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INDIANA GAP ANALYSIS: IMPLICATIONS FOR BIODIVERSITY CONSERVATION AND RESTORATION

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ABSTRACT: The Indiana Gap Analysis Project and the proposed Indiana Biodiversity Protection and Restoration Framework, as part of the nationwide Gap Analysis Project, will confront the critical environmental problem of declining biodiversity. Some estimates place the current rate of extinctions worldwide at about 1,000 times the natural rate. The U.S. Fish and Wildlife Service currently lists approximately 640 species as threatened or endangered, and approximately 2,118 additional species are candidates for listing. A National Wildlife Federation report indicates that 43% of these Federally listed species are wetland dependent. Therefore, the loss of nearly 87% of Indiana's historic wetlands reflects a significant regional loss in biodiversity.

Gap Analysis is being developed by the U.S. Fish and Wildlife Service primarily to assess biodiversity on a continental scale. Narrowly defined, Gap Analysis will allow gaps in species' representation (i.e., biodiversity) to be identified in areas where the long-term maintenance of native species and natural ecosystems is the goal. Gap Analysis represents one method to identify and subsequently to provide data for improving the protection of endangered elements of biodiversity. While Gap Analysis has a strong research orientation, it is fundamentally a tool for conservation biology.

Through the metaproject approach, the Indiana Project has other applications in addition to the continental-scale analysis of biodiversity. The driving force behind the Indiana Project has been to develop a strategy for the long-term protection and recovery of the State's biodiversity. Gap Analysis will be used to aid in the restoration of wetlands and other ecosystems that are essential for the management of biodiversity in Indiana. The principal natural resource agencies and key non-governmental environmental organizations in Indiana will all be involved in the implementation of Gap Analysis.

KEYWORDS: Biodiversity, Gap Analysis, geographic information system, habitat restoration, landscape, metaproject, wetlands.

INTRODUCTION

Human beings are the principal agents of biodiversity decline (Ehrlich and Ehrlich, 1981) with wetlands (also savannas and prairies) proving especially vulnerable to anthropomorphic changes to the natural landscape. Wetlands, moreover, have a particular significance for biodiversity; a strong correlation exists between the loss of half or more of all the wetlands in the Midwest (and alteration of nearly all others) and the number of species listed as threatened or endangered. A National Wildlife Federation report indicates that 43% of the 595 plant and animal species listed by the U.S. Fish and Wildlife Service as threatened or endangered depend on wetlands for their continued existence (Hair, *et al.*, 1992). Perhaps even more alarming than the loss of wetland ecosystems and the species that depend on them is the general acceleration in the decline in biodiversity. Some estimates place the current extinction rate at 1,000 times the natural rate (Wilson, 1988).

Wetlands play a fundamental role in the natural landscape of the Midwest. Based on data provided by the Natural Resources Conservation Service (formerly the Soil Conservation Service) and the Indiana Department of Natural Resources, approximately 2.3 million ha (5.6 million acres) of wetlands covered nearly 25% of the present State of Indiana prior to European settlement in the early part of the 19th century (Indiana Department of Natural Resources, 1989). Indiana retains about 320,000 ha of wetlands (about 13% of the pre-settlement wetland area) in several major wetland regions. These regions are the Northern Indiana Kettle, Grand Kankakee Marsh, Muncie, Cincinnati, Blue River Valley, Lower Wabash River, and Ohio River Regions. Cowardin, *et al.* (1979) classify wetlands into five primary systems of which three, the palustrine, riverine, and lacustrine systems, exist in Indiana. Major wetland types occurring in Indiana include kettle wetlands, occurring primarily in the Northern Indiana Kettle and Muncie Regions, and floodplain or bottomland hardwood forest wetlands, occurring in all regions but most expressively in the Lower Wabash River Region. Historically, wet prairie covered a significant portion of the Grand Kankakee Marsh Region. This area was entirely drained in the early part of the 20th century.

Gap Analysis is an important tool for landscape-scale analysis. The U.S. Fish and Wildlife Service began developing Gap Analysis in the late 1980s primarily to assess biodiversity on a continental scale. Gap Analysis is a scientific approach to evaluating biodiversity and to providing the data necessary for the development and application of a biodiversity protection strategy. A rapidly changing natural environment coupled with our incomplete understanding of the fundamental dynamics of biodiversity suggest that a prudent course of action should be adopted to insure the continued benefits of a biologically diverse world to society. Such a prudent course requires, wherever practical, the protection and restoration of pre-settlement biodiversity.

