The Indiana Lake Michigan Coastal Program area of responsibility. The Indiana Lake Michigan Coastal Management Program (LMCP) has responsibility to support cultural and natural resources in the Lake Michigan watershed in Indiana, which is entirely within Lake, Porter, and LaPorte counties (Table 1).

Indiana Biodiversity Initiative goals, methods, and products. The Indiana Biodiversity Initiative is a group of agency, organization, and academic natural resource and conservation biology managers and researchers working together to develop a common basis for conservation land-use planning in Indiana. We use a sequence of mapping exercises to identify areas that offer strong potential to conserve biodiversity. We develop maps of areas with high potential for biodiversity conservation for the natural regions of Indiana (Homoya et al. 1985). Our map base is a kilometer grid that matches the UTM grid.

We begin with the plant species and high-quality plant community information from the Indiana Heritage Database, the GAP map of general land cover of Indiana , the National Wetlands Inventory (NWI) of wetlands of Indiana, and the map of existing areas protected for conservation (primarily public lands, with some additional lands such as Nature Conservancy holdings). We use these three maps in Phase I to identify the plant-related features for conservation and we use C-Plan, a spatial-optimizing program that identifies land areas that fulfill a conservation objective using the smallest footprint. Because of this spatial optimizing, C-Plan identifies those areas with the highest concentration of desirable characteristics – numbers

The current project is an update of that portion of the Northwest Morainal natural region assessment within the LMCP boundary using 2003 aerial orthophotographs and on-the-ground verification where necessary. The original land-cover classification used for the natural region assessments is the Indiana GAP map, which dates to 1992. Additional wetlands information was taken from the NWI for Indiana was completed by the early 1980s. Finally, rare species and high-quality community data came from the Indiana Heritage database, which is continuously added to, but not regularly checked to confirm continued existence of observed species or communities. The project provides the LMCP with an updated understanding of those areas originally identified as being of potentially high conservation value. In addition, a threats assessment was conducted to indicated which areas identified in the original assessment, and unaffected by change, are most at risk of future modification that may affect their conservation value.

Thirty-seven percent of the area in the Lake Michigan watershed was identified as having high potential conservation value during the original Northwest Morainal natural region assessment (Table 2, Figure 2). Thirty percent of the identified area was selected only by the Phase I vegetation conservation process, 42% was selected only by the animal habitat conservation process, and 28% was selected by both processes. The selected areas increased from west to east, with 26.5% of the selected area in Lake Co., 30% in Porter Co., and 43.5% in LaPorte Co.

Eight animal species were selected as umbrella species to represent habitat needs for the Northwest Morainal natural region (Appendix 2). The American badger (*Taxidea taxus*; state endangered) is a grassland mammal that represents grassland species generally, and the specific needs of burrowing mammals. The blue-spotted salamander (*Ambystoma laterale*; state species of special concern) and Blanding's turtle (*Emydoidea blandingii*; state endangered) both need aquatic habitat, but the salamander uses vernal pools and other ephemerally wet habitats, whereas Blanding's turtles need year-round water; both species need adjacent upland habitats as do many

Table 2. Northwest Morainal natural region assessment results within the Lake Michigan Coastal Management Program boundary. Cells in the map might be selected during vegetation selection (Phase I) or during animal habitat selection (Phase II) or during both. Interior cells were 1 square kilometer, but cells along the boundary might be any size up to 1 square kilometer.

All cells selected in Phase I	34,039.8	84,112.4	21.6
Cells selected only in Phase I	17,590.4	43,465.8	11.2
All cells selected in Phase II	40,767.6	100,736.8	25.9
Cells selected only in Phase I	24,318.2	60,090.2	15.4
Cells selected in both Phase I & II	16,449.5	40,646.6	10.4
	58,358.0	144,202.6	37.0

Ground verification. When inspection of the orthophoto was not sufficient to confirm or clearly correct the original classifications, we visited the sites and identified the present ground cover. We also used ground verification when the 2003 image showed recent development or when we considered it possible that more development might have occurred in the intervening 2 years. Obviously, in instances where new development has only begun since the 2003 image, we had no way of detecting such development. Thus, the classification of habitat in the potential-high-conservation-value cells can only be considered updated to 2003, but it will sometimes be accurate to summer 2005.

When updating the NWI classifications, we generally did not try to identify hydroperiod of any changed classifications that might include a hydroperiod classifier. For example, if an emergent wetland originally classified as PEMC

Changes in wetland types were also recorded on the NWI layer (Table 4). The original NWI layer for Indiana was finished in the early 1980s and was considered to be quite accurate at that time. Considering the age of the database, we found surprisingly little change, but this may be because the larger changes in wetland area were detected in the GAP database's generally larger

addition, protecting and restoring adjacent areas that are presently in manipulated land covers such as row crop. Thus, areas shown in IBI products are not necessarily at their most productive in terms of biodiversity, but, once protected, should be capable of improvement.

Invasive species threaten native habitats and complicate or defeat restoration efforts of all kinds. In the Northwest Morainal region, tree of heaven (*Ailanthus altissima*) is becoming well established in forests, where it replaces understory and overstory trees, alike. It reproduces profusely and seems entirely comfortable with the regional climate. Garlic mustard (*Alliaria petiolata*) invades forest understories, displacing spring ephemeral herbs and reducing the availability of host plants for butterflies and other insects. Purple loosestrife (*Lythrum salicaria*), reed canary grass (*Phalaris arundinacea*), and common reed grass (*Phragmites australis*) invade wetlands, reducing diversity of plants and animals. These are only examples of some of the broad categories. Control of these species is difficult once they become established – preventing establishment in the first place is the best course of action. The IBI products do not account for presence of invasive species, but distribution of particularly problematical species is often well understood, as are means for preventing establishment and control methods (if any). Existing protected areas or areas consider for future protection will benefit from strong invasive species control efforts.

