ELSEVIER

Environmental Science & Policy 3 (2000) 347–356

Environmental Science & Policy

www.elsevier.nl/locate/envsci

A targeting approach for ecosystem protection

Amy T. Mysz, Charles G. Maurice *, Robert F. Beltran, Kendra A. Cipollini [1], John P. Perrecone, Karen M. Rodriguez, Mary L. White

US Environmental Protection Agency, Region 5, Critical Ecosystems Team, 77 W. Jackson Boulevard, T-13J, Chicago, IL 60604, USA

Abstract

The Critical Ecosystems Team of the US Environmental Protection Agency (EPA), Region 5, has developed an approach to prioritize and target ecologically high-quality areas for enhanced environmental protection in the Midwestern states of Illinois, Indiana, Ohio, Michigan, Minnesota and Wisconsin. Using this approach, we intend to employ a pro-active strategy to protect the environment by protecting and restoring natural ecosystems rather than the traditional EPA approach of remediating and attempting to restore already degraded habitats. The approach consists of two components: (1) partnership and (2) criteria. For the partnership component, we collected, mapped, and summarized information on ecosystems considered critical to federal and state agencies, tribes and non-profit organizations. Multi-county areas with high numbers of ecosystems identified by a variety of partners were designated as 'Ecologically Rich Regions'. These Ecologically Rich Regions highlight broad geographic areas where there are high levels of partner interest and, correspondingly, areas with high potential for forming collaborative partnerships for enhanced environmental protection. The second component, which relies on criteria, is still under development and defines critical ecosystems as having three important properties: (1) high ecological diversity, (2) potential for long-term sustainability and (3) presence of relict native ecosystems or communities. The information compiled under both components of this ecosystem targeting approach will inform ecological risk managers and assessors about important ecosystems that should be considered in risk management and assessment processes. Published by Elsevier Science Ltd.

Keywords: Critical ecosystems; Ecological risk assessment; Ecologically rich regions; Midwest

1. Introduction

Since its creation in 1970, the United States Environmental Protection Agency (EPA) has made great strides in fulfilling its mandate to protect the environment from anthropogenic impacts, but its job is far from over. The environmental statutes that EPA is responsible for administering are compartmentalized according to single media or problems, such as water, air, wastes, pesticides, or toxic substances, and as a result, EPA programs have followed this structure. This compartmentalized strategy was effective in solving the pressing environmental problems of the past; however, we have entered a new era of problems that may be equally harmful to the environment but are less obvious. Traditional single, environmental media approaches fail to address the complex and interconnected relationships among all aspects of the environment. Today, chemical pollutants, for example, are not considered the only threat to the environment. Physical and biological stressors (e.g. urban sprawl and invasive species/diseases) are also known to have tremendous adverse effects on ecosystem health. In order to continue protecting the environment successfully, EPA must develop innovative approaches to execute its statuatory mandates more fully and to confront environmental problems and challenges. This paper discusses one approach being used by EPA Region 5[2] to identify and target ecosystems for protection and restoration.

* Corresponding author. Tel.: +1-312-886-6635; fax: +1-312-886-9697.

E-mail addresses: maurice.charles@cpa.gov (C.G. Maurice), kcipollini@tnc.org (K.A. Cipollini).

[1] Present address: The Nature Conservancy, 6375 Riverside Drive, Suite 50, Dublin, OH 43017, USA.

[2] Region 5 is used throughout this paper to refer to Region 5 of the United States Environmental Protection Agency, whose geographic jurisdiction encompasses the Midwestern states of Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin.

1462-9011/01/$ - see front matter Published by Elsevier Science Ltd.
PII: S1462-9011(00)00104-0

