Amended Draft Final Report

Biodiversity Conservation Possibilities and Threat Assessment for the Indiana Lake Michigan Coastal Management Program:

an update and analysis of part of the
Northwest Morainal Natural Region assessment
of the Indiana Biodiversity Initiative

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Introduction

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).

Table 1. Study area by county.

County		Area in hectares	Area in acres	% of total
Lake		69,439	171,583	44
Porter		52,396	129,470	33
LaPorte		35,870	88,635	23
	Total	157,704.5	389,688	100.0

The Northwest Morainal Natural Region. The Lake Michigan watershed is a portion of the Northwest Morainal Natural Region, the smallest of Indiana's natural regions, but one of the most diverse (Fig. 1). Its northern position brings in elements of the boreal forest, including bogs; its eastern position gives it prairies, ranging from sand to mesic prairies; its position at the shore of Lake Michigan brings dune and swale topography and the march of successional habitats from ephemeral dune plants to mesic forest. The Valparaiso Moraine that marks the southern portion of natural region was once marked by extensive oak savanna, now often changed to forest by fire suppression.

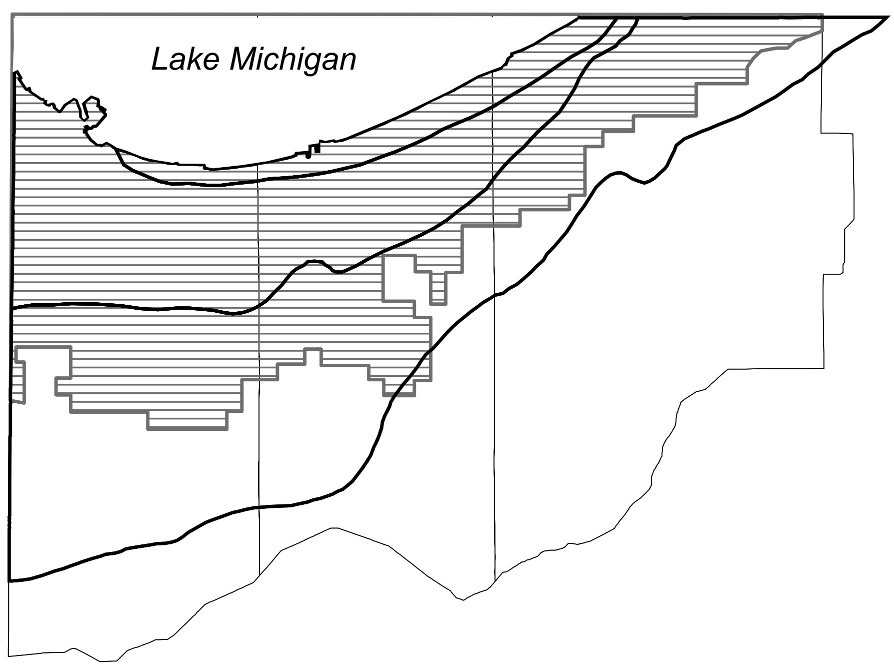


Figure 1. The Indiana Lake Michigan Coastal Program terrestrial area (grey outline and horizontal hatching) with Lake, LaPorte, and Porter counties (thin black lines). The Northwest Morainal Natural Region and its 3 subregions are shown in heavy black lines

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 of rare species, availability of high-quality habitats, or large blocks of more common habitats.

After the areas with high plant conservation potential have been identified, we use those and the map of existing areas protected for conservation as a starting point for identifying lands that protect animal species, in Phase II. Because we lack the time and information to identify lands that meet needs of all animal species in a given natural region, we identify umbrella species (Lambeck 1997) whose habitat needs encompass the habitat needs of many other species. For each natural region, 6-9 species are selected and their habitat needs are modeled (Appendix 2). Then, using a supplement to the ArcView GIS program, we identify areas that meet the habitat needs of the umbrella species while avoiding habitats that would be hostile to them (often, urban habitats, for example). The animal modeling program gives preference to areas that are already protected, or that were identified for plant conservation, when these are appropriate, so as to continue to minimize the extent of the land areas identified and to cluster habitat blocks.

The final product for any given natural region is a map identifying those square kilometer blocks that have best met the plant and animal conservation criteria of the two phases of the select process. We also suggest possible corridors, often river corridors, but also ridgelines and even powerlines, which may serve to connect blocks of habitat. We provide users with the map as well as with a wide range of auxiliary maps, the color orthophotos, and the appropriate USGS 1:100,000 maps. A “conservation features” layer permits users to click on any particular cell and learn what animal species models select that cell, how much area is available in several habitat types within the cell, and how many rare plants or high-quality plant communities have been identified in the square.

We stress that our product maps are only advisory and must be updated by local users familiar with their own planning needs (as is being done in this contract). Our maps were created with databases that are constantly being made obsolete by new development and by other changes in land use. In addition, they were developed using only our criteria for biodiversity conservation; different, or more tightly focused, criteria would target other areas.

The current project

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.

The original assessment

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.

	Area in hectares	Area in acres	% of total area
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
Total Phase I and Phase II cells	58,358.0	144,202.6	37.0

other aquatic and semi-aquatic vertebrates. Scarlet tanagers (*Piranga olivacea*) and red-shouldered hawks (*Buteo lineatus*; state species of special concern) are forest birds; red-shouldered hawk habitat typically includes some bottomland forest near water. Golden-winged warblers *Vermivora chrysoptera*; state endangered) represent species using shrubby habitats. The Karner blue butterfly (*Lycaeides melissa samuelis*; Federal endangered) uses networks of small areas of open habitats. For this species, we borrowed a model created by The Nature Conservancy and used it without alteration as it relied on expert information not otherwise readily available. Eastern massasaguas (*Sistrurus catenus*; Federal candidate species) use a mosaic of upland and wetland habitats that offer protective cover. The area needs of red-shouldered hawks and scarlet tanagers ensured that blocks of forests would be selected, and the badger served a similar purpose for grasslands.

