EMAP and Other Tools for Measuring Biodiversity, Habitat Conditions, and Environmental Trends

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Abstract.-- Several research efforts that will contribute to assessment and monitoring of neotropical migratory birds are described, including: 1) the use of neotropical migrants in the Environmental Monitoring and Assessment Program (EMAP) as potential indicators of general environmental condition and biodiversity; 2) EPA's Habitat/Biodiversity Research Initiative to assess the comparative risks to biodiversity, including neotropical migrant birds; and 3) other EPA research to develop tools for assessing status and trends of neotropical migratory birds at various spatial scales.

INTRODUCTION

In September, 1990, the U.S. Environmental Protection Agency (EPA) Science Advisory Board (SAB) released a report entitled: *Reducing Risk: Setting Priorities and Strategies for Environmental Protection* (U.S. Environmental Protection Agency 1990). In this report, the SAB made several recommendations about existing and emerging ecological problem areas and the Agency's effectiveness in resolving these problems. One broad recommendation was that EPA attach as much importance to reducing ecological risks as to reducing human health risk. Citing both ecological and human welfare concerns, the SAB also strongly encouraged EPA to address the loss of terrestrial and aquatic habitats. In short, the SAB ranked habitat degradation and loss, species extinction, and loss of biodiversity among the highest environmental risks facing EPA and other governmental agencies today.

Historically, EPA has assumed a secondary role in habitat protection compared to several other federal agencies. Now, habitat protection is a more common factor in EPA actions. Current directions at EPA include an increased emphasis on risk-based assessment of environmental problems and nationwide monitoring of status and trends in ecosystem extent and condition. These activities illustrate EPA's movement towards a more comprehensive approach to environmental risk management. In support, EPA's Office of Research and Development is developing the methods and technical information needed to address ecological risks to habitat and biodiversity.

This paper will describe several research efforts that will potentially contribute to assessment and monitoring of neotropical migratory birds. These include: 1) the use of neotropical migrants in the Environmental Monitoring and

Assessment Program's (EMAP) as indicators of general environmental condition and biodiversity; 2) EPA's Habitat/Biodiversity Research Initiative to assess the comparative risks to biodiversity, including neotropical migrant birds; and 3) Other EPA research that will be developing tools for assessing status and trends of neotropical migratory birds at various spatial scales.

NATIONAL

EMAP Design as a Tool for Monitoring Neotropical Migrants and Biodiversity

EMAP is a nationally integrated ecological research, monitoring, and assessment program (Messer et al. 1991). Its objectives call for monitoring the condition of the nation's ecological resources and providing unbiased estimates of status, extent, change, and trend with known confidence. Building on the experience of previous surveys, the EMAP sampling design incorporates a randomized systematic triangular grid (fig. 1) to ensure random selection and appropriate spatial distribution of samples (Overton et al. 1990, White et al. 1992). The base density results in approximately 12,600 grid points in the conterminous United States. The grid arrangement makes it easy to either increase or decrease the grid density. The triangular grid system establishes a hierarchical relationship among grid densities, so those grid points from lower density grids are subsets of higher density grids. Specific multiple factors (e.g., 3-,4-, and 7-fold) are available to increase or decrease the base grid density to accommodate the sampling requirements for ecological resources of differing spatial density.

Several features of the EMAP grid make it appropriate for planning and conducting regional and national level biological surveys. The design structure provides for good spatial distribution of sampling sites and for repeated sampling in time while maintaining the spatial distribution. The spacing and timing of sampling may be adapted to the characteristics of the resource. The probability basis of the EMAP design provides quantitative inferences with known confidence.

EMAP has organized sampling efforts around major resource groups (e.g., surface waters, wetlands, forests) that provide one focus for surveying of biodiversity, as exemplified in pilot studies already underway on fish, bird, and vegetation diversity. The resource group focus can be supplemented by surveys conducted by taxonomic group (i.e., neotropical migrants) to capture wide-ranging and habitat-transitional species. Finally, the EMAP design is based on a global geometric model (White et al., 1992) and, therefore, provides a basis for an international survey.

