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Management of Biological Diversity in the Central Hardwood Region

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Introduction

Biological diversity, an increasingly important issue, is central to the consideration of emerging resource management paradigms such as sustainable development and ecosystem management. Biological diversity, or biodiversity, is "the variety and abundance of species, their genetic composition, and the communities, ecosystems, and landscapes in which they occur" (Society of American Foresters), or more simply "the variety of life and its processes in an area" (US Congress). Biodiversity, in general, involves the composition, the structures, and the functions of ecosystems.

By best estimates, the earth contains between 5 and 10 million species, with some estimates ranging as high as 80 million species. Only about 1.4 million of these species are cataloged and described, about 500,000 of which occur in the United States. While natural ecological processes continually add and eliminate species from ecosystems, exponentially increasing human populations continue to result in increased impact on ecosystems, thereby accelerating the rate of species loss world-wide.

Estimates suggest that, globally, extinction rates of birds and mammals are currently as much as 400 times higher than at any time in recent geologic history. Extinctions of all species have been estimated at 4,000 to 6,000 species per year, a rate 10,000 times greater than at any time since humans started practicing agriculture. These numbers do not include the unknown number of species already lost due to human activities. Conservation of biodiversity is recognized as a national and global priority, and resource management professions are being called upon to develop ways of more fully incorporating this goal into their management approaches.

The purpose of this paper is to provide an overview of the biodiversity issue as it applies to forest resource management and offer recommendations for incorporating biodiversity considerations into management decisions. The discussion includes why biological diversity is important, what factors affect biodiversity, and what is the current status of biological diversity in the Central Hardwood Region. We attempt to provide managers with information needed to better incorporate biodiversity into their management decisions.

Elements of Biodiversity

What exactly is biodiversity? It is too simplistic to say it is just numbers of species, because biodiversity is much more than that. Diversity is considered on at least three distinct levels: genetic, species, and community or ecosystem diversity.

Genetic diversity is the variation in genetic composition among individuals within populations of a given species. This may be the least understood element of biodiversity, even though the source of all biological diversity ultimately lies at the genetic level. Genetic diversity allows species to adapt to varied and changing environments, and is the basis for the evolution of new species.

Ecosystem diversity is the variety of unique habitats occurring in an area. This might include the variety of stand ages or conditions within a small drainage, the diversity of habitat conditions occurring over a larger landscape, or the mix of landscapes occurring throughout the Central Hardwood Region. Providing a diversity of ecosystems ensures that the habitat needs of a large number of species will be met.

Species diversity is the variety of species within a defined area. This is the most readily recognized level of diversity, and the primary level of interest for the conservation of biodiversity. Genetic diversity is critical to the adaptability and survival of species; and ecosystem diversity provides the variety of habitats necessary to support diverse species. Ultimately, however, the goal of conservation biology is to maintain as many individual species as possible.

Importance of Biological Diversity

Forest ecosystems are extremely complex entities. Even in relatively simple systems, there are vast numbers of species involved in various ecological processes. For example, insects and microorganisms are not readily obvious but are critical to nutrient and energy cycles.

The diverse organisms and structures contained within ecosystems are largely responsible for the continued health, functioning, and productivity of those ecosystems. Reduction of diversity has direct impact on the benefits society derives from ecosystems. The reasons we should be concerned about biodiversity can be grouped into four general categories: economic, ecologic, intrinsic, and legal.

Economic Values

All species have potential to be of some utilitarian value to humans. On a percentage basis, the number of species which may ultimately prove economically valuable is probably small. But, because we cannot readily predict which species will be of value in the future, the extinction of large numbers of species is reducing the opportunity to discover potentially important plants and animals. For example, wild relatives of domesticated species are a source of genetic diversity that has, on occasion, been needed to the protect the benefits we derive from crops and livestock. However, many of these wild relatives are threatened with extinction, and their loss could be economically damaging. Organisms unrelated to currently exploited species, might prove to be equally critical in the future, but are harder to identify at present.

Food resources represent the most obvious use made of natural organisms. Currently, 90 percent of the world's food supplies come from less than 25 plant and animal species, but thousands of additional species are used in lesser amounts. Supporting these exploited species requires healthy ecosystems composed of myriad other species needed for pollination, decomposition, nutrient cycling, and other vital ecosystem processes.

Medicines derived from natural plants and animals are also tremendously important. Currently, over 25 percent of all prescription drugs are derived from naturally occurring substances. Quinine, a common treatment for malaria, and penicillin are examples of widely used drugs made from natural sources. Chemicals from the rosy periwinkle of Madagascar are used in the treatment of childhood leukemia, and new cancer treating drugs are derived from the Pacific yew. These are two examples of compounds derived from plants that are being threatened with extinction through loss of their native habitat.

Nearly $20 billion per year is spent worldwide on pesticides. Estimates suggest that as much as 10 times this amount is provided "free" each year by natural parasites and predators, reducing losses to both agricultural and forestry interests. Insects and other organisms are important in crop pollination as well. In the United States alone, crops valued at around $30 billion depend on insects for pollination. Natural organisms also provide nutrients for crops and natural systems. An estimated $50 billion worth of atmospheric nitrogen is supplied to agriculture world-wide by soil microbes.

There are many other economic values, either realized or potential, that strengthen the arguments to conserve biodiversity. Plants provide fiber and fuel, native wildlife serve as gene pools for domestic livestock, and many industrial chemicals are derived from plant compounds. For example, a chemical in pawpaw is being isolated as a natural insecticide. In addition to these clearly exploitive uses, a huge world-wide ecotourism industry is largely dependent on the diverse flora and fauna supported by wildland ecosystems. Many states, including some in the Central Hardwood Region, now publish wildlife viewing guides, and many businesses are capitalizing on the public's appreciation of wildlife and natural environments.

Perhaps the most important economic reason for maintaining diversity is to provide a hedge against changing economic conditions. While we know what species have economic value in today's economies, it is impossible to tell what species may be of value in the future, especially when we factor in rapidly changing technologies and potentially changing climates.