Using project results to understand threats to conservation in the original IBI selected sites. The aerial photos are a powerful tool for investigating changes to specific IBI selected sites, as are the updated GAP and NWI layers. We were not able to ground-truth species sites from the Heritage database, but continued existence of relevant habitat serves as a partial check. In the accompanying GIS database, the ”LMCP cells – conservation features” layer provides a summary of what phase of modeling selected each cell, what the areas of major habitat types were based on the original GAP, NWI, and Heritage data, and which specific animal models selected cells that were identified during Phase II modeling. By using the updated GAP and NWI layers, users can determine whether cells have changed, and whether the changes are likely to affect conservation value. Remember that some changes may increase conservation value, as when an abandoned field begins to grow back into natural cover.

The maps of predicted future land cover change are necessarily somewhat vague and provide only general guidance for predicting future sprawl. Special areas remaining in Lake and Porter Counties are likely to have high property values, and may have poor connectivity with other similar sites. However, where such sites have unique occurrences of rare species or high-quality communities, they may be well worth preserving. Many species do not require large area, although poor connectivity tends to result in the slow loss of species from small sites because

There may be somewhat more enthusiasm for additional development in LaPorte than in Lake Co. (given the more depressed economy in the former) although resistance was also evident during field work. Signs protesting development plans were evident in more than one area. More noticeably, where green space is rare, local populations may rally to support conservation use of remaining natural areas even where development profits might be quite high.

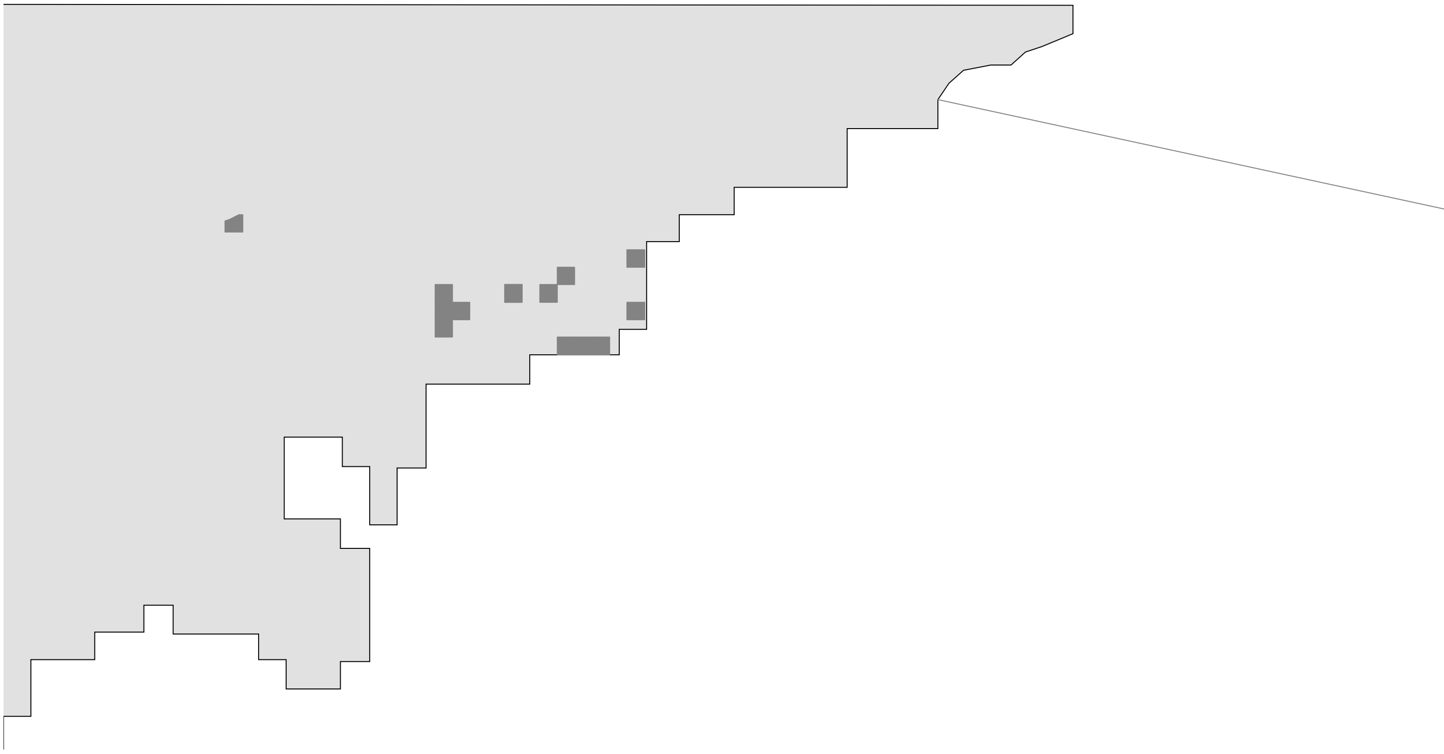
We used the updated databases to rerun both the Phase 1 (major and high-quality plant communities and rare plants) and Phase 2 (umbrella animal species) analyses within the LMCP area of responsibility.

Phase 1 was rerun with updated GAP, NWI, and Heritage databases. Largely as a result of the increase in urban areas, the rerun solution is only 92.6% of the area of the earlier solution (Table 5) and is shifted to the east relative to the earlier solution (Figure 9).

Table 5. Areas in LMCP area of responsibility, managed areas (for rerun), total Phase 1 area and total Phase 1 area outside managed areas for original and updated.