Biodiversity as an Indicator of Ecosystem Condition

Two projects are underway within EMAP to evaluate habitat and biodiversity metrics as indicators of ecosystem condition.

EMAP - Forests

In the first, EMAP-Forests is sponsoring a project under Thomas E. Martin, U.S. Fish and Wildlife Service, to develop indices of biotic integrity (after Karr 1981) for forest ecosystems. Dr. Martin is attempting to identify suites of bird species that are clearly indicative of either undisturbed ("healthy") or disturbed ("unhealthy") forests. Forests are classified as healthy or unhealthy based upon the total number of species and their abundances in each group for a given forest stand. Thus, the approach is aimed at identifying those tracts of forest that are suitable (i.e., healthy for forest-dwelling migratory birds as a group).

The work in progress is investigating indicators of bird populations and a parallel set of indicators based on vegetative characteristics of the breeding habitat. The thrust of the work is to establish the relationships between habitat characteristics and the health of the forest bird communities on a site-by-site basis. Preliminary results indicate that vegetative indicators based on breeding habitat show promise in reflecting the health of breeding bird communities. This means that the collection of vegetative characteristics can be done in the EMAP framework in lieu of collecting information directly on bird populations.

EMAP - Surface Waters

The second project is being supported by EMAP - Surface Waters and conducted by Dr. Raymond J. O'Connor, University of Maine. It is similar to the EMAP - Forests project in that it is attempting to identify metrics of suites of bird populations indicative of the condition of lake ecosystems. Censuses of the birds of 20 selected lakes in New England were conducted during the 1991 breeding season. Habitat measurements were also made at census locations.

Individual bird species showed little evidence of sensitivity to anthropogenic impacts. However, when species were classified by guild membership, the relative abundance of several guilds proved sensitive to anthropogenic impacts. Two indicators based on the bird data were developed and were shown to detect anomalous lakes (O'Connor, personal communication). One indicator predicted species richness at each lake on the basis of physical attributes of the lake, with deviations from predicted values reflecting anomalous conditions. The other characterized lakes as a multivariate function of the bird guild composition, with the function value altering with stressor intensity.

Biodiversity as an Endpoint

This project, also conducted by Dr. O'Connor, is currently investigating the usefulness of the U.S. Fish and Wildlife Service Breeding Bird Survey (BBS) protocol for developing indices of biodiversity within the EMAP sampling frame. Specifically, the project is developing ways to add habitat measurements to the Breeding Bird Survey routes and to analyze the BBS data in conjunction with these habitat characteristics. This project is investigating local and landscape habitat characteristics and is developing guild classifications for the bird species. In addition, the project is addressing some of the biases in the Breeding Bird Survey, such as the road-bias of the routes, by investigating alternatives, such as checkplots, and comparing the results to those from the BBS.

Habitat/Biodiversity Initiative

Habitat alteration and destruction with consequent biological depletion are among the greatest ecological threats facing the nation (U.S. EPA 1990). Three factors are thought to contribute to the problem. First, habitat modification may often be the inadvertent result of independent and poorly coordinated land use decisions that result in habitat fragmentation. This isolates certain species in ever smaller patches of suitable habitat and creates barriers to movement between patches. Second, the cumulative effects of local habitat modification and contamination reduce the quality of remaining habitat patches. Third, these factors in combination alter competitive relationships and predator/prey relationships within habitats. Invasive, introduced species then can displace native indigenous species, with consequent loss of native biodiversity in the landscape.

Along with other federal and state agencies, EPA shares a responsibility for the conservation of natural resources and protection of the environment. Implicit in many of EPA's legislative mandates, and found throughout its regulatory authorities, is the notion of maintaining natural biodiversity. One of the problems facing federal agencies is that habitat stewardship is divided among many land ownerships, each with a different perspective on risks and values. As stated by the Council on Environmental Quality (1991) "Piecemeal management -- ignoring the interdependence of parts of any ecosystem that happen to be separated by political boundaries or by lines of land ownership -- can lead to environmental and biological decline." To stem further loss of habitat and biodiversity, it is necessary to develop a federal partnership that recognizes the complexity of multiple-ecosystems, multiple-values and multiple-stresses associated with landscape mosaics of interacting ecological systems distributed among federal, state, and private ownerships.