Ecological Services

Conservation of biodiversity is important to the maintenance of many of the processes and functions of ecosystems in both natural and human dominated settings. For example, plants provide air and watershed protection. Root systems help hold soil in place and reduce erosion. Slower runoff rates facilitate water infiltration into the soil and increase recharge of groundwater supplies. Plants filter pollutants from both air and soil.

All organisms contribute to nutrient cycling. Plants sequester large pools of nutrients, retaining them on the site. Various animals and microorganisms actively decompose organic matter, slowly releasing nutrients for reuse by other plants and animals. Mycorrhizal fungi form symbiotic relationships with plants providing for more efficient exploitation of available site nutrients.

Plants and animals facilitate soil formation and maintenance. Root penetration contributes to the physical breakdown of rock, and root exudates contribute to chemical weathering of mineral substrates. Burrowing and tunneling organisms aid in physical development of soils by mixing organic and inorganic materials. By-products of decomposition help develop the physical structure of soils and provide nutrients for other organisms.

Animals are important in the reproductive cycles of many plants. Natural pollination of flowering plants often depends on insects, and seed dispersal is frequently facilitated by birds or other animals. In the Central Hardwood Region, rodents play an important role in seed dispersal of large seeded hardwoods. Even insects such as ants can be important in transporting seeds away from parent plants to more favorable locations for germination and growth.

Carbon sequestration is another ecosystem function recognized rather recently for its importance. Natural systems, particularly forest systems, often store huge amounts of carbon in branches, stems, and roots. This helps relieve the buildup of carbon dioxide and other greenhouse gases in the atmosphere. These gases may be responsible for changes in our climate, often referred to as "global warming."

An important role of many species, including many "minor" species typically receiving little attention, is that of indicators of ecosystem condition. Species found in a given habitat reflect environmental conditions over time and space. Indicator plant species are frequently used in ecological classification systems to estimate the potential of the site to support different communities. Animal populations, such as some species of song birds, mussels, and minnows, are often very sensitive and reveal information about environmental conditions. Unfortunately, we often lack knowledge of what individual species are indicating. We do know, however, that a reduction in biodiversity often indicates a change in ecosystem condition, even when we do not fully understand the interactions causing the reduction, nor the long-term implications of loss of diversity.

Diverse ecosystems are widely believed to be more resilient to disturbance or stress, and will likely be better able to adjust to external stresses or changing conditions. Most ecosystems have some level of built-in functional redundancy; that is, multiple species perform the same ecosystem functions. As individual species are lost, ecosystems are generally able to compensate. However, if enough species are lost, or if particularly critical species are lost, significant changes in ecosystem structure or function can result. We will never completely understand how ecosystems function or the roles played by each individual species, let alone understand all of the complex interactions occurring between species and between ecosystems. Therefore, it behooves us as managers, as well as members of ecosystems, to conserve as many species as possible; or, as Aldo Leopold put it, "... keep every cog and wheel ...."

Intrinsic and Aesthetic Values

Not all of the benefits of conserving biological diversity can be measured in economic terms, or in terms of the ecological services provided. Many people feel there is an intrinsic value to living things, and people have a moral responsibility to protect species. This attitude is reflected in the high priority our society places on protecting endangered species, the cultural and religious significance placed on many species and ecosystems, and the expressed willingness of many people to make substantial social and economic sacrifices in order to conserve wildlife and wildlife habitat. A reflection of the aesthetic appreciation for biological diversity is the widespread success of the ecotourism industry, illustrated by the fact that each year over 270 million visits are made to national parks in the United States alone.

Legal Considerations

The United States Congress, Office of Technology Assessment lists 29 laws related to the maintenance of biological diversity, dating back to the Lacey Act of 1900 which governed interstate transport of wildlife. Most of these laws have been directed at specific groups of species or specific habitats. Several other laws indirectly promote diversity through their impacts on maintaining environmental quality or through regulation of land use. These include the National Environmental Policy Act (NEPA), the Clean Air Act, the Clean Water Act, and the Multiple Use Sustained Yield Act.

At least two laws provide legal mandates for the protection of biodiversity. The National Forest Management Act (NFMA) of 1976 requires that management of national forests occur in such a way that minimum viable populations of all native plants and wildlife be maintained. This law applies, of course, to lands managed by the USDA Forest Service.

The Endangered Species Act (ESA) of 1973 requires protection of threatened or endangered species on all lands. Thus, if an animal listed under the ESA is found on any property, private or public, then the owner of that property is legally required to ensure that management of the land does not threatened the continued existence of that species. Endangered plants are protected on federal lands by the ESA; however, protection on private lands generally depends on individual state regulations. While the ESA does not specifically mandate conservation of biodiversity, providing for the continued existence of rare species, and the ecosystems upon which threatened and endangered depend, ultimately enhances diversity at the regional level.

Considerations of Scale

Biological diversity is the variety of some element of interest, commonly species, within a given area. The area of interest is arbitrarily defined, and can range in scale from small microsites up to the entire planet. There is no single scale at which biodiversity is addressed. A complete approach to management of biodiversity requires consideration across multiple scales.

Local biodiversity is the variety of species (or other elements) occurring within a relatively homogenous community, such as a single stand of trees. It is at this scale that land managers are generally most comfortable. Managers are accustomed to manipulating stands to create desired habitat conditions, whether for a specific wildlife species or for meeting the regeneration requirements of a given plant species. Local diversity is typically affected by structural elements of the stand; tree density, snags, coarse woody debris, size diversity, foliage distribution, canopy gaps, and woody species mix.

Landscape level biodiversity refers to the diversity that exists between stands. From a species diversity standpoint, it is the difference in composition among communities, or the change in species composition occurring along environmental gradients. A specific stand may be no more diverse than other stands in the landscape, but differences in species composition between stands increase the diversity of the entire landscape. From a more practical management perspective, landscape diversity is the variety of habitat conditions occurring across a landscape consisting of many stands. Landscape level biodiversity is influenced by such factors as vegetation types, patch sizes, stand ages, land uses, and the degree of landscape fragmentation and connectivity.