2. Background

For the purposes of this paper, ecosystems are considered to be native biota and their associated abiotic environment within the natural landscape. Region 5 recognizes the urgency and importance of protecting ecosystems across the Midwest and, in 1995, made protection and restoration of critical ecosystems one of its five priorities. In exploring options to address this priority, Region 5 decided to enhance protection of the environment by considering whole ecosystems rather than compartmentalizing the environment into its separate parts. Additionally, Region 5 decided to shift some of its focus from traditional remediation of degraded habitats to protecting the relatively few remaining habitats of high ecological quality. In response to this enhanced view of environmental protection, Region 5 established the Critical Ecosystems Team (Team) in 1997. The Team consists of representatives from each of the Region 5 Divisions and Offices, such as the Water Division and the Office of Strategic Environmental Analysis, to ensure input and support from all Region 5 programs. The mission of the Team is to champion the protection and restoration of Midwestern critical ecosystems, and to assist in promoting and incorporating more holistic environmental protection and restoration approaches into the entire spectrum of Region 5 planning and activities. Examples of these activities include permitting, enforcement, allocation and oversight of grants, and facilitation of remedial actions and community-based efforts. In order to firmly establish and formally recognize ecosystem protection and restoration as a priority, Region 5 stated that we will 'inventory and assess the Region's most important ecosystems and with our partners we will identify problems and take action to protect and restore these natural areas.' (US Environmental Protection Agency, 1998a).

One of the Team's first tasks is to define and identify 'critical ecosystems' in the Midwest. In developing our approach, the Team recognized that many agencies and organizations have a wealth of ecological information. Many of them have already identified critical or priority habitats, or have established methods for targeting ecosystems based on their particular perspective or mission. Some examples are in Table 1. While some approaches are similar to that taken by the Team, none of them satisfy the unique needs and perspectives of Region 5. The EPA lacks sufficient data regarding the occurrences and specific locations of ecologically significant places, and must rely on other agencies and organizations not only for ecological information, but also to enhance and coordinate successful ecosystem protection efforts. The EPA is a regulatory agency and does not own or manage lands, so its role in protecting ecosystems is not restricted to specific property boundaries. Rather, EPA has the responsibility and authority to affect broader ecosystem protection through the implementation and oversight of its overarching environmental statutes. In addition to these broad responsibilities and authorities, EPA undertakes initiatives in specific locations and must be selective in where it focuses resources.

The Team is employing an approach that is consistent with the unique mission, perspective and regulatory authority of EPA. This is an integrated approach that consists of two separate but linked 'components,' which incorporate diverse, multimedia perspectives with criteria. This approach promotes coordination among partners[3] and allows Region 5 and other organizations[4] to broaden our view of ecosystem protection.

The two components in the Team targeting approach are the 'criteria component' and the 'partnership component' (Fig. 1). The 'criteria component' is an effort to identify ecologically significant places consistently and quantitatively in the Midwest. The criteria component is a long-term endeavor and is still under development. It is a place-based enterprise that will be used to highlight a few exceedingly significant places in the Midwest for which extraordinary protection and ecological enhancement opportunities will be explored and activities will be promoted.

The 'partnership component' relies on the knowledge and expertise of a variety of environmental protection and natural resource management organizations to identify ecologically important areas. In contrast to the criteria component, the partnership component is already developed and is a collaborative enterprise. The partnership component is the primary focus of this paper and is already sporadically being used by Region 5 staff for routine regulatory and oversight activities. The ecosystems identified by the partners were mapped and used as a tool to determine where interests and priorities overlap. Using this tool, Region 5 and other organizations can direct efforts better toward developing partnerships and incorporating different perspectives into their ecosystem protection efforts.

3. Methods

As previously stated, the methodology for identifying critical ecosystems will incorporate a two-component approach, the criteria component and the partnership component, as described separately below.

[3] From the Team perspective and for the purpose of this paper, the term 'partners' is used to refer to federal and state agencies, tribes, and non-governmental organizations that have collaborated with Region 5 during this effort.

[4] For the sake of brevity, the term 'organizations' is used throughout this document to refer collectively to federal and state agencies, tribes, and non-profit organizations.