LEVELS OF BIODIVERSITY

Focusing our efforts on the protection and restoration of biodiversity will enable scientists to address the management of wildlife and natural resources in the broadest possible terms. Based on the existing level of development, the immediate large-scale restoration of pre-settlement landscapes appears unrealistic or, at least, impractical (Noss and Harris, 1986). Therefore, protection and restoration of pre-settlement biodiversity means protection and restoration efforts that produce habitats that function sufficiently like pre-settlement landscapes to protect the remaining pre-settlement ecosystem, species, and genetic diversity.

Biodiversity can be defined as the variety of life and its processes, or as the variety of living organisms, their genetic differences, and the communities and ecosystems of which they are a part. Biodiversity can be evaluated on four levels: genetic diversity, species or population diversity, ecosystem diversity, and landscape diversity (The Keystone Center, 1991). (Although genetic diversity is not addressed directly in this paper, the author recognizes that interrelationships exist among these four diversity categories (Soule, 1983).)

Species diversity is used most often to measure biodiversity, possibly because species diversity is easy to quantify. The *State Heritage Program* (jointly established by the Indiana Department of Natural Resources and The Nature Conservancy) tracks both Federal and State endangered and threatened species. The U.S. Fish and Wildlife Service now lists approximately 640 species as threatened or endangered in the United States, and approximately 2,118 species are candidates for listing (Szymanski, pers. comm.). The State of Indiana lists 100 threatened, endangered, or special concern species of terrestrial animals and 323 threatened or endangered species of plants (Indiana Department of Natural Resources, 1990). The U.S. Fish and Wildlife Service, through the *Endangered Species Act,* compiles detailed information on species prior to listing them as threatened, endangered, or candidate species and prepares recovery plans for species once they are listed. Despite this focus, biodiversity protection at the species level, while essential, remains expensive and uncertain.

The evaluation of wetland loss is an example of ecosystem-level diversity analysis. Significant effort has gone into the evaluation of wetland resources in Indiana. These analyses document the human impacts, particularly after European settlement, on all wetland regions and all wetland types in the Midwest. Estimates of the extent of pre-settlement wetlands and information from the U.S. Fish and Wildlife Service's *National Wetland Inventory* suggest that Indiana has lost approximately 1.4 million ha or 86% of its pre-settlement wetlands (Indiana Department of Natural Resources, 1989). The U.S. Fish and Wildlife Service compiled the following wetland loss estimates for the States surrounding Indiana: 85% in Illinois, 90% in Ohio, 81% in Kentucky, and 50% in Michigan (Dahl, 1990). As discussed above, wetlands in Indiana and the Midwest are key components of both the pre-settlement and the modern landscape and, therefore, are essential to the maintenance of biodiversity in this region. However, wetland protection efforts, as an example of ecosystem-level protection, have also proved to be expensive, difficult to carry out, and of questionable success.

Forman and Godron (1986) define a landscape as a number of interacting stands or ecosystems repeated in similar form over a wide area (km^2). The use of landscape-scale analysis to address biodiversity issues follows in part from the movement away from managing for alpha or species diversity on specific protected areas. Increasingly, scientists are pointing out that managing for gamma or landscape diversity is the best means of preserving biodiversity. Naveh (1994) states that gamma diversity "... is the most important index for the determination of biodiversity because it incorporates both [alpha and beta (habitat) diversity] measures and is affected by the ecological heterogeneity within and between different habitats" (see Whitaker (1965) for a discussion of alpha, beta, and gamma diversity). Grumbine (1990) believes that broad agreement now exists among conservation biologists that species-level approaches to the conservation of biodiversity must be augmented by landscape-level approaches that account for ecosystem-scale patterns and processes. Scott, *et al.* (1988) state that managing for biodiversity at the landscape scale using Gap Analysis may prove more cost effective and more efficacious than the single species approach as more species become threatened and endangered. Their viewpoint defines a fundamental assumption of Gap Analysis, reflects the perceived economies of scale to be gained from managing at higher levels of biodiversity, and underlines the uncertainty of recovering species whose populations fall below a certain minimum number of individuals.

