart's criterion of 50 times mean patch size, a landscape of pine/spruce forests in northern Minnesota would have to be 2.4 million acres, and a northern hardwood landscape about 11,500 acres to be at the minimum dynamic area. Both fires and windstorms have irregular shapes, often with skipped areas in the middle as well as irregular edges with many finger-like indentations. The consequences of these irregular shapes on natural fragmentation and patchiness of the landscape are largely unstudied.

The following sections describe the dynamics of natural disturbances in major Minnesota forest types. Figure 2.2 shows the Natural Heritage Program generalization of Marschner's (1974) map of presettlement vegetation. As yet, there is insufficient knowledge of natural disturbance regimes to describe details of natural ecological processes that occurred in the various subdivisions of forest types, classified by the Natural Heritage Program (section 2.2.2). In any case, these descriptions set the stage for the natural structural and functional diversity of Minnesota forests. The terms *primary* and *secondary* forests refer to the original pre-European settlement forests (including remnants that have escaped logging to the current time), and forests that have been logged, respectively. Primary replaces the old term *virgin*, which is no longer used in the scientific literature. The emphasis here is on natural disturbance regimes. For regeneration and perpetuation by management, see the silvicultural guidelines in the Silvicultural Systems Background Paper (Jaakko Pöyry Consulting, Inc. 1992a).

Jack Pine. Although jack pine-dominated forests occurred throughout ecoregions 1 through 4, they were originally concentrated in two areas: (1) on nutrient poor, droughty sand outwash, forming the southwest edge of ecoregion 4 in the north central part of Minnesota (Almendinger 1985), and (2), on thin sandy soils on rock outcrops in the border lakes region (Marschner 1974). The major natural disturbance regime in jack pine forests was one of catastrophic crown fires at intervals of about 50 years (Heinselman 1981), so that a majority of primary jack pine stands were young and even-aged. Jack pine has serotinous cones—the cone scales are temperature sensitive and require high temperatures to open and release the seeds. After a fire, thousands of seedlings per acre germinate and form a dense closed canopy within several years. Harvesting that exposes mineral soil and leaves slash with cones near the ground can also function like a fire.



Source: Adapted from *The Original Vegetation of Minnesota*, a map compiled in 1930 by F. K. Marschner from the U.S. General Land Office Survey Notes and published in 1974 under the direction of M. L. Heinselman of the U.S. Forest Service. Published (in color) by the Minnesota Department of Natural Resources 1988.

Figure 2.2. Presettlement vegetation of Minnesota, based on a generalization of Marschner's (1974) map, done by the MNDNR.

High temperatures near the ground serve to open the cones and release seed. Also, in a few areas, cones are not all serotinous and jack pine can develop in uneven-aged stands.

There are some important differences between jack pine forests along the southern border of ecoregion 4 (which coincides with the edge of jack pine range) and those in the border lakes ecoregion. The southern jack pine forests have oaks (red, pin and bur) as associated species, and the forests experience high canopy-tree mortality and decadence by age 60 to 80 years. The stands may succeed to a mixture of oaks with red and white pines or red maple as associates. Some of the jack pine stands on very dry soils probably burned every few years, resulting in a pine savanna. In the border lakes, black spruce, another species with serotinous cones, is associated with jack pine, in addition to lesser amounts of oaks. If a stand escapes fire, it may last well over a hundred years before canopy-tree mortality is significant, and individual trees may live 200 years or more. Unburned stands may succeed to black spruce or balsam fir, with white spruce and white pine as associates.

Dense stands of jack pine, particularly in northern Minnesota, frequently had little understory, or an understory of mosses where mixed with black spruce. More open stands on dry sites had understories with blueberries (*Vaccinium* sp.), grasses, bracken fern (*Pteridium aquilinum*), and wintergreen (*Gaultheria procumbens*) (Curtis 1959, Ohmann and Ream 1971).

Great Lakes Pine Forest. The original red and white pine forests were scattered throughout ecoregions 1 through 4, with major concentrations in the border lakes and along the shore of Lake Superior. The forests are on thin glacial till over bedrock in the border lakes, on sandy moraines or outwash throughout ecoregion 4, and on lacustrine clay deposits near Lake Superior. Some significant stands also existed around swamps and on steep rocky topography in ecoregions 5 and 6. Neither species has serotinous cones. Both are long-lived (up to 400+ years), and attain large size—especially white pine.

The disturbance regime that perpetuated red/white pine forests in presettlement times was more complicated than that for jack pine forests. Catastrophic fires occurred at long intervals of about 200 years, with low intensity surface fires at 20- to 40-year intervals (Frissell 1973, Heinselman 1981). After the catastrophic fires, new seedlings gradually colonize the burn over a period of 10 to 30 years, under a light canopy of earlier established or faster growing species such as aspen. Surface fires often scar and kill a few mature pines, causing canopy openings that lead to recruitment of young pines. Thus, older stands can become multi-aged.

Succession in red/white pine forests depends on the type of soil. Physiographically dry sites that have thin soils, or are very sandy, may develop nearly pure pine stands, with a minor component of maple, birch and aspen, maintained for centuries by light surface fires. On sites with deeper, more loamy soil, intermittent surface fires may be infrequent, and succession to various mixtures of red maple, sugar maple, yellow birch, balsam fir, white spruce, and white cedar will begin within 200 to 300 years (Heinselman 1981). The species composition of trees replacing the pines depends on the local seed sources.

Understory composition of white and red pine forests was composed of shrubs such as bush honeysuckle (*Diervilla lonicera*), blueberry (*Vaccinium* sp), and sweet fern (*Comptonia peregrina*), and herbs such as sarsaparilla (*Aralia nudicaulis*), canada mayflower (*Maianthemum canadensis*), and large-leaved aster (*Aster macrophyllus*) (Curtis 1959, Ohmann and Ream 1971).

Boreal hardwood-conifer. These forests, dominated by aspen, paper birch, white spruce, and balsam fir, were found throughout ecoregions 1 through 4, but were more common near the Canadian border. Compared to the pine forest types, these forests occurred on deeper, more mesic, relatively nutrient rich soils. They represented the southernmost extension of the boreal forest that covers most of northern Ontario. Any one acre on the ground could have been dominated by any of the four main species, or a mixture of them, so that they formed a patchy landscape mosaic. The characteristics of the original patchwork are unknown. All four main species of this forest have a natural lifespan of 60 to 100 years. However, in the far northern part of the state, individuals of all four species can live for 200 years or more.

These forests were perpetuated by catastrophic fires at intervals of 80 to 100 years (Heinselman 1981). All four species are poorly adapted to withstand the physical effects of fires (even light surface fires). However, aspen and paper birch have abundant, light, widely dispersed seeds, and the ability to resprout after the tops are killed. They can become established in huge numbers within a few years after a fire. White spruce and balsam fir have relatively poorly dispersed seeds—they spread from scattered *survivor trees* and increase gradually over a period of several postfire decades. If no further fires occur, spruce and fir can dominate a stand, because their seedlings can grow in the shade of the forest floor, and replace adult trees as they die. However, these old spruce and fir stands are subject to budworm attacks, which can kill or weaken large areas of forest. Budworm-killed trees greatly increase the chance of another forest fire, due the abundance of dead-and-dry wood. For this reason, upland spruce-fir forests in Minnesota probably never attained an old growth all-aged status for very long. In fact, in presettlement times, much of the boreal hardwood-conifer forest in Minnesota was dominated by aspen and birch. In an analysis of presettlement vegetation based on 19th century land surveys, Marschner (1974) did not recognize an upland spruce-fir forest type in northern Minnesota, but a mixture which he mapped as aspen-birch (conifer).

However, there is more aspen forest today (as a proportion of forest) and much of it resulted from conversion of conifer types.

One variant of the boreal hardwood-conifer forest is the white cedar-birch-aspen type. This forest was distinct from swamp-conifer white cedar forests, and occurred chiefly on clay and silt loam soils on the highlands in ecoregion 3—the Lake Superior North Shore. Very little is known about the dynamics of these forests, although the moist soils and proximity to Lake Superior suggest that fires were not as frequent as in aspen-birch-spruce-fir forests.

In some areas, shrubs were well developed, with fly honeysuckle (*Lonicera canadensis*), bush honeysuckle (*Diervilla lonicera*),. and round-leaved dogwood (*Cornus rugosa*) prevalent. In areas without shrubs, a mixture of small herbs known as *Canadian carpet* was often present. Canadian carpet was composed of Canada mayflower (*Maianthemum canadensis*), twinflower (*Linnea borealis*), bunchberry (*Cornus canadensis*), large-leaved aster (*Aster macrophyllus*), wild sarsaparilla (*Aralia nudicaulis*), blue-bead lily (*Clintonia borealis*), goldthread (*Coptis groenlandica*), and several clubmosses (*Lycopodium* sp.) (Curtis 1959, Ohmann and Ream 1971).

Swamp Conifers. These forests (mapped as peatland on figure 2.2) include peatland black spruce, tamarack and white cedar. Black spruce and tamarack are associated with peatlands, and often occur on moss mats, floating moss mats, or hillside seepages. On sites with little nutrient input from groundwater (Ombrotrophic, areas on granitic bedrock), sphagnum moss often dominates, the ground water is very acid and black spruce is the most abundant tree species. On sites with slightly better nutrient supply (oligotrophic), mosses other than sphagnum can dominate, and tamarack becomes more abundant. Peatlands with relatively high decomposition rates, and relatively thin peat (relatively nutrient rich minerotrophic soils) tend to develop black mucky soils, where white cedar reaches its maximum abundance. White cedar is also favored in wetlands on northern areas with calcareous soil.

Peatlands develop slowly over a period of several thousand years, during which the peat grows thicker until decomposition nearly equals the rate of new peat formation by the shallow layer of living moss at the surface. The peat may continue to support productive black spruce/tamarack forest as it develops, or it may become more saturated with water so that the trees become more stunted as time goes on. At some point, enough nutrients may accumulate from precipitation or other inputs that decomposition increases, the climate may change to favor increased decomposition, the peatland may erode, or burn during a drought (Heinselman 1970). Thus, there is a complicated web of successional possibilities that depends on the climate, random disturbances, and changes in drainage caused by stream meandering and development of the peatland itself. Some peatland black spruce forests burned with an average rotation period of about 150 years, while others were skipped for centuries (Heinselman 1981).

Understory composition in acid black spruce and tamarack forests had ericaceous shrubs such as Labrador tea (*Ledum groenlandicum*), several species of blueberry (*Vaccinium* sp)., cranberry (*Vaccinium* sp.), and creeping snowberry (*Gaultheria hispidula*). Herbs included several species of cotton grass (*Eriophorum* sp.), sedge (*Carex* sp.), and horsetails (*Equisetum* sp.). Several rare orchids such as arethusa orchid (*Arethusa bulbosa*) and ram's head ladyslipper (*Cyprepedium arietinum*) occur in lowland black spruce forests.

White cedar forests had a different understory, with marsh ferns (*Thelypteris palustris*), cinnamon ferns (*Osmunda cinnomomea*) and oak ferns (*Thelypteris phegopteris*). Small herbs included naked miterwort (*Mitella nuda*) , several bedstraws (*Galium* sp.), enchanter's nightshade (*Circea alpina*), and the state flower, showy ladyslipper (*Cyprepedium reginae*). Shrubs were mainly several varieties of currents and gooseberries (*Ribes* sp.) (Curtis 1959).

Minnesota's peatland forests are among the most natural ecosystems left in the state. Because they are not very productive, and difficult to access, peatland forests are a low priority for timber harvest, and to this time, peat mining has not progressed very far. Minnesota has the largest area of peatlands among the 48 states, about 25 percent of the total. Extensive peatland development began about 8,000 ybp in ecoregions 1 and 4. For several thousand years, the peatlands were unforested and dominated by sedges and sedge peat. About 4,000 ybp, the climate became cooler and wetter, and forests began to invade the peatlands. By 3,000 ybp, *Sphagnum* moss became well established, and the current *Sphagnum*-spruce forests developed (Heinselman 1970).

Floodplain forests (also called lowland hardwoods), occurred in seasonally flooded wet spots, along the edges of marshes, and river floodplains. They generally grew on black mucky soils with relatively good nutrient supply, similar to soils in white cedar forest. Along rivers, soils varied from mucky in old oxbows to recently colonized sand bars.

In northern Minnesota, lowland hardwoods were usually distinguished by the presence of black ash, and mixed with red maple and yellow birch in variable proportions. Black ash is relatively slow growing and lives for 150 to 300 years, at which time it attains a diameter of 10 to 20 inches. The understory in black ash forests has many sedges (*Carex* sp.) and wildflowers, such as marsh marigold (*Caltha palustris*), and blueflag iris (*Iris virginica*). Virtually nothing is known about natural disturbance frequency in black ash forests. Periodically, flooding caused by beavers and periods of several years with high water tables killed stands of trees. Gaps caused by windthrow were frequent, because the water-soaked soils do not provide good anchorage for trees.

In southern Minnesota, floodplain forests were characterized by cottonwood, green ash, and silver maple. All of these species grow fast, attaining diameters up to 4 feet (more for cottonwood) within 50 to 60 years. Cottonwood and silver maple are short-lived; the wood becomes very brittle by age 50 and the trees collapse on windy days or during winter ice storms. Catastrophic disturbance (of unknown frequency) was caused by windstorms, and erosion from the ever-changing course of rivers. The understory was very lush, with jewelweed (*Impatiens* sp.), asters (*A. ontarionis*), and nettles (*Urtica dioica*, *Laportea canadensis*) attaining a height of 5 feet by midsummer. These forests were the only ones in the Upper Midwest to have many vines, including a form of poison ivy (*Rhus radicans*), grapes (*Vitis* sp.), and virginia creeper (*Parthenocissus quinquefolia*) (Curtis 1959).

Northern Hardwood forest occurred in scattered patches throughout ecoregions 3 and 4, mostly on relatively deep, nutrient rich, loamy soil. The sites occupied by these forests were relatively free of catastrophic forest fires. On the North Shore of Lake Superior (ecoregion 3), hardwood stands occurred on the tops of major ridges, which experience much warmer growing season temperatures than lowlands near the lake. The major tree species—which are excluded by frequent forest fires—were sugar maple and basswood. White pine, yellow birch, red oak and red maple were small but significant components. Balsam fir and ironwood were common understory trees, rarely attaining canopy status in these forests. Minnesota northern hardwood forests contained the western-most outliers of eastern hemlock, a species which dominated huge areas in Wisconsin and Michigan, and now listed as of special concern in Minnesota.

Seedlings of the major tree species—sugar maple and basswood—are shade tolerant, and able to grow slowly on the forest floor for years, until a canopy tree above dies, releasing the seedlings into a canopy gap. Canopy gaps formed by the death of two or three adjacent trees during severe thunderstorms were large enough for species of intermediate shade tolerance (yellow birch, red oak, red maple and white pine) to maintain a low but constant population. Thus, these forests could attain multi-aged or all-aged structure through the action of a shifting mosaic of gaps, and perpetuate themselves indefinitely without major disturbance.

Because northern hardwood forests occupy sites not prone to dryness, and their leaf litter makes poor fuel, forest fires were infrequent. Rotation periods for catastrophic fires were one to two millennia or more, and surface fires occurred perhaps every one or two centuries. Most areas in Minnesota experience high winds of thunderstorm downbursts once or twice each decade. In northern hardwood forests, such downbursts would topple the *crop* of rotten old trees that had accumulated since the last downburst, creating the gaps necessary for regeneration. At intervals of 1,000 to 2,000 years, an unusually severe downburst or tornado would catastrophically level all trees larger than 4 to 6 inches in diameter (Frelich and Lorimer 1991). These major blowdowns produced much slash and created the rare fuel conditions favorable for a major intense fire. If a major windfall burned, the area would be invaded by a mixture of paper birch, yellow birch, quaking and bigtooth aspen, red oak and white pine. The process of succession back to maple and basswood as dominants would begin immediately and take about 200 years to complete. However, if a drought did not occur within a few years after the blowdown, the area would not burn usually, and many small seedlings released from shade of the canopy would grow rapidly, forming a new canopy with similar species composition to the old within ten years.

Northern hardwood forests are well-known for their display of early spring wildflowers (spring ephemerals) that bloom before the trees fully leaf out in May—although not all have stands have abundant spring ephemerals. The flowers include large-flowered trillium (*Trillium grandiflora*), wild oats (*Uvularia* sp.), toothwort (*Dentaria* sp.), several violets (*Viola* ssp.), yellow trout lilies (*Erythronium americanum*), Dutchman's breeches (*Dicentra cucullaria*), hepatica (*Hepatica acutiloba, H. americana*), and twisted stalk (*Streptopus roseus*). The flowers of the Canadian carpet are also present, along with shrubs such as leatherwood (*Dirca palustris*) and fly honeysuckle (*Lonicera canadensis*), and woodferns (*Dryopteris austriaca*).

Maple-basswood. This forest type is essentially the same as the northern hardwood, except for the more southerly location (ecoregions 5 and 6), and absence of conifers and yellow birch. Called the Bigwoods by settlers, maple-basswood forests occupied loamy soils on sites sheltered from prairie and oak-savanna fires by lakes, rivers, and rough topography (Grimm 1984). Generally, prairie fires moved from southwest to northeast, so that maple-basswood forests occurred on the northeast sides of lakes, ridges, and rivers (if they were oriented northwest-southeast). If an area was skipped by fires long enough for sugar maple to invade, then changes brought about by the trees themselves, such as higher humidity under the canopy, and relatively nonflammable forest floor material, caused a further decrease in fire frequency. One unusual tree species in the maple-basswood forest region was Kentucky coffeetree, the seeds of which were used by Native Americans in a type of dice game. They transported the species to their village sites, where some seeds were lost and grew into local populations of trees (Curtis 1959). Thus, the Kentucky coffeetree represents both a biodiversity and cultural resource.

The disturbance regime in these forests was probably similar to northern hardwoods, except that disturbance would have been a little more frequent, since there is a gradient of increasing severe windstorm frequency and drought frequency towards the south. Another disturbance that occurred in the bigwoods region, as well as the oak savanna, woodland and forest, was caused by the now extinct Passenger pigeon. These birds gathered in huge numbers in the fall (hundreds to thousands per tree) in areas known as roosts, which were within regions with abundant mast—principally oaks in Minnesota. Roosts were used until mast within flying distance was consumed, and the birds moved south, spending the winter in the southeastern U.S. Roosts ranged in size from a few hundred acres to several square miles in size. Most of the trees and understory vegetation were killed by a combination of physical breakage by the weight of thousands of birds, and accumulation of dung up to several inches deep (Schorger 1955). Areas of forest killed by Passenger pigeons were probably small compared to the areas disturbed by fires and severe windstorms, but may have been significant in parts of Minnesota originally occupied by oak forests.

Understory vegetation of maple-basswood forests was similar to that of the northern hardwoods. Bloodroot (*Sanguinaria canadensis*), mayapple (*Podophyllum peltatum*), blue cohosh (*Caulophyllum thalictroides*), and waterleaf (*Hydrophyllum virginiana*) were common additional early spring bloomers, while northern herbs such as blue-bead lily (*Clintonia borealis*) and clubmosses (*Lycopodium* sp.) were less abundant or absent in some stands.

Oak Woodland and Brushland occurred throughout ecoregions 5 and 6. The degree of canopy closure depended on fire frequency, which in turn was influenced by soil texture and proximity to rivers, lakes, wetlands and other physiographic barriers to fire. Sites exposed to the sweep of prairie fires coming from the southwest and on coarse sandy soils were burned mainly in springtime every one to five years. These sites had true savanna with scattered bur, and pin oaks within a grassland matrix. White oak and shagbark hickory also occurred in savannas in ecoregion 6, especially on blufflands along the Mississippi River (Curtis 1959, Nuzzo 1986). A small amount of bur oak savanna on mesic soil (black-soil savanna) occurred in southeastern Minnesota. Both bur and pin oak are capable of producing grubs, or seedlings with an extensive root system that can survive yearly burning for decades, until a chance period of protection from fire allows the top to develop into a tree (Curtis 1959). Once bur oaks are tree size (>4 inches diameter), they are essentially immune from fires, because their corky bark insulates the tree from grass fires, which pass by rapidly. Pin oak may be killed by fire at any age. In addition to fire, the savanna was maintained in an open condition by severe droughts, which could kill a quarter of trees on sandy soils (Faber-Langendoen and Tilman, in prep.).

Sites somewhat sheltered from fires, and/or on slightly more loamy soil, did not burn as often as savannas, and grew into woodlands with less than 30 percent open grassland. Because fires were less frequent on these sites, more fuel would build up between fires and therefore fires were more intense. The result was even-aged stands, probably with rotation periods of 50 to 100 years (Faber-Langendoen, Frelich and Tilman, in prep.).

Sites well sheltered from fires developed closed-canopy oak forest, and were dominated by red oak and white oak. Such stands probably occurred as inclusions within the bigwoods. Without fire, these forests succeed to sugar maple and basswood (Curtis 1959, Grimm 1984, Will-Wolf 1991). The estimated rotation period of intense fire for maintenance of mesic red and white oak forests on the landscape is estimated at 100 to 300 years (Whitney 1986, Will-Wolf 1991). Oak forests were probably also disturbed by Passenger pigeons as described above under maple-basswood forests.

Oak savannas had understories with many grasses, including big bluestem (*Andropogon gerardii*) , little bluestem (*Schizachyrium scoparium*), and indian grass (*Sorghastrum nutans*). Shrubs such as hazel (*Hamemelis virginiana*), and several wild roses (*Rosa* ssp.) were abundant. Herbs included lead plant (*Amorpha canescens*), indian paintbrush (*Castileja canadensis*), canada anemone (*Anemone canadensis*), and sunflowers (*Helianthus* ssp.). Closed canopy oak forests developed an understory intermediate between oak savanna and maple-basswood forest.

Aspen Parkland. Within the eastern half of the U.S., aspen parkland was unique in Minnesota. It occurred on the extreme western edge of ecoregion 1, forming a buffer between the prairie and forest. The aspen parklands had many small stunted quaking aspen and oaks, which were in groves separated by grasslands. They were maintained by frequent surface fires (10-year rotation period, Heinselman 1981). Aspen trees have thin bark, and are easily killed by fire. However, they can resprout from underground roots, forming scattered dense young thickets.

2.1.3 Forests and Old Growth Then and Now

Current Forest-FIA Forest Types.
The following classes of forest types in Minnesota are defined by the Forest Inventory and Analysis (FIA) unit of the USDA Forest Service, North Central Forest Experiment Station (Leatherberry 1991, Kingsley 1991, Murray 1991). Forest types are a classification of forest land based on the species forming a plurality of tree stocking. Forest types recognized in the FIA data and codes are summarized in table 2.1. Scientific names of tree species are listed in appendix A.

Current forest area in this analysis is timberland plus reserved forest (other and nonstocked forest are not counted), obtained from the Maintaining

Table 2.1. FIA classification of forest types.

Code	Description
1	*Jack pine.*—Forests in which jack pine comprises a plurality of the stocking. (Common associates include eastern white pine, red pine, aspen, birch, oak, and maple.)
2	*Red pine.*—Forests in which red pine comprises a plurality of the stocking. (Common associates include eastern white pine, jack pine, aspen, birch, and maple.)
3	*White pine.*—Forests in which eastern white pine comprises a plurality of the stocking. (Common associates include red pine, jack pine, aspen, birch, and maple.)
12	*Black spruce.*—Forests in which swamp conifers comprise a plurality of the stocking with black spruce in the most common. (Common associates include tamarack and northern white-cedar.)
13	*Balsam fir.*—Forests in which balsam fir and white spruce comprise a plurality of stocking with balsam fir the most common. (Common associates include aspen, maple, birch, northern white-cedar, and tamarack.)
14	*Northern white-cedar.*—Forests in which swamp conifers comprise a plurality of the stocking with northern white-cedar the most common. (Common associates include tamarack and black spruce.)
15	*Tamarack.*—Forests in which swamp conifers comprise a plurality of the stocking with tamarack the most common. (Common associates include black spruce and northern white-cedar.)
16	*White spruce.*—Forests in which white spruce and balsam fir comprise a plurality of the stocking with white spruce the most common. (Common associates include aspen, maple, birch, northern white-cedar, and tamarack.)
50	*Oak-hickory.*—Forests in which northern red oak, white oak, bur oak, or hickories singly or in combination, comprise a plurality of the stocking. (Common associates include jack pine, elm, and maple.)
70	*Elm-ash-soft maple.*—Forests in which lowland elm, ash, red maple, silver maple, and cottonwood, singly or in combination, comprise a plurality of the stocking. (Common associates include birches, spruce, and balsam fir.)
80	*Maple-basswood.*—Forests in which sugar maple, basswood, yellow birch, upland American elm, and red maple, singly or in combination, comprise a plurality of the stocking. (Common associates include white pine, elm, and basswood.)
91	*Aspen.*—Forests in which quaking aspen or bigtooth aspen, singly or in combination, comprise a plurality of the stocking. (Common associates include balsam poplar, balsam fir, and paper birch.)
92	*Paper birch.*—Forests in which paper birch comprises a plurality of the stocking. (Common associates include maple, aspen, and balsam fir.)
94	*Balsam poplar.*—Forests in which balsam poplar comprises a plurality of the stocking. (Common associates include maple, aspen, and balsam fir.)

Productivity and Forest Resource Base Technical Paper (Jaakko Pöyry Consulting, Inc. 1992c). This quantity is referred to as "productive closed-canopy forest." Woodland acreage was not included in the total because there is no direct comparison possible between presettlement and current woodland types. Most of the current unproductive forest is black spruce and tamarack, and these types were probably counted as open peatlands in Marschner's analysis of presettlement forest. In presettlement times, most of the unproductive forest was oak savanna, which has today been converted to timberland due to fire suppression. The small acreage of "other and nonstocked" land in the FIA data does not have a forest type and cannot be compared with data from Marschner's map.

Presettlement Forests-Marschner's Map.
Areas of presettlement forest were obtained from a map based on mid-19th century General Land Office (GLO) surveys of Minnesota (Marschner 1974, Heinselman 1974). The map shows, at a scale of 1:500,000, the distribution of 11 types of forest over the state just prior to homesteading by immigrants. A copy of a reduced-size version of the map is shown in figure 2.2. Cushing (for this report) superimposed a rectangular grid of 10x10 km squares, based on the Universal Transverse Mercator grid, on Marschner's map and recorded for each of the 2,285 squares a visual estimate of the percentage of the square occupied by each of the map units. These data were pooled for the state by map unit for comparison with the estimates of current forest area. Because Marschner's map types differ from the FIA classification, some FIA types had to be combined to make comparison possible (table 2.2). The first column in table 2.2 also shows the name given to each forest type for this report, used in tables 2.3 to 2.5.

Table 2.2. Marschner's map and FIA covertypes/equivalency for the purpose of comparing presettlement forest area of Minnesota with the current area.

Forest Type Map Units		
This Report	FIA Types	Marschner Types
Jack pine	Jack pine	Jack pine
Red-white pine	Red pine, white pine	White + red pine, white pine
Boreal hardwood-conifer	Paper birch, aspen balsam fir, white spruce, balsam poplar	Aspen-birch (conifer)
Swamp conifer	Black spruce, northern white cedar, tamarack	Conifer bog
Oak-hickory	Oak-hickory	Aspen, oak, oak openings
Riverbottom	Elm-ash-soft maple	Riverbottom
Northern hardwood	Maple-basswood	Bigwoods, mixed hardwoods, aspen-birch (hardwood)

Table 2.3. Comparison of presettlement and current forest area (Forest=productive closed-canopy as defined in accompanying text) (thousands of acres).

Forest Type	Presettlement	Current
Jack pine	1,903 (7.0%)	578 (3.7%)
Red-white pine	3,500 (12.9%)	505 (3.2%)
Boreal conifer-hardwood	6,408 (23.7%)	8,058 (51.1%)
Swamp conifer	6,668 (24.6%)	2,846 (18.1%)
Oak-hickory	1,899 (7.0%) 3,849[a]	1,135 (7.2%)
Riverbottom	1,332 (4.9%)	1,151 (7.3%)
Northern hardwood	5,384 (19.9%)	1,481 (9.4%)
Total forest Total forest+savanna	27,095(100.0%) 30,944	15,754[b] (100.0%)

[a] The 1,899 figure is aspen-oak type (table 2.2), a closed canopy type. The 3,849 figure is acreage of oak savanna.
[b] For reasons explained in the text, this figure does not include woodland or "other and nonstocked" land.

Calculation of presettlement old growth.
The formula in Van Wagner (1978) and the disturbance rate, can be used to estimate the proportion of forest that would have been old growth forest in presettlement times for each forest type. This estimate depends on the assumption that susceptibility to disturbance is fairly constant with respect to stand age. The proportion of the landscape that would be greater than x years old is then e^{-px}, where x is 120 years (90 years for boreal conifer-hardwood type, MNDNR definition of old growth) and p is the annual probability of disturbance (reciprocal of rotation period). Table 2.4 shows estimated average rotation period for each forest type in the state, based on the literature cited in the natural history section above, and the resulting proportion of old growth for each forest type. Multiplying the percent of old growth by the area of presettlement forest from table 2.3 yields an estimate of presettlement old growth (table 2.5).