Table 1
Examples of various ecosystem prioritization methods

Author or Institution	Method	Goals	Approaches and/or Products	Scale of Analysis	Progress
United States Environmental Protection Agency Region 5[a]	Partnership component	Identify ecosystems important to partners	Survey partners and generate information clearinghouse GIs- and internet-based maps, database, and summaries	EPA Region 5 (IL, IN, MI, MN, OH, WI)	More than 60 organizations contacted Maps and database generated Ongoing information gathering and product refinement
	Criteria component	Identify few most ecologically significant (critical) ecosystems	Rating of ecosystems based on ecological criteria	EPA Region 5 (IL, IN, MI, MN, OH, WI)	Criteria metrics currently under development
United States Geological Survey (Scott and Jennings, 1997)	GAP analysis	Identify native animal species and communities not adequately represented in existing conservation lands	Standard methodology and GIS archiving format	United States; 1:100,100	445 contributing organizations; Region 5 states to be completed by 2003
The Nature Conservancy (1997)	Ecoregional Conservation Planning	Identification of biodiversity targets and selection of conservation sites	Identify targets Set conservation goals Selection of sites Setting priorities on sites Strategies and implementation	United States; within ecoregions as defined by Bailey small and large patch	Portfolios are being assembled
Chicago Wilderness (Hill, 1999)	Biodiversity Recovery Plan	Protect natural communities in the Chicago region and restore them to long-term viability, in order to enrich the quality of life of its citizens and preserve global biodiversity	Involve citizens Improve scientific base Protect important natural communities Restore communities Manage for biodiversity Develop citizen awareness Foster sustainability Enrich quality of life	Metropolitan Chicago, IL: biological community	Draft plan submitted for public review September 1999
US Environmental Protection Agency (1997)	Priorities for Ecological Protection: Discussion Document for EPA	Stimulate EPA personnel discussion and propose a process	Ecological risk assessment Community-based environmental protection	United States; no scale suggested	Follow-up Ecosystem Targeting workshop held in July 1998 Priorities are set within each EPA region
US Environmental Protection Agency (1998b)	Targeting Regional Priority Places	Report of EPA meeting and discussion to update EPA personnel on ecosystem targeting techniques	Multiple methods reported	United States; no scale suggested	Priorities are set within each EPA region

Table 1 (*Continued*)

Author or Institution	Method	Goals	Approaches and/or Products	Scale of Analysis	Progress
World Wildlife Fund (Olson and Dinerstein, 1998)	Global 200	Conserve distinctive ecoregions Species endemism Unique higher taxa Unusual ecological or evolutionary phenomena Globally rare habitat type	Species richness	World: habitat type	Identified 136 terrestrial, 36 freshwater, 61 marine ecoregions
Hyman and Leibowitz (2000)	Ecological Benefit versus Restoration Effort Model	Develop a framework to prioritize ecosystems and that is repeatable, highlights assumptions, and allows comparisons	Model ecological benefit of restoration Rank multiple sites to determine best benefit-to-effort ratio	Variable	Two examples given
White et al. (1999)	Hierarchical Framework for Conserving Biodiversity	Answer two questions: (1) What are the associations of factors that relate to biodiversity? (2) Where are the most important locations of biodiversity?	Statistical analysis of a biodiversity response variable against environmental factors Integer programming optimization techniques	Variable: 640 km^2 cell size	Oregon and Pennsylvania
Daily (1999)	Scientific Basis for Managing Ecosystems	Characterize and manage ecosystems as capital assets	Quantify scales of delivery, transport, consumption, substitutes, and recovery potential Interdependency of ecological services	World; habitat	Seven examples given

[a] Topic of current manuscript.

3.1. Criteria component

The Team is developing an approach to generate a rating methodology to identify places in Region 5 that are of highest quality and are ecologically most significant. The rating methodology will consist of metrics that incorporate three ecologically important properties that are well recognized by ecologists. We will base each of the following criteria on its associated presence or condition relative to intrinsic features and presettlement conditions: (1) presence of an indigenous ecosystem and biological community types (used as an indicator of relative ecological diversity); (2) levels of stressors, and the proximity and connectivity to similar high-quality biological communities (used as an indicator of long-term self-sustainability); and (3) numbers and rarity of native species and natural features (used as indicators of surviving relict native ecosystems). In the absence of detailed data to apply these criteria quantitatively, we are in the process of exploring metrics that will provide acceptable estimates using available data. This rating methodology is viewed as an iterative process that will be adjusted to incorporate new information, partner comments, and experience. As a result, initial analyses and corresponding ratings will tend to be fairly subjective and rely more on professional judgement, whereas future analyses and corresponding ratings will be more quantitative.