	Total		Outside Managed Areas	
	acres	cells	acres	cells
LMCP Area	406,232	1644		
Managed areas at time of rerun	44,782	181.3		
Original Phase 1 area	84,213	341	42,396	172
Rerun Phase 1 area	78,010	316	33,228	134.5

The rerun Phase 2 solution was 30% larger than the clipped Phase 2 solution from the Northwest



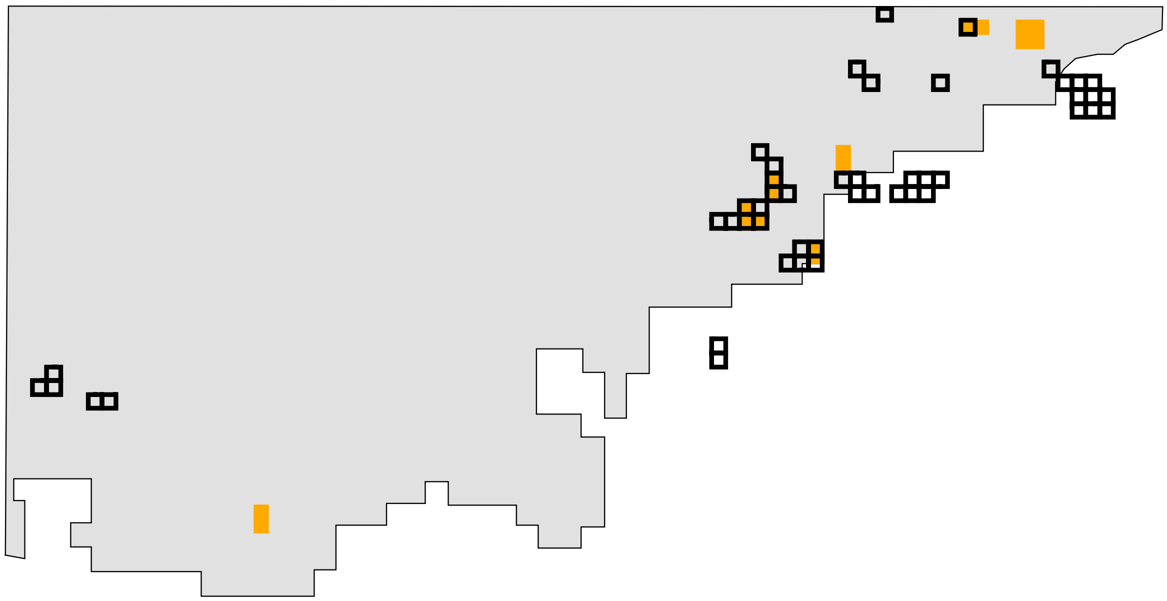


Figure 12. LMCP American badger solution (orange) with original natural region solution (outline).

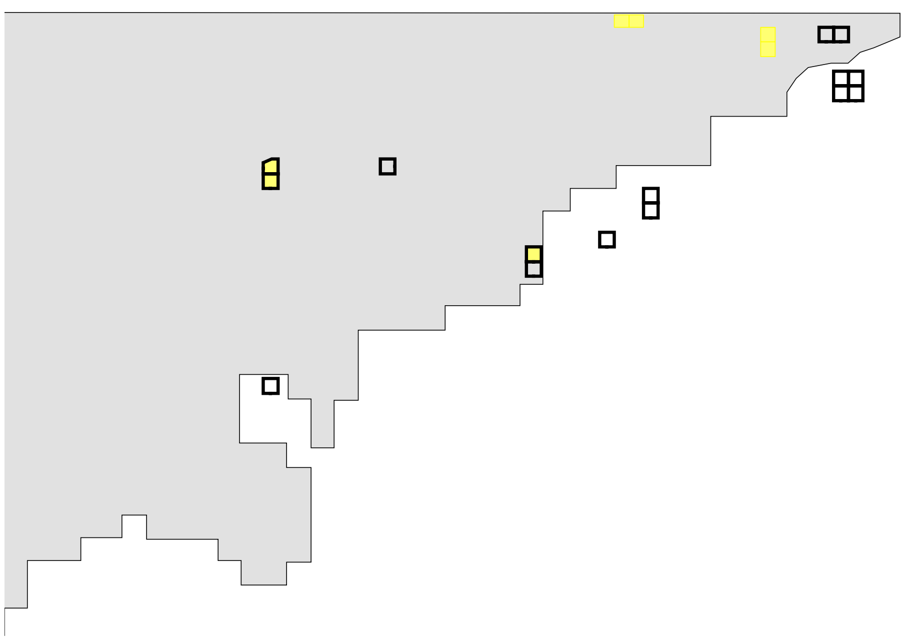


Figure 13. LMCP golden-winged warbler solution (gold) with original natural region solution (outline).

caused a cell to be selected. In using Phase 1 outputs for prioritization, users should bear in mind that Phase 1 selected cells are not created equal, in terms of high quality habitat or special features. Users' own goals will determine how Phase 1 results are best used.

Phase 2 models are designed to model habitat use by species whose habitat needs are similar to or encompass those of many other species in the ecosystem. Models are designed to capture the best habitat according to published data on the species.

Many places within the LMCP area that are not Phase 2 outputs may actually harbor these species. In some cases these areas may be sinks for species - places that attract animals but are more likely to kill than sustain them. Areas may be sinks due to mortality particular to urban and suburban settings (traffic, cats, dogs, etc.), lack of appropriate breeding habitat, or mortality from mesopredators tolerant of humans (e.g., raccoons). In the case of a species such as Blanding’s turtle, adults may survive for long periods in sink habitat.

In other cases, umbrella species may be present in unmapped habitat because nonbreeding individuals often live in areas not suitable for breeding and rearing young, because published accounts of species needs do not completely represent acceptable habitat, or because available maps to not entirely or correctly identify all ground cover.

In any event, the purpose of mapping umbrella species is not to predict their occurrence, but rather to identify areas of good habitat that will support the umbrella species and other species with similar or overlapping habitat needs - areas that are good prospects for conservation actions. Appendix 2 provides technical details for each umbrella species model. Grassland, wetland, forest, and shrub species were selected, as well as the Karner blue butterfly, which uses small pockets of native herbaceous vegetation.

Note that several models accept pasture as acceptable primary or secondary habitat. Pasture is not always a high-quality habitat for species evolved for native grasslands, however, it is often the only potentially friendly habitat. As well, pasture (and the row crop with which it often alternates) can be restored to native species, whereas urban and suburban areas are generally not available for restoration.

Phase 2 models cannot speak to all aspects of animal needs. During meetings with the CELP group, several kinds of unmet need were discussed. Migratory stopover habitat for waterfowl and shorebirds, and corridor habitat (address in Phase 3, but not in detail) were some of the most urgent needs mentioned. Species with special habitat needs (large snags for nesting birds, specific larval food plants for Lepidoptera, e.g.,) may also need additional considerations beyond those covered by the umbrella species models. Users whose responsibilities include such concerns will need to make use of other information, such as Important Bird Area maps, to ensure that specialized needs and non-resident habitat needs are met.