LANDSCAPE ANALYSIS/GAP ANALYSIS

Gap Analysis will allow the identification of gaps in species' representation (biodiversity) in areas set aside for the long-term maintenance of native species and natural ecosystems (Scott, *et al.,* 1987, 1988, 1993). Gap Analysis includes the processes by which partnerships are developed, geographic data sets are constructed, data analysis is carried out, and data are applied to actual systems. Gap Analysis can be divided into three phases: the 1) construction, 2) analysis, and 3) application of a data set. Although Gap Analysis projects tend to proceed in this order, the phases are not discreet. In Indiana, analysis and application for biodiversity protection and restoration will occur during the construction phase using interim data; this approach to Gap Analysis is termed a **metaproject**. Metaprojects involve the application of Gap Analysis methods or data, often sponsored by cooperating organizations, to complete the Gap Analysis data sets and to address State or regional problems of conservation or restoration. Beginning with the Jefferson Proving Ground Metaproject in 1993 and a 3-4 year statewide project in 1994, Gap Analysis will be used to evaluate, conserve, and restore terrestrial biodiversity in Indiana. (Aquatic Gap Analysis has just begun as a pilot project in one State.)

Gap Analysis can be applied in three ways: 1) continental-scale analysis of biodiversity (the narrow construction of Gap Analysis); 2) intra-regional analysis; and 3) intra-State analysis to address a variety of State-level resource issues. These applications define the specific data sets, the level of detail that will be incorporated into the geographic information system, and how the constructed data sets will be used. Congressional funding for Gap Analysis supports only each State's contribution toward a continental-scale analysis of biodiversity. Other applications of Gap Analysis must be funded by the individual States. Metaprojects which address intra-regional and intra-State issues require more data, more detail, and more funding than has been allocated to Indiana for its contribution to the continental-scale analysis.

The U.S. Fish and Wildlife Service is carrying out this work in cooperation with three principal partners: Indiana State University, the Indiana University School of Public and Environmental Affairs, and the Indiana Department of Natural Resources. The Indiana Project will also be conducted in close cooperation with the U.S. Forest Service, the Natural Resources Conservation Service, the U.S. Geological Survey, and a number of other organizations, including non-government environmental organizations. The following data sets will be developed for submission to Utah State University for continental-scale Gap Analysis:

1. **Vegetation Maps.** Maps will be developed using 1992 or later Thematic Mapper™ satellite imagery and various ancillary data sets on a scale of at least 1:100,000. A 100-ha minimum mapping unit (MMU) will be validated in the State of Indiana for use in the continental-scale analysis

of biodiversity. For the intra-regional and intra-State analyses, data will be stored for 30 m x 30 m plots and a MMU of approximately 2 ha.

2. **Terrestrial Vertebrate Distribution Maps.** Maps will be developed within the Indiana Department of Natural Resources's *Advanced Revelation-Based Indiana Fish and Wildlife Information System* for all 539 terrestrial vertebrate species in Indiana. Interfacing these data with a map of actual vegetation will produce current distribution maps for virtually all terrestrial vertebrate species.

3. **Managed Areas Database.** This database will be developed using the Indiana Department of Natural Resources's *Managed Areas Database* supplemented with information from the U.S. Forest Service and other databases containing information on the landholdings of Federal, State, and local entities (including significant private land management organizations). Each parcel will be ranked based on its level of protection for biodiversity.

4. **Rare, Threatened, and Endangered Species Database.** This component of the Indiana Project will be based on the *Indiana Heritage Database* and will incorporate available ancillary data.

5. **Wetlands Database.** This data set will be developed from the U.S. Fish and Wildlife Service's *National Wetlands Inventory* and ancillary data, including satellite imagery.

Due to the foresight of the agencies responsible for wildlife management in Indiana, much of this information already exists in digital form and now resides (although not in final form) within the *Indiana Gap Analysis Database.* The other databases will allow a more detailed analysis of biodiversity or will prove useful for intra-State or intra-regional analyses. Additional data sets might include: pre-settlement vegetation, cultural features (roads, railroads, airports, and other types of infrastructure), soils, invertebrate distribution (butterflies and, possibly, aquatic invertebrates), socio-economic data, contaminants data, climatic data, and population viability data. Some of these data sets are currently under development as parts of various metaprojects.

Most States are not ready to apply the products of Gap Analysis, because they are still in the construction phase of the project. A few States, mostly in the West, that started Gap Analysis projects in the late 1980s, have virtually complete data sets. California, Oregon, Arizona, and Idaho have begun to use Gap Analysis in a variety of application environments. California, for example, has used Gap Analysis in the regulatory arena (see McDonald (1994) for a discussion of landscape-scale planning efforts in California). Oregon, Arizona, and Tennessee have initiated partnerships to use Gap Analysis as the basis for broad biodiversity protection strategies (Defenders of Wildlife, 1994). In Indiana, the metaproject approach will allow the early application of Gap Analysis.