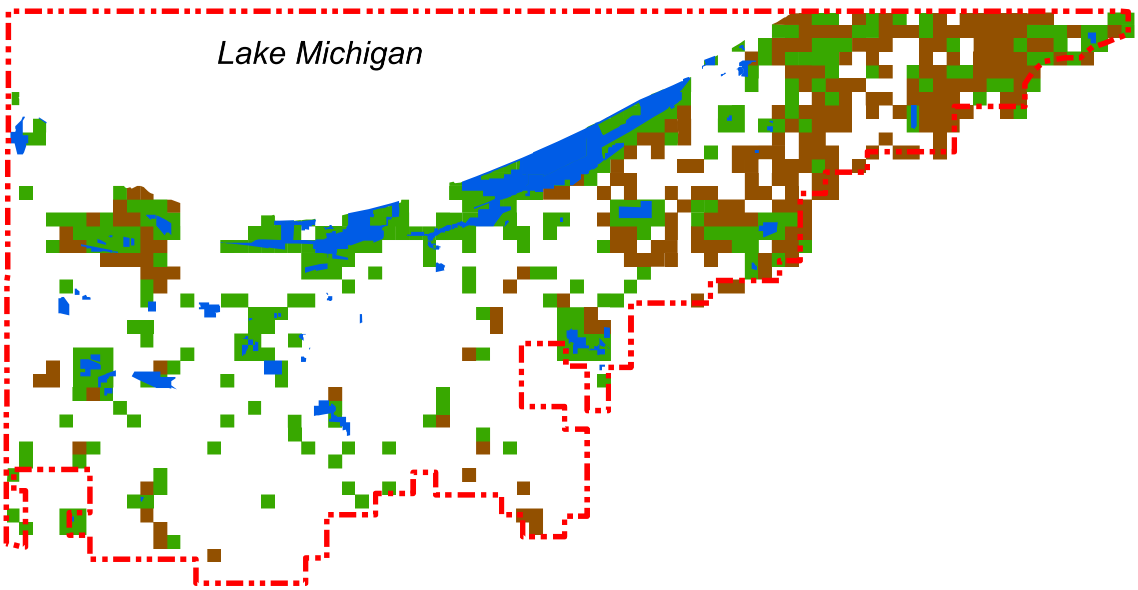


Figure 2. Areas selected during the original Northwest Morainal natural region assessment that fell within the LMCP boundary. Existing managed areas (parks, preserves, etc.) are shown in blue; additional areas added during Phase I are green, and additional areas added during Phase II are shown in brown (some cells were selected during both phases).

Updating the Conservation Maps within the LMCP boundary

Assessment from color orthophotos. We updated the classification of habitats in the Phase I and Phase II output cells using 1-m-resolution color orthophotos flown in 2003 and the Advanced Identification (ADID) wetland survey conducted in 1996-2002. The GAP maps, Heritage records, and NWI classifications used for the original work were compared to these more recent layers, and changes were made as appropriate. For Phase II squares, in which the choice of cell was sometimes affected not only by habitat in the square, but also by habitat in a buffer area surrounding the square, we also updated information in the buffer (buffer distances ranged from 100-500 m for species for which buffers were used – see Appendix 2).

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 (C is a hydroperiod classifier) had become a deciduous-forested wetland, we typically classified the new wetland as PF01, not PF01C.

Areas updated. A total of 194 of 607 cells (32%) were updated or corrected as a result of aerial photo inspection of ground truthing. Changes were as simple as changing a polygon labeled “row crop” to one labeled “pasture/grassland” or as involved as redigitizing boundaries and relabeling several polygons in the cell. In some instances it was easy to differentiate a correction from an update (an old, heavily wooded suburban area originally identified as forest needed correction; a new, sparsely vegetated suburban area originally identified as forest needed updating). Other changes, however, were less clear, particularly those involving row crops and pasture in areas that switch from one to the other; identifications involving short-hydroperiod wetlands and pastures were similarly difficult as well, owing to the very dry summer preceding the ground check. We only indicated a correction when we were quite certain the modification was the result of an error in the original classification; thus the type of modification (update or correction) is biased toward “update.”

Redigitizing. Corrections and updates made during inspection of color orthophotos or during ground verification were incorporated into updated GAP, NWI or Heritage databases as appropriate. GAP and NWI layers were then rebuilt to reestablish topology, and polygon sizes were checked to ensure that no slivers (small unclassified polygons) were introduced during the redigitization. GAP changes were made in 159 cells (141 updates, 8 corrections, and 10 cells with both), NWI changes in 43 cells (41 updates, 2 cells with updates and corrections), and the 2 changes were made in the Heritage database (one species occurrence and one high-quality habitat occurrence eliminated, in separate cells). Figure 3 shows the location of cells where changes were made as a result of ground- or air-photo-based inspection. The accompanying GIS allows users to investigate specific changes in individual cells.

Update for urban/suburban land cover. We limited intensive scrutiny of the original habitat layers to the cells and buffers that were composed the recommended conservation areas from the original IBI process. However, during this process we realized that the extent of urban and suburban expansion was likely to affect any new IBI-style assessment of the region. Because of the impact of urban/industrial and suburban development on habitat, we attempted to update these cover types over the entire LMCP area of interest, from the 2003 color orthophotos (Figure 4). Some older neighborhoods with heavy tree cover may have been missed, as these can be difficult to detect from aerial photos, however we are confident that we detected the large

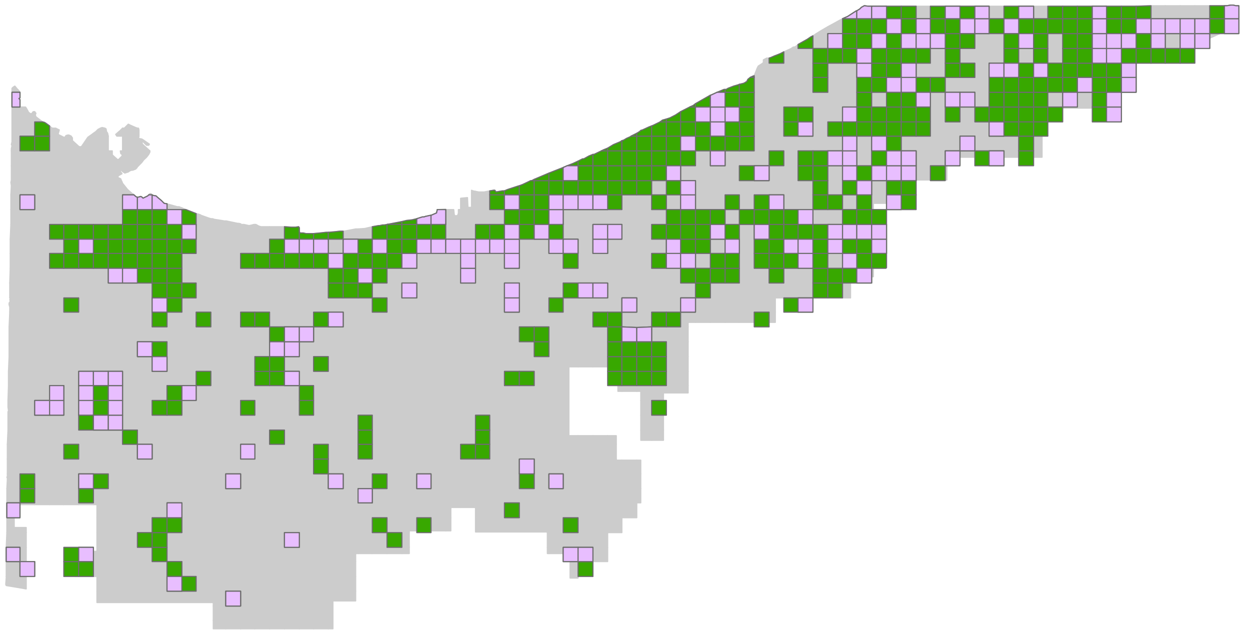


Figure 3. Recommended cells updated during the current project. Green areas indicate potential high-conservation cells identified in the original IBI process that did not have changes requiring updating. The violet cells are those containing one or more polygons that were modified (corrected and/or updated) during the present project.