Calculation of current old growth and old forest.
The area of old growth in presettlement times will be compared with area of current old plus old growth forest (see definitions in section 1.4). The purpose here is a rough estimate of timberland and reserved forest at least 120 years old, which was obtained from the Maintaining Productivity and the Forest Resource Base technical paper (Jaakko Pöyry Consulting, Inc. 1992c).

Minnesota currently has about 15.8 million acres of closed canopy productive forest, about 58 percent as much as in presettlement times. In terms of proportion of the landscape, the state currently has substantially less jack, red and white pine forest, swamp conifers, and northern hardwoods now (table 2.2). The proportion of forest in the oak-hickory covertype is about the same, and the proportion of riverbottom and boreal conifer-hardwoods is much greater. The presettlement oak savanna has been converted to farmland or grown into closed-canopy forest after cessation of presettlement fires.

Table 2.4. Proportion of the presettlement landscape that would be old growth forest (> 120 yr, 90 yr boreal conifer-hardwood), depending upon the frequency of catastrophic disturbance. Assumes constant probability of disturbance with age.

Rotation period (yr)	Percent old growth	Forest types
50	9	Jack pine
100	41	Boreal hardwood-conifer
200	55	Red-white pine, swamp conifer, riverbottom, oak-hickory[a]
1000	89	Northern hardwood

[a] Most oak-hickory in the Lake States would fall in this category. However, Marschner's aspen-oak type, which is really aspen parkland, was maintained by surface fires, and may not have had true catastrophic disturbance.

Table 2.5. Comparison of presettlement old growth forest with current old growth and old forests (thousands of acres).

Forest Type	Presettlement (Percent)[a]	Current (Percent)[a]
Jack pine	171 (9)	5.3 (0.9)
Red-white pine	1,925 (55)	26.4 (5.2)
Boreal conifer-hardwood	2,627 (41)	168.7 (2.1)
Swamp conifer	3,667 (41)	288.4 (10.1)
Oak-hickory	b	51.4 (4.5)
Riverbottom	734 (41)	39.1 (3.4)
Northern hardwood	4,792 (89)	31.5 (2.1)
Total	13,916 (51)	610.8 (3.9)

[a] percent of total forest type area from table 2.3.
[b] Nearly all of the original oak-hickory type was savanna or aspen-oak parklands, and the concept of old growth does not apply.

There are currently roughly 610,800 acres of old and old-growth forest, compared with nearly 14 million acres originally (table 2.5). About 4 percent of current forests are old or old growth, compared with 51 percent in presettlement times. Cunningham and Moser (1938), state a contrasting view (adopted by the Maintaining Productivity and Forest Resource Base Technical Paper, Jaakko Pöyry Consulting, Inc. 1992c), that only about a third of Minnesota's original forests were *old growth sawtimber*. This is not inconsistent with the estimate here of 51 percent, because black spruce and other forests that may meet the 120-year-old criterion used in this report, may not meet Cunningham and Moser's definition of sawtimber—15 inches dbh.

2.2
Diversity of Plant Communities

2.2.1
Flora of Minnesota

Flora refers to an inventory of plant species present in a region and their geographic distribution there. A thorough inventory of the vascular plants of Minnesota has been published by Ownbey and Morley (1991). They list 2,010 species, of which 392 have been introduced in the past 150 years and are now naturalized. Among the bryophytes, Janssens (1988) estimates that the number of species of mosses in Minnesota is probably similar to the number in Wisconsin, which is put at 380. Lichens are better known, and Wetmore (1988) estimates that there are more than 550 species in Minnesota.

The abundance and distribution of plants of economic or aesthetic importance is generally well-known, but many less conspicuous species are known only from where they have been collected or otherwise noted by field botanists. The distribution maps published by Ownbey and Morley (1991) are based on specimens of vascular plants preserved in the herbarium of the University of Minnesota, St. Paul. Because some of these specimens were collected as long ago as 1849, a species may have disappeared from some of the localities shown on its map. Indeed, Smith (1988) cites many instances where a rare plant once collected at a certain locality has been sought there recently without success.

In a study of the distribution of plants that reach the limit of their geographic range in Minnesota at or near the former prairie-forest border, Wheeler et al. (1992) concluded that the number of specimens of vascular plants from the forested part of the state is still too few for reliable mapping of range boundaries. Instead they examined distribution maps for prairie and open woodland species. These have been collected extensively during recent systematic surveys of prairie counties by the MNDNR and The Nature Conservancy.

Within the forested region, published floristic surveys have been limited to a few counties mostly within the southern half of the state, with the notable exception of Cook County (Butters and Abbe 1953). Lakela (1965) contributed greatly to plant collections from the northeastern part of the state, and the flora in and around Itasca State Park has also been well explored. Other valuable information comes from floristic sampling of the vegetation in areas of special interest, although the taxonomic resolution of the resulting species lists may be less complete. Among the useful studies are those reported by Dean (1971), Grigal and Ohmann (1975), Janssen (1967), Ohmann and Ream (1971), Sather (1980), and Wheeler and Glaser (1977).

2.2.2 Plant Communities

Plants commonly grow together in combinations or assemblages of species that appear distinctive, and these are considered plant communities (or covertypes). Pine forest, maple forest, and conifer bog are three familiar examples. Plant communities are recognized for convenience, and many different classifications are possible and in use. Types may vary from place to place and change over time. The distribution of vegetation types, like the distribution of individual species that compose it, is influenced by factors that vary in importance over a wide range of spatial and temporal scales. The major divisions of the vegetation of the state before 1850 into prairie, deciduous forest, and mixed coniferous-deciduous forest is undoubtedly influenced by regional variation in climate, although the temporal scales at which the influence operates is not yet understood. As one examines vegetation with increased spatial resolution the number of distinguishable vegetation types increases, as does the number of factors that control the spatial heterogeneity. Within ecoregions, topography, hydrology, substrate, and soil type have major effects. Moreover, landscape processes that vary greatly in intensity, frequency, and spatial extent have powerful effects on the local structure and composition of vegetation. These processes include weather, such as windstorm, heavy rain and snowfall, and drought; fire; flooding; erosion and siltation; outbreaks of insect herbivores and diseases; grazing and browsing; and logging.

Natural Heritage Classification

The FIA classification consists of broad forest types that often combine more than one ecologically significant covertype. Another classification of forest types is being developed by the Natural Heritage Program of the MNDNR (Minnesota Natural Heritage Program 1992; table 2.6). It is part of a more extensive classification of natural communities in the state, and it considers characteristics of topography, hydrology, landforms, substrates, soils, and natural disturbance regimes as well as vascular plants. The MNDNR classification distinguishes open woodlands and savannas, which the FIA would place with medium to poorly stocked stands of forest. The savannas once formed a buffer between the prairie and forest ecoregions, but with control of the fires that kept them open, they are now rare. The MNDNR forest community types are summarized below, with their approximate equivalents in the USDA Forest Service classification.

Table 2.6. Natural Heritage Program classification of Minnesota community types.

Community Type	Definition
Forests	Trees > 70% cover
Aspen	Tree cover > 70% aspen. Associates: paper birch, oaks, green ash. FIA equivalent: Aspen (part).
Aspen-birch	Tree cover >70% aspen, paper birch, or a combination. FIA equivalent: aspen(part), paper birch
Mixed oak	Tree cover <70% aspen and paper birch, oak generally >30% and typically mixed with other trees. FIA equivalent: Oak-hickory (part).
Northern hardwood	Canopy mostly sugar maple, basswood, or both, with up to 20% conifers; or conifers present in understory. Associates: red oak, green ash, elms, yellow birch. FIA equivalent: Maple-basswood(part).
Maple-basswood	Canopy mostly sugar maple, basswood, or both, with no conifers or only scattered white pine; no conifers in understory. FIA equivalent: maple-basswood (part), oak-hickory (part).
Lowland hardwood	Canopy mostly black ash, green ash, yellow birch, red maple, elm. FIA equivalent: elm-ash-soft maple (part).
White pine	Conifer canopy mostly white pine, often with red pine, hardwoods often present; hardwoods and balsam fir common in understory. FIA equivalent: White pine.
Jack pine	Canopy >70% jack pine; with occasional oak, aspen, birch, red pine. FIA equivalent: Jack pine.
Red pine	Canopy mostly red pine, <70% jack pine; with occasional oak, aspen, birch. FIA equivalent: red pine.
Upland white cedar	Canopy mostly white cedar, on upland sites; associates balsam fir, yellow birch, pap birch, white spruce, black spruce. FIA equivalent: Balsam fir(part), white spruce(part).
Spruce-fir	Canopy mostly white spruce, black spruce, or balsam fir. FIA equivalent: Balsam fir(part), white spruce(part).
Mixed pine-hardwood	Canopy a mixture of jack pine or red pine, with oak, aspen or paper birch. FIA equivalent: jack pine(part), red pine (part).
White pine-hardwood	Canopy a mixture of white pine with red oak, sugar maple, white oak, black oak or white ash. FIA equivalent: Oak-hickory(part).
Boreal conifer-hardwood	Canopy a mixture of white pine, balsam fir, white spruce, or white cedar, with aspen, paper birch, red maple. FIA equivalent: Balsam fir (part), white spruce(part).
Northern hardwood-conifer	Canopy a mixture of white pine, balsam fir, white spruce, or white cedar, with sugar maple, yellow birch, basswood, red oak, green ash, black ash and elm. FIA equivalent: balsam fir(part), white spruce(part), maple-basswood(part).
Savanna and Woodland	Trees 5-70% cover. Savanna: matrix surrounding trees >30% open grassland, tall brush generally sparse. Woodland: matrix surrounding trees <30% open grassland, tall brush sparse to dense.
Oak savanna	Trees mostly bur oak, northern pin oak or black oak, often with some aspen. FIA equivalent: oak-hickory(part).

Community Type	Definition
Aspen openings (a savanna)	Trees mostly quaking aspen or balsam poplar, with less oak; a mosaic of aspen groves and brush prairie. FIA equivalent:aspen(part).
Aspen woodland	Tree cover >70% aspen. FIA equivalent: aspen(part).
Mixed oak woodland	Tree cover <70% aspen; canopy with a mixture of oak, green ash, or basswood, with or without aspen. FIA equivalent:oak-hickory(part).
Red cedar glades	Savanna with trees mostly red cedar, often with stunted oak.
Jack pine barrens	Savanna of jack pine, often mixed with stunted oak and young aspen. FIA equivalent: jack pine (part).
Northern conifer scrubland	Savanna of stunted jack pine, black spruce, or both, often with stunted oak and aspen. FIA equivalent: jack pine(part).
Jack pine woodland	Woodland, trees mostly jack pine; brushy openings include prairie species. FIA equivalent: Jack pine(part).
Northern coniferous woodland	Woodland, trees mostly jack pine, black spruce, or both; brushy openings with forest species. FIA equivalent: jack pine (part).
Wetland Forests	
Black spruce bog	Tree cover >30%, strongly dominated by black spruce. FIA equivalent: black spruce(part).
Silver maple floodplain	Canopy >70% silver maple, with green ash, black ash, elm or hackberry. FIA equivalent: Elm-ash-soft maple (part).
Black ash swamp	Canopy >50% black ash. FIA equivalent: elm-ash-soft maple (part).
Mixed hardwood floodplain	Canopy <70% silver maple, with black willow, cottonwood, river birch, elm, green ash, bur oak, or box elder. FIA equivalent: elm-ash-soft maple (part).
Mixed hardwood swamp	Canopy <50% black ash, with mixed hardwoods. FIA equivalent: Elm-ash-soft maple(part).
White cedar swamp	Canopy white cedar, often with some tamarack; Sphagnum mostly absent. FIA equivalent: northern white cedar.
Tamarack swamp	Canopy mostly tamarack, often with paper birch or black ash; sphagnum present or absent. FIA equivalent: Tamarack.
Black spruce swamp	Canopy dominated by black spruce, with minor tamarack and hardwoods; Sphagnum present. FIA equivalent: black spruce(part).

2.2.3
Within Community Diversity

Species Richness

The diversity of plant species certainly varies from one community to another, but data with the required taxonomic precision are still too few to permit quantitative comparisons. One can, however, make some qualitative estimates of diversity. The categories in table 2.7 are suggested by the data presented by Wheeler and Glaser (1977) in their description and sampling of vegetation in a portion of Itasca County. They made relevés, a sampling method that visually estimates the abundance or cover of all species, in plots 400 m^2, a standard size for forest communities. Diversity is accordingly expressed as the number of vascular plant species in plots of that size (table 2.7)

Table 2.7. Summary of relevés (400 m^2 plots) showing species richness within Minnesota plant communities.

Category	Species per 400 m^2	Examples	Species per 400 m^2 range	No. of relevés	Source
High	>50	Aspen forest	51-68	5	(1)
			21-32	15	(2)
		White cedar swamp	42-87	8	(1)
			24-42	6	(2)
		Mixed oak forest	49-66	6	(4)
Moderate	35-50	Northern hardwood forest	36-45	5	(1)
			17-35	16	(2)
		Maple-basswood forest	20-52	27	(4)
		Black ash swamp	25-39	10	(2)
		Soft maple floodplain forest	32-55	4	(1)
		Fir forest	19-31	4	(2)
		Red pine/jack pine forest	43-48	5	(1)
			18-36	27	(2)
Poor	20-35	Tamarack poor-fen forest	13-42		(3)
			7-13	6	(2)
		Black spruce spring-fen forest	10-35		(3)
Impoverished	<20	Black spruce bog	7-15	3	(1)
			5-10	8	(2)

Sources: (1) Wheeler and Glasser (1977); Itasca County.
(2) Janssen (1967); Clearwater, Hubbard, Koochiching, and Mahnomen Counties.
(3) Glaser, personal communication; Koochiching and Beltrami Counties.
(4) H. Mason, personal communication; Rice County.

Data in table 2.7 derived from relevés by authors other than Wheeler and Glaser (1977), are consistently lower in number of species within the same vegetation type, a probable bias resulting from lesser taxonomic precision. This intra-observer variability makes it impossible to compare the species diversity of forest types from one region of the state to another, because individual observers have worked only in limited regions, and the degree of taxonomic precision has not been standardized. The county biological surveys being carried out by the MNDNR with uniform standards should correct this problem. Until then, the characterization of the species diversity of forest types, even by the four classes defined in table 2.7, must be tentative.

Aspen forest, white cedar swamp, and mixed oak forests generally have the highest local diversity; whereas black spruce stands have the lowest (table

2.7). However, every community has some species different than other communities. Also, those species that occur in several different communities, occur in different combination in each community, with unique functional attributes. For example, white oak occurs in both oak savannas and as a minor component in maple-basswood forest. In the savanna, it grows in small groves, providing habitat for birds that nest in tree/grassland mixtures. It also shades a small area, keeping down growth of grasses, which gives shrubs such as wild rose (a woodland edge species) a niche in the savanna. In the maple-basswood forest, white oak provides a food source for deer and bluejays, and casts shade that is less dense than the sugar maple and basswood trees, giving wild blackberries—which require more sunshine than other woodland shrubs—a niche in the forest.

Thus, the relevés only measure diversity at a small-scale. Managing the forest for maximum small-scale diversity may work against regional diversity, which requires many community types on the landscape.

2.3 Genetic Diversity

2.3.1 Forest Trees

Generally, forest trees have high levels of within population (within-stand) genetic variability. In some species, tree pollen can be dispersed over a distance of tens of miles, so that relatively high gene flow occurs between stands. Unless there are major barriers to tree pollen dispersal, a high level of between-stand variability does not develop. Instead, a gradual change in gene frequencies (clinal variation) may occur along a gradient of temperature or precipitation. This seems to be the case in Minnesota, which has no major barriers to gene flow, such as mountain ranges. Some exceptions to this generalization about Minnesota are:

1. The North Shore (ecoregion 3), which has a distinctly different climate than areas just a few miles further inland.

2. Outlying populations that are habitat islands. Habitat islands include lowland conifers in ecoregions 5 and 6, and sugar maple stands in ecoregion 3. Populations at the edge of a tree species range tend to occupy habitat islands and are sometimes genetically different from populations in the main range.

3. A few species, such as basswood, are insect-pollinated, and gene flow is much more localized than with wind-pollinated species. Gene flow between populations may be prevented by smaller discontinuities in the

forest than for other species. The result may be the development of more local distinct genotypes, but this has not been studied.

Many provenance studies have been done at a scale of the Lake States or the northeastern U.S., in which seeds from many localities are planted in a common garden. The growth of seedlings from different sources are then followed for several to many years to look for differences in features such as height and diameter growth rates. Statistically significant differences that show up are genetic because the environment is the same in common garden experiments. Few provenance studies include more than one or two populations within Minnesota. No studies have been found that look for genetic differences between habitat islands such the North Shore sugar maple stands, or studies that examine genetic differences between adjacent stands at the township or county scale. The following is a summary of selected provenance studies:

Jack Pine. The species has continuous genetic variation correlated with climate. Jeffers and Jensen (1980) divide the range into three seed source zones (figure 2.3). In Minnesota group 1 occurs in ecoregions 1, 2 and 3; group 2 in ecoregion 4, and group 3 in the extreme southeastern part of ecoregion 4 and extreme northeastern part of ecoregions 5 and 6. Performance of trees may be reduced if seed sources from outside these seed source zones is used. For example, 20-year survival of seedlings from seed source 1591, 1592, 1593, and 1602 (figure 2.3) ranges from 81 to 92 percent when planted at site 1 in Superior National Forest (figure 2.d), but is only 34 to 46 percent when planted at site 10 (Jeffers and Jensen 1980).

Red Pine. The species has a relatively low level of genetic variability. However, there is continuous genetic variability with latitude, and detectable differences in height growth occur among populations from within 100 miles of each other in Minnesota (Wright et al. 1972). The only distinctive division in the species seems to be that Upper and Lower Michigan, separated by the Straits of Mackinac, have distinct genetic races of red pine (Wright et al. 1972).

Tamarack. Unlike most conifers, there is some variation among stands within ecoregion-sized units of land in the Lake States (O'Connor et al. 1985). Continuous variation along latitudinal lines is relatively weak. This could be due to founder effects, where one or a few individuals are dispersed to a habitat island—isolated bogs or fens in the case of tamarack—and determine the genetic makeup of the entire local population.

White Cedar. The species is known to have two separate ecotypes—lowland and upland. Populations can be genetically distinct even at distances less than a mile (Musselman et al. 1975), as long as the physiography allows for both lowland and upland types. Little is known about genetic variation within each of the two ecotypes.

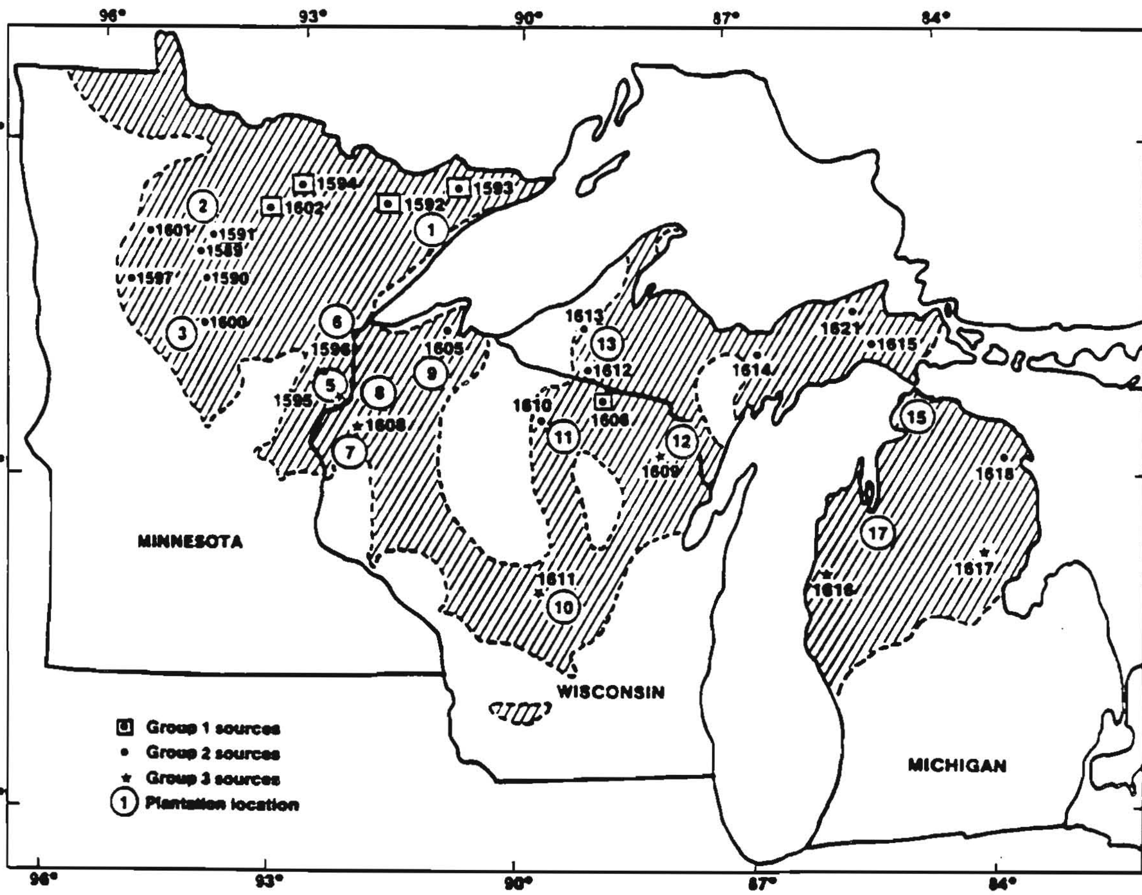


Figure 2.3. **Map showing locations of jack pine seed collections and zones 1 through 3 from Jeffers and Jensen (1980). The shaded area shows the range of jack pine in the Lake States. The seed source data show a gradual cline from north to south. However, for convenience, Jeffers and Jensen divided the seed sources into 3 groups; group 1, northeastern Minnesota, group 2, north central Minnesota, north central Wisconsin and Upper Michigan, group 3, near southern edge of range.**

Red Oak. There are many genetic differences in characteristics such as time of leaf out, leaf coloration in fall, and growth rates, all of which vary continuously with latitude. The clinal variation is steep enough so that significant differences are apparent among populations in ecoregions 4, 5 and 6 in Minnesota (Kriebel et al 1976).

Red Maple. This species has clinal genetic variation in growth rates across Minnesota in population from ecoregions 2, 4 and 5 (Townsend et al. 1979).

Black Walnut. Similar to red oak and red maple, there is clinal variation across latitude. Because Minnesota is at the northern edge of the range (ecoregion 6), Minnesota seed sources are uniquely hardy (Bey 1979).

Conclusions About Genetic Variability of Forest Trees.

1. Very little (nothing for most species) is known about genetic differences at small spatial scales from individual stands to areas the size of counties.

2. Most tree species in Minnesota exhibit gradually changing genetic adaptations to gradually changing climate over the state. Care should be taken not to fragment populations along the northeast-southwest climate gradient in the state so that natural gene flow is prevented.

3. The cline in genetic variability across the state is strong enough so that there are significant genetic differences in tree populations at the ecoregion scale.

4. Significant genetic variability among local populations is more likely to occur when the populations occur on habitat islands, such as bogs or hilltops. Although only a few habitat islands have been studied, preliminary indications are that they may have unique genetic composition, and a conservative approach to harvest should be adopted.

2.3.2 Forest Herbs

In general, the genetic architecture of forest herbs is different from that of trees. Forest herbs tend to have relatively high among-population variation. Herbaceous plants which are annuals, or pollinated by animals, or self-pollinated have from 21 to 51 percent of total genetic variation distributed among populations, compared to only 8 percent in long-lived woody species (Hamrick et al. 1991). Many forest herb species are capable of self-pollination, and one individual that is dispersed by a rare event to a new area of forest can establish a new population. The new population will be highly influenced by the genetic makeup of the founding individual, and will undergo a different course of natural selection than other nearby populations. Gene flow between populations of forest herbs is very limited because many species produce relatively little pollen, which is dispersed by insects rather than wind. Even those species that are wind-pollinated have relatively local dispersion because wind speeds under the forest canopy are greatly reduced compared to those experienced by wind-pollinated canopy trees. This contrasts with some herbaceous species of open prairies, which have widespread pollen and seed dispersal, and low among-population variation comparable to trees.

Local genetic variation has long been documented to be widespread among herbaceous plants (Bradshaw 1984). This variation helps herbaceous plant species exploit a patchy environment, survive unusual events such as disturbances, maintain abundant seed production, and adjust to long-term changes in climate or soil. Plants may have detectable genetic differences within several meters in patchy environments (Huenneke 1991). To preserve this within-species diversity, it is necessary to retain many populations throughout the range that are allowed to continue to interact with the natural processes (climate, fires etc.) that caused the original selection for adaptations.

Detailed studies of genetic structure of forest herbs in Minnesota are rare; however, several relevant examples are available.

1. Jewelweed (*Impatiens capensis*), an herb of moist forests, was studied in southern Wisconsin by Knight and Waller (1987). They examined six populations, five of which were within about 20 miles of each other, and found that there was no correlation among populations between genetic difference and geographic distance. The genetic differences among populations were very large.

2. Trout Lily in southern Minnesota. Pleasants and Wendel (1989) studied the widely distributed white trout lily (*Erythronium albidum*) and the rare endemic dwarf trout lily (*E. propullans*) which occurs nowhere else in the world other than Rice and Goodhue counties. The dwarf trout lily is believed to have evolved from white trout lily since the last glaciation, about 10,000 ybp. Although the white trout lily had relatively little among-population variation, there were three distinct genetic groups of dwarf trout lily, distributed among seven populations. As with the jewelweed, there was no correlation between genetic difference and geographic distance. Populations found only one mile apart belonged to different genetic groups in some cases.

3. Umbelliferae (Carrot family). Williams (1991) studied three species of woodland herbs from the carrot family: Honewort (*Cryptotaenia canadensis*), Sweet cicely (*Osmorhiza claytonii*), and black snakeroot (*Sanicula gregaria*), with many of the populations in southern Wisconsin. Genetic differences were detected at distances ranging from micro-scale (3 to 300 feet) up to macro-scale (30 to 230 miles). The degree of

genetic difference within short distances was correlated with the dispersal ability of each species.

Conclusions About Genetic Variability of Forest Herbs

1. Detailed studies of spatial genetic structure for most species are lacking. However, among those species studied there is a good correlation among life history traits and genetic structure.

2. In contrast to trees, genetically unique populations are likely to occur among stands at the township and county scale for many woodland herbaceous plants.

3.0 METHODOLOGY AND DATA USED

3.1 Habitat and Population Linkages

The emphasis in examining how timber harvesting and management may impact forest plants and endangered, threatened or special concern animal species, is based on the habitats of species rather than on the populations themselves. The forest management practices being analyzed in the GEIS affect species primarily through altering forest type and age class, which in turn comprises the substrate, and cover required by the animals and smaller plants. Habitat matrices, based on research by study group members, were applied to the listed animal species in the state. However, there is not sufficient data to construct habitat matrices, similar to those used by the wildlife subgroups in the Forest Wildlife technical paper, for understory plant species in Minnesota.

Major Assumptions

- Given the lack of data for analysis of individual plant species habitat, it is assumed that small plant diversity—as well as moss, fungi, and insect diversity—is dependent on structure at the community and ecosystem level. Further, it is assumed that the best way to maintain regional biodiversity and prevent species extinction, is to maintain *examples* of all natural community types recognized by the Minnesota Natural Heritage Program (table 2.6), in the context of a fairly natural landscape pattern.

- A second assumption is that wetlands embedded within forests will not suffer significant loss of biodiversity if mitigation strategies identified by the Forest Wildlife study group to maintain habitats and by the Water Quality and Fisheries study group to prevent nutrient and sediment impacts are followed.

3.2 Sources of Data

The technical assessment of increased harvest impacts on biodiversity and wildlife is being undertaken with a variety of information sources and synthesis processes. First, each study group member has thoroughly examined the technical literature on relationships between forest land animals or plants and the forest communities that are their habitats, particularly as these are affected by forest management changes. This review encompassed many unpublished reports and data sets, including some ongoing studies directly relevant to the GEIS issues that are being carried out by study group members themselves. State and federal agency personnel responsible for monitoring and protecting biodiversity in Minnesota's and other states forests were appropriately consulted.

FIA Data
Because information summarized from the USDA Forest Service's FIA plots was the only systematic, statewide source on forest-habitat data available, this study group attempted to tie the analyses of old forests and abundance of plant species of interest to the extent of specific forest types and age classes, as designated within the FIA system. The FIA system is described in the GEIS Workplan (Jaakko Pöyry Consulting, Inc. 1991) and the Maintaining Productivity and the Forest Resource Base technical paper (Jaakko Pöyry Consulting, Inc. 1992c).