The LMCP contract provided us an opportunity to step through the process of updating and finetuning the IBI process. True updating was not possible under a modest contract. We had discussed with contact groups how such updating might be done, and had concluded that a really thorough job would only be possible with the assistance of a group of volunteers - school groups perhaps. As we prepared to run Phase 1 the second time, it was frustrating to know that our urban habitats were fairly well up to date, but that more thorough ground-truthing had only been done in the original Phase 1 cells within the LMCP. Some proportion of those cells would not be

Background and summary of ongoing efforts. The IBI team did not consider aquatic habitats in its initial work because early efforts to do so resulted in the understanding that an aquatic version of IBI would need to work from a different founda

The MoRAP framework and a similar approach by the Nature Conservancy involve four components that identify biologically important ecosystems in a region and their relative threat from potential stressors.

Create maps that hierarchically classify freshwater systems
Develop models that predict species distribution and relay that information into a GIS
Identify ownership and level of protection of land parcels in a region
Create maps of human stressors

The development of the hierarchical classification and the aquatic species emphasis varies by region and pilot project. The goal is to break the landscape into distinct ecological units at several integrated spatial scales using parameters such as drainage boundaries, taxonomic differences, geology, stream size, and gradient (Sowa et al. 2004). The MoRAP classification uses 8 different spatial scales ranging from continental and regional scope to the stream reach level. Alternatively, the Nature Conservancy breaks the classification into four spatial levels (Higgins et al. 2005). In both systemsef

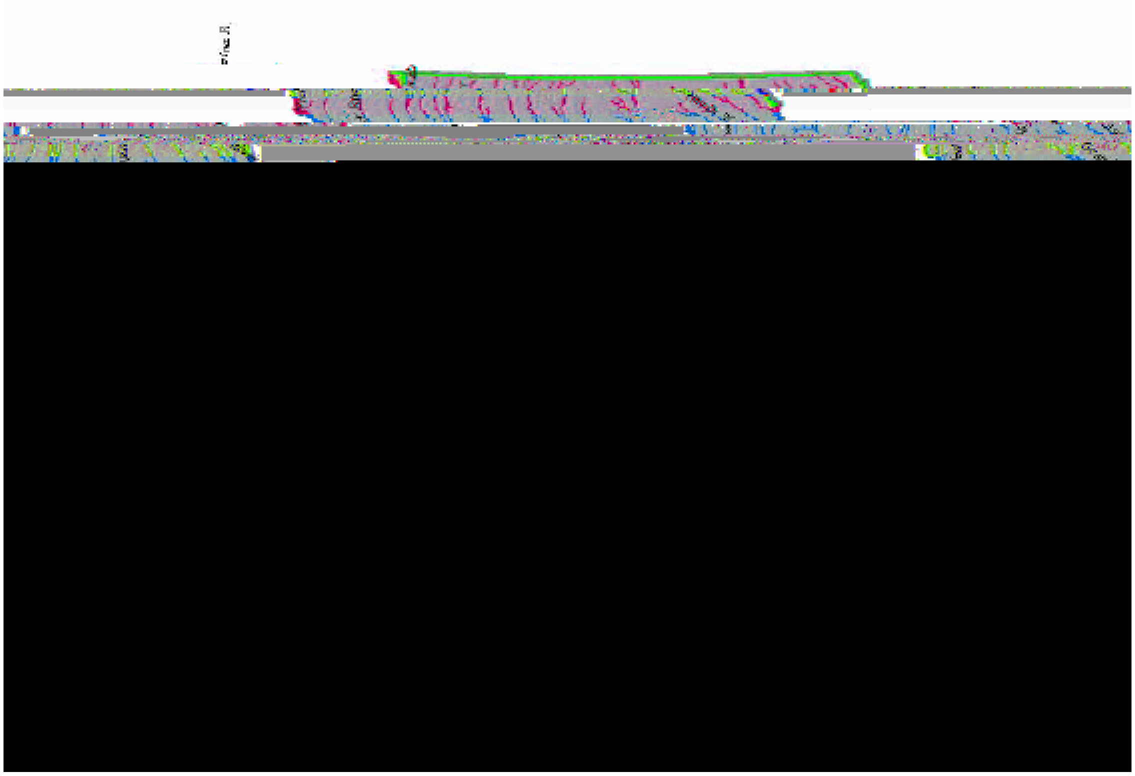


Figure 18. Map showing aquatic subregions of Missouri (Sowa et al. 2004).

The top level in the Nature Conservancy framework appears to be a simplification of the first four levels in the Missouri framework. The Nature Conservancy defines this level as an Aquatic Zoogeographic unit. (Higgins et al. 2005). The aquatic zooge