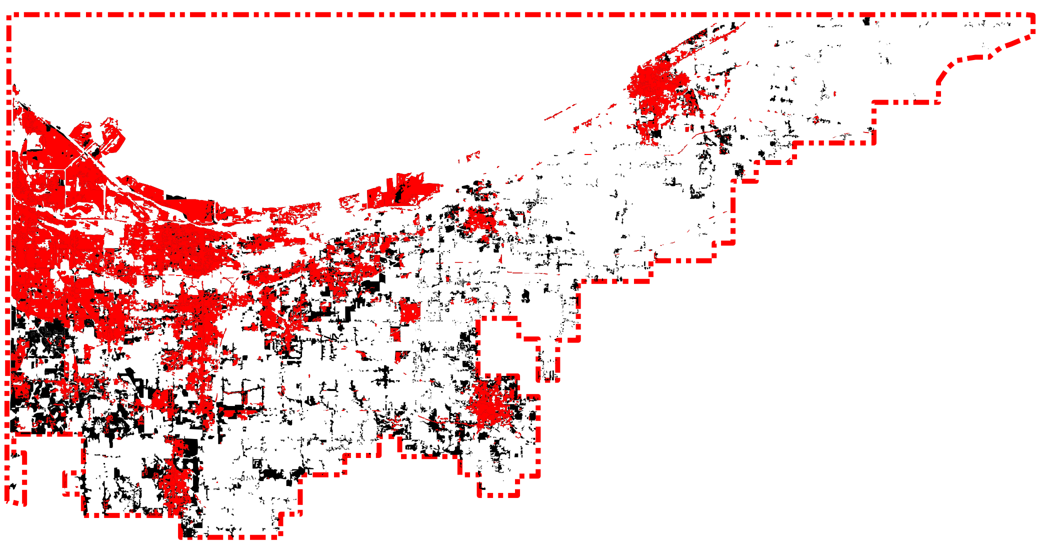


Figure 4. LMCP boundary showing the original extent of developed and urban areas in red and additional areas detected on 2003 color orthophotographs in black.

majority. The added urban areas are predominantly in the southern part of the LMCP area, and predominantly in Lake and Porter Counties. However, the "salt and pepper" effect of newly developed areas in LaPorte Co. indicates that habitat loss is becoming an issue there, as well.

Change assessment in the areas recommended for conservation in the original IBI product. After the base habitat layers were updated, we conducted a change assessment in order to understand which habitats within the recommended cells had been most affected by land cover changes in the intervening years.

Low-density urban areas (suburbia) comprised the fourth largest land cover class in the 1992 classification; it advanced to third following the updates and corrections. High-density urban area went from fifth to fourth. Row crops and forests remained, respectively, first and second, but pasture/grassland fell from third to fifth.

Pasture/grassland and row crops had the greatest net losses (Table 3), some owing to misclassifications one for the other, but most owing to development. Terrestrial deciduous forest had similarly large losses. These three classes were the largest in the original 1992 classification, so the percent losses were concomitantly reduced, but still exceeded 10% in all cases and 25% for pasture/grassland. The “loss” of the "developed nonvegetated" class reflects primarily the urban reclassification – areas identified as developed nonvegetated in the original GAP classification (possibly because they did not have spectral signatures that fit well into high- or low-density urban classifications) were reclassified to high- or low-density urban during the overall urban-area check conducted during this project.

Table 3. Comparison of area in major land-cover classes in the original Indiana GAP map (1992) and following the ground and airphoto work on this project. Land-cover classes are ranked by magnitude of absolute change in area.

Land Cover	2003 acres (GAP update)	% of total area (update)	1992 acres (GAP)	Change (acres)	Change (ha)	Change (%)
Pasture/Grassland	33158	8.6	46278	-13120	-5310	-28.4
Row Crop	99174	25.8	111685	-12511	-5063	-11.2
Terrestrial Forest Deciduous	75614	19.7	86937	-11323	-4582	-13.0
Developed Non-Vegetated	9102	2.4	12682	-3580	-1149	-28.2
Unclassified Cloud/Shadow	93	0.0	809	-716	-290	-88.5
Water	6445	1.7	7146	-701	-284	-9.8
Palustrine Herbaceous Deciduous	9725	2.5	10411	-686	-278	-6.6
Palustrine Forest Deciduous	25421	6.6	25745	-324	-131	-1.3
Terrestrial Shrubland Deciduous	4011	1.0	4178	-167	-68	-4.0
Terrestrial Forest Mixed	1035	0.3	1093	-59	-24	-5.4
Terrestrial Forest Evergreen	897	0.2	949	-52	-21	-5.5
Palustrine Shrubland Deciduous	983	0.3	1013	-30	-12	-2.9
Palustrine Woodland Deciduous	124	0.0	152	-28	-11	-18.1
Terrestrial Woodland Deciduous	2744	0.7	2747	-3	-1	-0.1
Palustrine Sparsely Vegetated	457	0.1	406	51	21	12.5
Developed Urban High Density	41092	10.7	32245	8847	3580	27.4
Developed Urban Low Density	74610	19.4	39954	34656	14025	86.7

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 wetland polygons (Table 3). Whereas the NWI changes are quite modest, with the largest change being a 30-acre gain in small ponds, the GAP wetland changes show approximately 1000 acres of wetland loss. The GAP loss of water habitat is primarily due to conversion of large bodies of water - hundreds of acres - at Burns and Indiana Harbors to developed industrial land cover.

Table 4. Changes in National Wetland Inventory areas by wetland class.

Wetland Class	**Total Area**		**Area Lost**		**Area gained**		**Net difference**		
	ha	acres	ha	acres	ha	acres	ha	acres	% of class
Palustrine emergent	4289.2	1735.8	-7.8	-3.1	6.2	2.5	-1.5	-0.6	0.0
Palustrine forested	7756.1	3138.8	-29.8	-12.0	11.0	4.5	-18.7	-7.6	-0.2
Palustrine scrub/shrub	1154.6	467.2	0.0	0.0	3.8	1.5	3.8	1.5	0.3
Ponds	405.9	164.3	0.0	0.0	74.7	30.2	74.7	30.2	18.4
Other wetlands	881.2	356.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Overall	14486.9	5862.7	-37.5	-15.2	95.7	38.7	58.2	23.6	0.4

Threat Assessment

Development. Development is the principal threat to habitat in the LMCP area of concern. We discovered during ground verification that even where a land-cover change may initially seem benign to wildlife – as when an agricultural field is allowed to revert to grasses and shrubs – such changes often result from purchase of the land for development that may not occur immediately. So although the apparent change increases useful habitat, the longer-term change is increased habitat loss.