Harvesting Scenarios
As required in the FSD, the potential impact of timber harvesting on wildlife was evaluated for three levels of harvest—base, medium, and high. The Maintaining Productivity and the Forest Resource Base Study Group supplied projections of Minnesota's forest resource base for each of the next five decades under each of the three levels of harvesting. The second run scenarios were used for this paper. These projections include postcutting acreages and age-class distributions of each FIA covertype, in each of the seven ecoregions. These data were then used to estimate the amount of habitat available for communities, old forests, and species of interest.

Alternative Statewide Timber Harvesting Scenarios Analyzed
The purpose of discussing alternatives in an EIS is to compare the environmental impacts of the proposed project with other reasonable alternatives to the project, including the alternative of no action. In the case of this GEIS, the proposed project was defined in terms of the state's cumulative timber harvesting and related activities. Therefore, alternatives addressed in the GEIS were defined as different levels of statewide timber harvesting and forest management activity. In addition to examining the existing levels of harvesting, potential future timber harvesting levels were

also analyzed to identify impacts that would result if such levels of statewide activity were actually achieved.

The FSD specified that, to the extent possible, all issues were to be reviewed from the following three levels of statewide timber harvesting and associated forest management activity:

4.0 million cords. This was the level of statewide timber harvesting activity that occurred in 1988, the most recent year for which data was available at the time the document was drafted (1990).

4.9 million cords. This is the level of statewide timber harvesting activity estimated to occur by 1995. (This also approximates a 50 percent increase in timber harvesting and associated forest management activity over 1988 statewide harvest levels.)

7 million cords. This is the estimated maximum annual volume of timber available for harvest statewide for all tree species in the year 2000. (This also approximates a 100 percent increase in timber harvesting and associated forest management activity over 1988 statewide harvest levels.)

These alternatives provide for analysis under three different perspectives:

1. the current level of timber harvesting and forest management activity;

2. a level of statewide timber harvesting activity that is estimated to occur within the next five years if proposed expansions occur; and

3. projected long-term future maximum recommended annual statewide timber harvest levels.

These demand levels were updated to account for developments that occurred after the FSD was written (Jaakko Pöyry Consulting, Inc. 1991).

Maintaining Productivity and the Forest Resource Base Technical Paper
An assessment of the amount of old forests and tree species mix at the end of the 50-year harvesting period required results of analyses from the Maintaining Productivity and the Forest Resource Base Technical Paper (Jaakko Pöyry Consulting, Inc. 1992c).

Natural Heritage Program
The Minnesota Natural Heritage Program is a cooperative program with MNDNR and the Nature Conservancy. Program personnel collect information on occurrences of rare species and natural communities throughout the state. The data is stored in a database management system and is available to researchers and managers.

The study group also received data on old growth acreages, old growth candidate stands, and other old growth forest data from Natural Heritage staff.

Literature Review
The literature review and input from the background papers on harvesting systems and silvicultural systems were used to identify: (1) those known habitat attributes for plant species that would be impacted by changes in age, composition, and spatial patterns of forest stands; (2) case studies in which timber harvesting and forest management activities have led to changes in plant communities; and (3) specific information on rare or endangered species associated with any forest system within the state. Much of this literature was used in the description of Minnesota plant communities in section 2 above.

3.3 Methodology

3.3.1 Old Growth and Old Forests

Following the MNDNR guidelines, the study group looked at old and old growth forests (see definition in section 1.4) in the following FIA covertypes: red pine, white pine, black spruce, northern white cedar, tamarack, white spruce, oak-hickory, elm-ash-soft maple, and maple-basswood.

Old Forests
Projected acreages of forest by age and covertype, from the Maintaining Productivity and Forest Resource Base report, were used. Acreages of forest greater than 120 years old (90 years for white spruce), were summed separately for timberland, unproductive forest, and reserved forest, for 1990 and 2040. Note that unproductive forest (woodland with open canopy) is a different community type from timberland (which is closed canopy), and that for maintenance of biodiversity, old woodland is just as necessary as old timberland.

Some assumptions and caveats:

- The current age distributions recorded for reserved forest are only approximate, having been estimated from aerial photos.
- The projections assume no natural disturbance within unproductive and reserved forest. In reality, there are large areas within the BWCAW, which contains most of the states' reserved forest, that have budworm damage and other fuel buildup due to fire suppression. Large uncontrollable fires are likely to occur in the next 50 years. Prescribed

fires and windstorms are also likely to recycle much of the reserved old forest.

- A small acreage of plantation forest may be included as old forest in 2040.
- FIA area estimates have large errors (as a percent of the estimated area) when estimated acreages are small, for example < 100,000 acres, as they generally are for old forests.
- The FIA stand age variable has limitations discussed in the Maintaining Productivity and the Forest Resource Base Technical Paper.

Old Growth Forests

The likely impact of timber harvesting on old growth was done by synthesis of the available literature, data, and personal discussion with Minnesota Natural Heritage staff involved with the old growth program. Dr. Lee Frelich, one of the preparers of this technical paper, is also on the MNDNR Commissioners Advisory Committee that deals with designation of old growth in Minnesota state lands.

3.3.2 Tree Species Mix

The study group has interpreted *composition* to focus on the major commercial tree species, while *tree species mixture* involves all species, no matter how sparse or of what commercial value. Two issues will be addressed under *tree species mix*: (1) continued presence of minor tree species, and (2) possible exclusion of late successional species in short rotation aspen forests. The issue of preserving genetic diversity of major commercial near the edge of their geographical range in Minnesota is addressed under the genetic diversity section below.

Minor Tree Species

The 1990 FIA data set on statewide number of stems greater than 4.95 inches dbh was used to determine which are minor species in Minnesota. Several non-native species (Ailanthus, black locust, Siberian elm, Scotch pine, ponderosa pine, and apple) were excluded from the list. Also excluded were trees that occur primarily along river floodplains (black willow, silver maple, green ash, cottonwood), or open habitats (hawthorn, wild plum, red mulberry, chokecherry, pincherry, peachleaf willow), the "other hardwood" category, and black maple, which was included with sugar maple. Mountain maple was excluded because it has a large representation among stems between 1 and 4.95 inches dbh, indicating that the species is doing well, and it does not normally grow to 5 inches dbh in Minnesota.

Of the remaining 41 species, all those with less than 5,000 total stems, or 18 of the 41, are judged by the study group to be minor species in Minnesota.

This number of stems is about 3 percent of the average for the 11 most abundant commercial species in the state. Four species that are so rare that none were recorded by the FIA were added to the list: eastern hemlock (*Tsuga canadensis*), honeylocust (*Gleditsia triacanthos*), sycamore (*Platanus occidentalis*), and yellow oak (*Quercus muhlenbergii*). Heart-leaved birch (*Betula cordifolia*) was added to the list because little is known about its status and distribution. It is probably included with paper birch in the FIA data, since it is very difficult to identify in the field.

Using the species-habitat linkage approach, the Maintaining Productivity and the Forest Resource Base Group estimated the number of stems on FIA plots in 2040 by multiplying the future acreage of covertypes/age classes by the 1990 species composition for each covertype/age class. Tables were produced for all forests in the state and for individual covertypes, so that significant impacts on minor species could be determined.

Assumptions and other caveats:

- Many of the minor tree species have small sample sizes in the FIA data set.
- It is assumed that regeneration for each species will continue at the same frequency in future forests of the same age/covertype as in the recent past.

Conifer Component in Aspen Stands
Intensive silviculture for maximizing production of fast regenerating species, such as the aspens and white birch with their generally short rotations, will hold the landscape in its current condition of domination by early successional stages. Such management could decrease acreage of forests with species that regenerate later in succession, often under the canopy of the early succession species. Important among the latter are widespread conifers such as balsam fir, white spruce, black spruce, and northern white cedar, along with deciduous species such as sugar maple, mountain ash, basswood, and yellow birch.

Some common forest types require a continued presence of seed trees for regeneration, and such types often will not regenerate back to the former density and composition if totally cleared over large areas. These include black spruce, red pine, white pine, and the oaks.

Because the aspen type covers such large areas in Minnesota and has a short rotation—generally 40 to 60 years—frequency of development of conifer understories by age was estimated from the following sources:

1. Frequency of conifer understory in aspen in FIA data, 1977 and 1990.

   Assumption:
   - Any changes in the proportion of aspen forests with conifer understories is representative of future changes.

2. Development of late successional species in terms of cubic foot volume in yield tables (Hahn and Raile 1982). In addition to the volume from the yield tables, the percent volume of conifers by age class was calculated for the aspen forest type within the aspen-birch and northern pine survey units.

   Assumptions:
   - The chronosequence of stands by age class in the data is representative of successional processes, rather than unique historical events.
   - Cubic foot volume is highly correlated with seed production under typical forest conditions.

3. Conversion of other forest types to aspen was estimated from comparison of forest type transitions from 1977 and 1990 FIA data (see Maintaining Productivity and the Forest Resource Base Technical Paper, tables 4.1 and 5.8).

   Assumptions:
   - Probability that stands will convert to aspen during the next few rotations is stationary.
   - Availability of seed sources and forest floor conditions for reestablishment of conifers in aspen understories will remain constant.

3.3.3 Genetic Diversity

A number of issues will be addressed by the study group under this heading, including fragmentation, deer browsing, invasion by exotic species, planting of hybrids, and major tree species reaching their range limit.

In Minnesota, the loss of isolated breeding populations is unlikely to ever be a problem for forest birds or medium to large-sized mammals because of their mobility. However, it could well become a problem for herbaceous plants (as well as insects, amphibians, reptiles, or small mammals). Based on the literature review in section 2.3 and knowledge of seed and pollen dispersal by study group members, a qualitative table of susceptibility to fragmentation by trees and herbaceous plants was compiled (see section 4.5.4, table 4.8). Two of the study group members have experience with dispersal. Cushing is a paleoecologist who works with pollen analysis and also produces the daily pollen counts for common allergens (ragweed pollen, etc.) for the Twin Cities metro area. Frelich participated in studies of pollen dispersal with the Margaret Davis paleoecology lab at the University of Minnesota for 4 years.

Assessment of deer browsing, exotic species, hybrids, and species reaching their range limit was done by literature review and synthesis (to the extent possible) by study group members.

3.3.4
Rare Plant Species and Communities

Two main sources were used: (1) MNDNR listing of endangered species (Coffin and Pfanmuller 1988), and (2) the occurrence list of endangered species and communities, produced at the study team's request by Mary Miller, of the Natural Heritage Program. Both were searched for occurrences of rare plants or communities likely to be affected by harvesting. The habitat of each species was taken into account, so that species found in nonforested habitat (marshes, etc.), and communities such as talus slopes were not counted. The number of rare species and communities for each ecoregion likely to be impacted directly by logging was compiled, for a qualitative assessment of impact. The only way to give a quantitative assessment of harvesting impact on these populations and communities would be to know every stand that would be harvested over the next 50 years—spatial information that is not available from the analysis of timber harvesting scenarios generated by the forest change and scheduling model.

3.3.5
Endangered, Threatened and Special Concern Wildlife Species

A comparison of relative abundance of each species of birds and small mammals in 1990 and 2040 was done by the habitat-linkage approach. The result is a population index involving (1) establishing the relative abundance of each species on each FIA covertype and age class, (2) summation of the relative abundances for each species over the existing landscape, given the current distribution of FIA covertypes and ages, and (3) summation of the relative abundance in the year 2040, using the projected distribution of FIA covertypes and ages from the second run harvesting scenarios, for base, medium and high scenarios. Analyses were done separately for all forest lands (including timberland, unproductive and reserved) and timberland only. Herps were assessed on the basis of available habitat acreage only. Details of the methodology are contained in the Forest Wildlife Technical Paper (Jaakko Pöyry Consulting, Inc. 1992b).

3.4 Limitations

This section discusses major general limitations in making the assessment of likely changes in biodiversity as a result of increased timber harvesting. Specific limitations of analyses are given above, in section 3.3.

3.4.1 Limitations of the FIA

The FIA data supposedly includes, besides presence of commercial trees, many measures that are needed to characterize habitat potentials. However, many of the listed variables had not been measured consistently, or could not have been measured because of the season in which plots were visited. This was a major factor in the direction of analysis taken by the study group.

1. *Forest typing*. FIA covertype designations are too general to describe many natural plant communities. In several cases, one FIA covertype includes several unique communities. For example, the balsam fir type contains parts of upland white cedar forest, spruce-fir forest, boreal conifer-hardwood forest, and northern hardwood-conifer forest. All of these communities have different combinations of species, spatial patterns, and disturbance regimes.

2. *Small-scale habitat factors*. There are numerous critical aspects of habitat that vary at a much finer scale than the dominant forest tree species. Some examples include abundance of woody debris, structure and species composition of the shrub layer, understory herbs, portion of the forest comprised of dead and dying trees, amount and nature of slash and unmarketable trees left after cutting. Such details are included in the FIA database, but not always consistently. Furthermore, the process of extracting all these variables, even if the data were complete, from the 13,536 plot records was far beyond the scope of this effort.

   An implicit assumption of the analysis here for projecting future habitats was that the distribution of the small-scale features will be similar, covertype by covertype, to what is found today. However, it is almost certain that this assumption is unrealistic. Harvesting is likely to affect all of these local habitat features, if by no other means than lowering the average age of stands. Accumulation of many small-scale features is simply a function of age—from tree cavities and downed logs to more heterogeneous mosaics of shrubs and trees. Some of these problems may be mitigated through selected silvicultural practices.

3. *Spatial factors*. The FIA database contains only limited spatial data which do not allow assessment of the areal patterns of harvest areas or

the juxtaposition of other forest types and ages. These factors are important not only in assessing the short-term impacts of timber harvesting but also in understanding the spatial composition of future forests. Although qualitative incorporation of these factors was attempted, this aspect of biodiversity has been difficult to deal with adequately in the GEIS process. Issues such as insularity, fragmentation, and nature of adjoining stands do not apply only to ungulates, carnivores, and other wide-ranging species, but to hundreds of species of small plants as well.

4. The FIA database has relatively little information on the characteristics of reserved forests, so that in most cases it is difficult to include reserved forests in analyses linking habitats with species abundances.

3.4.2 Limitations of the Harvesting Scenarios.

The FIA database and model of growth and harvest upon which the harvest scenarios in this project are based, while very useful for projecting economics and yield from harvesting on a regional basis, is not designed to characterize how the forest landscape responds to harvest (or nonharvest).

From the output of the forest change and scheduling model, questions raised by study group members include the following:

1. Postcutting successional sequences. The model cannot take into account the full and complicated web of successional stages that occurs in the aspen-birch-spruce-fir mixture that occupies much of ecoregions 1 through 3 and the northern half of ecoregion 4. Some stands will succeed from aspen to conifers, but others may succeed to shrublands if there is an insufficient conifer seed source nearby, and no disturbance to regenerate the hardwoods.

   Study reporting often emphasizes aggregate statistics for each covertype. However, as mentioned above, each FIA covertype is actually several different communities, each with distinct successional processes. It is these processes that often are important to biodiversity, rather than aggregate growth.

2. Short-time scale of analysis. Fifty years is not a very long time span for forests that have existed for thousands of years. It is not long enough to develop a regulated forest—a balanced age class distribution. Minnesota has an unbalanced age class distribution as a result of turn-of-the-century exploitation and clearing. The projected increase in old growth forests (>120 years) over the next 50 years will be temporary—many old growth stands 50 years from now will reach the end of their life

expectancy and succeed to other types in the following 50-year period (2040-2090).

3. Lack of detail. This was especially important for spatial patterns at the landscape and local level, which are necessary for quantitative assessment of degree of isolation of plant populations—an area where harvesting has important potential impacts.

3.4.3
Lack of Information.

1. Plants. The knowledge on the diversity of plants within Minnesota is fragmentary. A complete inventory for the state is still lacking for some groups of plants—notably the bryophytes, lichens, and fungi. The distribution and abundance over the state of most species that have no economic significance is yet unstudied. The kinds of habitats in which they grow, and the associations they form with each other and with wildlife, insects, soil organisms, and type of disturbance, are poorly understood. Moreover, these abundance, spatial, and associational relationships have changed rapidly during the past 150 years and are continuing to change.

2. Degree of natural and man-made fragmentation and its impact. The 30 landscape patterns analyzed for this project (see Maintaining Productivity and Forest Resource Base Technical Paper, section 5.9), are not sufficient for detailed analysis of affects of fragmentation on biodiversity. Distributions of distances between stands of all covertypes and ages, by stand size class (acreage) and ecoregion, as well as what the intervening covertypes are, would be necessary for a comprehensive analysis of fragmentation and biodiversity in Minnesota.

3. Genetic variability of most plant species.

4. Lack of precise and detailed old growth data for reserved forests.

5. Lack of data on distribution of minor tree species and species near the edge of their range.

4.0
SIGNIFICANT IMPACTS

4.1
Significant Impacts Criteria

Impacts identified in the course of this study will vary in their significance and therefore in the need to develop a specific mitigation response. This is a critical stage of the study process, as these tests of significance will ultimately define the scope of policy recommendations developed by the GEIS.

Identification of an impact as being significant does not automatically prescribe a specific mitigation response. The significance criteria have been developed to be inclusive rather than exclusive. Their purpose is to identify the issues and circumstances where policy initiatives will be required. The range of possible policy responses, the factors used to choose between them, and the implications of selecting a particular response are all evaluated by subsequent criteria.

Criteria have been developed for each of the issues of concern in the FSD and are identified in the second section of this document. Therefore, because the criteria underpin the impact assessments to be undertaken in subsequent stages of the study, this aspect of the study will be made as clear as possible for interested readers.

For each significance criterion developed, several background factors were used to determine levels or thresholds when impacts are likely to be considered significant. They include:

- severity and spatial extent of impact;
- certainty of impacts;
- duration of impact (irreversibility);
- consideration of existing guidelines and standards; and
- biological and economic implications.

The first factor identifies the likely extent and severity of an impact. Impact extent varies considerably ranging from very localized site specific impacts to those impacting a watershed, physiographic region, soil type, covertype, ecoregion or the entire state. The second factor identifies the degree of certainty that a predicted impact will occur. The key factors influencing certainty are identified for each criterion. The third factor incorporates the anticipated duration of the impact, and whether or not it is reversible. Duration is defined as very short-term—less than 2 years; short-term—2 to 10 years; medium-term—10 to 50 years; long-term—greater than 50 years; and irreversible. The fourth factor incorporates those existing standards and guidelines that are applicable to the respective issue areas. The fifth factor identifies the key biological and economic implications of the impact. These are particularly important in those circumstances where impacts are indirect. For example, loss of mast (e.g., acorns) producing trees is the impact criterion and what makes this loss significant is its effect on populations of animals dependent on these trees for food.

4.2
Old Forests

4.2.1
Significance Criterion Number 5

5. Changes to Minnesota forests - age class structure.

An impact is considered significant if the projected replacement age class structure of forests, by covertype, at the end of the 50-year planning period, is insufficient to provide replacement of mature stand acreage (i.e., sustainability of forest communities).

Severity and/or extent. Minnesota's forests as depicted by the 1990 FIA database have important age class distribution features. This criterion seeks to identify the circumstances leading to a change in the age class distribution. The criterion does not suggest that changes in one direction or another are necessarily desirable or undesirable. Nor does it presume that the current age class distribution is necessarily appropriate. The criterion will detect shifts in age classes and the implication of those shifts will be assessed against the current distribution to determine the positive and negative aspects of the change.

The concern of changing age class structure is not so much about increasing numbers and distributions of some species as it is about detecting major declines in any species or covertype area. The species composition, structure and dynamics of forests clearly can change as stands age. These changes have an important bearing on factors such as the habitat value for different species. Numerous implications will be developed in the technical papers. The threshold of significance is subjective because the degree of imbalance can vary with management intensity, harvest levels, and the definition of mature as linked to rotation age or other ownership objectives. The criterion will use the FIA estimate of age for each stand and will then compare the initial age class distribution with that projected for the end of the study period.

Certainty of impact. The certainty of impacts resulting from changing forest age class structure depends on several variables such as the existing forest age class structure and management objectives of landowners particularly as reflected in the rotation ages and silvicultural systems employed. In reality, it will be important to compare existing and projected age class structures, i.e., assess sustainability for timberlands separately and then all of the forest including reserved and unproductive reserved lands. Such a process treats both sustainability of harvest and habitat concerns.

Certainty of impact will vary between ownerships. State and national forests will likely maintain a more diverse age class structure in response to explicit policies that set aside timberland to meet other management objectives: old growth; maintenance of wildlife habitat; water quality buffers; and aesthetics. These ownerships control substantial areas of reserved forest lands that are managed in such a way as to promote old forest (e.g. BWCAW, Itasca State Park).

County managed lands will likely have less variation in the range of age classes. This reflects their narrower management objectives which typically emphasize timber production rather than the wider objectives of other public ownerships. On average, timberlands owned by forest product industries will likely be managed on shorter rotations to maximize timber productivity.

Only a relatively small proportion of NIPF owners actually manage their forests. Therefore, the age at which an NIPF forest is harvested will depend more on the owner's financial needs than any management objectives. Consequently, the concept of replacement of mature stands is not normally a management objective on NIPF lands. A proportion of NIPF owners will elect to forego harvesting. However, the high turnover of ownership means that little certainty can be attached to such a decision because subsequent owners may not adopt the same management.

In addition to differences between the objectives of owners, there are differences between species. Some, such as aspen and balsam fir are comparatively short-lived species. Others, such as sugar maple, may live for much longer periods, often with commensurately slower growth rates.

Duration of impact (irreversibility). Deliberate changes to age class distributions can only be achieved over very long periods if the objective is to replace mature stand acreage.

Biological implications. Stand age is important in determining the potential for stand growth and species succession. Changes in age class distribution reflecting shortened rotation lengths tend to increase average growth rates and reduce the likelihood of successional change in managed forests.

From a plant and animal diversity standpoint, the justification for a complete representation of forest age classes is that each age class provides habitat for a given set of plants and animals. Maximum biodiversity, therefore, is associated with a complete range of age classes for each forest covertype in each ecoregion.

Site nutrient balance is also sensitive to changes in age class distribution, particularly for certain covertype/soil type combinations.

Pest and disease susceptibility and vulnerability also change as the stand ages.

Economic implications. The growth rate and product mix yielded from a stand change as the stand becomes older. For even-age stands, growth rates typically increase following establishment, reach a peak as canopy closure is achieved and then show a decline as the stand matures. Net growth rates can show a more dramatic decline with increasing age due to losses to defect caused by insect and disease attack. The size of individual trees increases as the stand ages. Larger diameter logs can be used to produce a wider range of products than smaller diameter logs. Size (diameter) is an important criterion used in the selection of logs by the solid wood based industries, especially sawmills. Size is of less importance to pulp based industries.

Therefore shorter rotation ages may reduce the availability of larger logs, while at the same time increasing the productivity of the forest in terms of overall volume production. Longer rotations may increase the availability of large logs but sacrifice overall volume production. Either change would have impacts for industries set up to utilize the respective product categories. Rotation length can also be of importance to forest owners as it can determine the term over which an investment in forest improvement must be carried before returns are realized.

Tree size is an important aspect of forest aesthetics. The presence of large diameter older trees is an important element in recreational use of some areas which has implications for tourism/recreational industries set up to service these users.

4.2.2 Results

This section addresses the acreage of old forests now and in the year 2040, as projected by the timber harvesting scenario. *No significant impact were detected*. Most covertypes are projected to increase substantially. It appears that most of the projected increase in old timberland will come from acreages never cut during the 50-year planning horizon, and reflects the current overabundance of stands that date from major logging around the turn of the century. It is not clear whether these old stands would continue to exist in the following 50-year period as the forest approaches a *regulated*, or balanced age-distribution condition.

Red and White Pine

The acreage of old red and white pine on timberlands is currently quite small (table 4.1). Based on analysis of the three harvesting scenarios, old red pine acreage would increase from 1,800 to approximately 30,000 for the base and medium scenarios, or to 17,000 acres for the high harvest scenario. White pine increases would be similar in magnitude, going from the current 7,400 to 60,000-65,000 under the base and medium scenarios and 47,000 acres under the high harvest scenario. A quadrupling of old red pine and a sevenfold increase in acreage of old white pine forest is projected within reserved forests (table 4.2). Most of this reserved forest is in the BWCAW, and natural prescribed fire on 1500 acres per year is currently planned. At this rate of burn, about 10 percent of all forest would be burned during the 50-year planning horizon. Windstorms are also likely to damage old forests, nearly all stands over 120 years old will be hit with significant damage (10 to 30 percent basal area removal) during a 50-year period (Frelich and Lorimer 1991).

Swamp Conifers

The harvest scenarios project major increases in acreage of old black spruce, tamarack and white cedar forest area over the next 50 years. Old black spruce forest acreage would increase from the current 50,000 to 258,000, 115,000 and 80,000 acres under the base, medium and high harvest scenarios, respectively (table 4.1). White cedar would experience a three- to fourfold increase in old forest acreage under all three harvest scenarios. Old tamarack acreage would increase about fourfold from the current 43,000 acres under the base and medium harvest scenarios, but only increase to 70,000 acres under the high harvest scenario. Old woodland (unproductive) acreage would increase about threefold for all three swamp conifers, with no difference in level of harvesting among the base, medium and high harvest scenarios (table 4.2)

In all three species, the differences between the base and medium harvest scenarios is relatively small, but the high harvest scenario projects much less old growth timberland. Similar increases are projected for the reserved and unproductive forests (table 4.2).

White Spruce

A four- to sevenfold increase of the current 15,000 acres in old white spruce timberland is projected for the base and medium harvest scenarios, and a threefold increase for the high harvest scenario (table 4.1). Reserved old forest is expected to increase from 12,000 acres to 96,000 acres in the absence of major disturbance such as large fires or an extensive spruce budworm outbreak.

Elm-Ash-Soft Maple Forest

Old timberland in this type would increase from about 62,000 to 445,000, 377,000 and 256,000 acres, under the base, medium, and high harvest scenarios, respectively (table 4.1). The current negligible acreages in reserved and unproductive forest would increase to about 20,000 acres each (table 4.2).

Table 4.1. Area of old timberland now and projected in 2040 for the base, medium and high harvest scenarios (acres)*. See assumptions in section 3.3.1.

Forest Type	Current 1990	Harvest Scenario—2040		
		Base	Medium	High
Red pine	1,800	27,596	30,444	17,044
White pine	7,400	65,274	61,343	47,243
Black spruce	49,600	258,019	115,436	80,536
White cedar	48,000	196,500	182,469	154,890
Tamarack	49,200	214,704	183,490	71,407
White spruce	15,200	115,915	89,820	53,683
Oak-hickory	49,700	326,571	276,913	225,101
Elm-ash-soft maple	62,400	444,763	377,698	256,602
Maple-basswood	35,600	397,654	337,559	174,770

* Acreages are those determined from GEIS covertype algorithm (see section 4.10.1 of Jaakko Pöyry Consulting, Inc. 1992b).

Table 4.2. Projected area of old unproductive and reserved forest (acres)*. See assumptions in section 3.3.1.

Forest Type	Reserved		Unproductive	
	1990	2040	1990	2040
Red pine	19,400	79,000	0	900
White pine	3,600	25,100	1,300	1,300
Black spruce	0	53,500	108,200	302,700
White cedar	3,500	3,600	8,500	25,500
Tamarack	1,900	5,800	21,900	79,100
White spruce	12,200	95,900	0	0
Oak-hickory	0	4,312	1,700	11,819
Elm-ash-soft maple	0	20,400	7,000	18,022
Maple-basswood	1,400	6,848	0	0

* Acreages are those determined from GEIS covertype algorithm (see section 4.10.1 of Jaakko Pöyry Consulting, Inc. 1992b).

Oak-Hickory and Maple-Basswood

There is a common pattern to the projections of these two types.

Very large increases in old-growth timberland acreage are projected for all three harvest scenarios, with the final acreage proportional to the level of harvest (table 4.1). The forest change model projects 220,000 to 330,000 acres of old timberland oak-hickory in the year 2040 and 170,000 to 400,000 acres of maple basswood, depending on the level of harvest. Acreages within reserved and unproductive lands are negligible now and will still be in the future (table 4.2). Unlike the other forest types discussed so far, much of the oak-hickory type is in small parcels owned by numerous individuals. Thus, the projections indicate that the landscape will look more like southern Wisconsin and Michigan, which currently have acreages of old oak-hickory and maple-basswood forest in woodlots similar to that projected for the year 2040 in Minnesota.

4.3 Old Growth Forests

4.3.1 Significance Criterion Number 7

7. Old growth forests.

> An impact is considered significant if there is projected to be any net loss of area of forest meeting the DNR definition for old growth by covertype by ecoregion over the 50-year study period.

Severity and/or extent. The criterion is intended to identify circumstances leading to a loss in old growth statewide over the period of the study rather than the loss of any specific old growth stands. Minnesota has a very limited old growth resource, much of which is in highly fragmented small areas. Management to reflect these values is difficult, yet it is important to accord an appropriate level of sensitivity to this issue area because the resource is so limited. Values attributed to old growth include: aesthetics, biodiversity and cultural/spiritual.

