

ASSESSING BIODIVERSITY IN AGRICULTURAL ECOSYSTEMS
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-- Plenary Session 2 --

Linking Wild Species With Their Use of Different Agricultural Habitats

Tuesday 6 November 2001

Paper presented to the:

**OECD Expert Meeting on Agri-Biodiversity Indicators
5-8 November 2001
Zürich, Switzerland**

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Assessing Biodiversity in Agricultural Ecosystems

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Abstract

From the mid to late 1990s, the U.S. Department of Interior produced several assessment documents that provided; 1) a summary of existing monitoring programs and data sources, and 2) a national synthesis of status and trends in biological resources. It was evident from these reports that our knowledge of trend information on biological populations was seriously limited. Outside of birds, commercial fish, and species hunted for sport, we were unable to detect widespread significant changes in other biological populations. Since the middle 1990s, efforts to develop new protocols applicable to other taxa, and use them in broadly organized monitoring programs have increased. Since 55% of the U.S. land base (excluding Alaska and Hawaii) is devoted to agriculture, it is critical that new efforts are applicable in agricultural systems, and that strategies that deal specifically with agriculture ecosystems are scientifically valid. This paper will discuss new efforts in monitoring and related research, application of these efforts to agricultural systems, and the use of adaptive management strategies.

Keywords: biological monitoring, agricultural biodiversity, adaptive management, United States, indicators.

Introduction

Agricultural lands in the United States are critical for maintaining the biodiversity of native flora and fauna. If one considers all types of agricultural lands, cropland and grazing land, approximately 55% of the contiguous lower 48 states is devoted to agriculture. The impacts that this has on wildlife habitat in the U.S. is exacerbated by the fact that these agriculture lands are the most productive and have the greatest potential for sustaining diverse wild populations. By contrast, only about 5% of the conterminous land area, or about 400,000 km² is held in some type of conservation reserve (Scott et al., 2001) and these conservation areas make up only 1% of the most productive soils, and much of the conserved lands are at higher elevations—45% of conservation land is above 3075m (Scott et al., 2001). The consequence of this is that the greatest number of species that are federally listed as endangered in the US, occur on privately held lands (Groves et al., 2000), a significant proportion of which are agricultural.

It is also essential that in viewing the land base dedicated to agriculture that one considers the distribution of these lands across the landscape and within each ecoregion. Because of the extensive land base in the U.S., and the variety of ecoregions that exist in this land base, how the land is converted to agriculture within an ecoregion is important. If an extremely high percentage of a single ecoregion has been converted to agriculture, conserved lands in other regions will do nothing to protect species endemic to those converted areas. One example of this can be seen in western California where much of the coastal grassland habitat (>95%) has been lost to agriculture and urbanization (Veirs and Opler, 1998). Because of the high endemism in this area, this loss of habitat has resulted in over 150 imperiled species, mainly rare plants (Chaplin et al. 2000).

It is safe to assume that agricultural lands are important to sustaining biodiversity, and will become more important as habitat loss continues. Has agriculture already had an effect on biodiversity in the U.S.? Wilcove et al. (2000) ascertained that for 1880 endangered or imperiled species for which data could be found, habitat destruction was the leading cause of endangerment in 85% of the cases. The leading type of habitat destruction was agriculture development (38% of species), and the fifth most frequent type of destruction was livestock grazing (22% of species). Combining these two agricultural practices results in a significant amount of the habitat loss affecting biodiversity in the U.S. Improved understanding of what organisms use agricultural lands, and how agricultural practices can change to benefit the native flora and fauna are integral to the conservation of biodiversity.

Efforts in the US

In 1996, the Clinton Administration, working through the Office of Science and Technology Policy, requested the development of an environmental report card. This report card would identify a set of scientifically credible indicators to characterize the state of the Nation’s ecosystems. The task was led by the H. John Heinz III Center for Science, Economics and the Environment, a non-profit institution dedicated to improving the scientific and economic foundation for environmental policy. The Heinz Center has engaged the expertise and experience of the U.S. environmental monitoring programs and professionals, from across all sectors of government and industry to develop a suite of indicators that would be nonbiased, and scientifically sound. This State of the Nation’s Ecosystems Report (Heinz 2001) is still in draft form but provides information useful to the purposes of this conference.