To understand the likely pattern of development in the region, we consulted the Northwestern Indiana Regional Planning Commission report “2030 Connections.” Among the forecasts included in the report are maps of population change from 2000 to 2030, the 2030 anticipated growth areas, and the committed and 2030 proposed road network expansions.

Not surprisingly, areas of population change are most extensive on the western side of the LMCP area (Fig 5). The area affected by large decreases is greater than that affected by large increases, but note that the scale of decreases is much smaller than the scale of increases. The larger “decrease” category is for a decrease of ≥251 people/square mile, whereas the largest “increase” category is for an increase of ≥740 people/square mile.

The three counties within the Coastal Management Program boundary currently have very different population densities and change trajectories. Heavily urbanized Lake Co. had 975 persons/square mile according to the 2000 census. Over the periods 1990-2000 and 2000-2003, population change in Lake Co. lagged considerably behind state averages (1.9% *vs.* 9.7%, and 0.6% *vs.* 1.9%). However, because of the high initial population densities, these lower proportional increases still reflect considerable influx of people. Unlike Lake Co., Porter Co.,

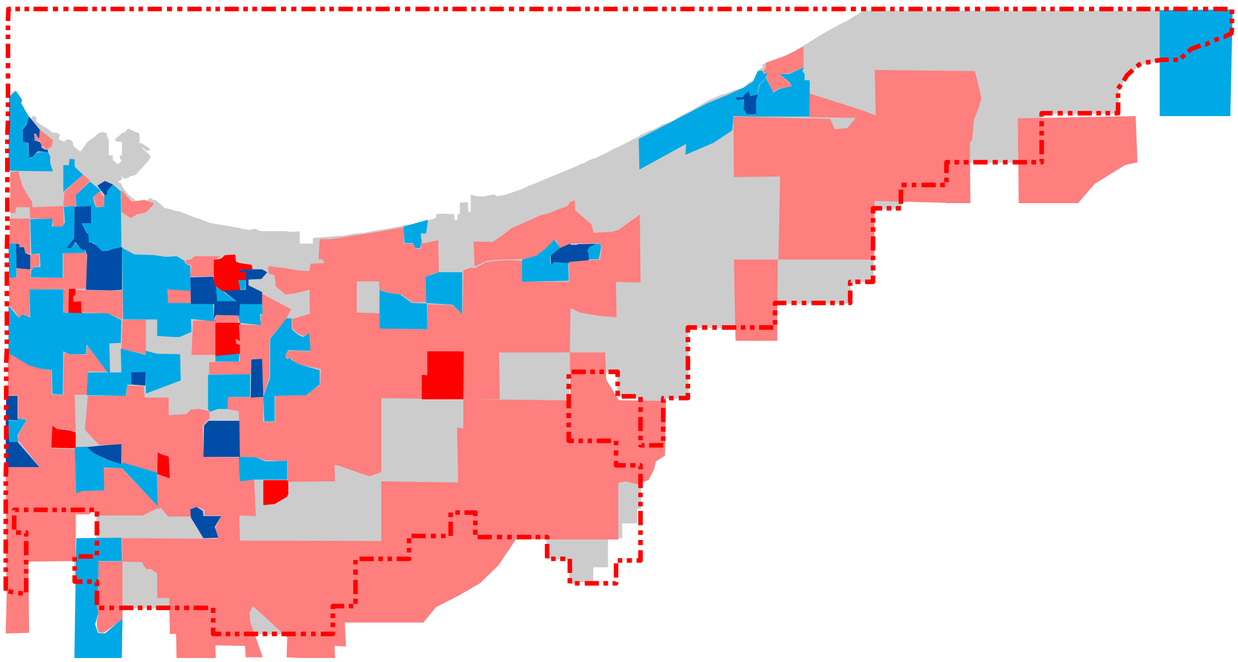


Figure 5. Areas where population is predicted to increase and decrease between 2000 and 2030, from the Northwestern Indiana Regional Planning Commission report “2030 Connections.” Pale red areas are predicted to increase by 26-740 persons/square mile. Dark red areas are predicted to increase by >740 persons/square mile. Light blue areas are predicted to decrease by 1-250 persons/square mile. Dark blue are predicted to decrease by >250 persons per square miles.

with 351.1 persons/square mile in 2000, grew faster than the state average over 1990-2000 and 2000-2003 (13.9 % *vs.* 9.7%, and 3.9% *vs.* 1.9%). Presumably this represents expansion of the Chicago-Gary influence zone. LaPorte County, with 184.1 persons/square mile in 2003, increased slowest of the 3 counties in 1990-2000 (2.8% *vs.* 9.7% in Indiana overall) and lost population during 2000-2003 (-0.2 persons/square mile). However, during ground truthing work in LaPorte Co., we saw several new developments in the planning or early stages (e.g., land no longer farmed, but not yet broken, or only initial earth moving begun). These tended to be single family homes, rather than apartment or condominium units, but in this sparsely populated, agricultural area, they represented a significant change in land use. Clearly, some of the predicted population increases are already beginning.

As we would expect, the highest concentration of potential high-conservation-value areas in the original IBI models was in the least urbanized area, in LaPorte County. Nevertheless, the two more urbanized counties contain over half the recommended areas, and virtually all recommended areas in the southern parts of Lake and Porter Counties are in development zones.

Predicted areas of residential growth (as indicated by municipal planning agencies) were rather evenly spread throughout the area (Figure 6). Most residential growth is predicted in areas that were not selected by the IBI modeling process. One concentrated area in LaPorte Co., at the southern edge of the LMCP boundary is an exception.

Areas with specific commercial, park, industrial, special use (as indicated by municipal planning agencies), like areas with predicted population increase, were more numerous in Lake and Porter counties than in LaPorte County (Figures 6, 7). The area involved is small relative to the IBI-selected cells, but there is a concentration in the Karner blue butterfly western conservation area (see Figure 17).