INDIANA GAP ANALYSIS METAPROJECTS

Houghton (1994) asserts that approximately 32% of the surface of the earth is actively managed as either cropland or pasture. In Indiana, nearly 80% of the non-Federal land (non-Federal land represents about 98% of the total available) is used either as cropland and pasture or has been developed. In Ohio, the acreage in cropland, pasture, and developed land accounts for nearly 70% of the non-Federal land (non-Federal land represents about 99% of the total available); and in Illinois, nearly 88% of the non-Federal land (non-Federal land represents about 99% of the total available) is so used. The figures for Kentucky and Michigan are approximately 54% and 46%, respectively (U.S. Bureau of Census, 1993). Modification of the landscape on this scale has resulted in several unique obstacles to retaining biodiversity: 1) a human-dominated landscape characterized by large human populations; 2) habitat fragmentation and pollution (Steadman, 1991); and 3) isolated populations with many species depauperate in genetic diversity (Soule and Wilcox, 1980).

In Indiana, Gap Analysis will focus on cooperative efforts with partners who will "jump-start" the application of Gap Analysis, who will serve as partners in pilot projects to evaluate methodology and data, who will help solidify partnerships within and without the Indiana conservation community, and who will produce products useful in the conservation of natural resources. Opportunities for the application of Gap Analysis will increase as data become more complete and as new data sets are incorporated into the database. The following metaprojects are representative of the range of projects currently underway as part of the Indiana Gap Analysis effort.

The *Bioreserve Metaproject* is a cooperative effort with The Nature Conservancy to provide a landscape analysis of two of The Nature Conservancy's "Hoosier Landscapes" last great places. Both the Blue River Project in southern Indiana and the Pigeon River Project in northeastern Indiana will protect important wetland habitat. The Pigeon River area also contains some of the finest remaining fen wetland in the State and possibly in the Midwest (Shuey, pers. comm.). Both areas have been preliminarily identified by The Nature Conservancy as important for preserving biodiversity in Indiana. The U.S. Fish and Wildlife Service will provide data for this metaproject to help The Nature Conservancy evaluate its assumption and to enable its land managers to approach management on a landscape scale. Data sets were under development for both projects at time of revision, and some pilot analysis is underway for the Blue River area.

A second metaproject is the application of a landscape approach to the U.S. Fish and Wildlife Service's *Partners for Wildlife* wetland restoration program. The study area for this metaproject encompasses most of the Eel River watershed in north-central Indiana. The goal of this pilot project is to identify restorable, drained wetlands on the watershed scale using a combination of satellite imagery and ancillary data. This approach should improve the efficiency and effectiveness of wetland restoration. Preliminary results suggest that the evaluation of satellite images in conjunction with ancillary data can help identify poorly to very poorly drained sites on a landscape scale. In addition, these data can be analyzed relative to important habitat features (e.g., existing wetlands, forest fragments, roads, or streams (Mausel, *et al.,* 1995)).

A metaproject designed to apply the Indiana Gap Analysis methodology and data to the pervasive problem of environmental contaminants in Indiana has also been initiated. The location of contaminants in the physical environment is being plotted and their movement both laterally and vertically through the food chain in several streams in parts of five Indiana Counties is being modeled. Gap Analysis may prove to be particularly useful when dealing with contaminants.

Because of the importance of wetlands within the Indiana landscape, many of the initial Gap Analysis metaprojects have a wetlands component. Conversely, these metaprojects will allow researchers to evaluate the usefulness of the Gap Analysis methodology in contributing to landscape-scale protection and restoration.

PROTECTION AND RESTORATION FRAMEWORK

The goals of the *Indiana Biodiversity Protection and Restoration Framework* will be dynamic but should include at least a development process, a protection and restoration strategy, and a method for strategy implementation.

Development Process. The Indiana Framework has begun to address the challenges of a landscape-scale protection and restoration project by establishing partnerships with the principal natural resource agencies and non-government environmental organizations in Indiana. Many organizations are currently involved in the planning efforts, not to mention actual implementation projects, that have the potential to affect biodiversity.

The North American Waterfowl Management Plan is a multi-national effort to restore waterfowl and wetlands in North America. The U.S. Fish and Wildlife Service has created a *Regional Wetlands Concept Plan* and is currently embarked upon a nationwide ecosystem management program. At the State level, the Environmental Law Institute has launched a project entitled *Protecting Biological Diversity in Indiana.* The Natural Resources Conservation Service has taken the lead in a multi-agency watershed planning project, and the Indiana Department of Natural Resources has initiated *The Indiana Wetlands Conservation Plan.* Non-government organizations have also established plans that involve biodiversity; e.g., the *1994-1998 Strategic Plan of the Hoosier Environmental Council* and the biodiversity metaprojects under the direction of The Nature Conservancy (see above).