Table 1: Types of systems addressed and categories of indicators

<i>System</i>	<i>Indicator Categories</i>
Coastal Waters	Extent
Farmlands	Fragmentation and Ecosystem Patterns
Forests	Plant Nutrients
Freshwater	Chemical Contaminants
Grasslands/Shrublands	Physical Conditions
Urban/Suburban	Plants and Animals
Nation	Biological Communities
	Plant Growth
	Food, Fiber, and Water
	Other Services, including Recreation

Source: State of the Nations Ecosystems Report. Heinz, 2001

Indicators were selected in ten categories for the Nation as a whole, and for six specific types of systems (Table 1). The draft indicators selected when taken together, are intended to provide a reading of the state of the U.S. environment as a whole, and thus are not just focused on biodiversity. In addition, in selecting indicators, experts were not limited to areas where they knew information existed. Instead, the intent of the report is to identify indicators based on what needs to be known rather than being limited to indicators that rely on existing data only. Therefore, for some indicators that may be included in the final product, insufficient data, or possibly no data will be available to describe the indicator. However, these indicators will provide guidance to policy makers and inform the public on monitoring or measurements that are needed to complete the State of the Nations Ecosystems.

Of the six ecosystem types that are being addressed in the State of the Nation’s Ecosystems, two incorporate agricultural systems—Farmlands, and Grasslands/Shrublands. This discussion will focus on the indicators developed for those systems.

The Farmland system includes areas used for agricultural production such as croplands, as well as areas associated with field edges, windbreaks, and nearby woodlots. Pasture is also included in this system so overlap with the grasslands systems is expected. Draft indicators for the categories associated with biodiversity in farmland areas are described in Table 2, in addition to a preliminary assessment as to whether data are available to quantify the indicator

Table 2: Biodiversity indicators for farmland ecosystems

<i>Indicator Categories</i>	<i>Indicators</i>	<i>Data</i>
Plants and Animals	What % of species found in regions with large amounts of farmland are increasing, decreasing, or stable? Of rare or declining species in this area, what % is increasing, decreasing, or stable?	No
Plants and Animals	In areas with large amounts of farmland, is most of the remaining vegetation native or non-native?	No
Biological Communities	What is the quality of the habitat in streams in farmland regions?	Some

Source: State of the Nations Ecosystems Report. Heinz, 2001

Examination of those indicators related to biodiversity--plants and animals, and biological communities, show that data are not available for adequately assessing this set of indicators. For the indicator on trends of species, the experts working on this Report recognize that most wildlife associated with farmlands are species that would have been found in the native habitat of the area before the land was converted to agriculture. This makes it impossible to report on the status of “farmland” species when it is indeed a mix of forest, shrubland and grassland species, which may be opportunistically using farmland. It is also impossible to adequately assess the status of native plant and animal populations on farmland because data are available for only a few species. Where data are available, for example for birds, declines in grassland groups have been documented. However, these data are developed on too large of scale to adequately determine the specific role of farmland relative to the other habitats mixed in with farmland.

The Grasslands/Shrublands system is defined as lands dominated by grasses, and would include, but not be limited to, rangelands and pastures. Thus considerable overlap with the Farmlands system occurs. Grasslands/shrublands make up the largest land cover type in the United States, and significant areas have been converted to agriculture. Grasslands indicators are similar to those for Farmlands and are identified in Table 3

Table 3: Biodiversity indicators for Grasslands/shrublands

<i>Indicator Categories</i>	<i>Indicators</i>	<i>Data</i>
Plants and Animals	What fraction of grassland species is at risk? What fraction is presumed secure?	Yes
Plants and Animals	What percent of grassland and shrubland plant cover is not native to the region?	No
Biological Communities	What is the ratio on non-native species to native species?	No
Plants and Animals	Are non-native bird populations increasing more than native populations?	Yes

Source: State of the Nations Ecosystems Report. Heinz, 2001

Because the Grasslands/shrublands is more inclusive of the habitat types found in the area than the farmland ecosystem, broad scale information can be applied to two of the suggested indicators. For example, for the first indicator in Table 3, the Report points out that one fifth of the 1900 species that depend on grassland habitats are at risk of extinction either because of their inherent rarity or because their populations have been greatly reduced (Association for Biodiversity Information, 2001). Grasshoppers and amphibians have been identified as having the greatest number of species in this category. For the fourth indicator, the Report states that between 1996 and 2000 significantly more invasive species populations increased than did native species. (Sauer et al., 2001). Data gaps prevented assessment of the other indicators.