3.2. Partnership component

The Team began the process of identifying critical ecosystems by utilizing the wealth of information held by other organizations. In January 1998, the Team sent a letter to 64 federal, state, tribal, and non-governmental organizations requesting a list of ecosystems considered critical by their organization, and information about actions being taken in those areas. Subsequent

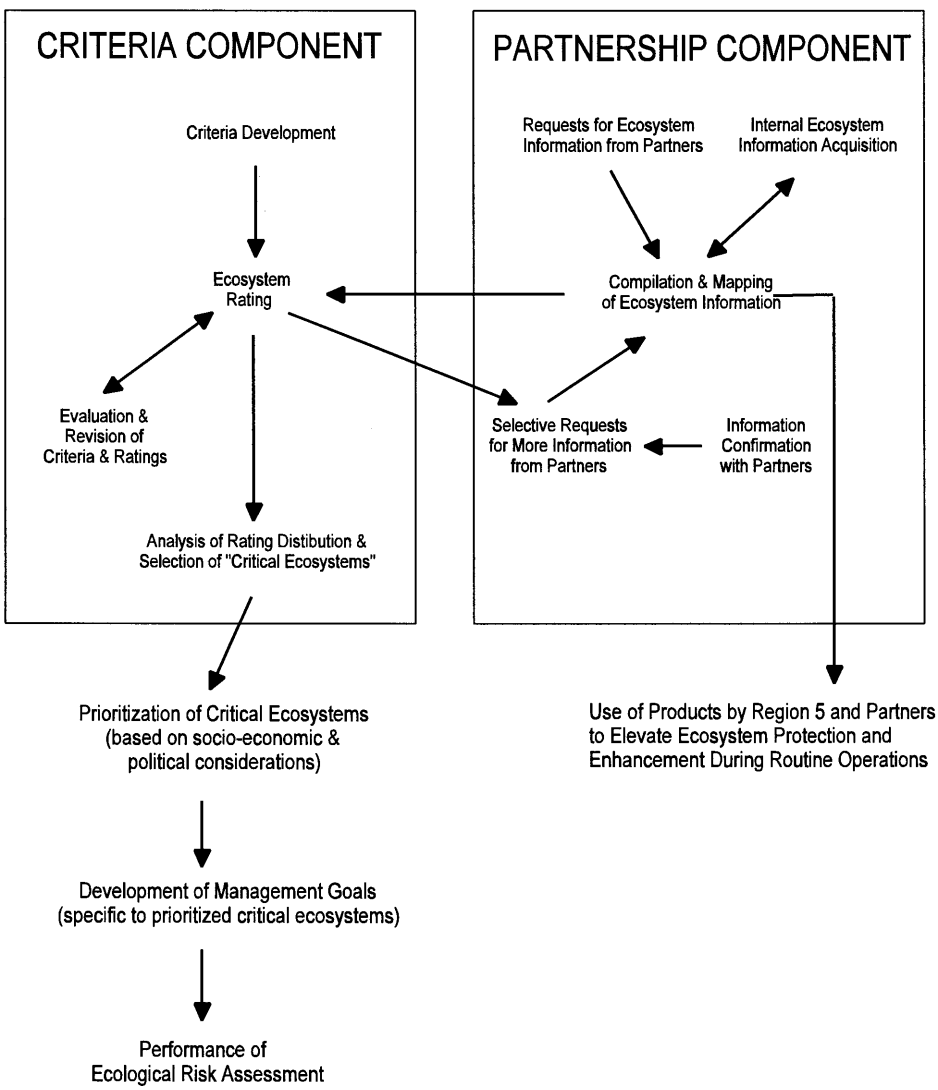

Fig. 1. Team ecosystem targeting approach, including the two separate but linked components.

Table 2
Organizations contacted for the partnership component of the targeting approach

Federal agencies
Dept. of Agriculture, Natural Resources Conserv. Serv.
Dept. of Agriculture, Forest Service
Dept. of Defense, Army Corps of Engineers
Dept. of Interior, Bureau of Land Management
Dept. of Interior, Bureau of Indian Affairs
Dept. of Interior, Fish and Wildlife Service
Dept. of Interior, Geological Survey
Dept. of Interior, National Park Service

Non-governmental organizations
The Nature Conservancy (regional and state offices)
National Audubon Society (regional office)
Sierra Club (Great Lakes Ecoregion Office)
National Wildlife Federation (regional office)

State agencies

Illinois
Dept. of Natural Resources
Environmental Protection Agency
Dept. of Agriculture

Indiana
Dept. of Natural Resources
Dept. of Environmental Management
Office of State Chemist and Seed Commissioner

Michigan
Dept. of Natural Resources
Dept. of Environmental Quality
Dept. of Agriculture