Although several informal, cooperative efforts to develop and test strategies for landscape protection and restoration have been started, no State agency or other body has yet to assume explicit responsibility for biodiversity protection and restoration in Indiana. However such a group might be constituted, the work of protecting biodiversity should embrace input from a variety of disciplines. Data from the Gap Analysis project as well as from other sources can contribute to a multi-organization forum with the mission of developing a comprehensive biodiversity strategy.

Protection and Restoration Strategy. The theoretical basis of the *Indiana Biodiversity Protection and Restoration Framework* is too complex to explain in a single, short paper. Some components of the Indiana Framework remain in the earliest stages of development at the U.S. Fish and Wildlife Service and presumably at other organizations as well. Nevertheless, some basic tenets exist that will work within a State- or regional-scale strategy to preserve and restore pre-settlement biodiversity. Selman and Doar (1992) have divided the key principles of landscape ecology into structural, functional, and temporal principles. With respect to the Indiana landscape, these principles may be summarized as follows:

1. **Structural.** The structural attributes of landscapes suggest that they vary with respect to the type and juxtaposition of patches, corridors, and matrix and, therefore, that they will also vary functionally with respect to species, energy, and material fluxes. Anthropomorphically enhanced landscape heterogeneity has apparently increased habitat for edge species but has decreased suitable habitat for interior species.

2. **Functional.** The continuous expansion and contraction of species among landscape elements significantly affects and is affected by landscape structure. Disturbance to the landscape produces an increase in the rate of inorganic nutrient redistribution, which is related to the intensity of the disturbance. Biomass and energy transfer across landscape boundaries (patch, corridor, or matrix) increases with landscape heterogeneity.

3. **Temporal.** Undisturbed landscapes move toward homogeneity in the horizontal plane (geographically across land) and become higher and more heterogeneous in the vertical plane (structurally and in species richness).

Conservation biologists have outlined some basic principles for the preservation of biodiversity (Grumbine, 1990), including 1) the necessity of large nature reserves to preserve biodiversity, 2) the need for extensive interconnections among the large reserves, and 3) the importance of natural processes including disturbance in preserving biodiversity. Noss (1983) believes an ideal scenario would result in the preservation of whole ecosystems with all their indigenous genetic diversity. He believes that this would require an opportunistic approach to acquiring both large and small reserves. In addition to simple acquisition, species, ecosystem, and landscape restoration must also ensure the long-term protection of the remaining pre-settlement biodiversity in the Midwest. From a practical standpoint, however, human beings and their products will comprise an important component in any protection and restoration strategy.

Strategy Implementation. Developing the tools to evaluate biodiversity and a strategy to protect and restore biodiversity may take several years. Implementation of a strategy resulting from that work will require decades and will undoubtedly require cooperation among a broad cross section of society. Nevertheless, even at this stage of the project, numerous opportunities exist to begin protecting and restoring biodiversity. The *Wetland Reserve Program,* the *Conservation Reserve Program,* the wetland and prairie restoration efforts of the U.S. Fish and Wildlife Service and others, State and Federal natural resource acquisition projects like the *North American Waterfowl Management Plan,* and other existing programs are having positive impacts right now. A possible by-product of the Indiana Gap Analysis project may be better coordination among these programs.

CONCLUSIONS

The natural landscape continues to change rapidly under the influence of human development. Biodiversity measured at both the species and ecosystem levels reflects a precipitous decline in numbers over the last 200 years. Biodiversity at the genetic, species, ecosystem, and landscape levels has a particularly strong association with wetlands in the Midwest. Most existing efforts to protect wildlife, wetlands, or even the natural environment lack sufficient breadth to protect and restore the remaining pre-settlement biodiversity.

The development of a guiding and coordinating landscape-scale framework may provide the scope needed for biodiversity protection. Furthermore, evidence suggests that approaching the protection and restoration of biodiversity at the landscape scale may prove more efficient (i.e., cost effective) and efficacious than other existing approaches. Gap Analysis should comprise an integral part in developing the requisite data to formulate the *Indiana Biodiversity Protection and Restoration Framework.*

The application of landscape-scale analyses to wildlife management questions has enormous biological and social implications. Significant changes might have to be made in the way resource agencies approach their missions. Organizations not currently concerned with biodiversity might be affected. Ultimately, the successful implementation of a biodiversity protection and restoration framework will depend on society's recognition of the importance of biodiversity and the will of the people to affect change.

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