Regionalization

As was briefly mentioned in the introduction, land use or conservation must be viewed within its ecoregion. If the native grassland habitat of an ecoregion is all converted to cropland, biodiversity will be lost and conservation efforts in other regions can do little to protect those species relying on that habitat. In the State of the Nation's Ecosystems, some effort is made to regionalize indicator data, however it seems insufficient to adequately address this concern. For farmlands, the extent indicator would be reported for 10 separate geographic regions. Although this division will help identify ecosystem types that may be at more risk than others, the geographic boundaries are more political (drawn on state lines) rather than ecological. Also, there is no plan currently to assess the biodiversity indicators (plants and animals, biological communities) on any regional or ecoregional basis.

For the grassland/shrubland system, regional assessment of information for the biodiversity indicators is planned, and the grassland habitat within the U.S. has been subdivided into three ecoregions (Figure 1). This division enables differentiation among grassland/steppe areas, desert/shrub, and California and coastal grass, shrub and chaparral. Partitioning data by these three ecoregions will provide a more detailed assessment than a national indicator would, however these areas are still very large, and combine a number of unique ecosystems. For example the Palouse Prairie grasslands (Smith and Collopy, 1998), and the Mojavean vegetation zone (Brussard et al., 1998) are in the same zone, yet are quite different ecologically.

Figure 1. Grassland/Shrubland Regions in the U.S.



Source: State of the Nations Ecosystems Report. Heinz, 2001

Improving our knowledge Base

The U.S. State of the Nation's Ecosystems Draft Report, and the Organisation for Economic Cooperation and Development Indicators Report express the need for more and improved information to adequately address the recommended indicators. The lack of status and trend information on habitats and even to a greater degree on populations of native, and non-native flora and fauna greatly reduce our ability to conduct these environmental assessments.

Biological monitoring information is critically needed and monitoring efforts need to be increased. Although the U.S. spends over \$600 million on environmental monitoring, population monitoring is limited and taxonomic coverage is not good. Cost is partly prohibitive for some species such as wide ranging marine species (e.g. whales, sea turtles), and the greatest investment of funds in marine environments is devoted to exploited populations of marine fish and shellfish. Funding is not always a limitation as some monitoring programs have generated critical status and trends information at a very reasonable cost, such as the U. S. Breeding Bird Survey, where volunteers provide much of the needed manpower.

In many cases, the limiting factor to expanding monitoring is the availability of standardized and scientifically valid protocols. Over the last few years there has been expansion of monitoring efforts with other species that over time will begin to provide the long-term trend information needed to critically assess populations. Some of these newer efforts include:

Amphibians: The concern over worldwide amphibian decline in the last 5-10 years has prompted an increase in U.S. investment into amphibian research and monitoring and the initiation of amphibian monitoring efforts. Several new programs have been initiated in recent years including the North American Amphibian Monitoring Program. This program is structured like the Breeding Bird Survey and monitors calling amphibians in the Eastern U.S. and Canada.

The Amphibian Research and Monitoring Initiative, which is coordinated by the U.S. Geological Survey (USGS), will establish a network designed to monitor the status and changes in the distributions and abundance of amphibian species and communities in the United States, and not

rely just on surveys of calling amphibians. A general national approach will use presence/absence of species at a collection of sites to estimate a population level parameter—proportion of area occupied by each species and a community level parameter—species richness. This program will also incorporate high intensity, selected field sites to determine demographic and life history characteristics of key species, study cause-effect relationships, and evaluate new techniques and protocols

Current research has also begun to demonstrate the value of agricultural lands to amphibian habitat. Constructed farm ponds have been found to provide significant breeding, rearing, and overwintering habitat for amphibians in the upper Midwestern U.S. Studies will examine amphibian individual, population and community health associated with land uses surrounding farm ponds, such as row crops, grassland, and grazed grassland, and what design features associated with a pond (size, depth, vegetation) will maximize amphibian benefits (Knutson, 2001).