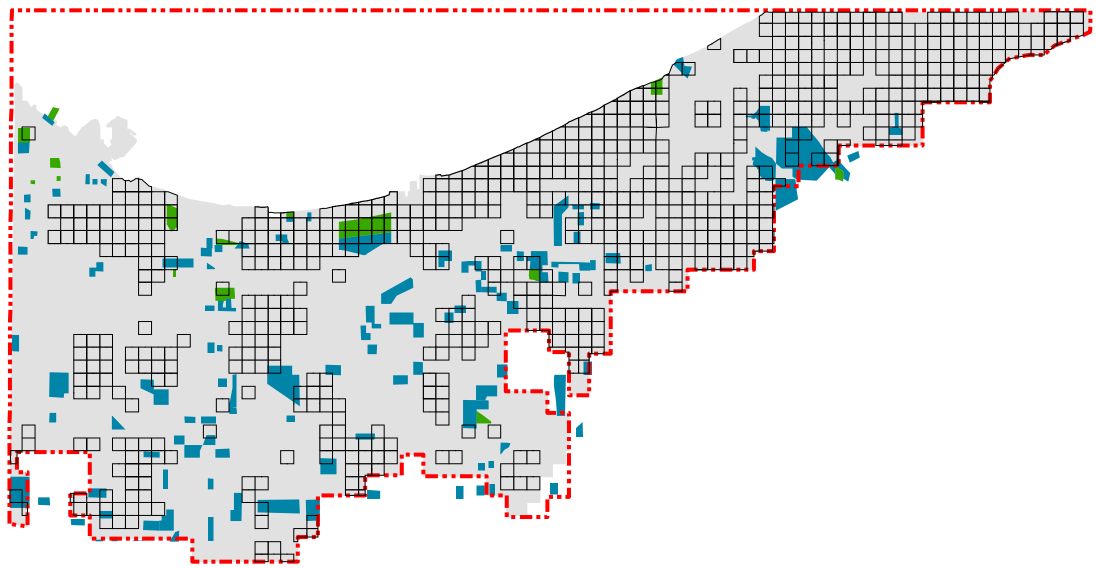


Figure 6. Predicted areas of residential development (blue) and open space (green), 2000-2030, from the Northwestern Indiana Regional Planning Commission report "2030 Connections." Black outlines show LMCP-specific rerun Phase 1 and Phase 2 solutions.

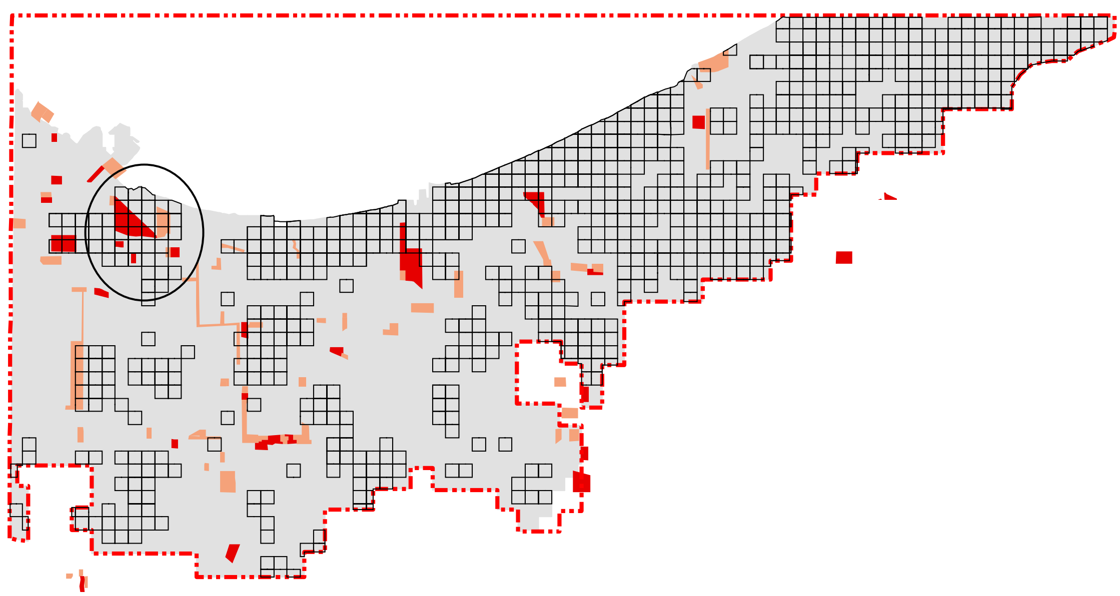


Figure 7. Predicted areas of commercial (orange) and industrial (red) development during 2000-2030 (black), from the Northwestern Indiana Regional Planning Commission report "2030 Connections." Black outlines show LMCP-specific rerun Phase 1 and Phase 2 solutions. The circle indicates a concentration of predicted development in the western Karner blue butterfly conservation area.

The map of the 2030 proposed road network expansion did not entirely match the 2030 anticipated growth areas map, although there is a better match with the population change match (Figure 8). The proposed projects particularly intersect potential conservation area in the northwest of the LMCP area and along the west edge of LaPorte Co., where the urban update showed already existing development.

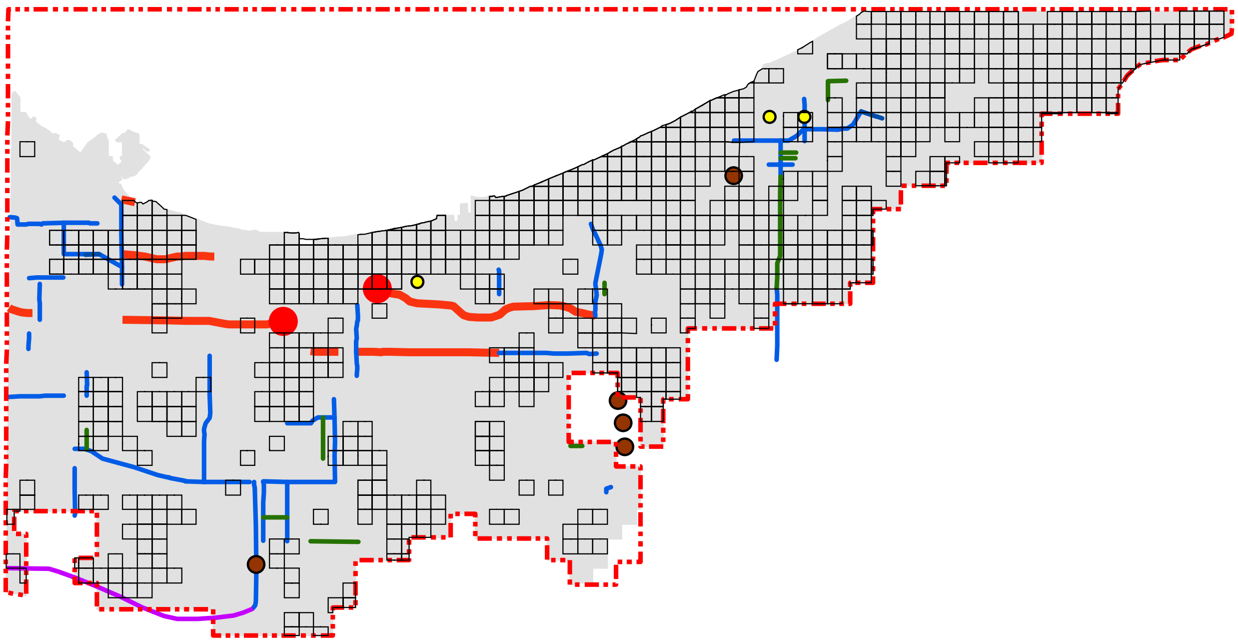


Figure 8. Committed and proposed transportation projects for 2000-2030 from the Northwestern Indiana Regional Planning Commission report “2030 Connections.” Black outlines show LMCP-specific rerun Phase 1 and Phase 2 solutions. Heavy red dots and lines show committed interchanges and roads. Purple lines show proposed new interstates, blue lines show proposed lane additions, green lines show proposed new roads, brown dots show proposed new interchanges and yellow dots show proposed interchange improvements.