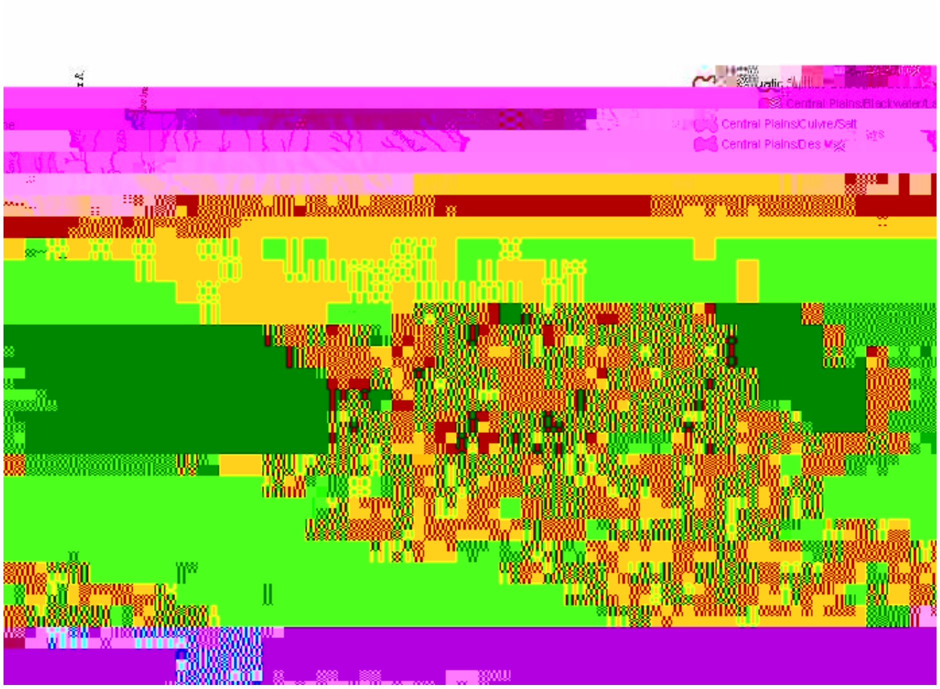


Figure 19. Ecological Drainage Units in Missouri (Sowa et al. 2004). Note that these units are substrata of Aquatic Subregions.

Level 7 in the Missouri Framework is Valley Segment type (Figure 20) which is a finer examination of differences in abiotic features in a watershed or subwatershed. Valley Segment types are mapped in a linear fashion as opposed to the creation of polygon boundaries in the other levels. Missouri used stream segments from the 1:100,000 USGS/EPA National Hydrography Dataset. Each Valley Segment Type

Figure 20. An example of Valley Segment Types within an Ecological Drainage Unit (Sowa et al. 2004).

Table 7. Examples of attributes from the Nature Conservancy's Framework to classify aquatic ecological systems and macrohabitats (Higgins et al. 2005).

Variable	*Rationale*	*Typical Classes*
Stream gradient	Linked to flow velocity, substrate material (cobble/ boulder vs sand/ silt), channel morphology and in channel habitat types	Low, medium, high, and very high
Stream and local connectivity/ drainage network position	Measured as type and size of macrohabitat immediately up and down stream. Identifies potential sources of organisms from different habitat types located in headwaters or slower waters downstream.	Upstream and downstream connectivity to various size classes of lakes or streams (e.g. headwater, small, medium, large streams, large rivers, coastlines, glaciers, or unconnected)
Lake Size	Related to lake depth, stability, thermal stratification regime, species composition and diversity	Small, medium, large, very large
Lake Shoreline Complexity	Corresponds to degree of shoreline habitat diversity	Simple (round, elongate), complex, very complex

approach, and considerable expert knowledge is also available to provide additional information on observed and potential areas of high diversity. Alternatively, it might be possible to use index data to understand where areas of high biodiversity are likely to be.

Index data, including the index of biotic integrity (*IBI* [italics used to avoid confusion with the

derived from vegetation and Digital Elevation Model data; however, the absence of high-resolution soils data for approximately one third of the state may preclude acquiring useful non-point source information in those areas. A digital data set of dams exists for Indiana

The LMCP as a pilot study area for an aquatic biodiversity and threats assessment.

An area roughly analogous with the LMCP (approximately the size of average 8-digit Hydrologic Units) would provide a useful pilot study to investigate an aquatic IBI process. The LMCP is located within a single major basin - the equivalent of MoRAP's aquatic subregions and TNC's aquatic zoogeographic unit. An assessment of the LMCP could be the equivalent of a single Natural Region Assessment. The IBI program conducted a pilot assessment using the Kankakee-Grand Prairie Natural Region. The pilot was an extremely important shakeout and highlighted problems and opportunities far better than any amount of theoretical discussion. Some aspects of the modeling process changed significantly; other aspects were approved and refined. During our public presentations on the existing natural region assessments, we have

1) Recommended grid cells resulting from the original IBI modeling efforts.

2) Original IBI recommended grid cells that were updated during this project.

3) GAP landcover

4) National Wetland Inventory map

5) Heritage plant species and high-quality plant community points

6) ADID wetlands maps

7) GAP landcover with updates from this project. Updating affects the original phase 1 and 2 recommended grid cells and buffer areas (when appropriate) surrounding phase 2 cells. Urban and suburban areas have been updated for the whole study area.

8) NWI map with updates from this project. NWI updates occurred in the original phase 1 and 2 recommended grid cells and buffer areas (when appropriate) surrounding phase 2 cells.

9) Heritage plant species and community points updated from this project

10) LCMP area – outline

11) Areas managed for conservation – state and national parks, state forests, state fish and wildlife areas, TNC properties, etc.

20) Porter Co. outline

21) LaPorte Co. outline

22) Lake Co. outline

23) Open space and park development predicted by 2030 – from the Northwest Indiana Regional Planning Commission maps

24) Special use development predicted by 2030 – from the Northwest Indiana Regional Planning Commission maps

25) Residential area development predicted by 2030 – from the Northwest Indiana Regional Planning Commission maps

26) Industrial development predicted by 2030 – from the Northwest Indiana Regional Planning Commission maps

27) Commercial development predicted by 2030 – from the Northwest Indiana Regional Planning Commission maps

28) New interchanges proposed for 2000-2030 – from Open space and park development predicted by 2030 – from the Northwest Indiana Regional Planning Commission maps

29) Intersection improvement proposed for 2000-2030 — from the Northwest Indiana Regional Planning Commission maps

30) New roads proposed for 2000-2030 –from the Northwest Indiana Regional Planning Commission maps

31) New interstates proposed for 2000-2030 – from Open space and park development predicted by 2030 – from the Northwest Indiana Regional Planning Commission maps