Regional biodiversity is the diversity that occurs across large areas consisting of several landscapes. This level of diversity considers the variety of habitats and species occurring throughout the larger region, e.g., the biological diversity of northern Indiana, or of the entire Central Hardwood Region. Regional diversity is affected by the variety of ecosystems present in the region, land use patterns, and the juxtaposition of diverse landscapes throughout the region.

Landscapes and regions, like ecosystems, are artificial constructs, and as such, their size and specific boundaries are arbitrarily defined. Regional diversity can be expanded to include the biodiversity of the entire United States. The ultimate conservation concern is with global biodiversity. Local land managers, however, do not typically work at these scales. Their efforts are more commonly focused on the impacts of local management activities on the biodiversity of relatively small regions, parcels, or ownerships.

Managers of biodiversity must also consider temporal scale. Ecosystems are not static systems. As communities change through time, the diversity of species and structures associated with them change as well. If specific landscape features or characteristics are being relied upon to provide important elements of biodiversity, then consideration must be given to the long-term risk of losing those features due to natural succession or catastrophic disturbance. On the other hand, situations where landscapes are completely protected from disturbance may also suffer from a loss of diversity over time. A comprehensive approach to managing biodiversity must consider natural temporal variations in ecosystems, including natural disturbance regimes.

Focus of Management Concern

What is the level at which biodiversity is best addressed? Historically, when managers considered biodiversity, the focus was on species diversity at the local level. Unfortunately, management to maximize species richness at the local level typically results in creation of large amounts of habitat favoring generalists, such as edge species (e.g., deer, quail) and species which utilize disturbed habitats (e.g., cowbirds). These species are generally common, particularly in landscapes highly influenced by human activity. Therefore, management at the local scale promoting already common species does little toward enhancing regional biodiversity.

Management that favors generalist species often does so at the expense of habitat specialists, less common species requiring specific habitat conditions. These are often the species most at risk of local or regional extinction. In forest management, the types of species frequently not adequately provided for are those requiring large, unfragmented blocks of mature forest conditions, or specialized habitats such as cliffs or rock outcrops, caves, seeps, and forest wetlands.

In the Central Hardwood Region, another group of species not being adequately addressed are those requiring large blocks of early successional forest habitat such as provided by large natural disturbance or created through the use of even-aged forest management techniques. Private forest landowners, who control the majority of the forestland in the region, generally do not practice even-aged management; and public land management agencies in recent years have moved away from creating large forest regeneration openings. Therefore, no major forest ownership group in the region is currently practicing management resulting in the creation of substantial amounts of early successional forest habitat.

The primary objective in the effort to conserve biodiversity is to maintain species diversity at the regional scale or higher. Specific attention is given to known threatened or endangered species, rare species or unique habitats, and species known to serve key functions in ecosystem processes such as nutrient cycling, decomposition, or predator-prey relations. Native species are generally given preference over exotics, although in many situations exotics will be impossible to eliminate and must be considered a part of the community. There are even situations where exotic species have become beneficial components of communities and help enhance overall biological diversity. For example, the honeybee is not native to North America, but is invaluable as a pollinator in many natural and agricultural plant communities.

Effective approaches to conservation of biodiversity must also focus on maintaining adequate representation of whole ecosystems. This provides a diversity of habitats and conditions required to maintain overall regional biological diversity. Ideally, these ecosystems should be large enough, and in suitable condition, to fully support the diversity of organisms naturally associated with them. This will rarely be possible, however, given the history of human activity in the Central Hardwood Region.

Factors Negatively Affecting Biological Diversity

The natural biological diversity of a region is determined by a number of physical and ecological factors. Physical factors include geographic location, climatic history, variety and extent of soil types, and natural landscape heterogeneity. Within the physical setting of a region, ecological processes affecting biodiversity include migration of organisms to and from adjacent regions, extinctions, and natural speciation and hybridization within the region. Natural disturbance regimes affect diversity by creating a mosaic of vegetation communities and seral stages at a variety of spatial scales, thus adding to the natural spatial variability of landscapes.

Anthropogenic, or human-caused, influences on ecosystems generally, but not always, negatively impact biological diversity. Human activities alter natural communities and landscapes, as do natural processes. However, the rate at which humans impose these changes generally exceeds the rate at which most existing species adapt or new species evolve. Over time, this has led to reductions or extirpations of many species across their native ranges.

Activities affecting biodiversity can be divided into those that convert wildland ecosystems to other uses and those that maintain the ecosystem but change its structural or compositional characteristics. The influence of both types of activities ultimately interact to impact regional biodiversity.

Conversion of Wildlands to Other Uses

Conversion of native ecosystems to alternative land uses may be the most damaging human influence on biodiversity. At the landscape or regional scale, agricultural, urban, and commercial development drastically alter ecosystem structure. At the local scale, these land uses physically eliminate most natural characteristics of the ecological community, thus effectively eliminating the majority of native species that occurred on the site.

Conversion of wildlands in the United States historically occurred as part of settlement and development of new regions. The area of forestland in the U.S. declined until the early part of this century. Since the 1920s there has been a net gain in forest area as agricultural land has been planted back into trees, or has been abandoned and naturally reverted back to forest vegetation. This trend has occurred in the Central Hardwood Region as well, where there has been a net increase in forestland over the past half century. Forest acreage in the region has essentially stabilized over the past few decades.

Attempts are also being made to maintain other wildland ecosystems in the region and throughout the country, including wetlands, grassland prairies, prairie savannas, deserts, and marine estuaries. In general, fewer acres have been converted for agricultural uses in recent years, and some marginal agricultural lands have been allowed to revert back to wildland conditions.