Other threats to biodiversity we have not addressed that affect quality of recommended areas. In the Northwest Morainal region, longterm land management practices often alter the value habitat to plant and animal species. Plowing, mowing, fire suppression and hydrologic change are the primary anthropogenic practices affecting land cover in nonurban-suburban areas. Black oak savanna has largely become forest. Due to the high density of homes in these forests, a return to the historical fire regime is unlikely, but there are other management approaches that can restore savanna. Fire would once have helped keep prairies free of woody plants, as well, however most areas that were once prairie are now in agricultural land cover. Many wetter prairies and other wetlands have been ditched and drained to make them suitable for farming. Complete restoration is time consuming and may be impossible to achieve.

The IBI products identify areas on the basis of existing natural habitats which are often only generally defined. For example, areas identified as grasslands include abandoned fields, pastures, hayfields, and golf courses. Biodiversity in such areas may be improved, or protection may be increased by changing land management so that higher quality habitat results. In 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 chance events cause local extirpations, after which recolonization is unlikely. The conservation community is increasingly stressing creative solutions to connectivity. Along these lines, the Nature Conservancy Karner blue butterfly conservation model includes powerline corridors because these have tended to go undeveloped, leaving small linear patches of useful habitat.

LaPorte County obviously offers more, and probably less expensive, opportunities for large-scale conservation, including the establishment of networks of protected areas. This relatively positive circumstance is eroding under increasing development, although it seems likely that considerable time will elapse before LaPorte Co. is developed to the extent of Lake Co., for example.

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.

Rerunning the IBI Protocol on the LMCP Area

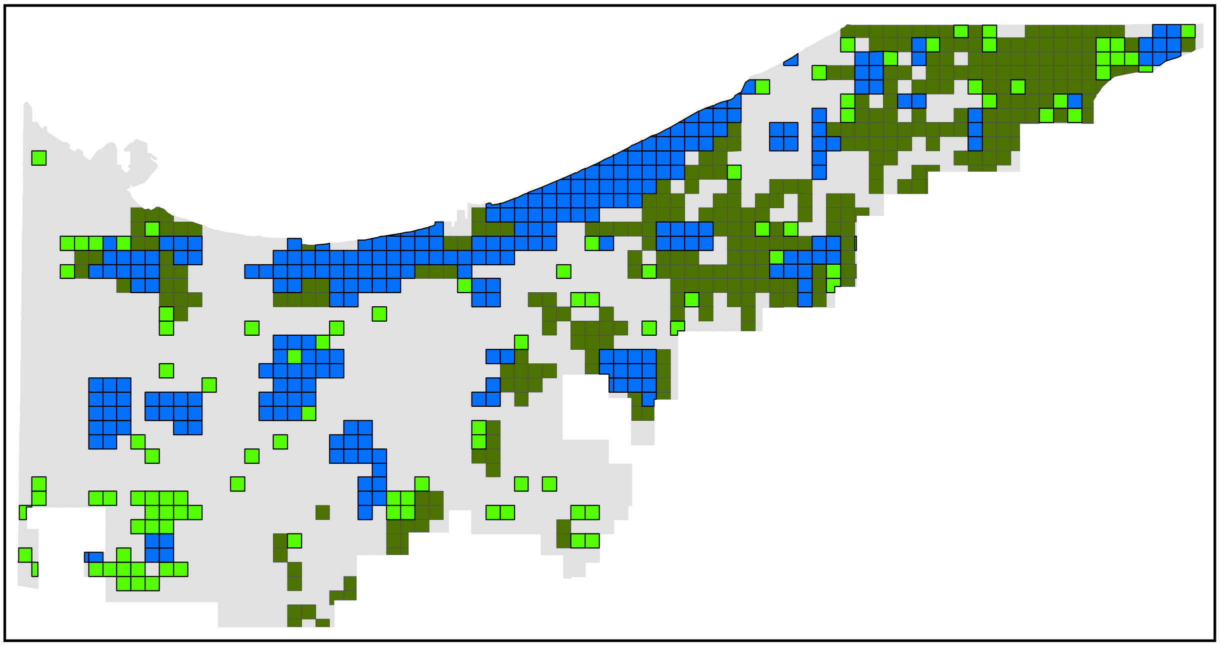
We used the updated databases to rerun both the Phase 1 (major and high-quality plant communities and rare plants) and Phase 2 (umbrella animal species) analyses within the LMCP area of responsibility.