Certainty of impact. Harvesting would eliminate values. Ability to protect small areas varies with ownership: the smaller the area and/or the less administrative control that exists, the more difficult it is to guarantee survival of old growth stands.

Duration of impact (irreversibility). Impacts would be long-term if viewed from the perspective of replacing old growth forest on a specific site.

Existing guidelines and standards. DNR old growth criteria have been used to identify old growth on state lands. The criteria apply to longer lived species/communities that include: black ash, lowland conifers, lowland hardwoods, northern hardwoods, red and white pine, white spruce and upland white cedar. Early successional or short-lived species such as aspen or balsam fir are not classified as old growth. Draft DNR guidelines for managed long rotation old forest.

Biological implications. Old growth forests fulfill an important role in providing habitat that favors some species. This includes several species of birds and five species of lichens. The lichens have only been found in old growth ecosystems. These forests also provide insight on the processes and changes that occur as forests age. An inherent *value* has been attributed to these forests that is related to their *naturalness*.

Economic implications. The presence of large, old trees is an important component of some recreation/tourism settings. Loss of this component would impact businesses dependent on these settings.

Linkage to other criteria.
- Forest recreation and aesthetics.
- Changes to Minnesota forests - age class structure.
- Forest dependent wildlife - habitats.

4.3.2 Result

Upland Forest Types and Lowland Hardwoods in Timberlands
The eventual amount of old growth already reserved depends on two factors: (1) the acreage of natural origin stands left, and (2) the political processes that determine how much of this remaining old growth is reserved. The Chippewa and Superior national forests, and the state of Minnesota, have completed inventories of *Old Growth Candidate Stands*, and *future old growth* (younger stands that will replace old growth stands that are destroyed by natural disturbance or succeed to another forest type), on their lands (table 4.3). Political pressures will probably lead to establishment of a target amount of old growth in each administrative unit, or possibly to all qualifying stands being designated as old growth and reserved. At most, half of all candidate stands on MNDNR lands will meet the criteria for old growth when surveyed in detail in the field (K. Rusterholz, MN Natural Heritage Old Growth Staff, pers. comm.). Similar proportions are likely to qualify as old growth on national forest lands. There is probably a small, but unknown amount of old growth on county and private timberlands in the state. The study group did not attempt to deal with this county and private old growth, due to a lack of data.

Timber harvesting per se will have no significant impact on old growth in these forest types, since each candidate stand and future old-growth stand will either be officially reserved or officially released for harvest after the appropriate administrative procedures.

Table 4.3. Acreage of old growth candidate stands by ownership, not including lowland conifers. SNF=Superior National Forest, CNF=Chippewa National Forest.

Forest Type	Ownership			
	MNDNR	SNF	CNF	Total
Oak	1,052	0	47	1,099
Northern Hardwoods	7,654	8,200	1,148	17,002
Upland White Cedar	3,326	nd	nd	3,326
White Spruce	661	1,800	nd	2,461
Red Pine	3,959	416	1,715	6,090
White Pine	1,803	1,638	255	3,696
Lowland Hardwoods/Black Ash	6,233	4,600	1,389	12,222
Total	24,688	16,654	4,554	45,896

Swamp Conifers

A large majority of the old swamp conifer acreage over 120 years of age is of natural origin, and therefore qualifies as old growth. This is due to the low priority lowland conifers have been given for harvesting, compared to upland types. As shown in section 4.2, there will be as much old lowland conifer forest in the future under the harvesting scenarios as there is now. However, acreage of old forest depends on a balance between old stands that are harvested and younger stands that grow into old age classes. At the current time, it is not certain how much of the younger swamp conifers replacing the cut older forests are of natural origin. None of the available timberlands >120 years old were cut in the base scenario (table 4.4). A large proportion of acreage was cut by the harvesting model for black spruce under the medium scenario, and all three swamp conifer types were cut under the high scenario. If the replacement stands are not suitable for future old growth, then *a portion of lowland conifer stands >120 years old that were cut in the harvesting scenarios may constitute a significant impact under criterion number 7.*

Table 4.4. Current acreage of old swamp conifers available for harvest and the acreage never cut during the harvesting scenarios.

Forest Type	1990	2040		
		Base	Medium	High
White cedar	128,100	128,100	125,300	108,200
Tamarack	26,200	26,200	25,200	10,200
Black spruce	35,500	35,500	14,200	13,000

Old Growth in the BWCAW
Heinselman (1973) dated the origin of nearly all stands in the BWCAW. Based on a minimum age of 120 years, about 159,660 acres (38 percent) of primary forests in the BWCAW would have been old growth as of 1992. Between the time the data were taken and today, a few thousand acres of old growth have burned, so that the total today is slightly less than 159,000 acres. The amount of old growth that continues to exist in the BWCAW will depend on the frequency of natural disturbances. The current plans call for natural prescribed fires to burn about 1,500 acres per year. This would lead to a fire cycle of 535 years, and 80 percent of all forests would be older than age 120 at some point in the future, well beyond the 50-year GEIS planning horizon. However, catastrophic windstorms will also blow down many stands, and there is the possibility of large uncontrollable fires in areas with dead trees resulting from spruce budworm and windfall. Changes in fire policy will also interact with future disturbances to determine the actual amount of future old growth within the BWCAW. The dynamics of old growth within the BWCAW will not be significantly impacted by timber harvesting and management. Nor, for the purposes of the GEIS, can a potential increase in old growth within the BWCAW be considered as a way to mitigate the significant impact of harvesting on lowland conifer old growth predicted above in most of the state, with the possible exception of ecoregion 2. This is due to the requirement in significance criterion number 7 that there should be no decrease in old growth in any covertype in any ecoregion.

4.4 Tree Species Mix

4.4.1 Significance Criterion Number 4

4. Changes to Minnesota forests - tree species mix

An impact is considered significant if projected gross changes in the relative proportion of any tree species exceeds 25 percent for the respective covertypes over the 50-year planning period.

Severity and/or extent. Minor species are important components of forest communities. A covertype or forest type classification is attributed to each of the USDA Forest Service Inventory and Analysis (FIA) plots. The covertype is classified on the basis of the species comprising a plurality of live tree stocking. Projected changes in the relative proportions of these species will be important indicators of change within a covertype. Such changes can also lead to a change in covertype area. Increasing as well as decreasing proportions will be addressed. For example, where aspen rotation is shortened, shade tolerant conifers such as spruce and fir may become less common. Other species such as yellow birch may be comparatively scarce due to earlier highgrading and a projected reduction in the proportion of this species will be of concern.

Certainty of impact. Changes will be interpreted based on the degree to which known requirements of the minor species are met by the assumed silvicultural activities and management objectives for each ownership.

The 1990 FIA will be used to provide the base data on species composition.

Duration of impact (irreversibility). Medium- to long-term impacts will occur because in many cases a reduction in minor species may only appear in the stand many decades after harvesting.

Existing guidelines and standards. Not applicable.

Biological implications. A reduction in these minor species can reduce biodiversity and change wildlife habitat values. For example, loss of a conifer understory reduces the habitat value of aspen stands for some species. A reduction in the diversity of a stand can increase the risk of pest and disease.

Economic implications. Possible changes in availability of desirable commercial species.

Linkage to other criteria.
- Forest dependent wildlife - food resources.
- Changes to Minnesota forests - age class structure.

4.4.2 Results

Minor Tree Species
Minor tree species are an important component of biodiversity. In many cases they are species near the edge of their range, or are species that simply are not abundant within their range:

American hornbeam
Bitternut hickory
Black cherry
Black oak
Black walnut
Butternut
*Eastern hemlock
Hackberry
*Heart-leaved birch

*Honeylocust
Kentucky coffeetree
Mountain ash
River birch
Rock elm
Shagbark hickory
Slippery elm
Striped maple
Swamp white oak
*Sycamore?
White ash
Yellow birch
*Yellow oak

* indicates that this species not included in the FIA data and analyses by covertype. Sycamore is listed with a question mark because it is not certain whether the species is native to the state. If any sycamore are found, they would be in the extreme southeast corner of ecoregion 6.

The analysis of stem numbers for the three timber harvesting scenarios in the year 2040 reveals *that two of the minor species would be significantly impacted (>25 percent reduction in stem number). These are Kentucky coffeetree (all three scenarios) and rock elm (high scenario).* Also, in the judgement of the study group, *significant impacts on honeylocust, yellow oak, and sycamore (if investigation shows it to be native) are likely under current levels of management.*

The five asterisked species in the listing are not included in the data. Four of these species (all except heart-leaved birch), and probably striped maple as well, are so rare in Minnesota that they should never be harvested, unless there is a clear plan for regeneration using native seed stock at the harvest site. Eastern hemlock is a state-listed species and should not be harvested in any circumstance.

Reduction of Conifer Component in Aspen Stands

Estimated acreage of aspen forest *with no or inadequate* conifer understory is high—about 73 percent in the 1977 FIA (Jakes 1980). In addition, the type change matrix from 1977 to 1990 indicates that aspen covertype increased by 12 percent among harvested, naturally regenerated stands. The following percentages of harvested forest stands were converted to aspen during the 1977 to 1990 period: white pine—43 percent, white spruce—43 percent, red pine—21 percent, black spruce—16 percent, and balsam fir—34 percent. Except for red pine, fewer FIA plots changed from aspen to conifer than from conifer to aspen during the 13-year period. These data seem to suggest that large-scale conversion of types to aspen is taking place.

However, the real question is whether the forests later succeed back to conifers at a rate sufficient to balance postharvest conversion. The same covertype change matrix that shows postharvest conversion to aspen also shows that only 89 percent of stands that were aspen prior to harvest remain aspen after harvest. Also, the covertype change matrix for older undisturbed stands shows some conversion of aspen to other types. Thus stands are converted in both directions and overall succession is not clear. One problem with the covertype change matrices is that they represent only 13 years; succession from aspen back to conifers often takes longer than 13 years and it is not certain that 1977 to 1990 is a representative time period.

Longer-term data for the conifer component in aspen stands comes from conifer volume and number of stems by age class. The proportion of conifer volume in the aspen forests is fairly constant with age, but begins to climb around age 80. It ranges from 16 to 23 percent in the aspen-birch unit and 9.8 to 17.5 percent in the northern pine unit for ages zero to 80. The conifer proportion climbs to about 27 percent in both survey units by age 90. Actual conifer volume grows from 67 to 424 cubic feet per acre from ages zero to 120, and 40 to 351 cubic feet per acre from ages zero to 90 in the aspen-birch and northern pine survey units, respectively. This conifer volume was well distributed among all site index classes.

Actual number of trees per acre for balsam fir in the aspen covertype starts at 19 per acre at age 5, and steadily climbing to 52.2 per acre at age 35 and 63 per acre at age 65. After age 65, the trends become erratic (table 4.5). Similar trends occur for white spruce and black spruce. The trend for white pine is an exception (table 4.5) because the number of stems does not rise substantially until after age 95. These data suggest that, except for white pine, there is currently a sufficient conifer component in the aspen stands for future seed source and maintenance of conifers as aspen stands reach old age.

Table 4.5. Number of stems per acre (>0.95 inches dbh) of selected conifers in the aspen covertype. 1990 Minnesota FIA data.

Age Class	Balsam Fir	White Pine	White Spruce	Black Spruce
5	18.8	.04	1.5	3.1
15	27.6	-	2.4	5.5
25	47.2	-	4.8	10.2
35	52.2	1.0	4.7	5.2
45	57.5	2.6	2.7	4.4
55	53.7	2.9	5.3	6.8
65	63.1	1.1	5.9	8.6
75	54.2	1.9	5.3	4.7
85	90.2	4.9	8.3	6.9
95	65.5	6.9	7.4	5.1
105	117.6	55.0	-	7.4

In summary, the data are ambiguous. Data on development of the conifer understory by age—not available at this time—would be necessary to really determine at what age it is safe, on average, to harvest aspen stands without causing permanent future loss of the conifer component. In addition, the degree of site disturbance, time of year of harvest, amount of residual left after harvest and other factors are certain to influence the successional sequence.

It could be that the low proportion of aspen stands with conifer understory is due to the fact that most stands are even-aged and dense. It is not uncommon for understory growth to be suppressed in young even-aged stands (10 to 50 years old) referred to as the *stem exclusion phase* of stand development. Stem exclusion occurs in all covertypes that have a dense canopy, including conifer covertypes. This suppression continues until canopy trees are large enough so that they leave substantial canopy gaps when they die, allowing more light to penetrate to the forest floor (50 to 90 years old in aspen), referred to as the *understory reinitiation* phase of stand development. Harvesting is known to speed up the process of succession to shade tolerant trees—balsam fir, white and black spruce in this case—by releasing seedlings from suppression on the forest floor. On the other hand, the aspen's ability to sprout prolifically after cutting gives it an advantage.

At this point, *the study group cannot predict whether conifers will be lost in short rotation harvest. But the impact on biodiversity would be significant, and directly proportional to level of harvest, if such a reduction in conifer component occurs.*

4.5 Genetic Variability

4.5.1 Significance Criterion Number 9.

9. Forest species - genetic variability.

An impact is considered significant if there is projected to be a loss of genetic variability in forest plant or animal species as measured by:

1. a reduction or isolation of habitat or communities supporting a species, or
2. a reduction of geographic ecotypes such that a species now present as a viable population disappears or is approaching extirpation from any ecoregion.

Severity and/or extent. Current knowledge of population genetics indicates that the relationship between geographic distribution and genetic variability is not well understood. The term geographic ecotypes refers to geographically distinct populations of a species that occur across an environmental gradient. This criterion therefore represents a conservative approach by linking loss of any geographically isolated element with the possibility of a loss in genetic variability. The uncertainties implicit in this approach will provide a degree of resolution capable of detecting gross trends. The criterion uses covertype as the most consistent indicator of past changes to patterns of vegetation. Past changes will be interpreted based on records of vegetation patterns in Minnesota prior to the large scale changes that followed European settlement. Interpreted changes based on future levels of harvesting will identify communities with diminishing geographic distributions and small, isolated populations. The terms *diminishing*, *small*, and *isolated* are not explicitly defined and will be used subjectively in the application of this criterion.

The criterion will be applied to both plants and animals. The focus will be on herbaceous plants and those species with small populations and/or limited geographic ranges which can be susceptible to a loss of genetic variability. This could adversely affect the ability of the species to adapt to change. Outlier populations may have distinctive genetic makeup due to geographic isolation. Those known to exhibit a high degree of genetic variability will be addressed as a priority. Changes to animal populations will be based on recorded changes to populations over time where such records exist; or on projected changes to habitat availability, in order to predict possible changes to distributions of animals.

Certainty of impact. The lack of data about most species make it difficult to interpret impacts with any degree of certainty. It is likely that impacts are more likely to occur on NIPF lands if only because of ongoing clearing of forests in the south and west of the state. Typically, NIPF owners are not aware of the value of maintaining genetic diversity.

Duration of impact (irreversibility). Loss of genetically unique ecotypes is irreversible.

Existing guidelines or standards. Not applicable.

Biological implications. Loss of genetically distinct populations will reduce biodiversity, and could increase pest and disease risk and hazard as resistance may vary between populations. Loss of genetic diversity may affect the capacity of a species to adjust to climatic change, particularly where outlier populations are lost.

Economic implications. Loss of genotypes may involve the loss of attributes that could be of particular commercial value, such as fast growth, good form or disease resistance.

Linkage to other criteria.
- Federal or state-listed species of special concern, threatened or endangered or their habitats.
- Changes to Minnesota forests - tree species mix.
- Changes to Minnesota forests - patterns of forest cover in areas of mixed land use.

4.5.2 Results: Major Tree Species Reaching Their Range Limit

Few habitats persist unchanged for long periods of time, even in the absence of human activity. Species that occur as small populations in local habitats are subject to local extinction. Other species may invade new habitats that form beyond the existing range. Examples are the immigration of conifer bog species to new wetlands as they developed farther south in response to cooling climate during the last 2000 years (Swain 1979) and the westward invasion of trees into prairie during the same period (Grimm 1983, Almendinger 1985). The landscape mosaic comprising species' habitats is always changing due to disturbances and shifts in climate. Therefore, preservation of populations near the edge of a species range is a very important component of biodiversity.

Nearly all tree species native to Minnesota have a range limit within the state (Burns and Honkala 1990a,b). This is because the state is located at the boundaries of three major biomes: the boreal forest, the deciduous forest and the prairie. Many tree species are limited in their range in Minnesota either to the northern part of the state (ecoregions 1 to 4) or the southern part (ecoregions 5 to 7).

The earlier discussion of spatial variation in genetic diversity of trees (section 2.3), makes it clear that most species have clinal variation from warm-dry climates to cold-wet climates (southwest to northeast in Minnesota). Therefore, *any harvest that eliminates or isolates one or more populations of species in the regions listed in table 4.6, constitutes a significant impact on genetic diversity*, under criterion 9.

Table 4.6. Major tree species with range limits occurring within Minnesota (ER = ecoregion).

Species	Location of Range Limit
Basswood	Northern Limit: ER 1,2,3
Balsam fir	Western Limit: W. ER 1,4; N ER 5 Southern Outliers: ER 5,6
Balsam poplar	Western Limit: ER 7 Southern Outliers: ER 4,5,6
Bigtooth aspen	Western Limit: W. ER 1,4,5
Black ash	Western Limit: ER 7; W. ER 5,6
Black spruce	Western Limit: ER 7; W. ER 1,4,5 Southern Limit: S. ER 4; ER 5
Bur oak	Northern Limit: ER 1,2,3
Jack pine	Southwestern Limit: ER 7; W. ER 1,4; N ER 5
Paper birch	Western Limit: ER 7; W. ER 1,4 Southern Limit: ER 5,6
Quaking aspen	Western Limit: ER 7
Red maple	Western Limit: ER 7; W. ER 4 Southern Limit: ER 5,6
Red oak	Northern Limit: ER 1,2 Western Limit: ER 7; W. ER 4,5
Red pine	Southwestern Limit: W. ER 1,4; N. ER 5
Sugar maple	Northern Limit: ER 1,2,3 Southwestern Limit: W. ER 4,5; ER 6
Tamarack	Southwestern Limit: W. ER 1,4; S ER 5; N. ER 6
White cedar	Southwestern Limit: W. ER 1,4; ER 5
White oak	Northern Limit: N. ER 5,6; S ER 4
White pine	Southwestern Limit: W. ER 1,4; ER 5,6
White spruce	Southwestern Limit: ER 7; W. ER 1,4; N. ER 5

4.5.3 Endangered Plant Communities

The Natural Heritage Program recognizes that plant communities are distinctive assemblages as worthy of protection as endangered species. In the future, the listing of many species as endangered can be avoided if all of the natural communities are protected with natural processes intact, so that habitats for species continue to exist.

The Minnesota Natural Heritage Program staff has provided tentative rankings for natural communities, based on the number and quality of occurrences in the state. The rankings are agreed upon through consensus of a group of experts:

1 = *Critically endangered* in Minnesota because of extreme rarity or because of some factor(s) making it especially vulnerable to extirpation from the state.
2 = *Endangered* in Minnesota because of its rarity or because of some factor(s) making it vulnerable to extirpation from the state.
3 = *Threatened* in Minnesota because it is rare or uncommon.
4 = *Special concern* in Minnesota because although it has many occurrences, there are widespread threats to its existence or many occurrences are of poor quality.
5 = *Demonstrably secure* in the state.
U = *Uncertain*, but possibly in peril.

The Natural Heritage Database separates several community types into geographic sections in the state, and the status is estimated separately for each of these sections, in effect advocating a geographically balanced representation of remnant rare communities. In cases where the data indicates that communities have different combinations of species, but these differences are not large enough to warrant a separation into several community types, subtypes are also recognized. Table 4.7 shows occurrence of critically endangered, endangered, and threatened forest and woodland communities by ecoregion.

Most of the occurrences of rare plant communities are in the forest transition zone—ecoregions 5 and 6—where agriculture and urban development have caused extensive habitat loss and fragmentation. In northern Minnesota (ecoregions 1 to 4) little survey work has been done to document occurrence of rare communities, and therefore accidental harvest is likely. Many of the occurrences are not protected, and *any harvest in a listed community would be a significant impact by criterion number 9. Accidental harvest of unidentified remnants of these natural communities is likely.*

The major implications of table 4.7 are:

1. Those natural forest communities dependent on frequent fire are endangered or critically endangered. This includes savannas and woodlands, both dominated by the pines and the oaks. The major problem has been fire suppression which has allowed former savannas and woodlands to convert to dense forests.

2. Those natural forest communities dependent on infrequent severe fires are endangered or threatened. This includes mixed oak forests, white and red pine forests, and pine-hardwood community types. The main problem with the pine communities, in addition to fire suppression, is a failure to restore the pine acreage after early exploitation and land clearing. Little attention has been paid to white pine regeneration for several decades, and although red pine has been extensively planted in

recent decades, most of it is still young. In addition, pine seed sources were removed over large areas in parts of the state, so that natural reseeding has been slow.

Table 4.7. Occurrence of critically endangered (1), endangered (2), or threatened (3) communities, by ecoregions. Subtypes and geographic sections recognized by the Natural Heritage Program are matched to the GEIS ecoregions as far as the data will allow.

Community, Status	Ecoregion						
	1	2	3	4	5	6	7
Oak savanna, mesic subtype,(1)					X	X	
Jack pine woodland (1)	X			X	X		
Oak savanna, hill subtype (1/2)					X	X	X
Oak savanna, gravel subtype (1/2)					X	X	X
Mixed oak forest, Bigwoods section, mesic subtype (2)					X	X	
Mixed oak forest, central section, mesic subtype (2)					X		X
Maple-basswood forest (Bigwoods section) (2)					X	X	
White pine forest, southeast section (2)						X	
Upland white cedar forest bluff subtype (2)						X	
Northern hardwood-conifer forest, bluff subtype (2)						X	
Oak savanna-bedrock bluff subtype (2)						X	
Jack pine barrens (2)	X	X		X	X		
White cedar swamp seepage subtype (2)	X	X	X	X			
Mixed oak forest, southeast section, mesic subtype (2/3)						X	
Mixed oak forest, southeast section, dry subtype (2/3)						X	
Northern hardwood forest (southern section) (2/3)						X	
Maple-basswood forest, southeast section (2/3)						X	
White pine forest, central section (2/3)	X			X			
Upland white cedar forest, yellow birch subtype (2/3)	X	X	X	X			
White pine-hardwood forest, southeast section, mesic subtype (2/3)						X	
White pine forest, southeast section, dry subtype (2/3)						X	
Northern hardwood-conifer forest, yellow birch-white cedar subtype (2/3)	X		X	X			
Oak savanna dune subtype (2/3)							X
Aspen openings (2/3)							X
Mixed oak forest, Bigwoods section, dry subtype (3)					X	X	
Mixed oak forest, northeast section (3)			X	X			
Northern hardwood forest, northern section (3)	X	X	X	X			
Maple-basswood forest, west central section (3)					X		X
Maple-basswood forest, east central section (3)				X	X		
White pine forest, northeast section (3)		X	X	X			
Red pine forest (3)	X	X	X	X	X		

Community, Status	Ecoregion						
	1	2	3	4	5	6	7
Upland white cedar forest (3)	X	X	X	X			
White pine-hardwood forest, north central section (3)	X			X	X		
Northern hardwood-conifer forest (3)	X	X	X	X			
Aspen brush prairie (3)							X
Black spruce bog, raised subtype (3)	X	X	X	X			
Black ash swamp, seepage subtype (3)				X	X	X	
Mixed hardwood swamp, seepage subtype (3)				X	X	X	
Mixed oak forest, central section, dry subtype (3)				X	X		
Maple-basswood forest, northern section (3)				X			
Northern conifer scrubland (3)	X	X	X	X			

3. Those natural forest communities that originally covered the bigwoods and prairie-forest transition (ecoregions 5 and 6) are endangered by clearing and conversion of land to other uses, primarily agriculture and urban areas. Included are mixed oak forests, *natural* maple-basswood forests, and the southernmost white pine and pine-hardwood forests.

4. Upland white cedar forests are now endangered. Like the former white and red pine forests, these have been converted to aspen types by land clearing. Reproduction is also hindered by the current high levels of deer browsing in parts of Minnesota.

4.5.4 Fragmentation

Inbreeding

The exact distance scale of isolation needed to cause inbreeding is unknown for forest trees and plants. The farther either pollen or seeds are dispersed, the more isolated a population can be without becoming inbred. Qualitative assessment of susceptibility to inbreeding due to fragmentation is possible, based on general knowledge of seed and pollen dispersal (table 4.8). *No significant fragmentation impacts due to harvesting are expected in Minnesota for species listed in the very low or low susceptibility groups.* This is because the species are widespread, and few populations are isolated by more than a few miles in Minnesota, the one exception being woodlots in ecoregion 7 (Scanlan 1981).

On the other hand, *forest harvesting will usually have a significant impact on the genetic architecture of forest herbs listed as high susceptibility (table 4.8).* Imposition of a different covertype between two populations of only a few hundred yards could cause loss of gene flow between populations. This may result in inbreeding and the loss of some populations.

However, other populations of forest herbs will have a large enough number of individuals and enough variability within one population, so that the population is viable, even when isolated. If gene flow is cut off, isolated populations could evolve into new varieties and (after a few thousand years), new species. This is exactly how the dwarf trout lily is believed to have evolved from the white trout lily. *There is no way to assess the number of species that would be affected without a detailed map of timber harvests.*

Table 4.8. Qualitative estimate of susceptibility to inbreeding due to fragmentation. The same species listed as high susceptibility (forest herbs) to inbreeding, species or groups of species in Minnesota. Pollen and seed dispersal effective distances: VL= very long distance (more than 2 miles), L=long distance (0.5-2 miles), M=medium distance (0.1-0.5 mile), S=short populations. The spatial scale of forest operations is similar to that of distance (<0.1 mile).

Species/Group	Pollen/Seed Dispersal	Geographic Scale of Genetic Variation	Overall Susceptibility
Aspen	L/VL	Ecoregion	Very Low
White, red and jack pines, birches	VL/M	Ecoregion	Low
Berry producing shrubs, cherry, mountain ash	S/VL	?	Low
Oaks	L/L	Ecoregion	Low
Spruces, white cedar, tamarack	M/M	Ecoregion	Medium
Walnut, hickory	M/S	Ecoregion	Medium
Maples, basswood, fir	S/M	Ecoregion	Medium
Forest herbs[a]	S/S	Township/county or smaller	High

[a] Forest herbs includes hundreds of species, and exceptions to short distance pollen and seed transport are sure to occur.

Direct Loss of Genetic Diversity

The same species listed as high susceptibility (forest herbs) to inbreeding, also have relatively fine-scale spatial differences in gene frequencies among populations. The spatial scale of forest operations is similar to that of genetic structure of forest herbs. Therefore, *losses of distinctive genetic material of forest herbs, caused by changes of covertype, such as plantations that extirpate local populations, will be significant for all harvest levels.*

Significant impacts are unlikely among species of the low susceptibility group. There is one exception, however. Habitat islands such as swamp conifers separated by many miles (mainly ecoregions 5 and 6), and other outliers (i.e. sugar maple in ecoregion 3) may have genetically distinct populations that would be lost if covertype conversions occurred.

Relationship of Fragmentation to Old Growth

Old growth forests are generally *interior* forests. Old growth communities are those that have an environment of low light (except for the top of the canopy), high humidity, and low windspeed. Old growth areas of 20 acres or more (MNDNR minimum area criterion) probably have some interior-type habitat in the middle (Levenson 1981). The entire area of a 20-acre stand can be made interior if a 300-foot buffer is around the edge. However, 100 acres or more of contiguous forest may be necessary for some pileated woodpeckers and other birds (see Forest Wildlife technical paper, Jaakko Pöyry Consulting, Inc. 1992b).

Thus old growth, as a community or communities, is highly susceptible to fragmentation. Harvesting activities which do not take into account the needs of old growth, as related to buffers, are significant impacts (see mitigation 5.4). The forest change and scheduling model *does not provide enough detail to assess in any quantitative sense, the potential impact of harvesting on the relationship of fragmentation to old growth.*

Relationship of Fragmentation to Climate Change

Timber harvesting at all levels can cause fragmentation that will have a significant impact on genetic diversity of forest herbs and trees under a changing climate. This is because plants have a difficult time moving to areas of suitable climate in a fragmented landscape.

4.5.5 Deer Browsing

The geographical distribution of forest covertypes and ages caused by forest management directly influences the local deer population, which in turn has consequences for biodiversity. Preliminary indications are that about 10 deer per square mile is the upper limit consistent with maintaining the natural species composition and structure of plant communities, and about five deer per square mile is thought to be a safe density. This is the density that probably occurred in the Lake States in pre-European settlement times (Frelich and Lorimer 1985, Alverson et al. 1988). Several species are reduced in abundance, or locally extirpated, by high deer populations, including showy and yellow lady slipper orchids, blunt-leaf orchid, tall northern bog orchid, purple fringed orchid, indian cucumber root, large flowered trillium, and Canada yew (Alverson et al. 1988, Frelich personal observation). In addition, deer browsing can change the entire species composition and dynamics of the woody plants in a community (Beals, Cottam and Vogl 1960, Frelich and Lorimer 1985). In Minnesota, deer can cause lack of success in regeneration for two important tree species—white cedar and white pine. Yellow birch, a minor tree species, and eastern hemlock, a special concern species, can also be reduced in abundance by deer browsing.