Predictions of future trends suggest that conversion of wildland to agricultural uses will continue to be minor. However, expanding populations will continue to result in losses of wildland ecosystems to urban and commercial development. Forestland in the U.S. is predicted to decrease by 4 percent over the next 50 years. Lower rates of forestland loss are predicted for the Central Hardwood Region.

Alteration of Ecosystem Structure or Function

Human exploitation of ecosystems, for commodity, recreational, or aesthetic purposes, has great potential to affect biological diversity. Much of the impact to biodiversity in the Central Hardwood Region results from activities which keep wildland ecosystems relatively intact, but cause some alteration in ecosystem structure or function. These can include activities such as timber harvesting, road and trail construction, or introduction of non-native species into the ecosystem. Again, many of these activities interact with the influences of land-use conversion to impact overall regional biodiversity.

Management activities changing the structure of ecosystems often impact rare or unique habitat features. Altering ecosystem structure may also alter hydrologic cycles, nutrient cycles, and other important ecological processes. Native biodiversity evolved under the influence of these processes, and is thus affected by ecosystem changes that alter them.

Ecosystems have also developed under the influence of natural disturbances, such as fire, windstorms, ungulate grazing, or natural predation—disturbances which may be important for maintaining some elements of biodiversity. Disturbance regimes, critical to the structuring of natural communities, have been dramatically altered by human exploitation of landscapes, thus influencing native species diversity.

The importance of scale is reemphasized here. Actions which reduce local, or on-site diversity may actually add to landscape or regional diversity. Rare or unique species, which contribute most to regional diversity, do not just occur in complex ecosystems, but may occur in fairly simple or species-poor communities as well. For instance, natural grasslands or prairie savannas are structurally simple but often contain rare species. Management designed to maintain these types of communities may intentionally reduce local diversity but enhance landscape or regional diversity.

Recognize also that while human disturbance generally reduces overall biological diversity, it is unavoidable in most ecosystems. All ecosystems experience some forms of human impact. Lack of management, particularly where natural disturbance regimes have been reduced or eliminated, will not necessarily enhance existing diversity, and will rarely restore natural levels of diversity.

The three major human influences on biodiversity of forest ecosystems are fragmentation of the landscape, silvicultural activities, and chemical inputs into the ecosystem. With all of these influences, at least part of the ecosystem remains essentially intact, but each can result in significant changes in ecosystem structure.

1. Fragmentation

Fragmentation of the forest landscape is a frequent result of management activities. Harvest units, roads, trails, and powerline or pipeline corridors can break up large, contiguous forest areas into a more fragmented mosaic of habitat types, patch sizes, and ages. This mosaic changes as ephemeral habitat patches (such as newly harvested stands) mature to later successional stages, and as new patches are harvested.

In the Central Hardwood Region, forest management causes less fragmentation than does conversion of forest land to other uses, which frequently leaves isolated patches of forest embedded in a partially developed landscape. This type of permanent fragmentation is common throughout the region, and has had a greater impact on forest biodiversity than traditional forest management.

Local biodiversity is significantly affected as forest patch size is reduced. An individual patch will not contain all the species typically represented in larger areas of similar habitat. Small, isolated patches of forest vegetation support smaller populations of species, making them more susceptible to local extinction. Patch size is particularly critical to so-called "area-sensitive" species; organisms requiring large patches of contiguous habitat.

Fragmentation also results in the creation of large amounts of edge habitat, the transition zone between two adjacent vegetative communities. "Hard" edges are where two communities of very different plant size and composition come together, such as the boundary between a mature forest and an agricultural field. "Soft" edges occur where there are more subtle differences in the composition and structure of adjacent communities, such as between a dry ridgetop chestnut oak community and a northern red oak-maple community on a mesic upper slope. Silvicultural practices such as clearcutting or group selection harvests initially result in creation of a hard edge which softens over time. Discussions of edge related effects generally relate to situations where relatively sharp contrasts in adjacent communities lead to greater influences on species composition.

Hard-edge habitats are characterized by higher light intensity, greater temperature extremes, and higher vapor pressure deficits than found in forest interiors. These changes in microclimatic conditions can alter the relative reproductive and competitive abilities of individual species, and lead to changes in the biological community along the forest edge. Hard edges may also provide easier access into the stand for predators, parasites, and alien species (e.g., foxes, cowbirds, red-tailed hawks). Many species that colonize disturbed sites are favored by edge conditions and can effectively out-compete species adapted to the closed canopy forest (e.g. bush honeysuckle, tree-of-heaven).

Edge conditions are created at the expense of interior forest conditions. Therefore, an increase in edge results in a decrease in habitat for species dependent on the conditions provided by forest interiors. The "edge effect" can extend from a few feet to as much as several hundred feet into the forest stand. In fragmented landscapes, if forest patches become small enough, they may effectively become entirely edge habitat, thus locally eliminating forest interior species.

Fragmentation can also impose barriers to species dispersal throughout landscapes by destroying corridors of vegetation used for travel between patches of suitable habitat. There is evidence that some species avoid forest edges (e.g. wood thrushes, white-footed mice) and others rarely cross large open areas (e.g. eastern chipmunks). Certain species of forest arthropods and small mammals have even been shown to be reluctant to cross forest roads or trails. Some plant species may require corridors of suitable growing conditions to disperse across landscapes, thus providing for the exchange of genetic material and the availability of species for normal successional changes in plant communities.

The ultimate impact of fragmentation on biodiversity depends on the scale at which impact is assessed. At the local scale, fragmentation often leads to increased biodiversity due to the creation of edge conditions. However, most species favored by edge are habitat generalists and are typically common. While few species are known to be entirely dependent on edge, many species are known to utilize edge habitats preferentially. If edge conditions were not available, the abundance of these species would likely decline. However, edge conditions are not limiting throughout most of the Central Hardwood Region. Creation of additional edge habitat, therefore, does little to promote regional biodiversity.