Phase 1

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



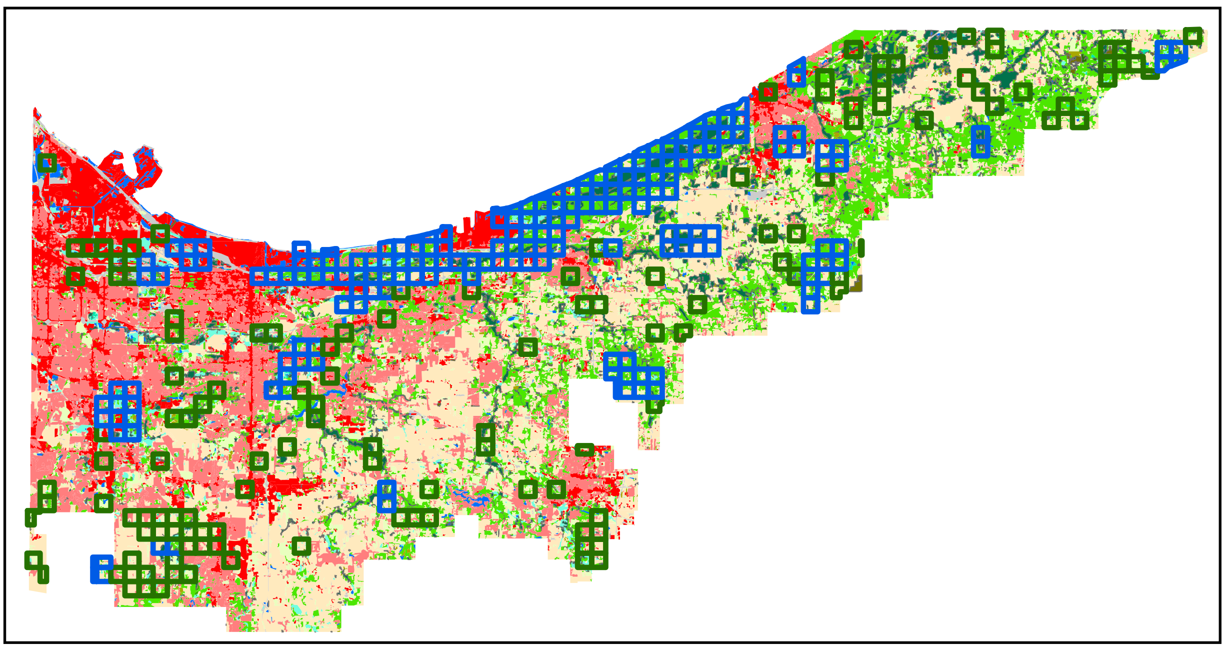


Figure 9. Upper pane: original phase 1 solution clipped from Northwest Moraine Natural Region. Lower pane: rerun Phase 1 solution showing managed areas (blue outline) and additional selected areas (green outline) over the updated GAP map. The GAP map shows urban areas in red, forested areas in green, wetlands and water in blues, and agricultural areas in light brown.

Phase 2

The rerun Phase 2 solution was 30% larger than the clipped Phase 2 solution from the Northwest Moraine Natural Region (Table 6). The same 8 species were used for both analyses, but the modeling process differed for some species between the two analyses. In particular, the wetland definitions used to find suitable habitat for blue-spotted salamander and Blanding's turtle were expanded to better interpret the intent of the model, resulting in increases in modeled habitat (Figures 10, 11).

Table 6. Comparison of Phase 2 solutions of the LMCP rerun and of the original Northwest Moraine Natural Region within the LMCP boundary.

	LMCP rerun		NWM within LMCP			
	acres	grid cells	acres	grid cells	change in area	% change in area
American badger	4,198	17	7,134	29	-2,936	-41%
Blanding's turtle	23,396	96	13,494	55	9,902	73%
Blue-spotted salamander	78,967	323	34,050	139	44,917	132%
Eastern massasauga	51,199	209	26,805	109	24,394	91%
Golden-winged warbler	1,647	7	1,972	8	-325	-16%
Karner blue butterfly	33,467	145	11,248	46	22,219	198%
Red-shouldered hawk	16,574	69	32,827	141	-16,253	-50%
Scarlet tanager	13,694	59	29,247	90	-15,553	-53%
TOTAL	**52,384**	**538**	**40,567**	**416**	**11,817**	**129%**

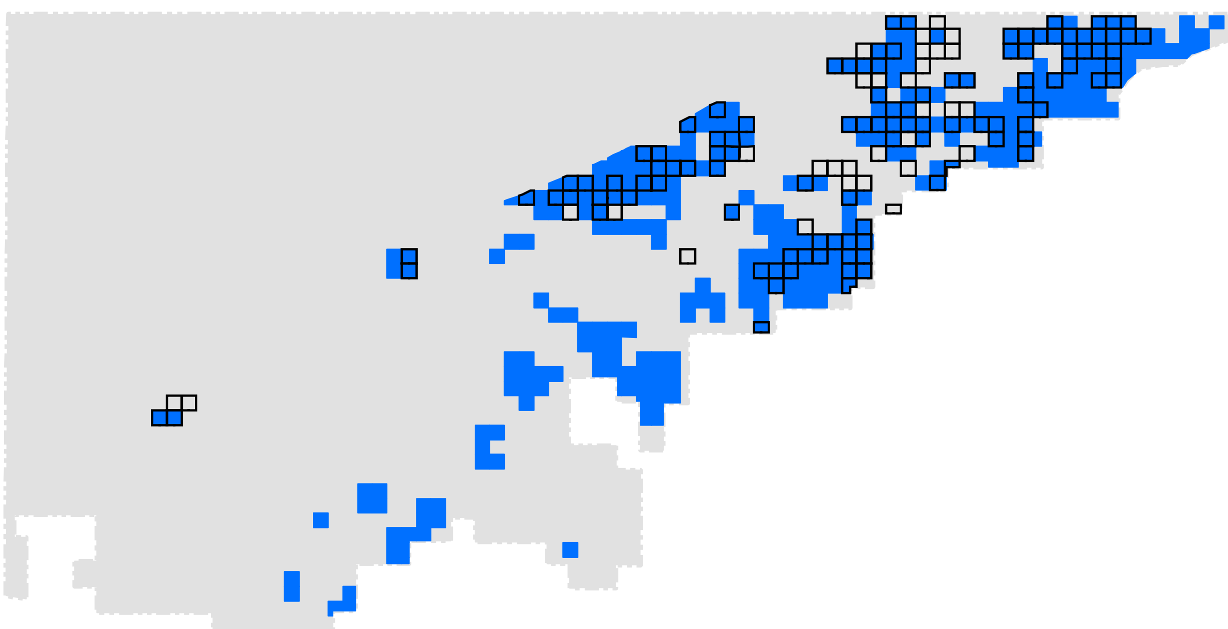


Figure 10. LMCP blue-spotted salamander solution (blue) with original natural region solution (outline).