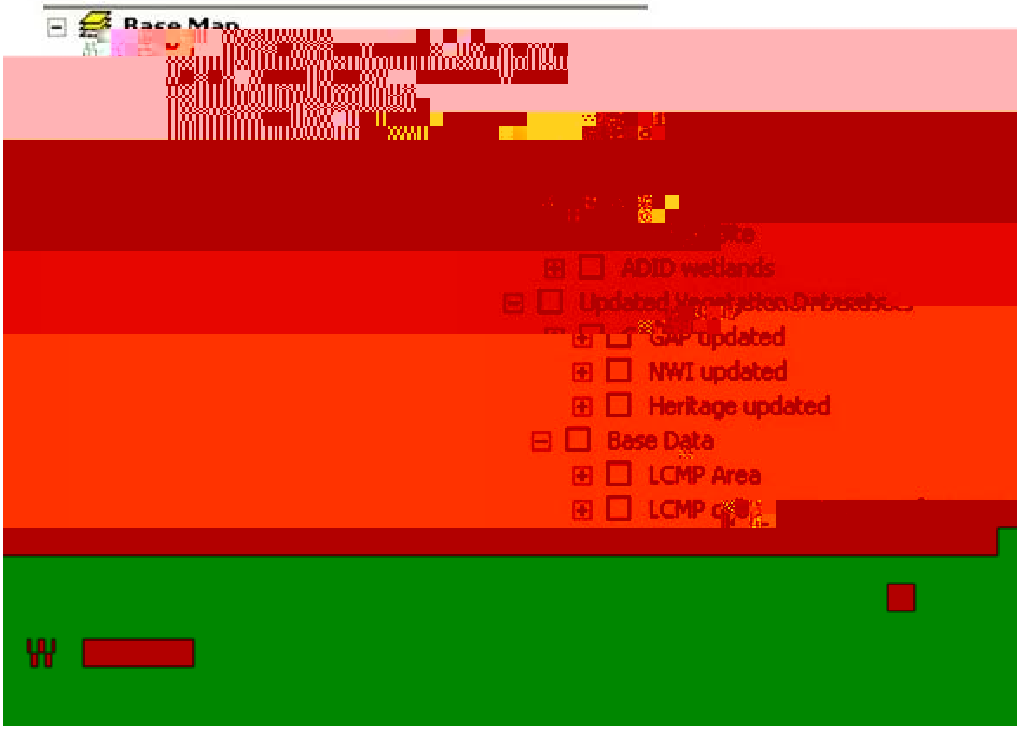
32) Interchange modification proposed for 2000-2030 – from Open space and park development predicted by 2030 – from the Northwest Indiana Regional Planning Commission maps

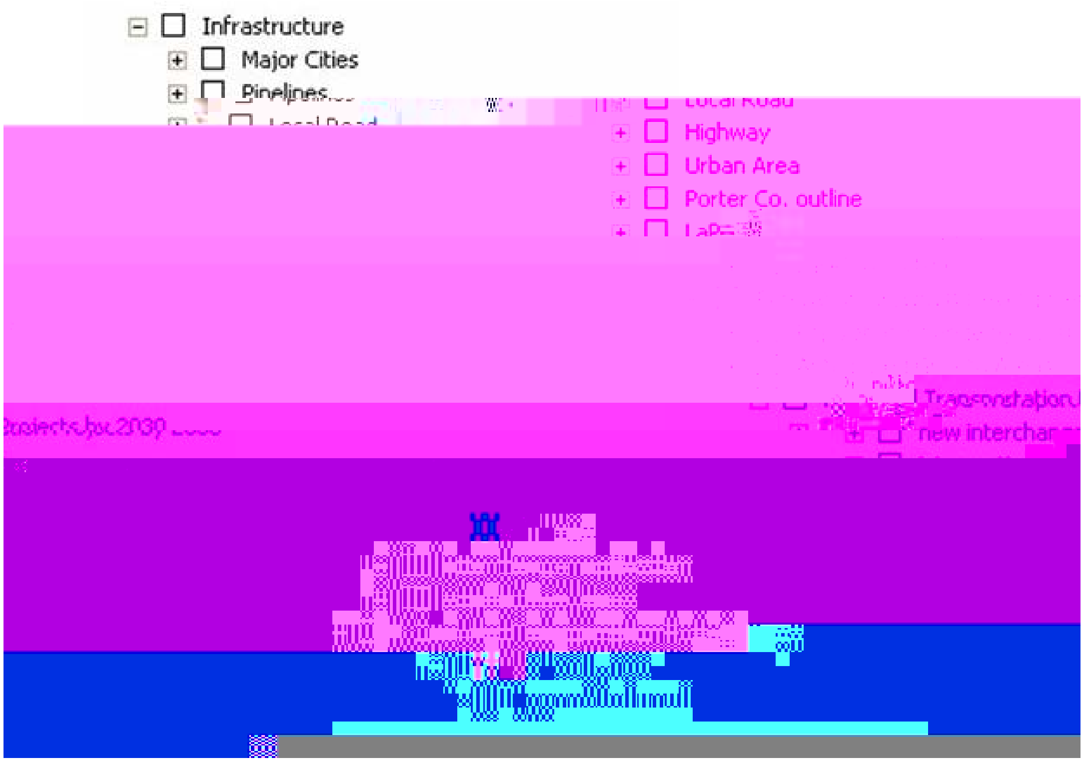
33) Added travel lanes proposed for 2000-2030 – from the Northwest Indiana Regional Planning Commission maps

34) Committed interchange projects for 2000-2030 - from the Northwest Indiana Regional Planning Commission maps

35) Committed road projects for 2000-2030 - from the Northwest Indiana Regional Planning Commission maps

36) Areas where population is predicted to decrea


ADID wetlands
GAP updated
NWI updated
Heritage updated
Base Data
LCMP Area


Infrastructure
Major Cities
Highway
Urban Area
Porter Co. outline

Blue-spotted salamander (state species of special concern)

Habitats: Ponds, marshes and palustrine forests of at last ¼ ha, with ephemeral standing water, adjacent to terrestrial forests of at least 5 ha

Hostile habitats: areas within 1 km of urban and other developed areas of at least 10 ha.

Buffer distance around primary cell to achieve habitat configuration: 100 m.

Karner blue butterfly (Federally endangered)

This model was created by John Shuey of the Indiana chapter of The Nature Conservancy and was incorporated without change into the mapping process.