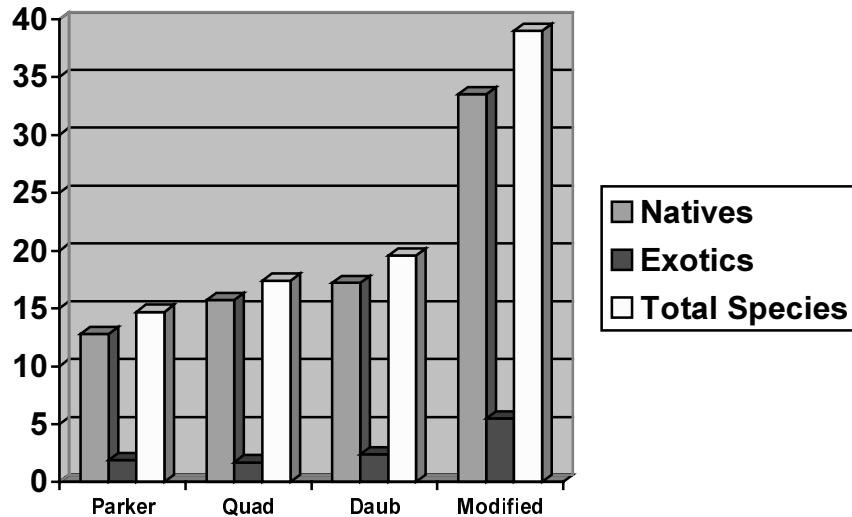
Bats: In addition to their value in natural habitats, bats provide significant benefits to agriculture as pollinators and as insectivores that can help in controlling some agricultural pests. A large number of bat taxa (26) have been identified as potentially at risk by the U.S. Fish and Wildlife Service, indicating the need for increased information on distribution, population status and trends, and life history requirements. Recent efforts are underway to further the science of bat monitoring. The “Workshop on Monitoring Trends in U.S. Bat Populations: Problems and Prospects” held in 1999, provided a forum for reviewing bat status and trends, identifying current methods and challenges involved in estimating bat populations, and recommending future monitoring efforts (O’Shea and Bogan, 2000).

The USGS has developed a Bat Population Database that is serving to synthesize existing information from published literature and state agency databases. The database will serve as a basis for hypothesis testing and statistical analysis and for designing long-term monitoring efforts (O’Shea, 2001). The efforts of this workshop and the development of the database will begin to provide scientifically credible data on bat status and trends and serve as a focal point for bat conservation information.

Invasive plants: Invasive species pose one of the singular most dangerous threats to maintaining biodiversity across the US. Destruction of fisheries, significant alteration of habitats, increased risk of fire, competition with native species, and devastating diseases are some of the impacts invasive species have caused. Invasive plants are closely linked to agriculture, particularly in rangelands. Noxious weeds have invaded over 17 million acres of public rangelands in the western US, driving out native species, and reducing the value of these lands for grazing (Westbrooks, 1998)

New methods for inventorying plants have recently been developed that are far more effective at characterizing both native and non-native vegetation (Figure 2). This is especially important for early detection of an invasive plant species (Stohlgren et al.1998). Improvements are also being made in resolution of vegetation measurements. Techniques that incorporate satellite imagery, high resolution aerial photography, and multi-scale field sampling can now create predictive, GIS-based models that can discriminate much finer detail and distinguish between small but unique habitats (Stohlgren et al.. 1997). This feature can be valuable when assessing the small habitats associated with intensive agriculture.

Figure 2. Comparison of methods for plant sampling



Source: Stohlgren et al.1998

Grizzly Bears: Although monitoring information on large mammals, especially those that are hunted for sport, has usually been available due to efforts of game managers, new techniques have been developed that can provide managers with improved information. Recent advances in genetic technology allow for identification of species, sex, and individuals from DNA extracted from bear hair and scats without handling bears (Kendall, 2001). DNA is analyzed from bear sign collected along survey routes and from a grid of systematically positioned hair traps. The number of individuals and species identified from survey routes yields minimum counts and a baseline index of population size. This is used to design a non-intrusive population trend monitoring scheme. Bears identified from hair trap collections will be used in a mark-recapture model to estimate the population density and will provide an independent calibration of the population index developed from survey routes. DNA profiles with information on the degree of genetic variation, relatedness of individuals, and sex can then be used to address bear conservation issues. These techniques could be applied to other species and generate individual and population level information on wildlife use of specific habitats, such as farmland. With the type of data on individuals generated by genetic techniques, the productivity of the habitat can be assessed with a much greater degree of confidence than with previous methods.