In response, we are proposing a multi-agency, collaborative project to develop the methods and data needed to assess risks to biodiversity. We propose to categorize and map the relative species diversity and landscape type diversity of each of about 12,000 sampling units (hexagons) based on the EMAP sampling grid covering the conterminous United States (fig. 2). The process (fig. 3) will include (1) compilation of The Nature Conservancy's detailed vertebrate species distribution and attribute data for each hexagon, (2) compilation of remotely sensed land characterization data , (3) determination of whether low-cost remote sensing data (Advanced Very High Resolution Radiometry, AVHRR) that describe landscape types will be an acceptable surrogate for habitat at the national scale, and (4) analysis of the species and land characterization data by different ecological weighting methods, spatial analyses, multivariate statistical pattern analyses, and protection optimization methods. This information, along with stressor data compiled from existing databases, will be evaluated and synthesized to quantify relative risks to biodiversity and landscape types by region and landscape type. Overall patterns that lead to high importance and vulnerability of natural landscapes and biodiversity will be identified.

In completing an assessment of the risks to landscape and biodiversity, methods of prioritizing the protection of both wildlife and landscape types are needed. Any policy recommendations must initially consider a variety of options and the amount of habitat and diversity protected under each option must be known.

Prioritization recognizes the need to establish a sequence of target areas for application of management and regulatory resources. Prioritization in this study will be done in two ways. First, individual species will be weighted by a variety of factors that represent their contribution to differing values associated with biodiversity. Such values might include importance in ecosystem function and sustainability, genetic "uniqueness", vulnerability to habitat fragmentation, and conservation importance (rarity). Second, individual landscape types, as represented by number and proportion of the spatial areas of particular remotely sensed classes, will be evaluated as a surrogate for landscape structural diversity.

Prioritization will be implemented by ranking cells according to the joint criteria of maximum coverage but minimum redundancy in species or landscape type occurrence. We will perform sensitivity analyses to examine the robustness of methods of weighting, aggregation, and ranking.

Expected benefits include (1) establishment of baseline conditions of species distributions and landscape types, (2) comparative risk assessment of stressors that threaten biodiversity, and (3) testing of methods that hold promise for significantly reducing costs of habitat monitoring, evaluation, and management. The project is designed to complement the higher resolution analyses of the Fish and

Wildlife Service's GAP Analysis Program by explicitly relating the distribution of anthropogenic stressors to biodiversity and landscape types through the risk assessment process.

Although the program's objectives are national in scope, several scientific issues will be addressed initially and resolved in an integrated series of pilot projects in different landscape types. The criteria used in selecting areas for the pilot projects will include availability and completeness of appropriate biological, landscape, and stressor data bases; a variety of cover types representative of those to be encountered in the national assessment; and ability to support ongoing research in EMAP and the U.S. Fish and Wildlife Service's GAP Analysis Project.

The pilot projects are being designed to address the following research issues and questions:

- Is the AVHRR land classification (Loveland et al. 1991) an ecologically meaningful representation of landscape diversity?
- Can vertebrate diversity be meaningfully associated with landscape diversity?
- Will existing stressor data bases allow an adequate characterization of risks to biodiversity?

The pilot projects will have somewhat different research orientations due to differences in data availability, scale, and issues being addressed. One or more of the following activities will occur as appropriate:

- Vertebrate species will be allocated to hexagons. In some cases rare plants and some invertebrates will be allocated as well.
- AVHRR landscape representations will be compared to GAP Thematic Mapper vegetation maps.
- Landscape and species data will be analyzed for spatial pattern, type of diversity represented, and interaction effects between the two kinds of data.
- Stressor data will be prioritized, analyzed for allocation to the hexagon spatial framework, and developed into a data base as feasible.