Great Lakes Science Center
1451 Green Road
Ann Arbor, Michigan 48105
Phone: (734) 994-3331
Fax: (734) 994-8780
http://www.glsc.usgs.gov/main.php?content=research_GAP&title=Aquatic%20GAP0&menu=research_NCE_GAP

The USGS Great Lakes Science Center is currently working with Wisconsin, Ohio, New York, and Michigan to develop a region

In addition to commonly used attributes in valley segment classification such as stream gradient and temperature, Ohio also incorporated characteristics of glacial drift and sinuosity into their framework. The state is working on including species distribution, human disturbance, and water quality data in their model to better identify unique and valuable aquatic habitats.

http://aquagap.cfe.cornell.edu/

Marci S. Meixler
Project leader
Msm10@cornell.edu
607-255-2023

Aquatic GAP analysis pilot project for New York is a collaboration between the New York State Department of Environmental Conservation, USGS, Cornell University, US Fish and Wildlife Service (Region 5), and the Wildlife Management Institute (Meixler and Bain 1998). The report for the pilot project includes detailed methods and a good review on the accuracy of their modeling. The species distribution modeling includes fish, macroinvertebrates, and mussels (Meixler and Bain 1999).

www.gap.uidaho.edu/Bulletins/11/AquaticGAPACTBasin1.htm

Alabama Gap Analysis Project
School of Forestry and Wildlife Science
108 White Smith Hall
Auburn University, AL 36849
Tel: 334-844-9295
Fax: 334-887-4509
silvaal@auburn.edu

The USGS and researchers from Auburn University and the University of Georgia are collaborating to apply aquatic GAP analysis to two watersheds in the Southeastern United States (the Alabama-Coosa-Tallapoosa (ACT) and Apalachicola-Chattahoochee-Flint (ACF) river basins) (Erwin et al. 2002). Currently the project has two papers in press for publication and they have received a grant for another project that includes water quality modeling. The general approach for these aquatic GAP analysis projects is to apply a hierarchical classification system for habitats and then model species distribution throughout the basins. Fish, aquatic reptiles, amphibians and aquatic invertebrates will all be included in the species distribution models. In addition to the GAP analysis project, the Georgia Department of Nature

http://oregonstate.edu/ornhic/aquatic_class.pdf
http://oregonstate.edu/

The Iowa Gap analysis website mainly describes efforts toward terrestrial analysis as opposed to aquatic methodology.

Lower Colorado River Aquatic GAP
http://www.k-state.edu/fisheries/lcr_gap/overview.htm

Kansas Aquatic GAP analysis

Kansas researchers are following the framework established by MoRAP to identify conservation areas in the Lower Colorado River watershed and in other locations throughout the state. Currently the state is focusing on mussel and fish species distributions to develop models within ecological drainage units. Valley segment classifi

Telephone: (814) 863-0002
FAX: (814) 865-3378
Email: wlm@psu.ed

Pennsylvania aquatic GAP efforts appear to be similar to other state projects in the classifying aquatic habitats. The attributes used to describe streams include stream order (size), geomorphology, zoogeographic basin, stream gradient, and land cover. Pennsylvania's approach differs with the development of Regional habitat insecurity index (RHII). This index was created with the purpose of establishing an objective way to measure GAP analysis results. The index determines the insecurity of species by looking at threats to potential habitat and the amount of available habitat. For each taxanomic group a threshold level was determined. Areas that had high indices for a number of taxa are designated as conservations gaps for the state.

See also Myers et al. 2000.

Higgins, J., M.T. Bryer, M. Khoury, T.W. Fitzhugh. 2005. A freshwater classification approach for biodiversity conservation planning. Conservation Biology 19(2): 432-445.

This article written by researchers at the Nature Conservancy provides an excellent summary of hierarchical approach to conserving freshwater biodiversity.

Sowa, S.P., D.D. Diamond, G.M. Annis, T. Gordon, M.E. Morey, G.R. Sorensen, and D. True. 2004. The Aquatic Component of GAP Analysis: A Missouri Prototype Final Report, Missouri Resource Assessment Partnership; University of Missouri Department of Defense Legacy Program. 120 pp..

This report provides an excellent description of the methods, rational, and results of the Missouri Pilot project on aquatic GAP analysis. This approach is worth examining because it has been followed by several states seeking to develop regional aquatic conservation tools using GIS. This report can be found on the Missouri Resource Assessment Partnership website at http://www.cerc.cr.usgs.gov/morap/.

National GAP Analysis webpage
www.gap.uidaho.edu
The website provides a summary of information on both efforts toward GAP analysis for terrestrial and aquatic systems. The website provides links to power point presentations concerning aquatic GAP analysis from a 2003 national meeting in Fort Collins, CO. These presentations provide a good summary of the methodology and attributes used by states. The presentations also include what classes particular attributes are broken into. There is a particularly good presentation on the development of a coastal aquatic classification system for the Great Lakes.

There are also links for electronic copies of the GAP Analysis Bulletin. This bulletin provides a summary of approaches used by states and or regional organizations. Articles concerning aquatic GAP analysis can be found on the national GAP analysis webpage at www.gap.uidaho.edu. These articles generally include what states plan to accomplish through aquatic gap rather than an evaluation of their methodology.

Bibliography [1]

Abell, R. 2002. Conservation biology for the biodiversity crisis: A freshwater follow-up: Conservation Biology 16:1435–1437.

Angelstam, P., G. Mikusinski, et al. 2003. Two di

Bronmark, C. and H. Lars-Anders. 2002. Environmental issues in lakes and ponds: current state and perspectives. Environmental Conservation 29(3):290-306.