These are but a few examples of improved monitoring methods and increased effort for different taxonomic groups that in the long term will produce the kinds of status and trends information needed to adequately assess agricultural systems. Increased efforts in other areas are also progressing that are not described in this paper, for example, butterflies, bees, and other pollinators, and freshwater mussels. Despite the increase in our capabilities to monitor new species through improved protocols, or enhanced monitoring activity, we will never be able to provide enough information on status and trends of populations to assure that biodiversity is being sustained. This is especially true for selected habitats, such as farmland, where issues of scale, as well as the mixture of habitat types complicate assessment efforts. Other approaches

may be needed to provide regulators and managers with information that will help take the greatest advantage of agricultural ecosystems.

Adaptive management:

One approach that may be used on the agriculture landscape would employ adaptive management strategies. This approach enables recognition of the uncertainty inherent in resource management and could provide a framework through which agricultural lands could best contribute to sustaining biodiversity. Adaptive management merely provides a structure for feedback between the management strategy and the assessment of progress toward a specified goal (Williams and Johnson, 1995). Adaptive management requires 1) focused management objectives, 2) monitoring of the resource and, 3) a process by which management decisions can be assessed.

Use of adaptive management requires that specific biodiversity objectives need to be established for the matrix of habitats that are incorporated into agricultural systems. Because agriculture lands are often already compromised in terms of their habitat value, it may not be feasible to expect them to maintain diverse biological communities—especially in row cropland. Instead, some attainable conservation objectives should be set for agriculture lands, and these could no doubt vary among crop types, and most likely among ecoregions. For example, along the west coast flyway in the U.S., habitat for migratory waterfowl has been greatly reduced by conversion to agriculture. Changes in agricultural practices in rice fields were tested that involved winter flooding of fields. These practices were evaluated and found to result in increased habitat for invertebrates that serve as a valuable food source to overwintering waterfowl (Hill, 1999), helping to bolster populations. This example demonstrates that by setting specific objectives that can be achieved on agricultural lands, and then monitoring for achievement of those objectives, changes in agricultural practices can be adopted that maximize the value of agricultural lands to sustaining biodiversity.

Conclusions:

1) Efforts in the U.S. at assessing the state of the Nation's ecosystems, and the efforts of the OECD to develop agri-biodiversity indicators show some remarkable similarities. Similarities can be found in the proposed U.S. indicators for measuring extent of croplands and grasslands, and the OECD wildlife habitats indicators. Also, the measures for assessing species and biological communities in the U.S. compare favorably to the OECD biodiversity indicators. The OECD has placed a greater emphasis on genetic diversity than the U.S., however, which seems to be a valuable inclusion.

2) One of the key similarities that both efforts describe is the shortage of information to adequately use the indicators to assess agricultural systems. This lack of information points to the need for more status and trend information on wildlife trends, improved techniques for collecting this information, and more effective tools for estimating population sizes and changes. It is critical to emphasize the need for the U.S. and OECD countries to enhance monitoring activities and increase the supporting science.

3) As was mentioned in the Introduction, the U.S. has converted extremely high amounts (+99%) of some systems with significant implications for the endemic species in these areas. Assessing agricultural systems on a more ecoregional scale would be an important feature to enhance the U.S. and the OECD efforts in agricultural biodiversity. Not only should farmland extent be considered ecoregionally, but specific regional indicators may be useful as well.

4) Employing adaptive management to agriculture lands could provide a usable framework for maximizing their benefits to biodiversity. With agricultural lands already being compromised in terms of their habitat value to broadly diverse biological communities, specific management objects could provide a much more realistic endpoint. This approach still requires monitoring to assess whether the agricultural practices are achieving stated goals, and the management feedback to make needed changes in those practices if achievement is not reached. One of the most attractive aspects of using adaptive management would be an indicator that could measure the percentage the agricultural lands that are using those agricultural practices that have been determined to meet intended management goals.

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