REGIONAL

EPA's Global Change Research Program has recently awarded a competitive cooperative agreement to Dr. W. Carter Johnson, South Dakota State University, to evaluate the potential consequences of global climate change and other

environmental factors on migratory waterfowl populations in the glaciated prairie region of North America. The investigators will be working in collaboration with related research programs in the U.S. Fish and Wildlife Service, U.S. Bureau of Reclamation, and the U.S. Geological Survey. Global circulation models project a warmer and drier climate for this region, and initial model simulations indicate that this could cause a dramatic decline in habitat quality and waterfowl production. The research will investigate the major factors affecting waterfowl populations through literature review, agency statistics, statistical analyses, simulation model development, and remote sensing. Simulations will enable assessment of the waterfowl resource and its vulnerability to the singular effects of climate change. A remote sensing protocol will be developed for early detection of the climate change signal in prairie wetlands.

WATERSHED

As a part of EPA's Midwest Agrichemical Surface/Subsurface Transport and Effects Research Project (MASTER), EPA is evaluating how changes in the composition and quality of habitat types and their spatial arrangement affect environmental quality, ecological processes, and species composition and abundance. The Walnut Creek watershed in Iowa, a watershed containing one of the U.S. Department of Agriculture Management Systems Evaluation Areas (MSEA) was selected for study.

The long-term goal of the terrestrial research is to develop a land-use plan for the watershed that maximizes ecological benefits to terrestrial flora and fauna while maintaining an acceptable level of agricultural production. Among the major research objectives are: (1) development of a landscape model for evaluating potential benefits to terrestrial biota from alternative land uses, management practices, and habitat manipulations without compromising commodity yields, and (2) evaluation of the impact of agrichemicals, other agricultural practices, and habitat factors on terrestrial biota.

SUMMARY

The EPA is currently developing tools that will enable managers to evaluate changes to biodiversity at national, regional, and watershed scales. These tools are being developed in cooperation with other federal agencies as well as with universities and will provide a framework for risk based assessment and management of habitat and biodiversity.