Minnesota
Dept. of Natural Resources
Pollution Control Agency
Dept. of Agriculture

Ohio
Dept. of Natural Resources
Environmental Protection Agency
Dept. of Agriculture

Wisconsin
Dept. of Natural Resources
Dept. of Agriculture

Tribes and tribal organizations

In Michigan
Bay Mills Indian Community
Chippewa-Ottawa Treaty Fishery Management Authority
Grand Traverse Band of Ottawa and Chippewa
Hannahville Indian Community
Huron Potawatomi
InterTribal Council of Michigan
Keweenaw Bay Indian Community
Lac Vieux Desert Band of Lake Superior Chippewa
Little River Band of Ottawa
Little Traverse Bay Band of Ottawa
Pokagon Band of Potawatomi
Saginaw Chippewa
Sault Ste. Marie Tribal Council
In Minnesota
Bois Forte Band of Chippewa
Fond du Lac Band of Chippewa
Grand Portage Band of Chippewa
Leech Lake Band of Ojibwe Community
Lower and Upper Sioux Indian Communities
Mille Lacs Band of Ojibwe
Minnesota Chippewa Tribe
Prairie Island Indian Community
Red Lake Band of Chippewa
Shakopee Mdewakanton Sioux
White Earth Band of Chippewa

In Wisconsin
Bad River Band of Lake Superior Chippewa
Forest County Potawatomi Community
Ho-Chunk Nation of Wisconsin
Lac Courte Oreilles Band of Lake Superior Chippewa
Lac du Flambeau Band of Chippewa
Menominee Indian Tribe of Wisconsin
Oneida Tribe of Indians of Wisconsin
Red Cliff Band of Lake Superior Chippewa
Sokaogon Chippewa Community
St. Croix Band of Chippewa
Stockbridge-Munsee Tribal Community

telephone calls and meetings resulted in the development of additional contacts. Our intent was to take a regional approach, so we contacted organizations responsible for implementation of protection activities over large geographic areas (Table 2). Overall, the Team contacted eight federal and 17 state agencies that make up the major natural resource, agricultural, and environmental regulatory agencies. In addition, the Team consulted all 33 federally recognized tribes in Region 5, as well as two tribal assistance organizations, and four major national non-profit conservation organizations. Individual contacts within each organization were identified because they were points of contact for previous environmental projects and grants involving EPA. In total, the Team spoke or met with over 300 people.

We attempted to include multiple divisions within organizations, e.g. air, water, soil, forestry, fish and wildlife, and nature preserves, so that broader views of the organizations were represented. We did not include county and municipal governments, local planning commissions, universities, and many of the small, local non-profit organizations that might have provided valuable input for the identification of critical ecosystems. Since these limitations adversely affected our ability to incorporate multiple perspectives and missions into an integrated ecosystem approach, we intend to continue gathering data and refining our ecosystem targeting efforts. During subsequent attempts to gather information, we will contact organizations that have not yet

provided input. We are also in the process of compiling similar information from within EPA, such as high-quality wetlands identified by Region 5's Water Division.

The information request sent to the partners did not define the term 'critical' or address scale so that the organizations could respond according to their own perspectives and priorities. Additionally, the Team did not request detailed data about the ecosystems to avoid excessively encumbering organizations. This resulted in responses that were vague and varied greatly in detail and scale. Additional information was requested during subsequent clarification discussions with partners. In general, responses indicated that most partners view 'critical' as meaning 'high quality' or ecologically diverse.

Using ArcView© geographic information system (GIS) software, we mapped the approximate ecosystem locations as low resolution, irregularly shaped polygons based on the level of detail provided by the partners. We needed to demarcate some ecosystems by the county boundaries within which they occur. Some responses could not be mapped at all because they were too expansive in scope or because information was lacking. For example, at least two partners identified all surface waters of a state as critical. Even though these responses could not be mapped, such generalized information is valuable because it provides an indication of the broad ecosystem types those partners view as important.

The primary objective of the partnership component is to optimize collaboration among organizations in order to maximize ecosystem protection and enhancement. We conducted overlap analysis using GIS to highlight county level areas containing the greatest numbers of ecosystems identified by a variety of partners. We designated several groupings of multiple counties having relatively large numbers of partner-identified ecosystems as 'Ecologically Rich Regions' (Fig. 2). We chose county as the initial unit of targeting resolution, rather than more ecologically relevant units, because it is the smallest, most common data layer available to Region 5 and because many EPA program databases are organized by county. In the future, as more data layers become available, we will summarize data by other units, such as watershed, airshed and ecoregion.