The current deer population in Minnesota is about 1,000,000 in June and 600,000 in the fall (posthunting). Statewide, that works out to about 12 deer per square mile (spring) or 7 per square mile (fall). However, there are regional variations in the number of deer. Some areas of the state have a low enough density of deer so that impacts on biodiversity are unlikely. The number varies from one deer per square mile in the BWCAW to 20 or more in some areas. *Significant impacts on biodiversity are likely under criterion 9 in areas where the spatial and temporal pattern of harvesting leads to high deer populations.*

4.5.6
Exotic Species and Hybrid Trees

The two major groups of exotics causing problems in Minnesota are buckthorns (*Rhamnus cathartica, R. frangula*) and non-native honeysuckles (*Lonicera tatarica, L. morrowii, L. x bella*). Although these shrubs have not yet attained the significance of purple loosestrife, they invade partially cut or open oak woodlands in ecoregions 5 and 6. Growth of native shrubs, tree seedlings, and forest herbs is suppressed by their dense thickets, which also can become an aesthetic problem (Converse 1988, 1989). The problem lies not with timber harvesting itself, but with distribution of these species for use in shelterbelts (Scholten 1988) and hedges, and the spread into forests from these plantings by berry-eating birds. *Therefore, the study group predicts significant impacts due to shelterbelt and ornamental planting, but no significant impact due to harvesting.*

No basis for assessment of impact of hybrid and non-native tree species is given in the harvesting scenarios. However, *there is potential for significant impact if planting of hybrid or non-native species becomes widespread.*

Natural genetic variability in forest trees is a concern in environmental conservation that occasionally conflicts with silvicultural efforts to find and introduce into forest lands newly selected genetic strains that presumably produce trees that meet economic needs better than native stock. The magnitude of the problem is little understood. Also, some exotic species such as buckthorn and honeysuckle can displace native species.

Conservationists prefer to follow a conservative strategy of not introducing any non-native strains into forests so as to keep Minnesota's vegetation as close to the original types as possible. Where more is known about the genetics of a species, harvesting and silvicultural practices should seek to conserve that gene pool. In the case of planted pines and spruces, available information indicates that introduction of new or different genetic materials has not been a problem to date.

If hybrid trees are to be used, then it is preferable that the areas of use be confined to intensively managed areas and private, industrial lands. It would seem appropriate that state and federal land agencies would urge landowners to use caution when considering the introduction of hybrid stocks. Cross pollination between hybrids and native stands, and invasion of native stands by hybrids is a concern. Use of hybrids and non-native species that are unlikely to cross with native populations and are not agressive invaders of natural stands are preferred.

Breeding of native species to favor faster growth and disease resistance may not be a problem as long as the full range of variation is retained in the overall population. This type of breeding can help combat the impacts of exotic diseases such as Dutch Elm Disease and White Pine Blister Rust. Also, rapid growing hybrids may lessen timber supply problems, allowing larger areas to be managed conservatively.

4.6
Rare and Endangered Species

4.6.1
Significance Criterion Number 8.

8. Federal or state listed species of special concern, threatened or endangered or their habitats.

An impact is considered significant if any harvest or forest management activity is projected to diminish the habitat and disturb a species listed as of special concern, threatened or endangered (either federal or state).

Severity and/or extent. The severity of impact will be assessed on the basis of the species current status (special concern, threatened or endangered) and the degree to which projected harvesting levels adversely impact habitat for the species. Changes in habitat availability for species with limited populations that are not currently on either state or federal lists will be assessed criteria numbers 9, 10, and 11.

Certainty of impact. Populations of listed species differ in terms of the species ability to rebuild population numbers and to cope with disturbance. Relevant factors influencing this ability include:

- species life history, dispersal ability, ecological and genetic factors; and
- management objectives and practices of landowners.

State and federal ownerships have policies that are directed towards improving conditions for species on these lists. Other ownerships have less explicit management objectives, with a consequent increase in the risk of adverse impacts.

Duration of impact (irreversibility). Medium- to long-term impacts would be associated with reductions of populations. The timeframe would depend on the factors identified above. Irreversible impacts could occur where a species is lost from within and outside Minnesota.

Existing guidelines and standards. MN: DNR guidelines and rules. Federal: Endangered Species Act. Federal and state ownerships actively manage lands to create the conditions needed to rebuild populations of certain listed species. This cán include setting target levels for these species.

Biological implications. There is the potential for a loss of biodiversity as these species diminish or are lost from the ecosystem.

Economic implications. Not applicable.

Linkage to other criteria.
- Changes to Minnesota forests - age class structure.
- Changes to Minnesota forests - patterns of forest cover in predominately forested areas.
- Changes to Minnesota forests - patterns of forest cover in areas of mixed land use.
- Forest dependent wildlife - food resources.
- Forest dependent wildlife - habitat.

4.6.2
Results: Endangered, Threatened, and Special Concern Plants

In general, the forest dependent rare plant species of Minnesota (table 4.9) are poorly adapted to trampling types of injury. Most (except for the one tree species listed) are of small stature and easily broken. *Any harvest that would allow heavy equipment to drive through a population of any rare plant species would be a significant impact.*

There are a large number of occurrences of endangered, threatened, or special concern plants within Minnesota's forests, in all ecoregions (table 4.10). The habitat data for the listed plants (table 4.9) is only anecdotal at this time; there is no data to allow construction of habitat matrices like those used to examine harvesting impacts on forest wildlife. In any case, the time schedule and level of funding for the GEIS do not allow the study group to construct habitat-abundance matrices for rare plant species, a task that would require the services of many researchers for several years. A list of occurrences, by township and range, for all rare plants and communities in Minnesota is maintained by the Natural Heritage Program.

Table 4.9 Forest-dependent, state-listed plant species in Minnesota, their ecoregional distribution, and type of habitat where each species has been observed to date.

Species	Status	Habitat
Ecoregion 1		
Rhizomnium gracile	proposed special concern	-poor fens under black spruce and northern white cedar
Ecoregions 1 and 4		
Cypripedium arietinum	endangered	-conifer bogs and upland conifer forests
Ecoregions 1, 2 and 4		
Arethusa bulbosa	special concern	-conifer swamps, floating mats, and fens
Tomenthypnum falcifolium	special concern	-forested swamps and poor fens
Ecoregions 1, 2, 3, and 4		
Lobaria quercizans	threatened	-on old trees in ash and cedar swamps, and on old yellow birch
Ranunculus lapponicus	special concern	-confier swamps
Cetraria aurescens	special concern	-on conifer back in old cedar swamps
Ecoregion 2		
Rubus chamaemorus	threatened	-black spruce bog; 2 sites known
Ecoregion 2 and 3		
Pseudocyphellaria crocata	endangered	-on rocks and trees in mature, moist hardwood and conifer forests
Pyrola minor	proposed special concern	-coniferous forests and bogs
Ecoregions 2, 3, and 4		
Phacelia franklinii	proposed threatened	-wooded slopes near Lake Superior, open jack-pine forest
Claytonia caroliniana	special concern	-maple-basswood northern hardwood forest
Sticta fuliginosa	special concern	-on trees in old, open cedar swamps
Ecoregion 3		
Lobaria scrobiculata	endangered	-mature conifer woods, on shady, north-facing cliffs near Lake Superior
Osmorthiza chilensis	endangered	-northern hardwood forest near Lake Superior
Polystichum braunii	endangered	-rocky slopes in northern hardwood forests; 2 sites known
Osmorhiza obtusa	proposed threatened	-aspen-birch-fir forest near Lake Superior
Adoxa moschatellina	special concern	-moist slopes in northern hardwood forests
Cetraria oakesiana	special concern	-on wood in old spruce-fir forest; 1 site known
coccocarpia palmicola	special concern	-on rocks in spruce-fir forest; 1 site known
Parmelia stuppea	special concern	-on northern white cedar; 1 site known

Species	Status	Habitat
Ecoregions 3 and 4		
Tsuga canadensis	special concern	-rocky slopes and protected ravines
Waldsteinia fragarioides	special concern	-upland pine forests, especially jack pine
Ecoregions 3, 4, 5, and 6		
Platanthera clavellata	special concern	-conifer swamps in north, wet meadows in south
Ecoregion 4		
Malaxis paludosa	endangered	-conifer swamps and groundwater fens
Muhlenbergia uniflora	proposed threatened	-wet sandy beaches
Botrychium mormo	special concern	-maple-basswood forests
Ecoregions 4 and 6		
Floerkea proserpinacoides	special concern	-moist deciduous forests and forested seeps
Hamamelis virginiana	special concern	-ravines and stream banks in hardwood forests
Hydrocotyle americana	special concern	-hardwood swamps, seeps and floodplain forest
Ecoregions 4, 5 and 6		
Carex woodii	special concern	-mesic slopes in deciduous forest; sensitive to cattle grazing
Cephalanthus occidentalis	special concern	-floodplain forest and meadow
Dryopteris goldiana	special concern	-moist wooded slopes
Ecoregions 4, 5, 6, and 7		
Panax quinquefolium	special concern	-hardwood forests, sensitive to clearcutting and cattle grazing
Ecoregion 5		
Carex conjuncta	threatened	-floodplain forest, deep valleys
Carex davisii	threatened	-floodplain forest, deep valleys
Ecoregions 5 and 6		
Erythronium propullans	endangered	-forested slope and floodplain
Desmodium cuspidatum	proposed special concern	-mesic deciduous forest
Ecoregions 5, 6 and 7		
Sanicula canadensis	special concern	-deciduous forest

Species	Status	Habitat
Ecoregion 6		
Carex crus-corvi	proposed endangered	-forested swamps in Mississippi River floodplain
Hydrastis canadensis	endangered	-deciduous forest
Montia chamissoi	endangered	-sandstone outcrop in deciduous forest, single site
Allium cernuum	threatened	-deciduous woodland; known only in a state park
Carex plantaginea	proposed threatened	-maple-basswood forest
Jeffersonia diphylla	threatened	-deciduous forest
Lycopodium porophilum	threatened	-wooded forest
Silene nivea	proposed threatened	-floodplain forest and meadow
Adoxa moschatellina	special concern	-moist, north-facing slopes in deciduous forest
Aster shortii	proposed special concern	-moist slopes in deciduous
Athyrium pycnocarpon	special concern	-wooded bluffs facing north and northeast, sensitive to cattle grazing
Carex laevivaginata	special concern	-floodplain forest and meadow
Carex laxiculmis	special concern	-slopes in maple-basswood forest
Desmodium nudiflorum	proposed special concern	-deciduous forest, 1 site known
Dicentra canadensis	special concern	-moist deciduous forest
Dodecatheon amethystinum	proposed special concern	-moist cliffs and north-facing wooded slopes
Ecoregion 6 (continued)		
Iodanthus pinnatifidus	proposed special concern	-floodplain forest
Leersia lenticularis	special concern	-floodplain forest
Orobanche uniflora	special concern	-deciduous forest and woodland
Paronychia canadensis	proposed special concern	-sandy upland forests
Phegopteris haxagonoptera	special concern	-north-facing slopes in elm, maple, oak, basswood forest
Poa wolfii	special concern	-wooded, north-facing talus slopes and cliffs; also on North Shore cliffs
Polystichum acrostichoides	special concern	-wooded slopes
Rudbeckia triloba	special concern	-moist woodland valleys and stream banks
Sanicula trifoliata	special concern	-deciduous forests, north-facing slopes
Scutellaria ovata var. versicolor	special concern	-floodplain forests in deep valleys or mesic forested slopes
Symphoricarpos orbiculatus	special concern	-open deciduous forest; 1 native site known
Ecoregions 6 and 7		
Trillium nivale	special concern	-moist hardwood forests on floodplains, slopes, and terraces

Table 4.10. Summary of the numbers of rare plant species likely to be impacted directly by harvesting, by ecoregion.

Ecoregion	Endangered	Threatened	Special Concern
1	1	1	5
2	1	3	7
3	4	3	12
4	2	3	17
5	1	2	6
6	4	5	24
7	0	0	3

4.6.3
Results: Endangered, Threatened and Special Concern Animals

The study group interprets *any decline* in projected habitat as significant under criterion number 8.

Birds
There are five state or federal-listed, forest-dependent bird species:

Osprey: An overall statewide increase is predicted under all three harvesting scenarios, both on commercial forest land and for all forest lands.

Bald Eagle: Stable statewide populations are predicted under all three harvesting scenarios.

Red-shouldered Hawk: *An overall statewide decrease is predicted under all three harvesting scenarios on timberlands and on all forest lands.*

Loggerhead Shrike: Significant increase in statewide populations under all three harvesting scenarios on timberlands or all forest lands.

Louisiana Waterthrush: Stable populations are predicted statewide for all three harvesting scenarios.

Herps
There are four state-listed forest-dependent species:

Wood turtle: Because the wood turtle primarily uses riparian buffer zones for nesting, which are reserved under the BMPs in the forest harvest model, no decline in area of habitat or in actual numbers are predicted under any scenario.

Timber Rattlesnake: Stable or slightly increasing acreage of habitat for all three harvesting scenarios.

Hognose snake: A >25 percent increase in habitat statewide under the base and medium harvest scenarios, and increase of 8 percent under the high harvest scenario.

Pickerel Frog: A large increase (>50 percent) in habitat acreage statewide under all three harvesting scenarios.

Small Mammals
There is one state-listed, forest-dependent small mammal:

Pine Marten: Statewide, *a significant decline in population index by 2040 is predicted for all forest lands, and on timberland only, under the high harvest scenario. Stable or increasing populations are projected for the base and medium harvest scenarios.*

Large Mammals
There is one threatened (state and federal) forest-dependent large mammal:

Timber wolf: Increased harvesting may have both positive and negative effects. Increased harvesting could lead to larger populations of deer and beaver, which are prey for wolves. On the other hand, more logging roads means more access for poachers, which have been a major problem for wolf populations. *No significant direct impact by harvesting is expected.*

5 POSSIBLE MITIGATION ALTERNATIVES

5.1 Mitigation Alternatives Criteria

These criteria will identify mitigation actions with the potential to address the significant impacts previously identified. The purpose behind this stage of the process is to identify mitigation actions which are effective and practical in a physical context, as well as the political, financial, and administrative environments in Minnesota.

Input from the technical experts, Advisory Committee, and the EQB are reflected in the criteria as presented. Unlike the significance criteria, the criteria developed to identify potential mitigation alternatives will be applied uniformly across all issue areas documented in the FSD.

Major considerations used in the development of criteria to identify mitigation alternatives include:

- financial considerations;
- administrative considerations;
- certainty of effectiveness; and
- social implications.

All recommended mitigations for preventing losses to Minnesota's natural diversity of plants and animals and to its wildlife resources from increased timber harvest must be based on sound information or best estimates of likely impacts. Some monitoring will always be necessary when a mitigation strategy is employed, to make sure the strategy is having the intended effects on populations of plants and animals. The mitigation strategies identified have complex effects on many species, and not all of these are well understood at this time.

5.2 Mitigation: Comprehensive Inventory

A coordinated statewide biodiversity survey on forest lands should be undertaken as soon as possible. This survey would be an expansion of the ongoing MNDNR County Biological Survey. The same level of detail should be attained on commercial and reserved forest lands. Historically, separate federal, state and county agencies responsible for natural resources have used different criteria and classifications for measuring the same entities on adjacent lands. In the future, these efforts should be coordinated among agencies.

The MNDNR's biological survey appears to be the best system for encompassing the data for biodiversity management on a regional scale in Minnesota. Unfortunately, this project is not due to complete all counties until 2020. The study group recommends expediting this schedule in the forested parts of the state.

5.3 Mitigation: Extended Rotation Forest

Approximately 25 percent of even-aged forests should be managed with extended rotations, which are 20 to 50 percent longer than optimum economic rotations. This reflects the tentative guidelines adopted by the MNDNR for its own forest lands. However, such extension of rotation ages needs continuing study as statewide goals for forest covertype acreage and age class balance are articulated. Extended rotation forest is not suitable for all forest lands or all ownerships. The forest change and scheduling model incorporated 20 percent extended rotation on state and federal forest lands, and more study is needed to determine if this is a sufficient amount to maintain Minnesota's biodiversity. The spatial distribution of extended rotation forest is also important; this is dealt with in mitigations 5.4 and 5.5.

Adoption of a formal extended rotation policy now will allow a substantial proportion of older forests to continue to exist as Minnesota undergoes transition from dominance of one age class to a uniform distribution of forest ages across the landscape.

The following rotations specified in the MNDNR draft guidelines are recommended:

Forest Type	Site Index	Extended Rotation Age
Jack Pine	50-60	60
Jack Pine	>60	70
Red Pine	55-65	120
Red Pine	>65	150
White Pine	55-65	150
White Pine	>65	180
Balsam Fir (upland, dry)	NA	60
Balsam Fir (transition, wet)	NA	70
Balsam Fir (swamp, wet)	NA	80
White Spruce	55-65	80
White Spruce	>65	100
White Cedar (mineral soil)	all	120-150
White cedar (organic soil)	>35	110-140
White Cedar (organic soil)	<35	130-160
Black spruce (mineral soil)	All	70
Black Spruce (organic soil)	>35	115
Black Spruce (organic soil)	<35	150
Tamarack (mineral soil)	All	70
Tamarack (organic soil)	>40	100
Tamarack (organic soil)	<40	120
Oak	50-60	120
Oak	>60	150
Black Ash	50-60	120
Black Ash	>60	130
Sugar Maple-Basswood	>60	120
Aspen	50-60	50
Aspen	>60	60
Paper Birch	50-60	60
Paper Birch	>60	80
Balsam Poplar	50-60	60

5.4
Mitigation: Connected Landscape

5.4.1
Extended Rotation Forest (ERF) Connected Landscape

A network of interconnected ERF or selectively cut buffers, corridors and larger areas of forest should be developed to the extent possible statewide.

Connectivity. Managers of forest lands should, on a cooperative basis among agencies, examine the spatial patterns of forest age classes within each ecoregion of the state. Core areas of old or old growth forest located in state parks, wilderness areas, wildlife areas, research natural areas and scientific and natural areas, should be linked by corridors of ERF-managed or selection cut forest (figure 5.1). In many cases, these networks could take advantage of riparian buffer zones, and/or be implemented by altering the spatial patterns of harvesting, rather than reduction of harvesting, on public forest lands. In some cases, private landowners may wish to participate by agreeing to alter the spatial pattern of harvest on their property. The more isolated a core forest area is from other forests, the more emphasis would be placed on establishing a connection to other forested areas. Southwest to northeast networks would be ideal, because they run parallel to Minnesota's major climatic gradient, however, it is a good idea to create linked networks of reserved areas and extended rotation forest wherever possible. The resulting landscape would be known as an *ERF-connected landscape*, and would closely resemble the Multiple Use Module (MUM) network of Noss and Harris (1986). Any one harvest within the ERF corridor should not extend more than one-half the corridor width. The ERF corridors would be quite wide—one-half to one mile (figure 5.1), so that if half was harvested the remaining half would still be wide enough to serve as a corridor.

5.4.2
Old Growth Buffers

Buffer zones around old growth islands within younger forests should be established, and specific management guidelines prescribed. Buffers should be a minimum of 300 feet in width, and managed under ERF guidelines, or by selection cutting. The purpose of the buffers is to reduce the edge effect that occurs when old growth is surrounded by open areas or by younger forest.

Buffers around old growth islands need not remove acreage from commercial timber harvest. Pie-shaped pieces of buffer could be harvested at intervals of two or more decades. Each harvest within the buffer zone should not affect more than one-fourth of the perimeter of the old growth core—with selection cutting recommended. It is recognized that strict rules would be difficult to implement or follow, thus flexibility to fit existing landscapes and situations is recommended. For example, note that presettlement old growth stands occasionally had heavy windstorms or fires that produced some edge effects. Therefore, if clearcutting was deemed the only feasible option for harvest within the buffer zone, it would be acceptable. Overall, the old growth core and buffer would resemble the long-rotation island concept of Harris (1984).

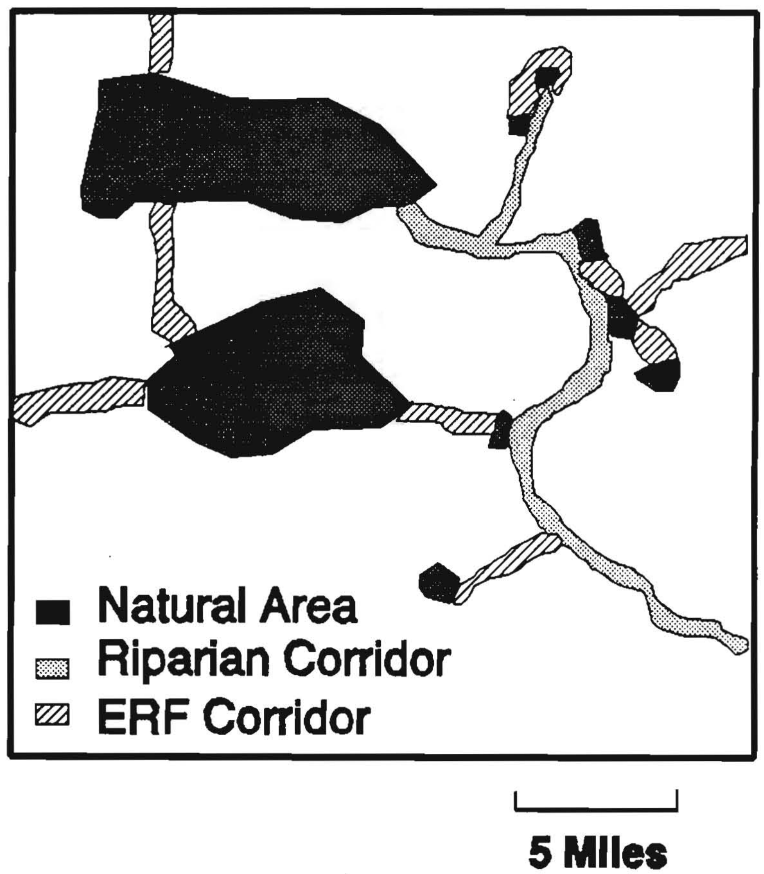


Figure 5.1. Hypothetical example of an ERF-connected landscape in which core natural areas are linked by riparian and/or ERF corridors.

5.5
Mitigation: Large Blocks of Mature Conifer Forest as Biodiversity Maintenance Areas

An area of at least 75 to 150 square miles in ecoregions 1, 3, and 4 should be managed as biodiversity maintenance areas, with a high proportion of mature conifer forest and large clearcuts. Mature conifer forests in large blocks would have little edge, and few permanent upland openings that are favorable to deer, and thus would harbor species and exhibit vegetation structure that are rare in areas with high deer populations. The large clearcuts would be 10,000 acres or more, but would follow BMPs and leave buffer zones along streams, and some standing trees and snags within the clearcut. This strategy would also mitigate impacts on the pine marten under the high scenario. If the ecoregions 1, 3 and 4 each had a 150 square mile biodiversity maintenance area, the total acreage would be 288,000, about 2 percent of all forest land in the state.

5.6
Mitigation: Prescribed Burning

Use of fire as a management tool to introduce disturbance into forest stands should be encouraged where this is feasible and meets management objectives.

Lack of disturbance is not necessarily best for all rare plants and plant communities. It should be emphasized that pristine forests were not all old stands: fires, wind-throw, and disease die-offs were a regular source of renewal. At any given time, those natural disturbances produced a mosaic of many different age classes, patch sizes and shapes, and species mixes, as is so well-documented by Heinselman (1973) for BWCAW forests.

Prescribed fire should be used to restore the following endangered or threatened community types:

1. Minnesota forest communities dependent on frequent fire. This includes savannas and woodlands, both dominated by the pines and the oaks. The major problem has been fire suppression which has allowed former savannas and woodlands to grow into dense forests.

2. Minnesota forest communities dependent on infrequent severe fires. This includes mixed oak forests, white and red pine forests, and pine-hardwood community types. Fire suppression has allowed many stands of these forest types to succeed to mesic hardwood forests.

Fire can also be used to control exotic species, competitive understory species, and insect infestations. Rather than working for removal or reduction of balsam fir, studies should be pursued on maintaining forests that are less susceptible to spruce budworm outbreaks. A key ecological and management issue here is judicious use of fire as a sanitizing agent in reducing prevalence of spruce budworm while protecting timber resources in those sites that are specified for harvest.

Prescribed fires are also recommended in oak forests of ecoregions 5 and 6, to help remove buckthorn, nonnative honeysuckle, and restore the functional aspects of former oak forests/savannas.

5.7
Mitigation: Return of Red and White Pine, and Upland White Cedar Forest

The state should undertake a 50 year program to expand red pine, white pine and upland white cedar covertypes. Compared to other covertypes, these covertypes have been disproportionally reduced in area as a result of harvesting. Recovery is unlikely unless future management is designed to favor these species.

White Pine can do very well when underplanted or seeded under aspen or paper birch covertypes. White pine is midtolerant of shade and the canopy prevents the formation of heavy dew in late summer—a factor that increases the risk of white pine blister rust when planted in the open in high hazard zones. One approach to increasing white pine would be to increase the white pine proportion within mixed-species aspen- or paper birch-dominated stands, by retaining at least two to four mature pines per acre to reseed the area after cutting. A second strategy would be to underplant a low density of white pine seedlings, which would be retained and become seed trees when the aspen or birch cover crop was harvested. This strategy would require careful monitoring due to the likelihood that deer browsing would kill the seedlings. A third strategy would be mixed-species plantations in areas where blister rust can be controlled. Both the seeding under aspen/paper birch and mixed-species planting could create fairly natural stands.

Red Pine can sometimes be established by natural seeding in seedtree cuts designed to favor the species. Plantations in mixture with other species should also be encouraged.

In the case of both red and white pine, the study group suggests examining Marschner's (1974) map of original forest vegetation to locate areas formerly occupied by pines and now occupied by birch or aspen. Because pines occupied these sites before, they may still be good sites for pines. In fact, local genetic races of red or white pines, as well as understory species that inhabited the original pine forests, may still be present.

Upland White Cedar will regenerate well under aspen or birch canopies in ecoregions 2, 3 and northern ecoregion 4. Regeneration strategies similar to those recommended for white pine—leaving seed trees during harvest, and seeding or planting to establish future seed trees—also work for white cedar. The major problem with white cedar regeneration is browsing by white-tailed deer, which favors cedar browse and cover during the winter.

5.8
Mitigation: Favor Tree Species Near the Edge of Their Range

Seed trees of species/ecoregions listed in table 4.6 should be left during harvest. If advance reproduction is present, use harvesting methods that will avoid damage to these stems. Regeneration of nearly all of the species benefit from scarification. The primary benefit of this strategy is to save genetic diversity among populations near the edge of the range which have adapted to the most extreme climate the species can tolerate.

5.9
Mitigation: Careful Use of Hybrid Trees and Exotics

Agencies should cease recommending all of the non-native honeysuckles and buckthorns for use in shelterbelts. The best strategy to avoid impacting biodiversity is to plan ahead and use hybrids or non-native tree species that meet one of the criteria from each of the following two lists:

1. Pollen production.
   a. Pollen biologically incompatible with native species.
   b. Pollen phenologically incompatible with native species, i.e., shed when native species are not flowering.
   c. Pollen not viable.
   d. Pollen travels only a short distance, or becomes nonviable quickly, and the non-native species are to be planted in an area geographically isolated from related native species.

2. Seed production.
   a. Produces nonviable seed, or is seedless.
   b. Produces seed that will not become successfully established in Minnesota's climate, even though adult trees are successful.
   c. Produces seedlings that are very poor competitors under natural forest conditions.

The major reason for careful use of hybrid and exotic species is to avoid future displacement of native species in forests, like that now occurring with purple loosestrife in wetlands.

5.10
Mitigation: Retain Conifers in Mixed Stands

Undertake research to develop alternative harvesting and silvicultural techniques that favor retention or replacement of conifers in aspen stands.

Given the current lack of information on successional patterns in the state's forests, it is prudent to use silvicultural and harvesting options that will insure a significant conifer component, especially in the aspen and paper birch covertypes.

5.11
Mitigation: Harvesting Near Imperiled Communities and Rare Species

Forest managers should attempt to maintain or increase coverage of imperiled types (those listed in table 4.5) and develop site-specific prescriptions to maintain populations of endangered, threatened or special concern plant species.

There are some rare tree species, which in the judgement of the study group, should be considered for listing as species of special concern. These include yellow oak, honeylocust, sycamore, and possibly striped maple.

Imperiled communities and rare species represent an important part of Minnesota's heritage and in general should be reserved from harvest, although without the inventory from mitigation 5.2, accidental harvest of occurrences of rare communities is likely. In some communities, harvesting may be consistent with the natural disturbance regime that perpetuated the community in presettlement times. In such cases, harvest may be acceptable, as long as silvicultural practices are adapted to the plant community needs. For example, maple-basswood in ecoregion 5 and 6 could be harvested by group selection, or extended rotation with clearcuts not removing more than a fourth of a given stand within one decade.