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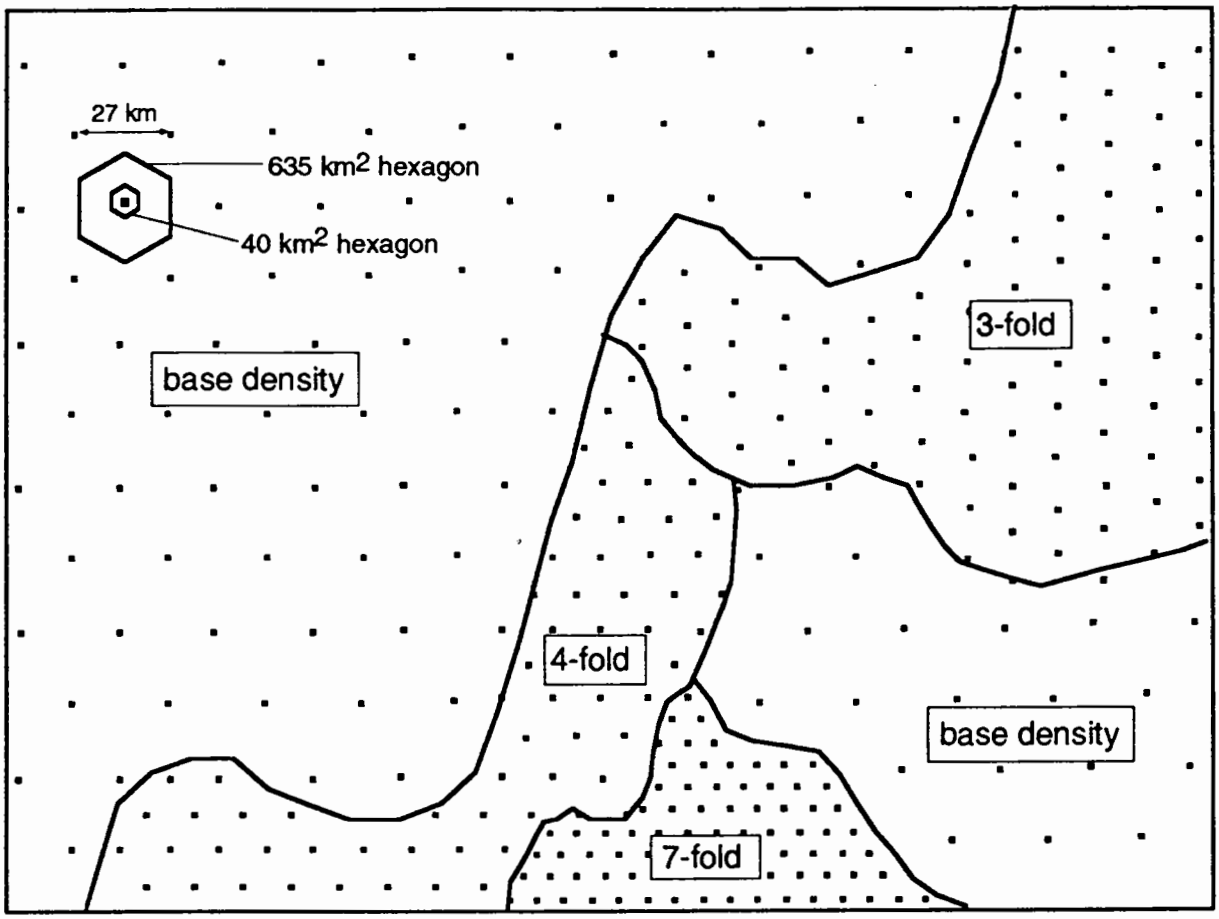
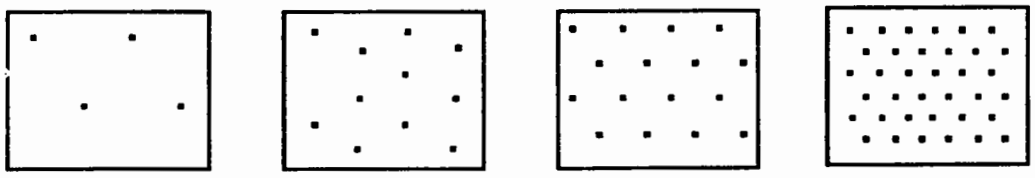
Figure 1. --The EMAP randomized systematic triangular grid system.

Figure 2. --The EMAP grid as an organizing framework for biodiversity, landscape, and stressor data.

Figure 3. --Analysis strategy for a synoptic national assessment of comparative risk to biological diversity and landscape types.