At the regional scale, the impact of fragmentation depends on the overall condition of the forested landscapes. Moderate fragmentation can create greater landscape heterogeneity. Maintaining a broad range of habitat conditions; including both edge and interior forest conditions, and both early- and late-successional stages; would enhance regional biodiversity. Unfortunately, in the highly disturbed landscapes typical of the Central Hardwood Region, excessive fragmentation has increased the threats to regional diversity as species requiring unfragmented habitats have declined or disappeared locally. For example, in the primarily agricultural portions of Indiana, many forest-interior bird species native to these areas are absent from the smaller woodlots remaining on the landscape.

2. Silviculture

Standard silvicultural treatments frequently reduce the complexity of forest communities. Many stand cultural treatments reduce the number of tree species in a stand by favoring only a few commercially valuable species. Thinnings remove smaller individuals, reducing the variability in tree sizes, and creating a more even spacing between trees. Harvest operations often reduce the number of standing snags or the amount of large woody material on the forest floor.

Structurally complex stands typically contain greater biodiversity than less complex stands. Trees of different size and morphology, irregular spacing, standing snags, and downed logs all create a greater number of unique habitats, or niches, thus supporting more species. Simplifying the structure and composition of forest communities through forest management activities generally reduces local biodiversity. There are cases, however, where relatively simple stand structures are important for certain unique or sensitive species. In the Central Hardwood Region, for example, savannas and oak barrens are structurally simple ecosystems that frequently support rare or unique plant and animal species (e.g. pink corydalis, beach heath, flower-of-an-hour).

The mixed hardwood stands in the Central Hardwood Region are naturally quite structurally diverse due to the wide variety of tree species commonly present. There is less reliance on intensively managed, even-aged plantations in this region than there is in some other regions of the country; and where even-aged management is practiced, stands are still able to develop complex structure. However, while the live tree component tends to be structurally complex, attention must still be given to providing adequate levels of snags and coarse woody debris, and to assuring that stands of varying structural characteristics are well represented across the landscape.

3. Chemical inputs

All ecosystems, regardless of how remote, are exposed to human-induced chemical inputs, some intentional and some not. All have the potential to affect biodiversity. The two main sources of these inputs are on-site use of chemicals for management purposes, and off-site pollution making its way onto the site. Pollution from off-site sources, such as air pollution or water pollution, are typically not under the control of forest managers. Managers do control the on-site use of chemicals and should recognize the potential impacts they can have on diversity.

Chemicals are used in forest management either as fertilizers to enhance growth of desired vegetation, or as pesticides to control unwanted plants or animals. Fertilizers differentially affect growth rates of species, thereby changing the competitive balance between plants. Enhancing plant growth changes the structure of the stand, particularly if understory growth increases. Greater nutrient availability may even change the species composition of the understory. Higher nutrient quality of the vegetation or greater structural complexity can also affect animal species composition on the site.

Pesticides are used to control unwanted species in forest communities. These typically include "weedy" plant species which compete with desired vegetation for site resources, or animal species such as insects or rodents that feed on or otherwise damage favored plant species. Managers must recognize that use of pesticides, even though effective as management tools, can adversely affect biodiversity. Reduction or elimination of some species, including non-target species, can change the competitive balance within the community, affecting compositional as well as structural diversity.

Conditions in the Central Hardwood Region

The Central Hardwood Region encompasses the majority of Illinois, Indiana, and Ohio, along with portions of Kentucky, Tennessee, Missouri, Iowa, Wisconsin, Michigan, and West Virginia. The forests of the region are dominated by oak, hickory, and mixed hardwood forest types, although there is considerable variation in the species mixes that make up these types. Regions adjacent to the Central Hardwoods historically have acted as sources of biological diversity. Ecological communities grading into the region include upland hardwood and conifer types from the north and east, Southern pine and bottomland hardwood types from the south, and prairie grasslands and savannas from the west. All of these communities contribute to overall regional biodiversity.

Within the Central Hardwood Region, there is considerable natural ecological diversity. In addition to the mixed hardwood forests, the region contains northern bottomland hardwoods, prairie and savanna grasslands, barrens, wetlands, and dunes. The extent of these community types, however, has been greatly reduced due to land use conversion or alteration of ecosystem processes, e.g. changing fire regimes in prairie savanna, draining wetlands for agricultural and urban development.

Natural landscape patterns in the region are quite diverse, with different physiographic conditions leading to the development of a variety of intermingled ecosystem types. This natural "fragmentation" was developed over geologic time frames and allowed species to evolve with, or adapt to, changing landscape patterns. The wide variety of habitat conditions in the region has favored high levels of biodiversity.

Nearly all landscapes in the region have been severely disturbed by past human activity, leaving the region highly fragmented, primarily by agricultural and urban development. The few large, unfragmented forest tracts remaining in the region are generally areas of public lands. However, approximately 90 percent of the forestland in the Central Hardwood Region is owned by private landowners, with an average ownership of around 50 acres. Within this framework, managers must find ways to incorporate biodiversity considerations into forestland management.

General Approaches to Management

Management for conservation of biological diversity can take two general approaches. One is the species management approach. This is essentially the current approach of the Endangered Species Act (ESA), and assumes that to ensure high levels of biological diversity we must provide for those species most at risk of extinction. Unfortunately, the list of species already at risk of extinction exceeds the capabilities of managers to address if they attempt to do so one species at a time. Table 1 shows the number of threatened, endangered, and sensitive species listed by individual states in the Central Hardwood Region. Not all species listed by each state are federally listed under the ESA, but the numbers clearly illustrate the problems encountered in trying to manage individual species.

The second approach to managing for biodiversity is the habitat, or ecosystem-based approach. This approach assumes that maintaining a wide variety of habitat conditions in appropriate landscape patterns will provide for the greatest number of plant and animal species. This is the approach most widely advocated by scientists and natural resource professionals, and it is one of the basic foundations of ecosystem management.