It is important to note that, if a given ecosystem was forwarded by more than one partner, the ecosystem was counted more than once in the total number of partner-identified ecosystems per county. In this way, we intentionally weighted partner-identified ecosystems by partner interest. For example, if three organizations identified the same ecosystem as critical in a given county, the partner-identified ecosystem count for that county would be three. Weighting the level of partner interest is important for Region 5 since areas of high partner interest have a greater potential for collaboration and, ultimately, for successful integrated ecosystem protection.

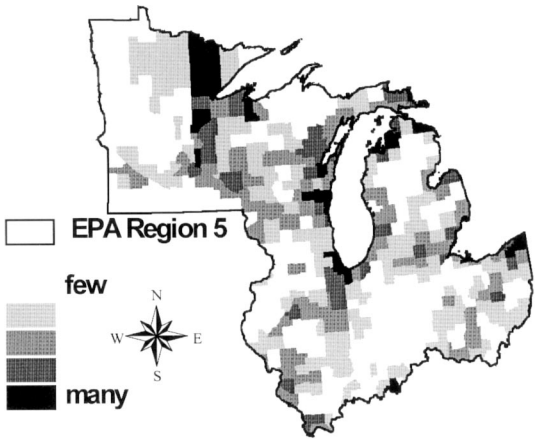

Fig. 2. Partner interest based on relative numbers of identified ecosystems. Over 500 ecosystems identified by partners were used to generate this summary map, which illustrates the locations of Ecologically Rich Regions.

4. Partnership component results

At this time, the results of the partnership component of the Region 5 ecosystem approach consist of four products: (1) ArcView© GIS map layers containing polygons of partner-identified ecosystems; (2) Lotus Approach© databases containing information about the partner-identified ecosystems and partner organizations and contacts; (3) maps and information regarding the partner-identified ecosystems on Enviro-Mapper©, a user-friendly, query-based geographic platform; and (4) the Ecologically Rich Regions map, which illustrates broad geographic areas of elevated partner interest, and associated descriptive text. The first two products are linked and contain the following information about each ecosystem: the name; the major natural community type(s) or feature(s) found in the ecosystem; the main threats; the reason the ecosystem is considered significant; the name of the organization and specific point of contact who provided the information; and the protection activities currently being conducted in the ecosystem. The Enviro-Mapper© platform is currently only available to EPA personnel on the EPA's internal Intranet; however, it will be provided to the general public via the Internet after routine EPA quality-control measures and approvals are completed. Users of the Enviro-Mapper© platform can click on a map to determine whether a partner-identified ecosystem exists in or near the selected location. If an ecosystem is present, the user can follow a link to a data table describing the ecosystem and the issues related to its protection.

At this time, the fourth product primarily consists of a map illustrating the locations of the Ecologically Rich Regions. However, we currently are developing summaries that will describe the natural features of these Ecologically Rich Regions organized by the Bailey ecoregion scheme (Keys and Carpenter, 1995). For these summaries, we are using information gathered from our partners, as well as other references and resources such as the Internet. The fourth product focuses on the Ecologically Rich Regions, so if information concerning ecosystems outside of the Ecological Rich Regions is desired, it must be obtained through one of the first three products mentioned above.

The organization of information presented in each Ecologically Rich Region summary is being modeled after the 'Biodiversity Investment Area' approach (Reid et al., 1998), which was developed by the EPA Great Lakes National Program Office (GLNPO) for nearshore terrestrial ecosystems in the Great Lakes. This organizational framework consists of five sections: (1) a summary of the natural and human history of the area describing the pre-settlement ecological systems and how humans have altered and impacted these systems; (2) 'Ecological Values' containing information on the natural resources found in each Ecologically Rich Region and the reasons why partners consider these ecosystems critical; (3) 'Multi-Partner Stewardship Efforts' describing the natural resource stewardship activities in each Ecologically Rich Region; (4) 'Human-induced Stresses Impacting the Region' outlining the major ecological stressors to the ecosystems, including physical, chemical, and biological impacts; and (5) 'EPA's Contribution' providing suggestions on how Region 5 can use its regulatory and enforcement authorities, as well as educational and facilitation activities, to protect and restore these areas.