Harvesting could be combined with restoration efforts in some imperiled communities. In areas formerly occupied by savanna, harvests leaving scattered groups of oaks or jack pine, followed by prescribed burning would be appropriate.

5.12
Mitigation: Resolution of Conflicting Management Goals

The state should develop and promote integrated resource management training and guidelines for managers and policymakers. These guidelines should be coordinated among federal, state and county agencies.

In many cases, conservation of biodiversity is in conflict with other management goals, or different types of biodiversity are in conflict, on one land unit, usually at the township or community scale. The following section lists likely conflicts.

Management for:

Local versus regional biodiversity.

High regional diversity does not always follow from high local diversity. The reason is that each community has unique species or combinations of species. Black spruce forests have low small-scale diversity in terms of the number of species present, but many of the species do not occur in other forest types. Aspen forests are among the most diverse at the within-stand scale. An entire ecoregion covered with aspen would probably have more species per acre than an ecoregion covered entirely by any other forest type. However, the ecoregion as a whole would not have nearly as many species present as any of the current ecoregions of Minnesota.

Generalist versus specialist species.

Aspen, white-tailed deer and ruffed grouse are generalist species that do well following disturbance on many types of landscapes. Management to increase populations of these species adds nothing to regional biodiversity, since they are nearly always present already. However, specialist species, such as orchids that grow in black spruce forests, old growth associated species such as Lobaria lichens, and fire-dependent species of oak and pine savannas, are likely to add significantly to both local and regional biodiversity. It is often impossible to manage the forest for both generalist and specialist species on the same land unit.

Edge versus interior species.

The more fragmented a forest landscape is, the greater the proportion of forest will be within a few hundred yards of an edge. Fragmentation will lead to a corresponding shift in species composition away from interior species. Examples of edge species in Minnesota are wild roses, blackberries, and grapevines. Interior forest species are typified by eastern hemlock, and herbs such as sweet cicely and woodferns. Both groups of species should be present on the landscape, but fragmented landscapes and interior species cannot coexist on the same parcel of land.

Planting versus natural regeneration.

Planting a forest, for example red pine plantations, can cause an unnatural change in covertype. Populations of forest herbs can be seriously affected, or locally extirpated, by plantations. Forest herbs are often adapted to survive the successional sequence after natural fires or windstorms, but not the heavy manipulation and change in canopy type and density that occurs after planting.

Harvest versus natural disturbance.

Harvesting is similar to natural windstorms in its physical effects (except for soil compaction). However, in presettlement times, most of Minnesota's forests were burned at intervals depending on the soil, aspect, and species composition of the site. Now, almost all disturbance is harvesting. This change in disturbance type is sure to change the structure and species composition of Minnesota forests in ways that cannot yet be predicted. Harvesting would more closely mimic the natural disturbance regime in wetter regions, such as eastern Wisconsin and most of Michigan, where wind was originally the most common disturbance.

Forest health versus biodiversity.

Timber management attempts to clean up forest stands so that fungi that rot trees, and insects do not cause loss of productivity. Intensive management for timber productivity is acceptable, as long as other parts of the forest are allowed to be influenced by natural processes. This includes the entire food chain and interactions between species that are based on rotten, dead, and insect-infested trees.

6 PREFERRED MITIGATION STRATEGIES

A variety of strategies can mitigate against adverse impacts of timber harvesting. The final criteria document (Jaakko Pöyry Consulting, Inc. 1992a) describes how such strategies would be identified and selected. The identification of strategies is described in section 6, Potential Mitigation Measures to Address Identified Significant Impacts.

6.1 Framework for Analyzing Mitigations and Selecting Preferred Mitigation Strategies

Criteria for selecting strategies are drawn from the final criteria document noted above and reproduced below:

> Based on an analysis of mitigation alternatives identified, preferred mitigation strategies will be selected by considering in relative terms:
> 1. the effectiveness at mitigating the identified significant impacts;
> 2. the beneficial effects on other resource values;
> 3. the adverse effects on other resource values;
> 4. the physical, biological, administrative (implementation and oversight), financial (costs, public and private, direct and indirect), and social (ability to organize, support and effect implementation) feasibility; and
> 5. the probability of success and duration of success.

In practice, the verbal and written input from the Advisory Committee on the potential mitigation strategies led to acceptance, rejection and/or refinement of the potential strategies. These results were then approved by the EQB and comprise the strategies considered and evaluated in detail. Additionally, for this analysis the above criteria were grouped as follows:

1. *Effectiveness* addresses a mitigation strategy in terms of its ability to either avoid or reduce the identified impacts.

2. *Feasibility* addresses the likelihood that the mitigation strategy can be implemented, based on existing or future economic, social, biophysical, or administrative constraints.

3. *Duration* of mitigation can best be scored into four classes: 1=long-term—greater than 50 years; 2=medium-term—10 to 50 years; 3=short-term—2 to ten years; 4=very short-term—less than 2 years.

4. *Concomitant effects* refers to those strategies that have the potential to significantly affect other resources. It is clearly fallacious to consider that any forest management practice will only affect a single resource; forests are intricately interacting ecosystems, and each practice affects many resources.

5. *Probability of success*, though not tabulated explicitly in the following tables, is a combination of effectiveness, feasibility and duration with minimal negative concomitant effects. The strategies identified as highly effective, highly feasible, of long duration and with minimal negative concomitant effects are assumed to have the greatest chance of success in the long-run.

These criteria were then applied to the various mitigation strategies for the purpose of comparison among them and to help determine preferred mitigation strategies.

6.2 Evaluation of Mitigation Strategies

Maintenance of biodiversity in managed forests is a very complex process, often with several mitigations necessary for a single impact, and multiple effects of each mitigation. A summary of the significant impacts, and effectiveness of each strategy, as judged by the study group (table 6.1) provides a useful starting before evaluating the feasibility of each mitigation (table 6.2).

Table 6.1. Effectiveness of mitigation strategies relevant to each significant impact, from 1=high to 3=low. Empty box= little or no effect.

Significant Impact	Mitigation										
	5.2	5.3	5.4	5.5	5.6	5.7	5.8	5.9	5.10	5.11	5.12
Decline of old growth swamp conifer forest	1	2	2	1							1
Likely decline of hemlock, yellow oak, honeylocust, sycamore, Kentucky coffeetree and rock elm	1	1								1	
Potential loss of conifers in mixed-species stands		1				1			1		3
Decline of tree species near the range edge	1	1	1	2	3		1			2	2
Decline of rare communities	1			2	1	1	3			2	2
Effects of fragmentation on forest herbs	3	2	1	2							3
Effects of fragmentation during climate change		3	1								2
Deer browsing	3			1							1
Potential displacement of native species by hybrids								1			1
Decline of rare plants species	1	1	1	2	1	1	3	3	3	1	3
Decline of red-shouldered hawk	1	1	1	3							
Decline of Pine marten	1	1	1	1					1		

Key for tables 6.1 and 6.2:

Mitigation:
- 5.2 Inventory
- 5.3 Extended Rotation Forest
- 5.4 Connected Landscape
- 5.5 Biodiversity Maintenance Areas
- 5.6 Prescribed Burning
- 5.7 Return of Red and White Pines, and Upland White Cedar
- 5.8 Favor Tree Species Near the Edge of Their Range
- 5.9 Careful Use of Exotics and Hybrids
- 5.10 Retain Conifers in Mixed-Species Stands
- 5.11 Careful Harvest Near Rare Species and Communities
- 5.12 Resolution of Conflicting Management Goals

Table 6.2. Evaluation of mitigation strategies for minimizing negative impacts of timber harvesting in biodiversity. Number of impacts mitigated shows how many of the total 13 potential negative impacts identified above would be helped by each strategy. The number of impacts highly mitigated is the number of impacts that received a 1 in table 6.1. Feasibility is ranked from 1=high to 3=low, and for duration from 1=long to 4=very short term. Rankings apply only to those impacts indicated in table 6.1. Concomitant effects refers to potential positive (+) or negative (-) effects on issues of concern from the FSD, other than those considered in this paper (genetic variability, biodiversity, old growth and old forests, endangered, threatened and special concern species). Blank means no significant concomitant effects expected.

Mitigation Strategy	# Impacts Mitigated/ highly mitigated	Feasibility Physical/Administrative/ Financial			Duration	Concomitant Effects
5.2	9/7	1	1	2	2	Forest Wildlife (+)
5.3	9/6	1	1	1	1	Recreation, Esthetics (+), Forest Health (-)
5.4	7/6	2	2	2	1	Forest Wildlife (+)
5.5	8/3	2	3	1	1	
5.6	3/2	2	2	2	1	Forest Wildlife (+)
5.7	3/3	1	2	3	1	Forest Wildlife, Recreation and Esthetics (+)
5.8	3/1	1	1	2	1	
5.9	2/1	1	1	1	1	
5.10	3/2	2	1	2	1	
5.11	4/2	1	2	2	1	
5.12	9/3	1	3	1	3	

Explanation of the ranks for these mitigations are as follows:

Inventory (5.2) is probably the most effective overall strategy at this time, because there is a need to simply identify occurrences of rare species and communities, and old growth so that forest managers can adapt harvest plans. Not all points on the landscape are equally important to protection of biodiversity. For example, small temporary wet areas within forests or stands used as stopovers by migratory song birds may contribute resources necessary for survival of many species at key times. Such natural features need to be inventoried. In the absence of complete inventory in the state's northern forest lands, many effects of harvesting on rare species and communities will be due to accidental harvest of sensitive areas. A complete inventory of biodiversity features of the state's forests would require a substantial investment of time and money over the next decade. Inventory alone is not sufficient to protect biodiversity; there need to be guidelines for management of rare features identified by inventory. However, inventory is the *starting point for protection of biodiversity.*

Optimizing timber harvest while guaranteeing preservation of statewide biodiversity requires, without question, uniform statewide information on existing and previous biota, without regard to current land ownership or jurisdiction. If the presence of a species or a whole biotic community is an objective of long-range planning within our state, then the current geographic status of those entities becomes a prerequisite to any planning strategies, to say nothing of implementation, however that may be directed.

Extended Rotation Forests (5.3) are effective overall because they directly help mitigate a large number of potential effects of harvesting on biodiversity. Extended rotation forests do not remove lands from the timberland base, yet they help provide many of the features of old growth forests over relatively large areas. The second run harvesting scenarios included 20 percent extended rotation forest on state and federal lands, and showed that a high yield of timber and pulpwood is still possible.

Generally, with increasing intensity of forest harvest, there is increased short-circuiting of plant succession and the development of structural diversity. Extended rotation forests assure the continued presence of large tree gaps, dead wood, and the species that depend on them, without being designated old growth and removed from the base of timberland. Extended rotations can mimic the natural rotation period for Minnesota forests more closely. Intensive management, with shorter rotations, is compatible with biodiversity, as long as other portions of the landscape are managed with extended rotations.

Connected Landscapes (5.4) are very effective at reducing the effects of fragmentation, without reserving large contiguous blocks of forest. They can be achieved by changing the spatial pattern of harvest, not the amount of harvest. However, it would be difficult to work out plans for the corridors, which would require interagency cooperation. The connected forest corridors would be managed under extended rotation forest guidelines, and would count as part of the recommended ERF forest percentage in the state.

By creating corridors for plant and animal species migration, this strategy would be the most cost effective way of allowing Minnesota's forest to respond to future climate change. Genetic variation in Minnesota generally occurs along a cline correlated with climate, from southwest to northeast. It is important not to disrupt the genetic spatial structure of forest trees by harvesting. Paleoecology shows that the climate has always been changing and this will continue, whether or not human-caused global warming occurs.

Tree populations must be able to respond to changing climate, and gene flow and seed movement should be allowed to occur from southwest to northeast. Also, in all ecoregions except the border lakes (ecoregion 2), old growth forests are probably too isolated to allow exchange of genetic material among old growth species.

Biodiversity Maintenance Areas (5.5) in Minnesota's northern conifer forests are very effective at reducing effects of fragmentation, by providing examples of a landscape that is managed for timber harvest, but with a natural spatial pattern. This means very large clearcuts to mimic the largest size (> 10,000 acres) of natural disturbances in Minnesota. Administrative and physical feasibility of these large clearcuts is moderate to low, because a large area within one administrative unit would have to be dedicated permanently to a biodiversity maintenance area. However, the financial feasibility is high because the mature forests within the area count as part of the total extended rotation forest in the state.

Reduction of deer browsing and grazing in biodiversity maintenance areas will allow combinations of species, interactions among species, and physiognomic structure of the forest to develop as they would under natural conditions. Conditions of low deer numbers already exist in the BWCAW, so that a biodiversity maintenance area is not necessary in ecoregion 2. Other suitable areas with low deer numbers may also exist and be revealed if mitigation 5.2 is carried out.

Prescribed Burning (5.6) is very effective for mitigating two impacts: the loss of rare fire dependent communities and the rare species that live in them. The physical feasibility varies a lot within the state, but is high in remote areas and low in heavily populated areas where there is potential liability for escaped fires. Financial feasibility is moderately low because prescribed burning is labor intensive with little or no gain in timber production results.

Return of Red and White Pines and Upland White Cedar (5.7). Many people would like to see more red and white pine on the landscape. The strategy outlined in the introduction for stopping the loss of biodiversity is to maintain the natural function of the forest landscape, including the balance of covertypes. It is difficult for the forest landscape of Minnesota to function naturally when a covertype once occupying 3.5 million acres now occupies only slightly over 400,000 acres. The physical feasibility for restoring these species is very high—there is a lot of suitable aspen forest within which the conifer component could be increased. However, the financial feasibility for replanting is low (about $127.00/acre), unless the species are restored by leaving individuals of currently existing seed sources during harvest.

Favor Tree Species Near the Edge of Their Range (5.8). Trees that are near the edge of their range are often poor competitors against other species that are in optimal habitat. To maintain their populations in the state, they should be retained in forest management—except in cases where it is known that their populations are stable or increasing.

The feasibility of this strategy is high because guidelines for leaving seed trees of the affected species/regions is all that is required.

Careful Use of Exotic and Hybrid Tree Species (5.9) will be very effective in preventing future loss of biodiversity due to displacement of native species by exotics. The physical, financial and administrative feasibilities are all high because this is a preventative strategy. Currently there is not a widespread problem. All that is required is development of guidelines for future purchases of exotic and hybrid stock.

Retain Conifers in Mixed-Species Stands (5.10). This strategy would be very effective in reducing the potential biodiversity effects of having a large proportion of the state or one ecoregion in one covertype, such as aspen. A substantial conifer component allows aspen stands to be used by many wildlife species and plants. Administrative feasibility is high, but economic feasibility is only moderately high because there would be some reduction in the amount of aspen pulpwood harvested per acre.

Careful Harvest Near Rare Species and Communities (5.11) is extremely effective at mitigating impacts of harvest on biodiversity. It is necessary in the case of most endangered, threatened or special concern species. The physical feasibility is high, but administrative and economic feasibility is only moderate because some the large number of species and communities would require many guidelines and some potential timber harvest would be lost.

Resolution of Conflicting Management Goals (5.12) would help managers look at biodiversity in a landscape context, rather than on a species-by-species basis. The most effective part of the strategy would be that it would help managers plan harvests to avoid future conflicts. Resolution of conflicting management goals is physically very feasible, and does not cost much since most managers are already involved with planning and continuing their education throughout their career.

Preferred Mitigations

Inventory of significant biodiversity features within Minnesota's forest lands, combined with a permanently ERF-connected landscape, restoration and retention of conifer cover, and careful harvesting near rare communities and plant species would appear to be the combination most suited to overall protection of biodiversity statewide. This combination has some positive ameliorative effect on all significant impacts of harvesting identified, except the potential effect of exotic and hybrid species. The main disadvantage is the physical and administrative difficulty of establishing a connected landscape. This is because these mitigations would have to be heavily concentrated on public forest lands, which may not always have the spatial extent or complex of communities needed. Also, all public agencies as well as interested private landowners would have to coordinate their efforts to an unprecedented degree. However, reducing fragmentation is biologically of overwhelming importance.

All of the mitigation strategies identified by the study group will be useful under some circumstances. The last strategy—resolution of conflicting management goals—would be the most useful way to develop a policy to determine when each mitigation should be applied.

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APPENDIX A - Scientific and Common Names

Trees:

Abies balsamea	balsam fir
Acer negundo	box elder
Acer nigrum	black maple
Acer rubrum	red maple
Acer pennsylvanicum	striped maple
Acer saccharinum	silver maple
Acer saccharum	sugar maple
Acer spicatum	mountain maple
Betula alleghaniensis	yellow birch
Betula cordifolia	heart-leaved birch
Betula papyrifera	paper birch
Carpinus caroliniana	blue beech
Carys cordiformis	bitternut hickory
Carya ovata	shagbark hickory
Celtis occidentalis	hackberry
Fraxinus americana	white ash
Fraxinus nigra	black ash
Fraxinus pensylvanica	green ash
Gleditsia triacanthos	honey locust
Gymnocladus dioicus	Kentucky coffeetree
Juglans cinerea	butternut
Juglans nigra	black walnut
Juniperus virginana	eastern red cedar
Larix laricina	tamarack
Ostrya virginiana	Ironwood
Picea glauca	white spruce
Picea mariana	black spruce
Pinus banksiana	jack pine
Pinus resinosa	red pine
Pinus strobus	white pine
Platanus occidentalis	American sycamore
Prunus pennsylvanica	pin cherry
Prunus serotina	black cherry
Prunus ssp.	wild plum
Populus balsamifera	balsam poplar
Populus deltoides	cottonwood
Populus grandidentata	bigtooth aspen
Populus tremuloides	quaking aspen
Quercus alba	white oak
Quercus ellipsoidalis	northern pin oak
Quercus macrocarpa	bur oak
Quercus muhlenbergii	chestnut oak

Quercus rubra . . . . northern red oak
Quercus velutina . . . . black oak
Salix nigra . . . . black willow
Tilia americana . . . . basswood
Tsuga canadensis . . . . eastern hemlock
Ulmus americana . . . . American elm
Ulmus rubra . . . . slippery elm
Ulmus thomasii . . . . rock elm

JAAKKO PÖYRY

JAAKKO PÖYRY CONSULTING, INC.

November 20, 1992

Dr. Michael Kilgore
GEIS Project Manager
Minnesota Planning Office
300 Centennial Office Building
658 Cedar Street
St. Paul, MN 55155

Dear Dr. Kilgore:

Attached are the peer review comments for the Biodiversity Technical Paper. The reviewers were:

- Mr. Steve Chaplin - The Nature Conservancy
- Dr. Thomas R. Crow - USDA Forestry Sciences Laboratory
- Dr. Malcolm Hunter - University of Maine

Also attached is a description of how our GEIS Study Team has responded to the peer reviews for this Technical Paper. Should you have any questions or comments, please advise me.

Respectfully yours,

James A. McNutt
Executive Vice President
and GEIS Project Manager

cc: Doug Parsonson
Alan Ek
Bob Dunn
Advisory Committee Members

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The Nature Conservancy

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November 10, 1992

Dr. James A. McNutt
Executive Vice President and
GEIS Project Manager
5510 Six Forks Road
Raleigh, NC 27609

Dear Dr. McNutt:

Enclosed is my formal review of the Biodiversity technical paper, a work product completed in conjunction with the Minnesota Generic Environmental Impact Study.

My submission of this review does not place me under any obligations, legal or otherwise, to the State of Minnesota or Jaakko Poyry Consulting, Inc. on matters pertaining to the GEIS work and end product.

Furthermore, I recognize that this review will become part of the public records of the State of Minnesota, as related to the GEIS project.

Sincerely,

Stephen J. Chaplin

Dr. Stephen J. Chaplin

cc: Dr. Michael Kilgore
State of Minnesota

MINNESOTA GENERIC ENVIRONMENTAL IMPACT STUDY

TECHNICAL PAPER REVIEW SYNOPSIS FORM

Biodiversity
Technical Paper Title

Reviewer details:

Name: Dr. Stephen J. Chaplin

Date Received: November 2, 1992

Title/Position: Midwest Director of Science

Due Date: November 9, 1992

Address: The Nature Conservancy
1313 Fifth St. S.E.
Minneapolis, MN 55414

Paper Component	Rating (circle one)					
Literature review	(1)	2	3	4	5	6
Evaluation of Existing Environment/Conditions	1	(2)	3	4	5	6
Significant Impacts - Assessment Methodology	1	(2)	3	4	5	6
Significant Impacts - Assessment Results	(1)	2	3	4	5	6
Mitigation Measures - Appropriateness	(1)	2	3	4	5	6
Mitigation Measures - Utility	(1)	2	3	4	5	6
Overall Technical Quality	(1)	2	3	4	5	6

Rating System

Adequate, no changes needed	1	
Some concern(s), no changes needed	2	(see attachment)
Moderate concern(s), some changes needed	3	(see attachment)
Major concerns, significant changes needed	4	(see attachment)
No comments	5	
Comments not required	6	

Reviewed by: Stephen J. Chaplin

Date: November 9, 1992

Biodiversity Technical Paper Review - Chaplin

There are a number of issues that I feel should be included or reexamined in the final draft of the biodiversity technical paper for the GEIS. They are as follows:

1. The approach of using natural biotic communities as the unit to organize biological conservation is a logical choice given the state of knowledge about many species and the complexity of natural systems. Ultimately, however, the species is the unit which must be used to insure that biological diversity does not decline. The species is the unit of biological evolution and is the repository of genetic diversity. Although we are not capable of dealing with all biological diversity at the species level now, we should use available knowledge to complement the community approach. Such a "coarse filter/fine filter" approach is essential because rare species are not always reliably associated with a given community type and certainly not a given occurrence of a community type. In addition, natural communities are largely human perceptions of divisions within continuous vegetational gradients. Conservation activities focused on natural communities often try to protect good examples of the modal types of each community, i.e. the example that "best" represents the type. Examples which represent the transition from one community type to the next often are not included in conservation planning and consequently the rare species associated with these ecotonal types may also be missed. Efforts to maintain the full range of biodiversity demand a species approach, where knowledge is available, to protect those species not adequately covered by a community approach. The technical paper largely uses this approach in 4.6.2 (page 80) but underemphasizes the species approach earlier (1.3.1, page 3).

2. The impact of timber removal on nutrient cycling is mentioned in several places (e.g. pages 6 and 94) but the problem of nutrient removal from the ecosystem when logs are transported away is not addressed. Especially in nutrient-poor habitats, a substantial portion of the available nutrients in the system may be stored in the 'wood' pool. Clearcutting may not mimic windthrow (page 94) at all in a nutrient dynamics sense because following windthrows, nutrients incorporated in the tree trunks will be released back to the site after decomposition. What effect nutrient impoverishment will have on the speed and nature of succession or the survival of rare species is probably difficult to determine but should probably be discussed as a possibility.

3. Functional diversity is discussed in 1.3.2 but hardly mentioned again. It is a difficult topic but there are a few things that could be done to mitigate some of the cumulative effects of timber harvest on functional diversity. Not all geographic places are equally important to biotic richness and diversity. For example, certain places such as critical migratory stopover sites, springs, salt licks, and some wetlands may be very important in maintaining large healthy populations of animals by supplying key nutrient, energy, or other resources in large amounts at key times. These places are scattered across the landscape and may be of limited areal extent, but play an inordinate role in maintaining the biotic richness of a region. Such critical functional diversity sites should be inventoried and protected.

4. Two other reasons for maintaining biodiversity might be included in 1.3.5. First, in a changing environment, today's rare species might become tomorrow's dominant. Natural communities as defined by today's dominants might be completely different in the future. Different combinations of species apparently have occurred in the past and at least some scientists suggest that novel combinations of species may await us in a world changed by global warming. Maintaining today's rare and uncommon species throughout their range may insure a viable forest under future conditions. A second reason to maintain rare species is our lack of knowledge about what role rare species play in ecosystem function. Ecosystems are so complex that it is likely we understand only a small fraction of the critical links in nutrient, energy or resource flow. It is also likely that some rare species play important roles in the functioning of the systems. Whether there are functional replacements for species undergoing local extirpation won't be known until after the extirpation occurs.

5. Public lands will play the key role in maintaining regional biodiversity in Minnesota (see 4.2.1). Although private lands can contribute greatly to biodiversity protection, public lands will have to provide all the parts of the biodiversity maintenance mix which can not be provided for on private lands. This means that those natural communities, species, old growth stands, etc. that are not adequately represented or protected on private lands must be dealt with on public lands even if that means that biodiversity protection activities will be more concentrated there than they would be if the entire land base could be treated equally with regard to biodiversity protection.

6. A comprehensive inventory is clearly the first step in mitigating timber harvest in specific but in all conservation planning as well. The MNDNR County Biological Survey has started this job and has the data system in place to manage the information. Further inventory should be an expansion of their work, not merely modeled after it as suggested in 5.2. In addition, agencies should coordinate efforts, but the example of the USDA Forest Service is incorrect. The Forest Species of Concern List as created in each Forest Plan should correspond to the state list of endangered, threatened, and special concern species. The Regional Forester's Sensitive Species List, however, is a multi-state list created at the USFS Regional level (Region 9 in this case) which includes only those species that are globally vulnerable. Species which are vulnerable in Minnesota but are doing well elsewhere would not automatically qualify for the Regional Sensitive Species list.

The Following Details the Responses to the Review
Forwarded by Steve Chaplin

The reviewer chose to circle all 1s and 2s on the Jaakko Pöyry evaluation form, with 1 indicating adequate with no changes needed, and 2 indicating some concern, but no changes needed. Therefore, the author did not interpret any of the following changes as necessary for the quality of the paper, but rather as optional fine tuning on his part.

Point 1:

The community versus the species approach to maintaining biodiversity issue was raised by the reviewer. The reviewer wants to emphasize that both the species approach and community approach are necessary, and that the author has adopted the community approach almost exclusively. The author agrees with the reviewer that both approaches are necessary. However, laws relating to endangered and threatened species mandate using a species approach for those species that are listed. The author's point is that managing for communities will prevent a lot of species from declining to the point of inclusion on the endangered/threatened list.

Changes made in the document: Paragraph 5 of section 1.3.1 ("The Biodiversity Issue") was reworded to reflect a better balance between species and community approaches.

Point 2:

Timber removal has important effects on nutrient cycling, which are not addressed in the biodiversity paper. The author believes that this is a marginal issue for biodiversity *per se*. This is more of an issue for the forest Soils Paper and for long-term sustainability of productivity.

Changes made in the document: none

Point 3:

Functional diversity is not mentioned after the introductory parts of the paper, especially as related to the critical nature of certain tracts of land that provide key resources at key times, such as for migratory species. The author agrees with the reviewer that this should be mentioned in more than one place.

Changes made in the document: A new statement is included about the need to inventory sites that serve critical functional needs of species in section 6.2 under the discussion of effectiveness of the inventory mitigation strategy.

Point 4:

There are two other reasons for maintaining biodiversity that could be mentioned in section 1.3.5. First, today's rare species may become a dominant under a changing environment. The author agrees with this, although in his opinion, reason 1 under section 1.3.5 already addresses this. Second, we currently have a lack of knowledge of the functional role that many rare species may play in ecosystem maintenance, and will not know what is being lost until it is too late.

Changes made in the document: Reason 1 in section 1.3.5 has been reworded to make the point about rare species today becoming tomorrow's dominant more obvious. The point about rare species playing unknown functional roles has been added as a separate reason to preserve biodiversity in section 1.3.5.

Point 5:

Public lands will play a key role in maintaining biodiversity in Minnesota forests -- most mitigation strategies will be heavily concentrated there. This is already mentioned in section 5 under mitigation strategies 5.3 and 5.4.

Changes made in the document: A statement was added under the preferred mitigation subtitle at the end of the paper about the role of public forests.

Point 6:

Future inventory of biological features of Minnesota forests should be an expansion of the MNDNR County Biological Survey, rather than modeled after it. Having thought about this since the paper was written, the author tends to agree.

Changes made in the document: Mitigation strategy 5.2 has been reworded to say that the County Biological Survey should be expanded quickly to cover forested parts of the state. The incorrect example the reviewer pointed out has been deleted.

After review by the Advisory Committee, please advise me if there are any significant issues you regard as outstanding. In the absence of such, this paper will be submitted to the EQB for formal approval.

Yours sincerely,

James A. McNutt
Executive Vice President
and GEIS Project Manager
November 20, 1992

United States Department of Agriculture
Forest Service
Forestry Sciences Laboratory
P.O. Box 898
Rhinelander, WI 54501
715-362-7474

Reply to: 2070

Date: November 12, 1992

Dr. James A. McNutt
Executive Vice President and
GEIS Project Manager
5510 Six Forks Road
Raleigh, NC 27609

Dear Dr. McNutt:

Enclosed is my formal review of the technical paper titled "Biodiversity", a work product completed in conjunction with the Minnesota Generic Environmental Impact Study.