Practically and conceptually, ecosystem-based approaches to managing biodiversity are the most promising. However, there are shortcomings to the approach, mostly due to inadequate information. We do not know what "appropriate" landscape patterns should be maintained. For maintenance of maximum biodiversity, the ideal would probably be to restore landscapes to conditions with minimum evidence of human influence. This will rarely be practical, however, in highly modified and disturbed landscapes such as those found in the Central Hardwood Region.

Given the realities of existing landscapes then, what is the most appropriate way in which to manage for biological diversity? Should we not manage at all and let nature take its course? Or should we aggressively manage to meet some predetermined landscape design? The answer to these questions is becoming clearer as our knowledge concerning the management of landscapes to benefit biodiversity continues to grow. The clearest answer right now is that appropriate management approaches will differ in specific situations. For instance, larger public ownerships may opt to take a long-term approach designed to

Table 1. Number of endangered, threatened, or "special concern" plant and animal species for states in the Central Hardwood Region. (Listed species often occur in more than one state)

State	Plants	Mammals	Birds	Fish	Reptiles/ Amphibians	Insects	Mollusks	Other	Total Animals
Illinois									
E	306 (2)	6 (2)	33 (4)	21 (1)	9 (0)	7 (1)	21 (5)	12 (1)	109 (14)
T	57 (7)	3 (0)	9 (0)	9 (0)	9 (0)	4 (0)	4 (0)	1 (0)	39 (0)
O	NA	NA	NA	NA	NA	NA	NA	NA	NA
Indiana									
E	189 (1)	6 (5)	20 (6)	12 (0)	5 (0)	20 (3)	15 (14)	NA	78 (28)
T	99 (3)	3 (0)	4 (0)	0 (0)	13 (0)	7 (0)	0 (0)	NA	27 (0)
O	**171 (22)	20 (5)	21 (6)	14 (7)	10 (6)	30 (6)	22 (8)	NA	117 (40)
Iowa									
E	64 (0)	4 (2)	9 (4)	8 (1)	13 (0)	2 (0)*	9 (5)	7 (0)	52 (12)
T	89 (5)	4 (0)	2 (1)	8 (0)	6 (0)	5 (0)*	6 (0)	2 (0)	33 (1)
O	234 (11)	1 (3)	2 (9)	2 (8)	0 (4)	25 (4)*	0 (5)	0 (8)	30 (41)
Kentucky									
E	145 (4)	7 (3)	19 (3)	19 (2)	6 (0)	1 (1)	24 (11)	12 (1)	88 (21)
T	84 (4)	3 (0)	9 (0)	12 (1)	8 (0)	1 (0)	6 (0)	8 (0)	47 (1)
O	66 (27)	6 (6)	17 (4)	33 (1)	14 (5)	13 (14)	5 (13)	13 (11)	101 (54)
Missouri									
E	245 (4)	4 (4)	10 (6)	19 (1)	8 (0)	3 (1)	14 (5)	4 (0)	62 (17)
T	*** (5)	*** (1)	*** (0)	*** (3)	*** (0)	*** (0)	*** (0)	*** (0)	*** (4)
O	292 (23)	20 (4)	41 (6)	47 (13)	22 (2)	52 (13)	27 (13)	27 (3)	236 (52)
Ohio									
E	221 (2)	4 (3)	25 (4)	25 (1)	8 (0)	24 (3)	30 (14)	0 (0)	116 (25)
T	159 (4)	0 (0)	1 (0)	8 (0)	2 (0)	0 (0)	6 (0)	1 (0)	18 (0)
O	256 (14)	20 (5)	30 (5)	25 (6)	19 (6)	17 (16)	20 (7)	7 (2)	138 (47)

E = Endangered, T = Threatened, O = Other designation (rare, extirpated, considered for listing, etc.), NA = Not available

* Butterflies only
** Does not include plants of special concern in Indiana
*** No state classification for threatened species
Data for this table were compiled from species lists developed by individual states.

achieve some desired future condition for large landscapes. Smaller private ownerships might be more likely to manage for specific stand-level characteristics to favor individual species.

A challenge in the Central Hardwood Region will be finding ways to significantly alter landscapes dominated by private land ownership. In order to do this, educational programs will be needed that stress the benefits of biodiversity to the private landowner. Technical assistance will be required from professionals who understand how to incorporate biodiversity considerations into their management recommendations. And it is likely that incentive programs will be needed to encourage private landowners to manage for biodiversity.

Another limitation to the ecosystem-based approach to managing for biodiversity is that without aggressive monitoring, we cannot be certain if all species are adequately provided for. It is therefore likely that some combination of ecosystem-based and species-based approaches will be needed. Using this combined approach, a wide range of ecological conditions would be maintained to provide habitat for as many species as possible. Specific efforts would also focus on the preservation of selected rare species.

Information Needs of Managers

Despite the acknowledged limitations in our understanding of how to manage for biological diversity, resource managers are still being asked, if not required, to consider diversity in their management decisions. What information, then, is most useful to land managers for managing biodiversity? One source of information is the list of sensitive plant and animal species for the area being managed. All states have a list of species which are considered endangered, threatened, rare, or in some way deserving of special attention within the state. These lists are a good place to start in selecting species to give special attention to, although there are legitimate reasons to manage for species which are not considered rare or sensitive. It's also important to realize that just because a species is on a state list does not necessarily mean it is endangered at a larger, regional level.

More important than a listing of sensitive species is an understanding of the habitats that support these species. Managers should be aware of habitats likely to be more important to the conservation of biodiversity, or what habitat characteristics may enhance diversity. Some habitats are inherently more valuable for biodiversity than others. For example, habitats associated with water (lakes, streams, riparian areas, wetlands, seeps) are often critical, not only to strictly aquatic organisms such as fishes and mollusks, but also to many terrestrial species intimately associated with these ecosystems such as amphibians, certain reptiles and birds, and hydrophytic vegetation.