5. Discussion

The ecosystem targeting approach is specifically tailored to meet the needs, interests, perspectives and priorities of Region 5. However, we anticipate that other organizations will find value in our approach and products. Partner-generated information about critical ecosystems provides a valuable resource never before available in one place. Although the ecosystem maps are not detailed, they provide an important overview for considering ecosystems in the context of broader surroundings. Information at this scale serves as a reminder that while ecosystems are highly fragmented, they coexist with, and are influenced by, other natural and human-made features. In order to protect ecosystems, we need to consider the interconnections among environmental components, to understand the values of each ecosystem, and to recognize the various stressors that threaten their existence.

The ecosystem maps provide information about the types of ecosystems various organizations consider critical as well as the location or distribution of the ecosystems. This information can be used to develop collaborative efforts, to provide a methodology for ecosystem targeting, and for overall awareness of valuable places. Some organizations may use the maps and associated data to determine common areas of interest leading to multi-organization collaboration and policy implementation on issues affecting overall ecosystem quality. Agencies that issue permits can consult the data to determine whether more stringent or special conditions should be placed on a permit in order to protect nearby ecosystems. The information might also be used to guide decision-making to remediate or to restore contaminated sites that occur near natural ecosystems. Finally, this information may be used for targeting enforcement in natural areas, or for providing information to assist in ecological risk assessments.

The maps and associated databases are not intended to be used alone. They are intended for use in conjunction with other information sources and should lead the user to seek additional information. Nevertheless, the potential uses for these tools are numerous. We anticipate that new applications will be discovered as the information is used over time.

Region 5 employees are currently exploring ways to use the maps, databases, and the preliminary Ecologically Rich Region summaries in their daily work. The Agency's primary work is regulatory, consisting of permitting and enforcement activities that are organized by single-media statutes. These statutes, however, allow latitude for protecting the environment holistically. For example, according to the Clean Air Act, an air permit can require emitting facilities to perform soil and vegetation analyses in cases where an ecosystem may be adversely impacted by air emissions. This stipulation was recently implemented in a permit for an air emitter in Indiana in order to protect a nearby high-quality ecosystem.

In another example, the National Environmental Policy Act (NEPA) must include ecosystem considerations in reviews of federally funded projects such as pipelines or highways. In a recent NEPA review of a highway development project, the ecosystem maps were used to determine whether the proposed highway corridors would impact important ecosystems in Wisconsin. The evaluation of a pipeline traversing an Ecologically Rich Region in Illinois also made use of the ecosystem maps. Finally, information in one of the preliminary summaries for an Ecologically Rich Region in Indiana was used by Region 5 senior management to evaluate the impacts of an airport expansion project.

In the area of enforcement, the maps, databases, and Ecologically Rich Region summaries can provide vital information as well. For example, traditionally, a com-

pany found guilty of violating an environmental law is assessed a fine for environmental damages. This fine is paid directly to the United States Treasury. As an alternative to a fine, EPA can suggest that the violator finance a Supplemental Environmental Project (SEP) whereby the money is redirected to finance activities such as ecosystem restoration or acquisition of property for conservation. Since a SEP is an option for a violator, it is to the environment's benefit for EPA to make SEPs more attractive and easy to implement. This requires having information about potential conservation projects and ecosystem locations on hand for EPA enforcement staff. Information provided by the maps, databases, and Ecologically Rich Region summaries can be used to formulate concrete suggestions for SEPs.

6. Conclusions

While EPA has made efforts in the past to analyze ecosystems, the described approach is an innovative and strategic initiative that links current regulatory programs and activities to ecosystem protection and restoration. Equipping EPA staff and our partners with these tools is a first step towards EPA viewing ecosystems holistically. This approach will assist EPA in coordinating with other organizations to develop an ecosystem-based approach to environmental problem solving.