Abstract:
Lakes and ponds are habitats of great human importance as they provide water for domestic, industrial and agricultural use as well as providing food. In spite of their fundamental importance to humans, freshwater systems have been severely affected by a multitude of anthropogenic disturbances, which have led to serious negative effects on the structure and function of these ecosystems. The aim of the present study is to review the current state of lake and pond ecosystems and to present a likely scenario for threats against these ecosystems for the time horizon of the year 2025. Predictions are based on a review of the current state, projections of long-term trends, for example in population and global climate, and an analysis of the trends in publications in the scientific literature during the past 25 years (1975-2000). The biodiversity of lake and pond ecosystems is currently threatened by a number of human disturbances, of which the most important include increased nutrient load, contamination, acid rain and invasion of exotic species. Analysis of trends suggests that older, well known threats to biodiversity such as eutrophication, acidification and contamination by heavy metals and organochlorines may become less of a problem in developed countries in the future. New threats such as global warming, ultraviolet radiation, endocrine disruptors and, especially, invasion by exotic species including transgenic organisms will most likely increase in importance. However [illegible]

features allow us to account for, and thus predict, variation in the composition of biota among individual sites. In general, we found that although landscape classifications accounted for more biotic variation than would be expected by chance, the amount of variation related to landscape features was not large. Thus, large-scale regionalizations, if used alone to specify expected biotic conditions, will likely have limited use in aquatic bioassesments, where it is critical to specify expected conditions as accurately and precisely as possible. Landscape classifications can play an important additional role, however, by providing an initial stratification of site locations to ensure that different landscape features are adequately represented in a sampling program. In general, we believe a tiered classification based on both reach-level and larger-scale landscape features is needed to accurately predict the compos

Roux, D., F. d. Moor, J. Cambray, and H. Barber-James. 2002. Use of landscape-level river signatures in conservation planning: a South African case study. Conservation Ecology 6. [online] URL: http://www.consecol.org/vol6/iss2/art6/

A strategy for assigning priorities in biodiversity conservation was developed for the rivers of the proposed Greater Addo Elephant National Park (GAENP) in South Africa. Due to the limited availability of biological information on the freshwater ecosystems of this area, a desktop approach, supplemented by aerial and land surveys, was used to devise a new river classification typology. This typology incorporated landscape attributes as surrogates for biodiversity patterns, resulting in defined physical "signatures" for each river type. Riverine biodiversity is considered to be conserved by including rivers of each type as defined by the respective signatures. Where options existed, and two or more rivers shared the same signature, a simple procedure was used to assign priorities to "similar" rivers for conservation. This procedure considered the extent of transformation, degree of inclusion within the park, irreplaceability or uniqueness, and geomorphological diversity of each river. The outcome of the study was that 18 of the 31 rivers within the GAENP must be conserved to achieve representation of all of the biodiversity patterns identified. It is concluded that, given further development and testing, the river signature concept holds promise for elevating the river focus in general conservation planning exercises.

Saunders, D.L., J.J. Meeuwig, and C.J. Vincent. 2002. Freshwater protected areas: strategies for conservation. Conservation Tciogy in16(1):30-41

Seelbach, P.W., M.J. Wiley, J.C. Kotanchik, and M.E. Baker. 1997. A landscape-based ecological classification for river valley segments in Lower Michigan. Fisheries Division Research Report 2036. Michigan Department of Natural Resources. Fisheries Division, Lansing.

TNC-FWI. (the Nature Conservancy – Freshwater Initiative) 2000. Tools for GIS analysis. The Nature Conservancy, Arlington, VA. www.freshwaters.org

Ward, J.V. and K. Tockner. 2001. Biodiversity: towards a unifying theme for river ecology. Freshwater Biology 46(6):807-819.

Abstract:
A broadened concept of biodiversity, encompassing spatio-temporal heterogeneity, functional processes and species diversity, could provide a unifying theme for river ecology. 2. The theoretical foundations of stream ecology often do not reflect fully the crucial roles of spatial complexity and fluvial dynamics in natural river ecosystems, which has hindered conceptual advances and the effectiveness of efforts at conservation and restoration. 3. Inclusion of surface waters (lotic and lentic), subsurface waters (hyporheic and phreatic), riparian systems (in both constrained and floodplain reaches), and the ecotones between them (e.g. springs) as interacting components contributing to total biodiversity, is crucial for developing a holistic framework of rivers as ecosystems. 4. Measures of species diversity, including alpha, beta and gamma diversity, are a result of disturbance history, resource partitioning, habitat fragmentation and successional phenomena across the riverine landscape. A hierarchical approach to diversity in natural and altered river-floodplain ecosystems will enhance understanding of ecological phenomena operating at different scales along multidimensional environmental gradients. 5. Re-establishing functional diversity (e.g. hydrologic and successional processes) across the active corridor could serve as the focus of river conservation initiatives. Once functional processes have been reconstituted, habitat heterogeneity will increase, followed by corresponding increases in species diversity of aquatic and riparian biota.

Weitzell, R.E. J., M.L. Khoury, P. Gagnon, B. Schreurs, D. Grossman, and J. Higgins. 2003. Conservation priorities for freshwater biodiversity in the Upper Mississippi River basin. Natureserve and the The Nature Conservancy.
http://www.natureserve.org/publications/upperMSriverbasin.jsp

Erwin, E.R., J. Peterson, B.J. Freeman, L. Kramer, and L.C. Freeman. 2002. Aquatic GAP: regional analysis of biodiversity in the ACT/ ACF Basins. GAP Analysis Bulletin 11:64-69.

Higgins, J., M.T. Bryer, M.L. Khoury, and T.W. Fitzhugh. 2005. A freshwater classification approach for biodiversity conservation planning. Conservation Biology 19(2):432-445.

Homoya, M.A., D.B. Abrell, J.R. Aldrich, and T.W. Post. 1985. The natural regions of Indiana. Proceedings of the Indiana Academy of Science 94:245-268.

Kula, S. and S.A. Covert. 2003. Results and applications of classifying stream habitats in Ohio using valley segment types. USGS National Gap Analysis Meeting, Fort Collins, CO.

Lambeck, R.J. 1997. Focal species: a multi-species umbrella for nature conservation. Conservation Biology 11: 849-865.

Loan-Wilsey, A., R.L. McNeely, P.D. Brown, K.L. Lane, C.L. Pierce. 2003. A comprehensive biological inventory database for the Iowa Aquatic GAP Project. GAP Analysis Bulletin 12:4-6.

McKenna, J.E., Jr., S. Morrison, D. McDonald, C. Castiglione, and K. Kowalski. 2003. Great Lakes coastal aquatic GAP analysis: habitat classification and application. National GAP Meeting, Fort Collins, CO.

Meixler, M.S. and M.B. Bain. 1998. Final Report Summary: New York Aquatic GAP Pilot

Sowa, S.P., D.D. Diamond, G.M.