Other unique habitats also tend to be disproportionately important for biodiversity. These include caves, cliffs, rock outcrops, and other areas with unique geological characteristics. Prairies, savannas, and barrens are examples of community types in the region which are valuable due to their limited distribution. While unique habitats are often not especially rich in local diversity, they are often critical to rare species that are important to overall regional diversity. In large part this is because these unique habitats are themselves often rare components of regional ecosystem diversity.

Not all threatened or endangered species are going to be maintained throughout their native ranges. Therefore, along with the knowledge of which species and habitats are important to the conservation of biodiversity, managers must know what the objectives and priorities related to biodiversity are. Regional priorities can frequently be found in recommendations and guidelines developed by state and federal agencies, as well as by interdisciplinary non-governmental organizations such as Partners In Flight and The Nature Conservancy.

Specific biodiversity objectives for a given piece of land will depend largely on who owns the land. On lands managed by federal or state land management agencies, objectives and priorities can be established centrally for relatively large areas. The preponderance of nonindustrial private forest landowners in the region, however, make it difficult to establish meaningful and consistent priorities for biodiversity over areas large enough to be ecologically significant. Managers may frequently face the dilemma of conflict between biodiversity concerns and other land management objectives.

Recommendations for Managers

Much remains to be learned concerning how best to approach conservation of biodiversity in highly disturbed, fragmented landscapes dominated by private ownership. However, there are things that managers should keep in mind when considering biodiversity in management decisions.

Managers must recognize that all lands contribute to overall biodiversity, even the highly disturbed or developed lands. In fact, several sensitive species in the Central Hardwood Region are dependent on human disturbance for their continued existence. For example, half of the threatened and endangered species examined at Indiana Dunes National Lakeshore in Indiana were found to respond positively to some human disturbances.

Different elements of biodiversity in the region will be provided by different lands. For instance, large areas of contiguous mature and late-successional forest will likely be provided by public land management agencies, while private lands will provide mostly mid-successional forest conditions. Managers of private lands can also contribute to regional diversity by protecting rare or unique habitats on their property.

Recommendations to managers include[1]:

- Recognize that no property exists in biological isolation. The biodiversity of an individual piece of land, and how that piece of land contributes to regional biodiversity, is largely determined by the surrounding landscape. A 40 acre patch of forest bisected by a stream may be much more important to biodiversity if embedded in a predominantly agricultural landscape than if surrounded by thousands of acres of forest.
- Be aware of how a given piece of land can contribute to regional biodiversity. This requires that managers have some knowledge of the unique or sensitive species that might exist in a given area.
- Recognize unique or otherwise important characteristics of the particular property. Rare and sensitive species are often found in unique sites such as wetlands, seeps, cliffs, rock outcrops, and streamside zones.
- Perform an assessment of the biological diversity of a property before prescribing management activities. This will determine if the property contains any unique habitats or sensitive species.
- Match proposed activities to the specific condition of a site. Some areas are appropriate locations for intensive activity and management, while others are more sensitive. This again requires a knowledge of potentially valuable elements of biodiversity in a given area of the region.
- Attempt to maintain native plant and animal species. Avoid introducing exotic plants and animals that have the potential to spread and displace native species, modify or disrupt natural communities, or reduce ecologic or economic values.
- Focus management on ecological communities, i.e., the ecosystem approach to managing biodiversity. The only practical way of addressing the habitat needs of many species at once is by managing for naturally occurring aggregates of species.
- Protect rare or ecologically important species that may not receive adequate protection under an ecosystem-based approach to management. The species-based approach will remain an important element in the effort to conserve biodiversity.
- Minimize habitat fragmentation. Large patches of undisturbed natural habitat are important to conserving biodiversity. Additional fragmentation in the already highly fragmented Central Hardwood Region reduces the availability of those habitat conditions that are rarest in the region. Where possible, forest patch size should be increased.
- Develop, maintain, or enhance connective corridors between patches of quality habitat in otherwise fragmented landscapes. This can be accomplished by maintaining natural vegetation along stream corridors, promoting the use of windbreaks and shelterbelts, planting trees and shrubs along roads, fences, and property boundaries, and reestablishing native community types on selected tracts of land.
- Maintain naturally occurring structural diversity. At the site or stand level, this includes providing for a diversity of tree species, as well as structural features such as snags and large woody debris. At the landscape level, efforts should be made at maintaining a variety of community types, successional stages, and patch sizes.
- Maintain or mimic natural processes. Naturally occurring processes, such as succession, disturbance, nutrient cycles, etc., have been important forces in determining native biodiversity, and should be provided for to the extent possible. Recognize, however, that large scale natural disturbance processes such as fire or flooding may be difficult to manage for. Tools such as prescribed fire or managed flooding are relatively easy to use at local scales; but, implementation over ecologically significant portions of most landscapes is difficult. Silvicultural treatments, or other vegetation management techniques, can also be used to mimic natural disturbances.
- Protect genetic diversity. Genetic variation within plant and animal populations provide species with greater flexibility to adapt to changing environmental conditions, thus increasing the probability of maintaining species viability. One way to protect genetic diversity is to protect isolated populations at the edges of species' ranges—populations that are often genetically

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[1] Many of these recommendations have been taken from: Biodiversity on private lands: an initiative of the President's Commission on Environmental Quality. March 1993.

distinct. Another way is to provide connective corridors to facilitate movement of organisms and prevent isolation of small populations.

- Monitor for impacts on biodiversity. Given our limitations in being able to predict long-term impacts of management on biological diversity, it is imperative that we monitor the progress of ecosystems to determine if biodiversity goals are being met. This also requires that we retain flexibility in our management to make future adjustments if monitoring determines that goals are not being achieved. Monitoring efforts will be made easier through the use of such new computer technologies as GIS; however, monitoring efforts on a predominantly private land base will be difficult.

Not all the above recommendations will be appropriate in all instances. Some may only be relevant for consideration in the management of larger blocks of public lands. Others, while appropriate for private land management, may not suit the objectives of a particular landowner. Professionals must be adaptable in deciding how and when to apply specific approaches to the management of biodiversity.