In order to apply the partnership component of our methodology, it is important to understand the limitations already mentioned throughout this paper. In addition, there are other limitations that must be considered when using the products; however, we believe that the ecological benefits will far outweigh any drawbacks resulting from the limitations. For example, because the scale of the mapping is coarse, it is not intended to be used to locate point data and isolated features. However, this scale allowed us to acquire information from some organizations that cannot release sensitive point data, and we believe that low-resolution, indistinct representations of this information are more valuable than their exclusion. There are no monitoring data associated with the ecosystems, although the partner information may be used to establish contact with the organization to investigate the existence of such data. Ecologically Rich Regions may be biased toward partner-identified ecosystems possessing controversial activities or features, or by being more accessible for investigation. Similarly, private property is often not inventoried and may be under-represented due to data gaps. Finally, there undoubtedly are high-quality ecosystems throughout Region 5 that were not reported by any organization and, therefore, do not appear in our ecosystem inventory and mapping.

Future work consists of two parts. As stated previously, the partnership component is an iterative effort. More organizations will be contacted, and previous contacts will be revisited for accuracy and updating. Equally important will be the continuing work on the criteria component of this approach. A defensible set of criteria that can be used to evaluate ecosystems will not only allow us to prioritize where to spend resources, but will allow us to consider areas that have not yet been identified in the partnership component.

Acknowledgements

We would like to thank John Schneider for his role in the Team's development and for providing additional perspective and ecological expertise. We extend our appreciation to Marcus Geist who provided ArcView expertise, Larry Lehrman who provided EnviroMapper assistance, Dan Mazur who provided ecological assistance during criteria development, and Pranas Pranckevicius who provided web page assistance. Our thanks also go to Anne Barton, Pete Caulkins, Don Cipollini, Tom Davenport, Jeffrey Gagler, Walter (Pete) Redmon, John Schneider, Anne Sergeant, and James White who provided comments on the manuscript. We would also like to thank other members of the Critical Ecosystems Team for their contributions to this work: Jorge Acevedo, Briana Bill, Mike Gentleman, Steve Gorg, Claudia Johnson, Brenda Jones, Margaret Jones, Jackie Kline, Larry Lehrman, Ivan Lieben, Meagan Smith, and Helen Tsiapas. Finally, we thank the Senior Leadership Team of Region 5 for their wisdom in forming the Critical Ecosystem Team and taking a broader approach to environmental protection.

References

Daily, G.C., 1999. Developing a scientific basis for managing earth's life support systems. Conserv. Ecol. 3 (2), 14 http://www/consecol.org/vol3/iss2/artl4.

Hill, B., 1999. Biodiversity Recovery Plan. Chicago Wilderness, Northeastern Illinois Planning Commission, Chicago, IL.

Hyman, J.B., Leibowitz, S.G., 2000. A general framework for prioritizing land units for ecological protection and restoration. Environmental Management 25 (1), 23–35.

Keys, J.E., Jr., Carpenter, C.A. (Eds.), 1995. Ecological Units of the Eastern United States: First Approximation. United States Department of Agriculture, Forest Service.

The Nature Conservancy, 1997. Designing a Geography of Hope: Guidelines for Ecoregion-based Conservation in The Nature Conservancy.

Olson, D.M., Dinerstein, E., 1998. The Global 200: a Representation Approach to Conserving the Earth's Distinctive Ecoregions. World Wildlife Fund-US, Washington, DC 158 pp., March.

Reid R., Rodriguez K., Mysz A., 1998. Biodiversity Investment

Areas, Nearshore Terrestrial Ecosystems. State of the Lakes Ecosystem Conference (Environment Canada and US Environmental Protection Agency, October 1998), background paper.

Scott, J.M., Jennings, M.D., 1997. A Description of the National Gap Analysis Program. USGS/BRD Gap Analysis Program, Moscow, ID 23 pp.

US Environmental Protection Agency, 1997. Priorities for Ecological Protection: An Initial List and Discussion Document for EPA. Office of Research and Development, Washington, DC EPA/600/S-97/002.

US Environmental Protection Agency, 1998a. Agenda for Action (Region 5, EPA-905-K-98-003, 1998).

US Environmental Protection Agency, 1998b. Targeting Regional Priority Places/Ecosystem Targeting: Criteria, Methods, and Data Sources. Office of Sustainable Ecosystems and Communities, Washington, DC December.

White D., Preston E.M., Freemark K.E., Kiester A.R., 1999. A hierarchical framework for conserving biodiversity. In: Klopatek, J.M., Gardner, R.H. (Eds.), Landscape Ecological Analysis, Issues and Applications. Springer, New York, Chapter 8.