My submission of this review does not place me under any obligations, legal or otherwise, to the State of Minnesota or Jaakko Poyry Consulting, Inc. on matters pertaining to the GEIS work and end product.

Furthermore, I recognize that this review will become part of the public records of the State of Minnesota, as related to the GEIS project.

Respectfully yours,

Thomas R Crow

THOMAS R. CROW
Project Leader

cc: Dr. Michael Kilgore
State of Minnesota

MINNESOTA GENERIC ENVIRONMENTAL IMPACT STUDY

TECHNICAL PAPER REVIEW SYNOPSIS FORM

Biodiversity
Technical Paper Title

Reviewer details:

Name: Thomas R. Crow — Date Received: ______

Title/Position: Project Leader — Due Date: ______
Address: North Central Forest Exp. Stn.
P.O. Box 898
Rhinelander, WI 54501

Paper Component	Rating (circle one)					
Literature review	1	2	(3)	4	5	6
Evaluation of Existing Environment/Conditions	1	(2)	3	4	5	6
Significant Impacts - Assessment Methodology	1	(2)	3	4	5	6
Significant Impacts - Assessment Results	(1)	2	3	4	5	6
Mitigation Measures - Appropriateness	1	(2)	3	4	5	6
Mitigation Measures - Utility	1	(2)	3	4	5	6
Overall Technical Quality	(1)	2	3	4	5	6

Rating System

Adequate, no changes needed	1	
Some concern(s), no changes needed	2	(see attachment)
Moderate concern(s), some changes needed	3	(see attachment)
Major concerns, significant changes needed	4	(see attachment)
No comments	5	
Comments not required	6	

Reviewed by: Thomas R Crow — Date: 11/12/92

Literature Review

The following are a few additional references that might be useful for this technical paper.

Johnson, W.C. 1988. Estimating dispersibility of Acer, Fraxinus and Tilia in fragmented landscapes from patterns of seedling establishment. Landscape Ecology 1: 175-187.

The relative dispersibility of Tilia, Acer, and Fraxinus is compared. Johnson concluded that forest patches isolated from seed sources by several hundred meters or more should have extremely low inputs of these wind dispersed species, especially Tilia and Acer.

Whitney, G.G. and W.J. Somerlot. 1985. A case study of woodland continuity and change in the American midwest. Biol. Conserv. 31: 265-287.

Authors make the point that fragmentation of forests into woodlots has resulted in the loss of few of the arboreal species, but the relative abundance of the more common species has shifted significantly. Site and history have created a unique temporal mosaic of species and successional patterns.

Noss, R.F. and L.D. Harris. 1986. Nodes, networks, and MUMs: preserving diversity at all scales. Environm. Manage. 10: 299-309.

Noss and Harris present an interesting concept for spatial design based on the intensity of management. This concept is consistent with many of the recommendations made in your technical paper.

Knowles, P. 1991. Spatial genetic structure within two natural stands of black spruce (Picea mariana (Mill.) B.S.P.). Silvae Genetica 40: 13-19.

Knowles, P., D.J. Perry, and H.A. Foster. 1992. Spatial genetic structure in two tamarack (Larix laricina (Du Roi)K. Koch) populations with different establishment histories. Evolution 46: 572-576.

Ledig, F.T. 1986. Conservation strategies for forest gene resources. Forest Ecology and Management 14: 77-90.

Namkoong, G. 1982. The management of genetic resources: a neglected problem in environmental ethics. Environm. Ethics 4: 377-378.

Namkoong, G. 1991. Maintaining genetic diversity in breeding for resistance in forest trees. Annu. Rev. Phytopathol. 29: 325-342.

McCune, B. 1988. Ecological diversity in North American pines. Amer. J. Bot. 75: 353-368.

These sources provide additional information that can be reported in the section on genetic diversity of forest trees (2.3.1). The references for black spruce and tamarack present information about the genetic structure at small spatial scales (stand level).

Evaluation of Existing Environment/Conditions

Your have done a very good job in describing the historic context and current conditions for forests in Minnesota. My only recommendation here is to consider using maps of presettlement vegetation and current vegetation developed for the Lake States by Forest Stearns. These maps provide a visual means for understanding the changes in the extent and composition of the forest since European settlement. They also provide the broader Lake States context in which Minnesota's forests exist.

Page 8 - "Clearcutting is similar to catastrophic windthrow..." I am not sure that I agree with this statement. Clearcutting removes a large portion of the total carbon from the site; carbon remains on site with windthrow. The importance of carbon in long-term site productivity is significant.

Page 8 - Indirect Effects - Fragmentation - A more comprehensive description of fragmentation might be desirable given its importance to the discussion of biological diversity. Fragmentation is simply the disruption of continuity. Important attributes of fragments include density, isolation, size, shape, aggregation, and boundary characteristics. In addition to small size and edge, other potential effects of fragmentation include isolation and increased vulnerability to extrinsic disturbances. A good review article on this topic is: Saunders, D.A., R.J. Hobbs, and C.R. Margules. 1991. Biological consequences of ecosystem fragmentation: a review. Conservation Biology 5: 18-32.

I am glad to see the emphasis on within forest fragmentation on page 10. As noted, this type of fragmentation is relevant to densely forested landscapes such as those in northern Minnesota, but has received relatively little attention in the literature. The Mladenoff et al. (1992) study showed that differences in patch size distributions were evident in comparing an old-growth landscape to a second-growth landscape. A few large patches were the dominant matrix feature in the old-growth landscape and these patches were the integrating (linkages) feature. Large patches were missing in second-growth landscape. The second-growth landscape was more fragmented.

Section 1.3.5 - Value of biodiversity - We tend not to value diversity unless it has human utility. This, in fact, is the reason why biological diversity is in trouble. Your section on value is strongly orientated toward the commodity and amenity values of biological diversity. There are intrinsic and moral values as well that merit attention.

Page 16 and Figure 1.1 - Ecoregions of Minnesota - While this work was "commissioned" by the Upper Great Lakes Biodiversity Committee, the project was funded by the North Central Forest Experiment Station and the work conducted by Dennis Albert. An appropriate citation is:

Albert, D. 1993. Ecoregion map and classification of Michigan, Minnesota, and Wisconsin. General Technical Report. USDA Forest Service, North Central Forest Experiment Station, St. Paul, MN.

Page 26 - Floodplain forests - A management guide is available for lowland forests dominated by black ash. The guide calls for no management on areas with a site index < 45 and single-tree selection in stands along streams and lakes. See: Erdmann et al. 1987. Managing black ash in the Lake States. USDA Forest Service General Technical Report NC-115. 10 p.

<u>Significant Impacts - Assessment Methodology</u>

Again, a good job of identifying and stating the limitations, assumptions, and caveats associated with the assessment. My concerns here are rather minor.

Page 51 - "....a qualitative table of susceptibility to fragmentation by trees and herbaceous plants was compiled." Unless I missed it, this table is not presented in your report. Why not include it?

Page 54 - "...model of growth and harvest..." I assume that this model is presented elsewhere in detail. It might be useful to at least present a brief description of the model in your technical report as well.

<u>Significant Impacts - Assessment Results</u>

Page 56 - Significant Impacts Criteria - Along with severity and spatial extent of impact, I would add frequency as an important factor to determine levels or thresholds when impacts are likely to be considered significant.

<u>Mitigation Measures - Appropriateness/Utility</u>

Some additional mitigation measures come to mind. They include: monitoring linked with adaptive management; alternative silvicultural approaches that maintain structural, compositional, and functional diversity; mechanisms to increase coordination and cooperation among ownerships; ecosystem management.

Among the items on this list, perhaps the most important is the concept of adaptive management. Because of lack of information and uncertainty associated with implementing the mitigation measures, linking monitoring to management is critical. Monitoring should be hypothesis driven to focus the collection of information relative to perceived problems. As new information is derived from both research and monitoring, adjustments are made in management practices and goals. (See Walters. 1986. Adaptive management of renewable resources. McGraw-Hill, New York.)

Alternative silvicultural approaches are briefly mentioned under retaining conifers in mixed stands (5.10), but this is a rich topic that could be explored in greater detail.

Many of the mitigation measures rely on a broader, contextual view of natural resource management. In order for this approach to be successful, a greater level of coordination among various ownerships is vital. Obviously, administrative boundaries and organizational structures are barriers to implementing a broad, landscape approach to resource management. In addition, there are concerns about private property rights. Possible mechanisms for coordination may be beyond the scope of this technical report; however, the need for coordination should receive greater emphasis.

Concerns about biological diversity are part of a larger concern about managing ecosystems. Resource managers need to move from managing a portion of the ecosystem, e.g., commercial trees and game species, to managing the whole the includes these important components. At present, a lack of a shared problem definition and consequently the lack of a common understanding of what ecosystem management is represents a major obstacle to its implantation.

Technical Quality

Overall, this is the most comprehensive assessment of biological diversity and its relation to resource management that I have seen. In my opinion, the framework for analyzing mitigations is sound given our current state of knowledge. Credit is due to Lee Frelich and those who helped him prepare this report.

Thomas R Crow

Thomas R. Crow

Date: 11/12/92

The Following Details the Responses to the Review
Forwarded by Thomas Crow

The substantial reviewer responses in subject areas market as 1s and 2s on the evaluation form were responded to only as the author deemed that the paper quality would be enhanced.

Literature Review

Nine additional references are given along with some suggestions on how they would be used in section 1 and 2 of the biodiversity paper. Six of these references (those by Namkoong, Johnson, Ledig, McCune, and Whitney) had been examined while the paper was being prepared. In the author's opinion, these references did not contribute to the points he was trying to make. The literature review strategy was to cite only references that are most relevant and of the highest quality, rather than citing all references comprehensively. The author spent a lot of time reading as many references as possible before deciding which to cite. After receiving the review, the author read the papers by Knowles on genetic structure of tamarack and black spruce forests of different origins, and decided they do not fit the level of detail and audience intended for the biodiversity paper. The over-riding point here is to show that there is a decline in regional genetic structure from southwest to northeast. The papers by Knowles provides more detail on genetic structure than is intended for the biodiversity paper.

The reviewer does give one reference which helps strengthen the points about connected landscapes made in the paper; this is the one by Noss and Harris (1986).

***Changes made in the document*:** Mitigation 5.4 has been reworded to refer to the multiple use module (MUM) concept of Noss and Harris, which is very similar to the proposed ERF-connected landscape proposed in the biodiversity paper. A new figure (5.1) has been drawn to made the description of the ERF-connected clearer.

Evaluation of Existing Environment

1. Use of the maps of pre-settlement vegetation by Forest Stearns was suggested by the reviewer. These maps do a good job of showing the overall context in change in the Lake States. However, some of the forest types recognized by the Stearns maps do not agree with the types analyzed in the comparison of pre-settlement with current vegetation of Minnesota. There are already three different typing systems discussed in the paper; the FIA, the Pre-settlement types from Marschner and the MNDNR Natural Heritage types. Using the Stearns maps would cause more confusion in an already complex situation. The map of pre-settlement vegetation currently in the paper is much more consistent in typing with the data actually presented.

***Changes made in the document*:** none

2. *Page 8*: The reviewer points out that clear-cutting is not totally analogous with natural windthrow. The author agrees.

Changes made in the document: The paragraph in question has been reworded to make clear that clear-cutting has physical similarities, but does not necessarily mimic the carbon storage and nutrient dynamics of windthrow.

3. *Page 8*: The reviewer would like to see a more extensive discussion of fragmentation. However, the discussion is already 1 3/4 pages, which is much longer than the other sections explaining the causes of loss of biodiversity in 1.3.4, thus fragmentation is emphasized relative to the other causes of biodiversity depletion. The purpose of this section is to make the point about why each cause of loss of biodiversity is important, rather than a complete review of each topic.

Changes made in the document: none

4. The reviewer seems to complement the discussion of within forest fragmentation on page 10. There does not seem to be a call for reworking the section.

Changes made in the document: none

5. The reviewer would like to add intrinsic and moral values to the list of values of biodiversity (section 1.3.5). The author tends to agree, however, the objective here was to list only values that can be documented factually, not to explore philosophical topics that are controversial.

Changes made in the document: none

6. The reviewer points out that the ecoregions work in Minnesota was commissioned by the Upper Great Lakes biodiversity Committee, and was carried out by Dennis Albert.

Changes made in the document: The wording has been changed to indicate that the ecoregion work was commissioned by UGLBC and the Albert reference has been added.

7. The reviewer points out a management guide for black ash. However, this reference does not really help with the description of natural dynamics of lowland hardwood stands, which is the subject of page 26.

Changes made in the document: none

Significant Impacts/Methodology

1. *Page 51*: The reviewer would like the table of susceptibility to fragmentation included in the paper. It is, but is at a different location (table 4.8, in section 4.5.4).

Changes made in the document: The reader is referred ahead to section 4.5.4 to see the table.

2. *Page 54*: The reviewer correctly assumes that the growth model is presented in detail elsewhere.

Changes made in the document: none

Significant Impacts/Assessment Results

The reviewer would like to add frequency as a factor to determine levels or thresholds when impacts are significant. However, this is in a section of language taken from the criteria for significant impacts document adopted by the EQB Advisory Committee and was therefore not changed.

Changes made in the document: none

Mitigation Measures/Utility

The reviewer would like to add several mitigation strategies including:

1. *Monitoring linked with adaptive management*: This is an important point.

Changes made in the document: A statement that monitoring should follow the application of any mitigation strategy has been added to the last part of the introduction to the mitigation section of the paper (section 5).

2. *Alternative silvicultural approaches*: The author agrees that this is a valid and important mitigation in that it creates habitat components that are necessary for individual species. However, this topic is extensively discussed in the GEIS Forest Wildlife paper, and it is most appropriate there. The wildlife paper looks at mitigation strategies that are necessary on a species-by-species basis, while this paper looks at the big picture for biodiversity. Some assessment of the impacts of alternative silvicultural approaches on plant species would be appropriate in the biodiversity paper. However, the available database is too small and of too poor a quality to address this point.

Changes made in the document: none

3. *Mechanisms to increase coordination and cooperation among ownerships*: The author agrees that this is important, and should have increased visibility in the paper.

Changes made in the document: Statements were added in the following two places: to the declaration of mitigation 5.12, stating that guidelines for preserving biodiversity should be coordinated among agencies, and to the end of the preferred mitigation section, stating that the preferred mitigations need to be coordinated among ownerships.

After review by the Advisory Committee, please advise me if there are any significant issues you regard as outstanding. In the absence of such, this paper will be submitted to the EQB for formal approval.

Yours sincerely,

James A. McNutt
Executive Vice President
and GEIS Project Manager

November 20, 1992

17 November 1992

Dr. James A. McNutt
Executive Vice President and
GEIS Project Manager
5510 Six Forks Road
Raleigh, NC 27609

Dear Dr. McNutt:

Enclosed is my formal review of the technical paper titled Biodiversity, a work product completed in conjunction with the Minnesota Generic Environmental Impact Study.

My submission of this review does not place me under any obligations or otherwise, to the State of Minnesota or Jaakko Poyry Consulting, Inc. on matters pertaining to the GEIS work and end product.

Furthermore, I recognize that this review will become part of the public records of the State of Minnesota, as related to the GEIS project.

Respectfully yours,

Malcolm L. Hunter, Jr.
Libra Professor of
Conservation Biology

MLH/sm

cc: Dr. Michael Kilgore
State of Minnesota

MINNESOTA GENERIC ENVIRONMENTAL IMPACT STUDY

TECHNICAL PAPER REVIEW SYNOPSIS FORM

Biodiversity
Technical Paper Title

Reviewer details:

Name: Malcolm L. Hunter Date Received: ____

Title/Position: Libra Professor of Conservation Biol. Due Date: ____
Address: Univ. Maine
Wildlife Dept.
5755 Nutting Hall
Orono ME 04469-5755

Paper Component	Rating (circle one)					
Literature review	1	2	(3)	4	5	6
Evaluation of Existing Environment/Conditions	1	(2)	3	4	5	6
Significant Impacts - Assessment Methodology	1	2	(3)	4	5	6
Significant Impacts - Assessment Results	1	2	(3)	4	5	6
Mitigation Measures - Appropriateness	1	(2)	3	4	5	6
Mitigation Measures - Utility	1	2	3	4	(5)	6
Overall Technical Quality	1	2	(3)	4	5	6

Rating System

Adequate, no changes needed	1	
Some concern(s), no changes needed	2	(see attachment)
Moderate concern(s), some changes needed	3	(see attachment)
Major concerns, significant changes needed	4	(see attachment)
No comments	5	
Comments not required	6	

Reviewed by: [signature] Date: 15 Nov. 1992

Biodiversity Review

<u>Literature review</u>

The literature review seemed a bit superficial with respect to some topics (notably, restoration ecology and the rationale for protecting biodiversity by protecting a representative array of ecosystems). Some of the best forest ecosystem research in recent years was conducted by James Clark in Minnesota; none of it is cited.

<u>Evaluation of existing conditions</u>

See papers of Clark.

<u>Methodology and Results</u>

Much of the biodiversity of Minnesota resides in small, non-forest ecosystems that are imbedded in forested landscapes and therefore very vulnerable to forest practices. Most of these are aquatic/wetland systems and often can be protected by protecting riparian areas, but to not evaluate this issue from a biodiversity perspective is an important oversight. Water quality and fisheries are not the whole story, especially in wetlands.

<u>Mitigation</u>

The ideas presented seemed reasonable and likely to be effective. I was surprised to see so much emphasis on extended rotation forests (25% of even-aged stands) and no discussion of the standard approach advocated by the World Conservation Union; (i.e., setting aside 10-15% of each ecosystem across the various ecoregions. Many would agree that we do not know if the attributes of extended rotation forests would substitute for forests allowed to grow old and be subject to natural disturbance reserves.

<u>Technical Quality</u>

I found the document to be reasonably well-written and convincing, but I have written many specific suggestions for improving it in the margins. Some of these are editorial in nature; many raise further questions about overarching issues.

I am sorry I cannot elaborate on these further here, but your schedule and other demands on my time prevent it.

Malcolm Hunter

The Following Details the Responses to the Review
Forwarded by Malcolm Hunter

Literature Review

The reviewer notes that the review on the topics of restoration ecology and the rationale for protecting biodiversity by protecting a representative array of ecosystems seems superficial. The subject of restoration ecology is mainly outside the scope of this document. The purpose here is to talk about how to practice forestry that is consistent with maintenance of biodiversity, not how to restore the landscape to pre-settlement condition. Processes that occurred in pre-settlement times do provide valuable lessons for forest management, and this is extensively discussed throughout section 1 and 2. Protecting an array of ecosystems is the main focus of pages 3 through 13. Given the mandate for this paper, and the audience it is intended for, the current literature review is adequate. The reviewer makes the point that research by James Clark should be cited. The author is very familiar with Clark's work and judges that it is not essential here. It is more relevant to global warming, and is cited in the Global Change background paper.

Changes made to the document: none

Evaluation of Existing conditions

The reviewer again mentions the papers of James Clark, however, they are hardly adequate to conclude much about the existing conditions of Minnesota. Clark's work, although important and of high quality, comes from one forest type in Itasca State Park. Minnesota's forests are so diverse, that Clark's study does little to characterize existing conditions of the state.

Changes made to the document: none

Methodology and Results

The reviewer mentions the many small wetlands embedded within Minnesota's forests, and correctly points out that little analysis has been done in this paper. This issue is dealt with as a habitat issue in the forest wildlife technical paper, and in the Water Quality and Fisheries technical paper. If the mitigations identified in the Water Quality and Fisheries paper to prevent nutrient and sediment loading are followed and the mitigation strategies identified in the wildlife paper to reduce the impact on herps and other species dependent on small wetlands are followed, then the impact of harvesting on biodiversity within wetlands will be minimized.

Changes made to the document: The assumption stated above has been added to section 3.1.

Mitigations

The reviewer would like to see discussion of World Conservation Union approach of setting aside 10-15% of each ecosystem in each ecoregion. Again, the purpose here is to talk about how to practice forestry that is consistent with maintenance of biodiversity. To not harvest large parts of the forest is not an option for unreserved forest lands in Minnesota.

Changes made to the document: none

Technical Quality

The reviewer finds the document generally well written but has provided handwritten comments in the margins. Many of these comments were very helpful. some other comments, such as what the meaning of the criterion numbers are, etc., were related to the fact that the reviewer is (very understandably) not familiar with the GEIS process.

changes made to the document: A majority of the handwritten comments have been incorporated into the revised document.

After review by the Advisory Committee, please advise me if there are any significant issues you regard as outstanding. In the absence of such, this paper will be submitted to the EQB for formal approval.

Yours sincerely,

James A. McNutt
Executive Vice President
and GEIS Project Manager

November 20, 1992

JANET C. GREEN
1754 Old North Shore Rd.
Duluth, Minnesota 55804

DATE: December 3, 1992; December 19th, additional comments in []

TO: Mike Kilgore, EQB project manager for the GEIS on Timber Harvesting

Comments on the BIODIVERSITY technical paper.

This paper is generally very well done but I have comments on several sections, some more serious than others.

Old Forests - p. 59-61 [See p. 225 in the Productivity paper for algorithm change for total white pine acres]

How is it possible for old forest acreage for white pine to go from 8,700 acres to 60-65,000 acres in 50 years? Is not this increase a result of redefinition of the cover type? How were the figures on ages of old forest in reserved status produced (I do understand it was from aerial photos, but the question is still - how?). Since most of these are in the BWCAW, how do the figures in table 4.2 square with the figures on the top of p. 65? Heinselman's aging of stands by fire origin should be a check on the aerial photo figures - they should at least be the same order of magnitude.

Old Growth - p. 62-65

The analysis is not complete or detailed enough to warrant the conclusion that the significance criterion will not be triggered. Unless actual and official policy determinations by the state and federal government as to their intentions for the protection of old growth are referenced, the conclusion that candidate stands and future old-growth stands will be "officially reserved" is completely speculative. Unless actual policy citations are presented from the state (either in documents signed by the DNR Commissioner or the Division of Forestry Director) and the federal government (either in language from the Chippewa and the Superior National Forests' plans or from specific units in their opportunity area plan implementation) this section is UNACCEPTABLE.

Background - In the four years that I have been involved in policy discussions on this issue exactly 29 acres of old growth have been officially classified as reserved outside those in already protected status. Using this as a measure of progress, at the end of the 50 year planning horizon 363 acres of old growth will be protected. Now, granted that activity has picked up recently (the last two years) particularly by the Minn. DNR, there is still no certainty that the process will produce the result described as "no significant impact on old growth". Both the DNR and the U. S. Forest Service have done inventories, but identification is not protection. The DNR has a field assessment process in place and a moratorium on harvest until the process is complete so their program has good potential for a protection end-point. The U. S. Forest Service has done some computer generated inventories but have not amended their plans to put in place any components of an old-growth policy. The Superior NF's plan does not mention old growth at all, and the Chippewa NF's plan explicitly says that stands " selected for old growth management can be harvested after they attain the old growth rotation age"(Report of the Chippewa NF's old growth team to the forest leadership team, December 1991). The Chippewa's present plan is essentially big tree management. Therefore, the old-growth identified in the Biodiversity report could all be cut on both forests unless there are policy changes.

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BIODIVERSITY technical paper comments, continued.

A worst case conclusion should be made that only the state will have a viable protection program and that there will be significant loss of area of forest in old growth. This, or any other realistic policy conclusion, would lead to a mitigation strategy that required the federal government and the state to make actual policy decision that would result in "no net loss of old growth". There is no mitigation identified in this technical paper for old growth loss. Unless this type of analysis is forthcoming in an addendum to the Biodiversity Technical Paper, this paper does not fulfill the scoping document requirement or the significant impacts analysis for this issue.
Note: Some of the counties have old-growth programs. They should be identified.

Minor technical points:

p. 93. Has anyone determined that striped maple actually occurs in the state?

p. 45. Since the Water Quality and Fisheries paper did not cover damage to minor wetlands and peatlands by the disposal of slash, bog vehicles or winter roads, should not that be covered in this paper? If not here, where?

[p. 72. Why was yellow birch not included on the list of major tree species with range limits in Minnesota? It may not be a major species here, but it certainly is further east. The point is on the range limit, not on how much this species contributes to timber production in Minnesota.]

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MEMORANDUM to the MINNESOTA ENVIRONMENTAL QUALITY BOARD concerning approval of the technical papers for the GEIS on TIMBER HARVESTING

TO: Mike Kilgore, Project Manager, GEIS on Timber Harvesting

FROM: Janet Green, Member, EQB Advisory Committee, GEIS on Timber Harvesting; (Forestry/Biodiversity Program Coordinator, Minnesota Audubon)

DATE: December 13, 1992

This is a summary of my comments, previously given in memos and meetings, on why the following Technical Papers should not be approved as submitted.

BIODIVERSITY

Old Growth (p. 62-65). Significance Criterion No. 7 - "An impact is considered significant if there is projected to be any net loss of area of forest meeting the DNR definition for old growth by covertype by ecoregion over the 50-year study period."

In this paper the analysis is not complete or detailed enough to warrant the conclusion that the significance criterion will not be triggered and therefore no mitigation is required. It also is in error in implying that old growth is, or even will be, managed on the federal lands to protect the existing or future stands of old growth, which in the case of upland conifers (pine and spruce) are in scattered, very small stands. It misinterprets anedotal statements of intent as policy by the U. S. Forest Service, and therefore assumes that no old growth will be lost.

As was pointed out in previous comments by me and by DNR staff, neither the Chippewa National Forest or the Superior National Forest have protection policies for old growth or for future (replacement) old growth in their forest plans; plans are the policy used to guide timber sales at the district level. Therefore, there is no reason to assume that no old growth will be lost while the Forest Service finally decides what it is going to adopt as old growth policy over the long-term. The Chippewa National Forest once started a good program of identifying and reserving old growth (both present and future stands); this action would have required an amendment to their forest plan. This program was stopped by the Regional Office of the Forest Service and any activity that would lead to a policy change in their plan was deferred for five years. With the Forest Service, actions speak louder than words.

Also, county and prizate ownerships were not even analyzed to determine what old growth might exist on these lands. Some counties even have old-growth programs under way; these were not surveyed. The data base used in this report gives information on age, type and ownership of the state's forests; it should be used for county and private lands which are 62% of the timberland in Minnesota. Granted it is not very accurate for small areas, but it is at least as good as the computer-generated stand lists that pass for inventory on the federal forests. Some indication of the proportion of old growth that might be on these lands should be given.

Since most of the analysis that leads to the conclusion that there will not be a net loss of old-growth is either incomplete or speculative, it would be prudent to conclude that there will be some loss of old-growth over the study period, and to recommend that mitigation take place through meaningful programs and policies by all governmental land managers and through incentives for private individuals. Unless that is done this paper should not be accepted.

The Following Details the Responses to the Comments on the Biodiversity Technical Paper Forwarded by Advisory Committee Member Jan Green

1. Old Forests.

a. The reviewer asks how old white pine acreage can go from 8,700 acres (7,400 acres in the revised version of the paper) to 60,000 in 50 years, because there is not enough in the 80 to 120-year-old categories today to produce that much white pine in the future. This projected increase is the result of the covertype change algorithm in the forest scheduling and change model--see page 120-122 and Appendix 2 of the Maintaining Productivity and the Forest Resource Base (MPFRB) paper. There is redefinition of covertype--because white pine (and white cedar as well) tend to occur in very mixed-species stands. A slight change in definition, in terms of proportion of white pine required to label the stand white pine, can lead to a large difference in the acreage. The MPFRB technical paper uses basal area to define forest types, while the FIA uses their own formula based on stocking.

b. The reviewer also asks how the figures for old forest in the BWCA were done. The figures for old forest in the reserved lands were produced by Dr. Alan Ek working with the MPFRB study group. Trees >120 years old in the BWCA often are only the same size as 60-80 year old trees outside the BWCA. The BWCA has extremely thin nutrient poor soils and cold climate with short growing season. When comparisons are made with old forests outside the BWCA and their more advanced canopy characteristics to estimate age of forests within the BWCA, then the acreage of old forest in the BWCA can easily be underestimated because the poorer growing conditions makes the BWCA forests develop slower and appear younger than they actually are. Table 4.2, p. 61., compared to the Heinselman data on the top of page 65, does heed to an apparent underestimation. This result is expected, given the different methodologies used.

2. Minor points.

P.93. The reviewer asks about striped maple occurrence in the state. The answer is yes. The new edition of USDA Silvics Handbook (USDA FS Agriculture Handbook 654. Silvics of North America: Volume 2. Hardwoods, page 53) shows one outlier in northeastern Minnesota.

P.45. The reviewer was concerned about protection of small wetlands within forests. This is handled in the Wildlife technical paper. Mitigation 6.9 (page 193, bottom) states that protection of small wetlands should be added to BMPs.

P. 72. It was asked why yellow birch was not included on the list of major species at the edge of their range. Yellow birch is included with the minor species (section 4.4.2, page 67).