Summary

Biodiversity is defined as the variety and abundance of species, their genetic composition, and the ecosystems within which they occur. Current levels of biodiversity in ecosystems throughout the world are declining at alarming rates, stemming primarily from pressures of exponential human population growth. In the United States alone, there are over 900 species of plants and animals listed as endangered or threatened under the Endangered Species Act, and another 3,500 awaiting consideration for possible listing.

There are many valid reasons to be concerned about the conservation of biodiversity. A large number of species have economic value, and all species have roles in ecosystem processes. Loss of diversity is threatening current and future economic benefits, and may eventually threaten the productivity, and even sustainability, of some ecosystems. Recognition of these values, combined with intrinsic values placed on species by society, have led to passage of numerous laws encouraging, and even requiring, conservation of species diversity.

Biodiversity can be considered on various spatial scales. Historically, resource managers have addressed species diversity at the local, or site level. This often led to creation of conditions favoring high densities of habitat generalists, such as commonly found in edge conditions. From a species conservation standpoint, however, concerns center more on rare species requiring unique or uncommon habitat conditions. The focus of conservation biology is maintaining species diversity at the regional scale or greater by providing for all native plant and animal species, with special consideration for those currently considered rare or endangered.

Human influences on ecosystems almost always negatively affect species diversity. Conversion of wildlands to urban, agricultural, or industrial uses has the most devastating impact on diversity. Impacts also result from activities which maintain the ecosystem, but change its natural characteristics through fragmentation of ecosystems, alteration of ecosystem composition and structure, and introducing chemical inputs to ecosystems.

There are two basic approaches to managing for the conservation of biodiversity. The individual species approach, used alone, is considered by most experts to be impractical given the large number of species threatened with extinction. A more promising approach concentrates on maintaining high levels of ecosystem diversity, thus providing habitat for a large number of species. Selected individual species will continue to be given individual protection as needed and determined appropriate.

The Central Hardwood Region was naturally quite diverse, with a wide variety of ecological communities native to the region. All ecosystems in the region, however, have been subject to considerable disturbance and alteration. Private lands, which make up most of the region, are highly fragmented. Most remaining wildlands are embedded in a matrix of agricultural and urban development. The few large, unfragmented wildland ecosystems remaining in the region are generally in public ownership.

Several recommendations can be made to resource managers concerning how to address biodiversity considerations. It is important to recognize, however, that biodiversity is but one of many potential objectives for a piece of ground, and it may not be the most important objective to a specific landowner. While all lands can, and probably should, contribute something to overall regional biodiversity, not all lands can and will be used to provide for the most critical elements of diversity. Private landowners that manage for biodiversity are, therefore, valuable resources themselves.

What is the outlook for biodiversity in the future? On one hand, human populations continue to grow, impacts continue to increase, and the number of imperiled species seems to be ever increasing. At times, it appears our efforts to make positive gains in preserving biodiversity seem futile. On the other hand, there is reason for optimism. The issue is receiving much attention, and our knowledge of how to manage for diversity continues to increase. There is also a great deal of public interest in maintaining viable populations of wildlife species and, as we've found in the past, when charismatic species become endangered there is considerable public support for protecting those species. As the public gains greater appreciation for the importance of biological diversity, it is more likely that additional steps will be taken for protection measures.

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Additional Suggested Reading

Barnes, T.G. 1993. *Biodiversity*. University of Kentucky Cooperative Extension Service, FOR-63. 8 p.

Barnes, T.G. 1994. *How we can manage for biodiversity*. University of Kentucky Cooperative Extension Service, FOR-64. 12 p.

Burton, P.J., A.C. Balisky, L.P. Coward, S.G. Cumming, and D.D. Kneeshaw. 1992. *The value of managing for biodiversity*. The Forestry Chronicle 68(2):225-237.

Coder, K.D. 1994. *Biodiversity management concepts*. University of Georgia, Extension Forest Resources Publication FOR94-8. 4 p.

Flather, C.H., L.A. Joyce, and C.A. Bloomgarden. 1994. *Species endangerment patterns in the United States*. USDA Forest Service, Gen. Tech. Rpt. RM-241. 42 p.

Franklin, J.F. 1993. *Preserving biodiversity: species, ecosystems, or landscapes*. Ecological Applications 3(2):202-205.

Langner, L.L. and C.H. Flather. 1994. *Biological diversity: status and trends in the United States*. USDA Forest Service, Gen. Tech. Rpt. RM-244. 24 p.

Miller, B.K. 1990. *Managing forest & wildlife resources: an integrated approach*. Purdue University Cooperative Extension Service, FNR-125, 17 p.

Ozier, J. 1994. *Endangered species and the private landowner*. J. For. 92(5):22.

President's Commission on Environmental Quality. 1993. *Biodiversity on private lands*. 21 p.

Society of American Foresters. 1991. *Task force report on biological diversity in forest ecosystems*. SAF 91-03. Society of American Foresters, Washington, D.C. 52 p.

Sources of Additional Information

Locations of information concerning endangered, threatened, or special concern species in the Central Hardwood Region.

Midwest Heritage Task Force
The Nature Conservancy
1313 Fifth Street, SE
Minneapolis, MN 55414

Illinois Natural Heritage Division
Department of Conservation
524 S. 2nd Street
Springfield, IL 62706

Indiana Division of Nature Preserves
Department of Natural Resources
402 W. Washington St., Room W267
Indianapolis, IN 46204

Iowa Natural Areas Inventory
Department of Natural Resources
Wallace State Office Building
Des Moines, IA 50319

Kentucky Heritage Program
KY Nature Preserves Commission
407 Broadway
Frankfort, KY 40601

Missouri Natural Heritage Database
Missouri Dept. of Conservation
P.O. Box 180
Jefferson City, MO 65102

Ohio Natural Heritage Program
Div. of Natural Areas & Preserves
Department of Natural Resources
Fountain Square, Building F
Columbus, OH 43224

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