Grid Density Enhancement

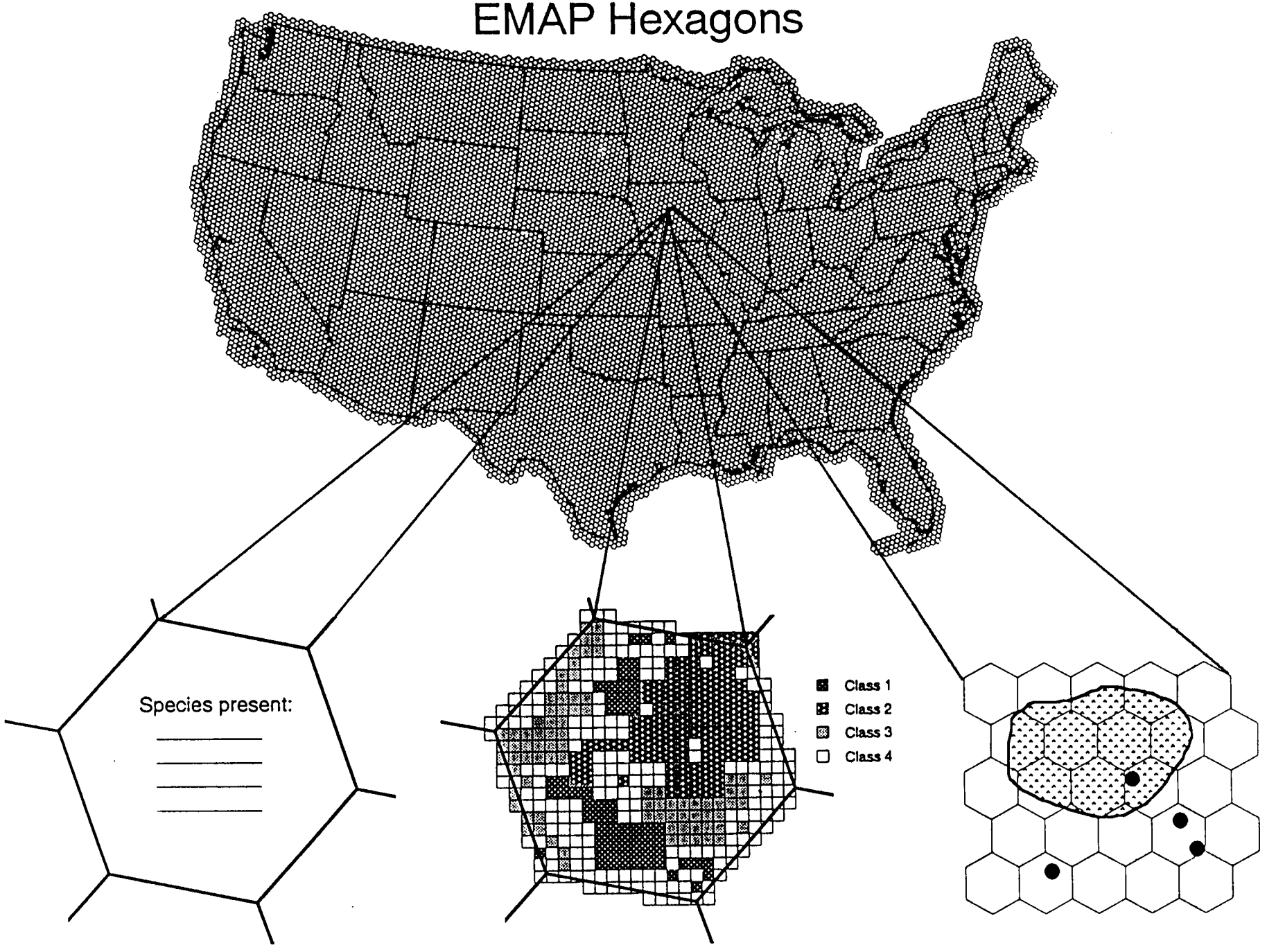




base density 3-fold 4-fold 7-fold

Enhancement factors for increasing the base grid density.

EMAP Hexagons

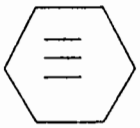


TNC species occurrence data

AVHRR landscape types

Stressor data

Analysis Strategy



Species occurrence data

For each vertebrate species (mammals, birds, reptiles, amphibians, fish):
- taxonomy
- biological description
- conservation status
- economic attributes
- spatial distribution
- migration attributes
- habitat characteristics
- food habits
- phenology

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Compute metrics:
- species richness
- functional diversity
- genetic diversity
- fragmentation
- conservation

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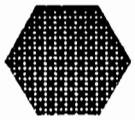
Analyze spatial patterns:
- maps by region
- aggregate hexagons
- contour maps



Landscape type data

For each AVHRR land type:
- vegetation type
- land cover type
- greenness attributes
- climate attributes
- terrain attributes
- Omernik ecoregion

▼

Compute metrics:
- composition
- dominance
- contagion
- fragmentation

▼

Analyze spatial patterns:
- maps by region
- aggregate hexagons
- contour maps

▼

Analyze joint patterns:
- classification
- ordination
- regression

Stressor data

Areal and point data:
- water quality
- toxics
- ag chemicals
- mining & forestry
- development

▼

Evaluate and allocate to hexagons or larger units as appropriate

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Analyze spatial patterns

Identify and prioritize areas of concern

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16. ABSTRACT

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