3. Old Growth.

The reviewer states that actual written policy needs to be in place on the national and state forests for the conclusion that significance criterion # 7 will not be triggered. Also, that the analysis is incomplete. The authors maintain that the technical paper is correct as written--old growth will not be cut without due process (planning and hearings etc.)--so that the amount of upland old growth eventually reserved will depend on the political process rather than timber harvesting. De facto policy to not cut old growth on the national and state forests is in place already. In addition, many old growth stands will be destroyed by natural disturbances or succeed to other forest types during the next 50 years. Various administrative units of government may decide to replace these stands with younger "replacement old growth". Surely, the total amount of old growth will eventually be determined by administrative goals pertaining to the desirable acreage of old growth than timber harvesting and forest management activities.

The reviewer also states that the biodiversity paper does not fulfill the scoping document requirements of the significance impacts analyses, and that no mitigation strategies were identified. All of this is not true. The document does indicate significant impacts on old growth swamp conifers (see table 6.1 on page 97), as well as mitigation strategies for this impact. Mitigation 5.4 is also aimed at maintaining the integrity of old growth forests. It is correct that there is no mitigation for *upland* old growth forests, because the study group judged that there would be no significant impacts (as explained in the paragraph above). Lowland old growth has not been as well inventoried as upland old growth, and there is the possibility that some will be unknowingly cut. In addition, most of the lowland conifer forest over 120 years old is probably true old growth, since it is probably of natural origin (Note the difference between old growth and old forests in the definitions on page 14).

The FSD also directs the biodiversity paper to analyze the extent to which old growth and old forest exists and how it is managed. The amount that exists is dealt with thoroughly in section 2.1.3, as well as in the MPFRB technical paper. This analysis includes all old forest, even county and private ownerships. Although there is no section entitled 'old growth management', comments on how most of the state's old growth (which is in the BWCA) is managed are on page 65. Additional comments are found in section 1.3.4 (page 7) and on page 20.

The reviewer suggested that old-growth on county and private lands be identified. Forest over 120 years old (90 years for white spruce) on county and private lands is included in the analysis of old forests (Tables 4.1 and 4.2, page 61). These tables include all ownerships. Estimation of the amount of true county and private lands old growth is not possible at this time. However, due to the way and purpose for which these landbases were built over time, only a small fraction of stands over 120 years of age are likely to be found.

This review was used as noted to revise the technical paper, as was appropriate, along with the other written Advisory Committee Members' review inputs. Additionally, the paper received one more careful editorial review for spelling, punctuation, and basic presentation style, and all final edits have been incorporated into the text. This response is therefore submitted to the EQB to become part of the formal public participation review package for the GEIS process.

Yours sincerely,

James A. McNutt

James A. McNutt
Executive Vice President
and GEIS Project Manager

December, 1992

The format used in the Biodiversity technical paper for evaluating feasibility of mitigation strategies was superior to the format used in the other technical papers (see Table 6.2, p. 98). Subdivision of feasibility into physical, administrative, and financial categories made it easier to evaluate the authors' rankings. It would have been helpful if the other eight technical papers had included this format for evaluating feasibility.

This is generally a good paper. However, the DNR has several major remaining concerns:

a) It is inappropriate to lump hybrid trees with exotic species in the Significant Impacts chapter (Section 4.5.6, p. 78-79) and the Mitigation Alternatives chapter (Section 5.9, p. 92). The impacts of hybrids versus exotics are quite different, and the mitigation strategies should be different. For example, implementing any of the four mitigation criteria relating to pollen production (p. 92) would eliminate hybrid aspen from further deployment. Both the DNR and the University of Minnesota have a considerable stake in the Aspen/Larch Genetics Cooperative, which would be adversely affected by this strategy. The ratings given for mitigation strategy 5.9 in Table 6.1 (p. 97) and Table 6.2 (p. 98) should be done separately for hybrid trees and exotic species.

   There is no clear definition of "hybrid trees" or of "exotics" in the paper. Clear definitions of these terms are needed. Even the seed produced in the DNR red pine seed orchard is by one technical definition hybrid, because the parent trees came from stands separated by many miles. The cornerstone of the DNR's white spruce genetic tree improvement program is spruce from southeastern Ontario, technically an exotic. However, even though this seed is hybrid, it is genetically **more** variable than that produced in a local, natural stand. The paper should point out that certain management practices can maintain and, in some cases, create genetic variability in forest tree populations (although this enhanced variability may not be part of the intrinsic biodiversity of Minnesota).

   The text in Section 5.9 (p. 92) should include a criteria list for species. For example, hybrid tree species should include only those species obtained from a certified tree improvement program.

b) Old forest, as addressed by the DNR, refers to "all forest types, including aspen, birch, and other seral species that do not develop into old-growth stands as defined by the Old Growth Guidelines. Typically, these old forest conditions develop at a stand age beyond present recommended rotation age." (Old Forest

Guideline Recommendations, DNR Old Growth Task Force, June 1991). This concept of old forest was completely ignored in the Biodiversity paper. Instead, the term "old forest" was used in the report for forests that met the age and type criteria in the DNR old growth definition, but for which the degree of human disturbance is unknown. This second definition of "old forest" defines a useful and necessary condition for addressing old growth, but the "old forest" definition used in the report is not the same as that used by the DNR.

By considering only forests of old growth types and ages, the report ignores all old (i.e., beyond rotation age) aspen, birch, balsam fir, and jack pine forests. Concern for old forests of these types is what led the Old Growth Task Force to develop Old Forest Guidelines in the first place and is the driving force behind the revision of these guidelines under the current name of Extended Rotation Forest Guidelines. Furthermore, consideration of those types that do develop into old growth only when they reach old growth age (i.e., 120 years), does not address what might happen to stands such as red pine stands between a current rotation age of 100 years and attaining old growth at 120 years.

The DNR definition of old forest (given above) should be used to determine the extent of these forests in Minnesota; how they are identified and managed; and how they are impacted by timber harvesting and management. It probably would be of interest to the EQB to run 20 percent of the aspen, birch, balsam fir, and jack pine cover types on extended rotation forest rotations to see what impact this has on the overall harvest levels of the three harvesting scenarios.

c) The paper does not explicitly address the role dedicated natural areas play in retaining areas of high local biodiversity (of statewide significance) as well as sites of high regional biodiversity, and how these areas can assist in conserving biodiversity in Minnesota and midwestern forests. The technical paper presents a hypothetical example of just such a scenario, yet never discusses this important existing option.

Page 15 of the DNR's June 3, 1992, memo on the Biodiversity paper recommended including a mitigation strategy to protect examples of undisturbed native communities of all types and ages. While this recommendation was not followed, at least in the Biodiversity paper, mitigation strategy 8.3.2 in the Productivity/Forest Resource Base paper (Public Acquisition of Key Patches of Forest Land, p. 268) addresses this need. However, a strong recommendation needs to be made in the Biodiversity paper that a comprehensive plan to identify and protect these special habitats should be developed and implemented as soon as possible. The need for such a strategy was pointed out by Malcom Hunter's peer review of the Biodiversity paper. A network of designated natural areas is an essential component of a strategy to maintain Minnesota's forest biodiversity.

d) Several of the mitigation strategy ratings in Table 6.2 (p. 98) are debatable. Mitigation strategy 5.4 (connected landscapes) should receive a 2 for all three feasibility ratings (instead of 3 for physical and 1 for financial feasibility). It is physically possible to created a network of interconnected areas, but there would be considerable financial cost (and opportunity costs) associated with doing this. The administrative feasibility of implementing 10,000 acre or larger clearcuts (see first paragraph on p. 90) is very low on any ownership. Therefore, the administrative feasibility rating for strategy 5.5 (Biodiversity Maintenance Areas) in Table 6.2 should be low (3) rather than moderate (2). The administrative feasibility of mitigation strategy 5.8 (favor tree species near the edge of their range) is likely to be moderate (2), since many common species are involved and implementation costs could be substantial. The administrative feasibility of this strategy is currently listed as high (1) on Table 6.2. The physical feasibility for retaining conifers in mixed stands (5.10), currently listed as high (1) in Table 6.2, should be listed as moderate (2). On some sites, it may be physically difficult or impossible to retain conifers in mixed stands.

e) The Biodiversity paper does not adequately address impacts of timber harvesting on biodiversity associated with wetlands. This issue is discussed on pages 3-4 of this memo.

ADDITIONAL COMMENTS

At a later date, the DNR plans to submit a number of editorial and other comments on the Biodiversity paper. This is due to the possibility of parts of this paper being used as a training manual for DNR field staff, as well as the agency's desire to have the paper be as accurate as possible. The DNR **does not** expect Jaakko Pöyry to respond to these additional comments in writing.

The Following Details the Responses to the Comments on the Biodiversity Technical Paper Forwarded by Advisory Committee Member Gerald Rose

Many of the review comments forwarded by Mr. Rose as a representative of the MNDNR often seem to be at a different level than the work scope. Mitigation strategies that address specific concerns of the MNDNR seem to receive a focus over the broad issues for the state as a whole. This is an important point to consider, because at times, responding to Mr. Rose's questions is outside the base scope of work here and may confuse the reader.

Hybrids and exotics. The reviewer objects to lumping hybrid and exotic species together, because they have different effects, then states that for example, the mitigation strategies given on page 92 would endanger the Aspen/Larch genetics cooperative. The authors see no connection between these two items. Mr. Rose states that the Aspen/Larch project would be adversely affected by application of mitigation strategy 5.9. How is not clear to the authors. Aspen pollen is not viable for very long after being shed, and its seedlings cannot grow in the shade and invade existing stands. Larch pollen does not travel long distances. It could well be that this project would meet requirements of mitigation strategy 5.9. Strategies such as 5.9 are exactly what government agencies should be thinking about, and the type of thing the GEIS is supposed to point out. Getting back to the opening point of the paragraph, that hybrids and exotics have different effects, the main concern for this study is displacement of native trees by hybrids or exotics. Displacement is displacement, whether by exotics or hybrids. There are some other effects which are different (such as changing gene frequencies within populations caused by breeding for fast growth), but these are more specific concerns, beyond the intended scope of this paper.

The reviewer's second paragraph makes a reasonable request for definitions of exotics and hybrids. Following is one of many possible definitions for each term, that reflects what was intended in the paper (these definitions are incorporated on page 16 as well):

Exotic. Any species not native to a given geographical region, such as an ecoregion.

Hybrid. Any cross between two species or varieties.

These are not strict definitions, and their use should not conflict with most tree-breeding programs. More discussion is needed of exactly what criteria will be used to decide what is exotic or hybrid for future policy decisions. This is a complicated subject that cannot be resolved in a broadly-scoped document like the Biodiversity Technical Paper.

Old Forest. The "definition" of *old forest* from the 1991 old growth task force report given by Mr. Rose also appears as part of the text of draft guidelines for extended rotation forest (4/8/92), where it does not say that this is the definition of old forest. This "definition" uses the word being defined (old forest) as part of the definition. What it essentially says is old forest is defined as forest with old forest conditions. Therefore, this is not a definition, and certainly not the final definition, which the FSD states should be used. In addition, this "definition" does not differentiate stands that were as old as old growth, but were not of natural origin. MNDNR also needs such a category and a clear final definition of old forest. The study group wonders if MNDNR really wants to define old forest as all forest that is between average rotation age and the ERF rotation age? If so, where do forests managed by selection cutting and other methods where the stand has no age fit in? Is a 90-year old aspen stand succeeding to maple an old aspen stand or a young maple stand? The definition needs to be worked out more so that it is applicable to the data and in the field.

In any event, the Maintaining Productivity and the Forest Resource Base technical paper addresses overall age structure of the state's forests, which would include the old forest beyond present rotation age for jack pine, balsam fir, aspen, balsam poplar, and paper birch types (the types that apparently can be old forest but not old growth). If one assumes an age of 70 years or more for old forest of these types, then the following acres of forestland result for 1990 and 2040 (table below). A substantial increase is projected for all types under the base and medium scenarios. For the high scenario, area of old forestland is projected to increase for aspen, balsam poplar and paper birch covertypes. Area of old jack pine forest land is projected to decrease slightly, mostly due to succession to other types within reserved lands. Area of old balsam fir forestland is predicted to decrease from 304,000 acres to 256,000 acres under the high scenario--a 16% decline. The study group does not consider this to be significant since most old balsam fir forest is expected to be heavily infected with spruce budworm anyway if not harvested. Maintaining balsam fir as a component in mixed aspen-conifer stands is a more important biodiversity issue than a small decline in old balsam fir cover type.

Note that mitigation 5.2 calls for managing 25% of all forest lands under even-aged management with ERF guidelines--which would ensure a steady supply of old forest in the future for all forest types under even-aged management.

Table x. Area of forestland projected in old forest (greater than or equal to 70 years of age) for several forest types in Minnesota (acres)[a]. Includes timberland, reserved and unproductive lands.

Forest Type	Current 1990	Harvest Scenario-2040		
		Base	Medium	High
Jack Pine	115,100	244,518	207,612	99,269
Balsam Fir	304,000	452,468	335,385	256,276
Aspen	467,500	982,911	961,039	837,726
Balsam Poplar	24,900	76,629	74,129	73,029
Paper Birch	324,400	643,809	559,835	352,494

[a] Acres as per GEIS covertype algorithm.

Natural areas. Mitigations 5.2 and 5.11 address exactly the need pointed out by the reviewer. 5.2 is for a comprehensive inventory and 5.11 is to protect occurrences of community types that are not common. Natural examples of nearly all forest community types are now rare, so that table 4.7 on page 74 lists most forest types in Minnesota as needing protection.

Mitigation strategy ratings. The reviewer lists several minor changes in rankings for table 6.2 (Page 98). Most of these suggested changes are reasonable, especially those dealing with financial and administrative feasibility, where the reviewer has a lot more experience than the study group. Therefore, the suggested changes, except for the change in mitigation 5.8, are incorporated.

Wetlands. This is handled in the Wildlife paper. Mitigation 6.9 (page 193, bottom) states that protection of small wetlands should be added to BMPs. Wetland analysis is also beyond the scope of a forest harvesting GEIS.

This review was used as noted to revise the technical paper, as was appropriate, along with the other written Advisory Committee Members' review inputs. Additionally, the paper received one more careful editorial review for spelling, punctuation, and basic presentation style, and all final edits have been incorporated into the text. This response is therefore submitted to the EQB to become part of the formal public participation review package for the GEIS process.

Yours sincerely,

James A. McNutt
Executive Vice President
and GEIS Project Manager
December, 1992

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December 23, 1992

Dr. Michael Kilgore
GEIS Project Manager
300 Centennial Building
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Dear Dr. Kilgore:

Please find attached my comments on the Biodiversity Technical Paper that has been developed as a resource for preparing the Draft and Final GEIS. It is my understanding that these comments will be included as part of the final published technical paper. I greatfully acknowledge the help of Dr. T. Bently Wigley, Forest Wildlife Scientist, Department of Aquaculture, Fisheries and Wildlife, Clemson University, in preparing these comments.

Sincerely,

Wayne Brandt

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BIODIVERSITY TECHNICAL PAPER

The primary data set utilized for modelling to prepare the GEIS technical papers is the Forest Inventory Analysis (FIA). Using this data as a predictor of habitat quality and biodiversity issues has inherent limitations. These limitations are important. No effort has been made to rectify or quantify these limitations and their influence on the model results. Since this was not done, additional efforts should have been undertaken throughout the paper to describe the effects of the data limitations, the uncertainty in analysis that they cause and their influence on the papers analysis.

It must also be noted that the modelling used for the Biodiversity and Forest Wildlife Technical Papers remains untested. Extrapolating habitat quality and genetic conclusions from FIA data is not something that has been routinely done. While not required by the Environmental Quality Board, it would have been useful to field test the model or to have utilized historical FIA data from 1936 and projected forward based on known harvesting activity to predict present levels of some wildlife populations or habitats.

The paper discusses the "alarming" rate of extinctions occurring worldwide. Given that most of these extinctions are occurring in tropical ecosystems, this is anecdotal information for the purposes of the GEIS. Forest management in Minnesota has not been shown to be a primary or contributing factor in this issue.

A greater concern, which is discussed in other technical papers, is the historical conversion of substantial portions of Minnesota's forestland to urban, agricultural and recreational uses. The biodiversity paper would have benefitted from a more extensive analysis of this issue.

The information related to forest fragmentation for this paper is primarily taken from studies that relate to urban and agricultural areas. Dr. John Faaborg (personal communication with Dr. Wigley), a well known expert in this field, has stated that forest management in forested areas does not result in similar types of fragmentation. Additionally, Thompson et al. (1992 Journal Wildlife Management 56:23-30) supports this view for some forest interior species.

One of the inherent difficulties in analyzing biodiversity is the choosing of a point in time to "benchmark" the analysis. The one constant in forest ecosystems is change. Where and how on the continuum of change any analysis is conducted can have a significant impact on the results. Choosing a reference point of the period prior to European settlement is no more valid than choosing today or 5,000 years ago.

As with any other point in time, the present day assemblages of flora and fauna are likely to be temporary irrespective of human activity. In fact, some scientists have argued that present assemblages in our region may represent historically high levels of species richness and diversity that are not likely to be sustained.

The paper, as with previous drafts, continues to struggle with the analysis of the conifer component of Minnesota's forests. The inherent bias in not accepting data which shows the continuation of conifers in similar percentages for like age classes in regenerated stands is a major weakness of the paper. The points at which this impacts this paper should be fully revealed so that readers can understand where the authors personal views override the data.

The paper does, appropriately, focus on larger scale issues in most instances. This is to the authors credit. The analysis of the diversity of plant and animal species within forested ecosystems is an area that has only recently emerged. Much is not known, and may never be known, about biological diversity. As with any newly emerging area of study, the GEIS analysis of biodiversity must be heavily qualified.

Minnesota is, however, fortunate to have inherently diverse forests. Though briefly described in the GEIS, it is important to note that Minnesota lies at the junction of several major ecosystems including prairies, southern forests and northern forests. Further, the ownership patterns of Minnesota's forest are extremely diverse. Private citizens own nearly 45% of the forestland, private industry owns another 5%, the remaining 50% is divided among federal, state and county ownerships.

Each of these owners has different management goals, be they the federal government or the small woodlot owner. The diversity of these owners and their goals as well as our forests geographical position have yielded forests that are and will continue to be inherently diverse.

Following are additional comments that relate the specific items in the paper:

1) Significant Impact #1 on the second page of the summary states "Predicted decline in area of old white cedar forest (high harvest scenario only)." This relates to section 4.2.2 on page 59 which states "Only one significant impact was detected-a a projected slight decline in old white cedar **timberland** under the high harvest scenario..." (emphasis added).

   The Final Scoping Document states clearly that issues are to be analyzed for all forest lands. This "impact" is found for timberlands only. The finding, which is not based on an analysis of all forestlands, directly contravenes the Final Scoping Document.

2) Significant Impact #2 on the second page of the Summary states "Predicted decline in area of old growth swamp conifer forest...". This relates to section 4.3.2 page 64 which states "a portion of lowland conifer stands greater than 120 years

old that were cut in the harvesting scenarios, may constitute a significant impact under criterion number 7." (emphasis added)

The finding of this impact does not attempt to apply the DNR definition of old growth as directed in criterion number 7 nor does it even find an impact. It speculates that the impact "may" occur and then lists it as an impact.

3) Significant Impact number 4 on the second page of the Summary states "Likely decline in conifer component of mixed species stands...". This relates to section 4.4.2 on page 69 which states "At this point, the study group cannot predict whether conifers will be lost in short rotation harvest. But the impact on biodiversity would be significant and directly proportional to level of harvest, if such a reduction in conifer component occurs."

   This speculative analysis is used to justify the finding of a significant impact. It is clearly not justified based on the application of significance criterion number 4 or on the papers own analysis.

4) Significant Impact #8 on the second page of the summary states "Loss of genetic diversity for trees and plants during future climate changes ..." This relates to section 4.5.4 on page 77 "Relationship of Fragmentation to Climate Change".

   This finding of significance based on criterion number 9 is speculative at best and predicated on the opinion that climate change will occur. It is clearly inappropriate.

5) The findings of significance for items 6, 7, 9 and 11 on the second page of the Summary are all speculative at best.

The Following Details the Responses to the Comments on the Biodiversity Technical Paper Forwarded by Advisory Committee Member Wayne Brandt

General text:

Modelling. The reviewer comments that there is no effort to quantify limitations inherent in the FIA data. Many of these limitations are pointed out in sections 3.3.1, 3.3.2, and extensively in 3.4.1. There is no way to quantify these limitations--the only way that could be done would be to have a complete inventory of all of the state's forest to compare with the FIA data. Such an inventory is called for in mitigation 5.2. It is well beyond the scope of the paper to develop new relationships between FIA data and habitat quality for biodiversity purposes. This was done for many species in the Wildlife paper, however, there was a long-term effort already underway to associate various species with covertypes. There is no such data available for the general topic of biodiversity. To develop new relationships would require an involved research project.

Also, note that the type of significant impacts identified are of a more general nature than in the wildlife paper. This was because the quality of the data is poorer for biodiversity in general than for wildlife. The impacts identified do not step beyond the bounds allowed by the data. For example, anyone could conclude that harvesting on a site occupied by a population of a rare plant, could cause physical damage to the individuals in the population, or that harvest of a rare forest community eliminates that particular occurrence of the rare community.

The study group agrees that a field test of the modelling would be desirable. But it was not required by the EQB.

Mention of worldwide extinction. Here the reviewer misses the point that good forest management is necessary *everywhere* to improve the biodiversity situation worldwide. This topic is only mentioned in a few sentences in the introduction, to help set the wider context in which Minnesota exists. There was no requirement in the FSD to limit the technical papers to just Minnesota.

Conversion of forest to other uses. This is done in tables 2.3 and 2.5, which show that there were 27 to 30 million acres of forest originally and only 16 million today. Many believe that there should be more forestland today.

Fragmentation. Most fragmentation studies do come from areas where much of the landscape has been converted to other uses. However, there is such a phenomenon as within forest fragmentation (see page 10). Research on this is just beginning. Although only known for a few birds species, within forest fragmentation does not appear to have a great effect. There is the possibility that there may be many species greatly affected, especially plants that have very short pollen and seed dispersal distances. In addition, there has not been enough time for within forest fragmentation to affect forest plant populations in Minnesota. We may have to monitor the situation for several more decades before the effects are known in detail.

Benchmark timepoint. The reviewer notes that a benchmark before European Settlement is no more valid than 5000 years before people (ybp) or any other. This is not true. The rate of change prior to European Settlement was only a tiny fraction of what it is now (less than 1/10). In fact, on a time scale of several decades to a couple centuries, the pre-settlement vegetation was very stable. This is the time scale relevant to humans. Therefore, the comparison with 1850 or so is the most valid baseline for our current situation. Some of the study group members are paleoecologists by training, and cannot be fooled by mixing of time scales. 5000 ybp is not a good comparison, because the climate was not the same 5000 years ago, and 5000 years is long enough so that the slow accumulation of change century-by-century is very large. The vegetation at the time of European settlement would be expected to be nearly the same as today if settlement had not occurred; the same is not true of 5000 ybp.

Another point is that the comparison with pre-settlement conditions provides background for the paper. All of the timber harvesting impact analyses compare 2040 with 1990, as required by the FSD.

Conifer component of aspen stands. There is no data sufficient at this time to predict the future conifer component of aspen stands. The summary (impact 4), and table 6.1, have been changed to state that there will be a "*potential decline*" in conifers, rather than a "*definite decline*". The original wording "*likely decline*", does not match up with the discussion in the text.

Specific comments:

1). Acreage of old white cedar forest: The 1990 acreages in the paper were in error. The FIA estimates of acreage for 1990 were incorrectly used rather than the GEIS algorithm acreages, which are directly comparable to 2040 projected acreages. This has now been corrected, and there is no longer an impact predicted on old white cedar forest.

2). The MNDNR definition of old growth is definitely applied here. The forest change and scheduling model predicts that some acreage will be cut under the medium and high scenarios. The wording on page 64 has been changed from "*may constitute*", to "*constitutes*".

3). See the comments on aspen stands conifer components and the responses to Jim Woerhles' review.

4). The reviewer states that the prediction that loss of biodiversity will result as the climate changes and species try to migrate in a fragmented environment is based on an opinion that climate change will occur. Climate change (of some type) **will occur**. The reviewer makes this point nicely himself in the last paragraph of his first page of comments "the one constant in forest ecosystems is change".

5). The reviewer claims that accidental harvest of rare forest communities (6) and physical damage to rare plant species on harvest sites (11) is speculative. The study group can be certain that harvesting machinery driving over delicate species such as ladyslipper orchids will cause damage to the population. Point 9 (loss of genetic diversity in herbs and reduction of tree species diversity through deer browsing) is almost as definite. This type of change has been recorded personally in the past by study team members. However, on the other hand, point 7 (loss of genetic diversity in herbs due to fragmentation) cannot be seen in any forest stand, yet it has a sound theoretical basis. The pollen and seed dispersal of many herbs can be measured in a few feet. Fragmentation (even within-forest fragmentation) will definitely cause isolation of populations. However, as pointed out in d) above, this will not be readily apparent for several decades.

This review was used as noted to revise the technical paper, as was appropriate, along with the other written Advisory Committee Members' review inputs. Additionally, the paper received one more careful editorial review for spelling, punctuation, and basic presentation style, and all final edits have been incorporated into the text. This response is therefore submitted to the EQB to become part of the formal public participation review package for the GEIS process.

Yours sincerely,

James A. McNutt
Executive Vice President
and GEIS Project Manager

December, 1992

December 8, 1992

FROM: Jim and Janet Woehrle

TO: Environmental Quality Board

COMMENTS ON GEIS TECHNICAL PAPERS

BIODIVERSITY

Peer reviewer Malcolm Hunter suggests that under mitigations that sets aside 10-15% in each ecosystem should be considered because it is the standard of the World Conservation Union. In response, Jaakko Põyry says - "Again, the purpose here is to talk about how to practice forestry that is consistent with maintenance of biodiversity. To not harvest large parts of the forest is not an option for unreserved forest lands in Minnesota." Says who? Is Jaakko Põyry now setting policy options for Minnesota's forest? This should be included as a mitigation.

The Biodiversity paper completely ducks the issue of loss of conifer component as mixed aspen stands are harvested. The paper admits that it appears that a large scale conversion away from conifers to aspen is taking place (page 67). What follows is a description of how conifers still really exist in aspen stands and increase in numbers as the aspen stand ages to 80. What the paper fails to acknowledge is the fact that aspen stands in the future will never live to the ripe old age of 80 but will be harvested as the Productivity paper states - at 40 year rotations. With short rotation forestry, it isn't hard to surmise that the management prescription for aspen will mean a great reduction of conifer types over time and a great increase in aspen. You don't have to have a doctorate in forestry to figure this out. All you have to do is observe clear cut mixed aspen forests and see what is growing to the exclusion of other trees -- aspen. When the stand is again cut in 40 years -- more aspen.

The failure of this paper to face the reality of loss of conifers to clear cutting for aspen regeneration is unacceptable and doesn't represent the reality of current forest management.

The Following Details the Responses to the Comments on the Biodiversity Technical Paper Forwarded by Advisory Committee Member Jim Woehrle

Reserved Forest. The fallout would be tremendous if the study group wanted 10 to 15% of all unreserved forest lands in Minnesota to be set aside. This is simply not a viable option. Besides, you **cannot** reserve some land and then milk the rest of the landscape dry. To preserve biodiversity, all of the landscape must be managed properly. Given the choice, it is probably better for biodiversity to manage all of the landscape using BMPs, with rotations that do a reasonable job of mimicking natural disturbances, than to set aside part of the landscape and manage the rest for maximum timber production.

Conifer issue. The conifer issue was brought up again. This reviewer critiques the paper for not saying that there will be a significant impact of harvesting, while Mr. Brandt critiques it for saying there will be. This does lead to confusion. This reviewer states that you don't need a doctorate to figure out that harvesting will cause a reduction in conifer component in aspen stands. Again, the study group emphasizes that the data are ambiguous. Minnesota has a lot of aspen at this time because of logging **followed by fire** early in this century. Since there is not fire associated with cutting now, it is not clear that future logging will have the same effect. The conifer component of mixed stands may depend on the time since fire, rather than logging. In some cases, logging can cause an advance to later successional species. Restoration ecologists use it for this purpose--to speed up succession. What is unknown at the current time, is whether the current management will have the same effect as management 60 to 80 years ago when most of our current stands originated. We simply do not know if history will repeat itself.

The reviewer also states that the paper "completely ducks" the conifer issue. The paper actually has two full pages of discussion and data analysis pages 67-69, and has a full page devoted to increasing red and white pine and upland white cedar forest (mitigation 5.7, page 91), a mitigation for large blocks of conifer forest (mitigation 5.5, page 90), and mitigation 5.10 (page 93) to carry out the appropriate research necessary to develop silvicultural methods needed to ensure continuation of conifers in mixed stands.

This review was used as noted to revise the technical paper, as was appropriate, along with the other written Advisory Committee Members' review inputs. Additionally, the paper received one more careful editorial review for spelling, punctuation, and basic presentation style, and all final edits have been incorporated into the text. This response is therefore submitted to the EQB to become part of the formal public participation review package for the GEIS process.

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James A. McNutt
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December, 1992