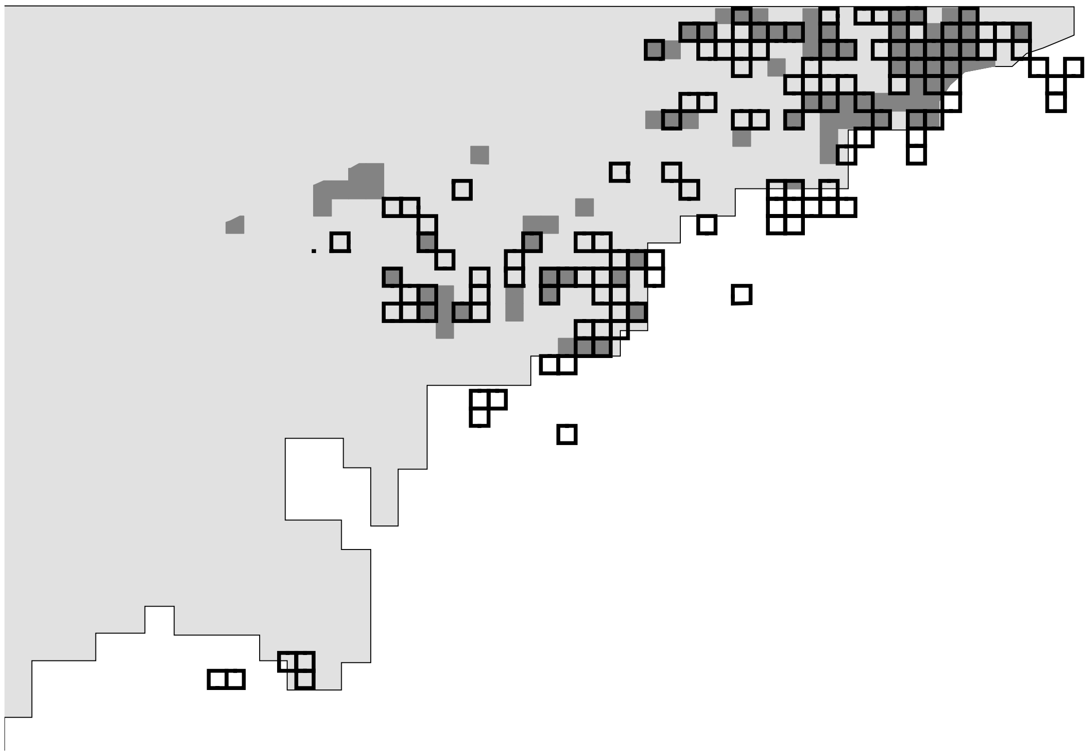


Figure 11. LMCP Blanding's turtle solution (grey) with original natural region solution (outline).

Decreases in badger, warbler, hawk, and tanager area (Figures 12-15) were likely a result of updates to urban areas in the GAP map. The changes in the area modeled as habitat for massasauga (Figure 16) are harder to understand. In theory, the same model was run in both instances, and there did not seem to be enough reclassification of habitat to account for the expanded area. The near doubling of area is unexplained. Possibly an error in parameter entry was not caught in the original model runs. After examining the aerial photos for selected areas, we are satisfied with the output of the present modeling runs for massasauga. The Karner blue butterfly map was expanded to include both eastern and western management units (Figure 17).

Interpreting model outputs

Phase 1 models are designed to preserve a part of all plant species and ecosystems recorded in the GAP, NWI, and Heritage databases. Even where only points (Heritage data) or small habitat patches (NWI) are involved, an entire grid cell will be designated for conservation in Phase 1. Cells in the worst conservation settings are eliminated during hand checking of Phase 1 output. However, given the intent to preserve all species and ecosystems, we try to err on the side of inclusiveness and countermand the model only in the cases where it seems very unlikely that restoration or habitat protection can be brought to bear. The overlay shapefile provides information on the which GAP habitats and general NWI categories fall within a grid cell, as well as the number of Heritage points in the cell and the umbrella species models that identified the cell. However, the C-Plan model used in Phase 1 does not indicate what characteristics

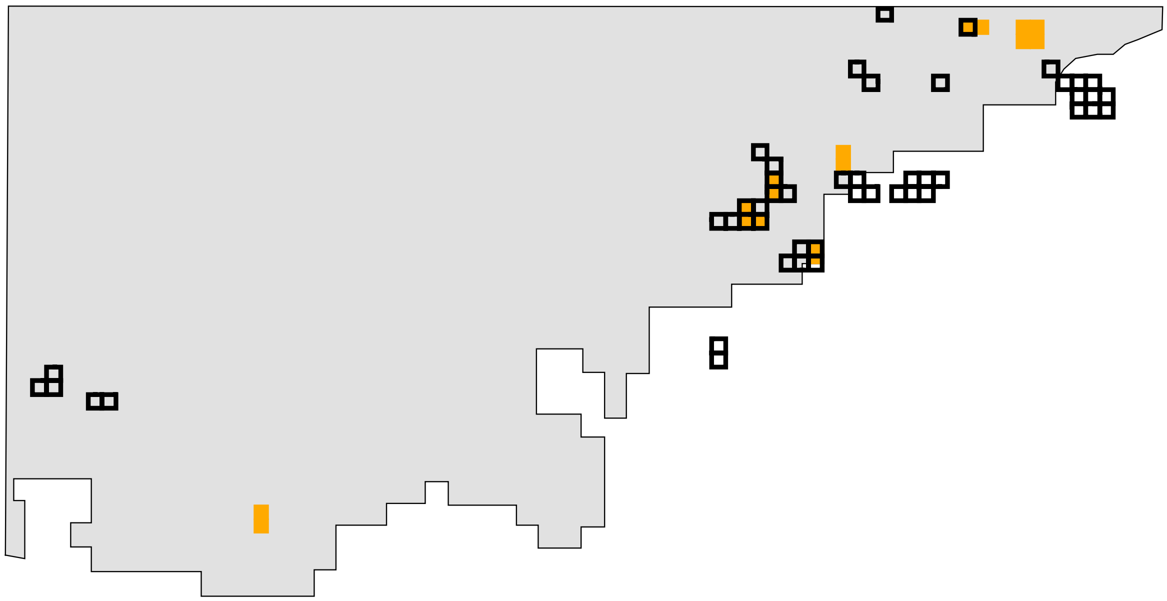


Figure 12. LMCP American badger solution (orange) with original natural region solution (outline).

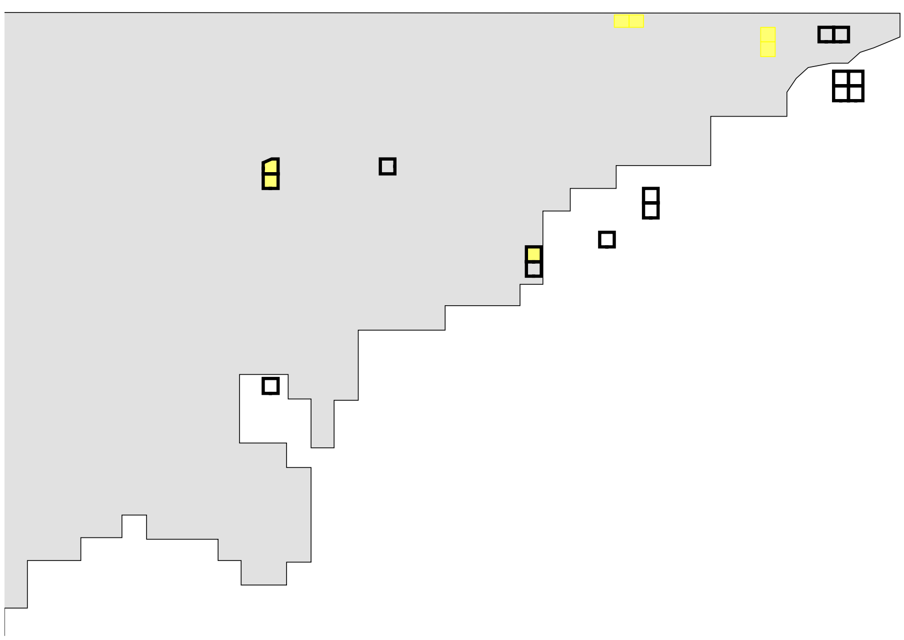


Figure 13. LMCP golden-winged warbler solution (gold) with original natural region solution (outline).

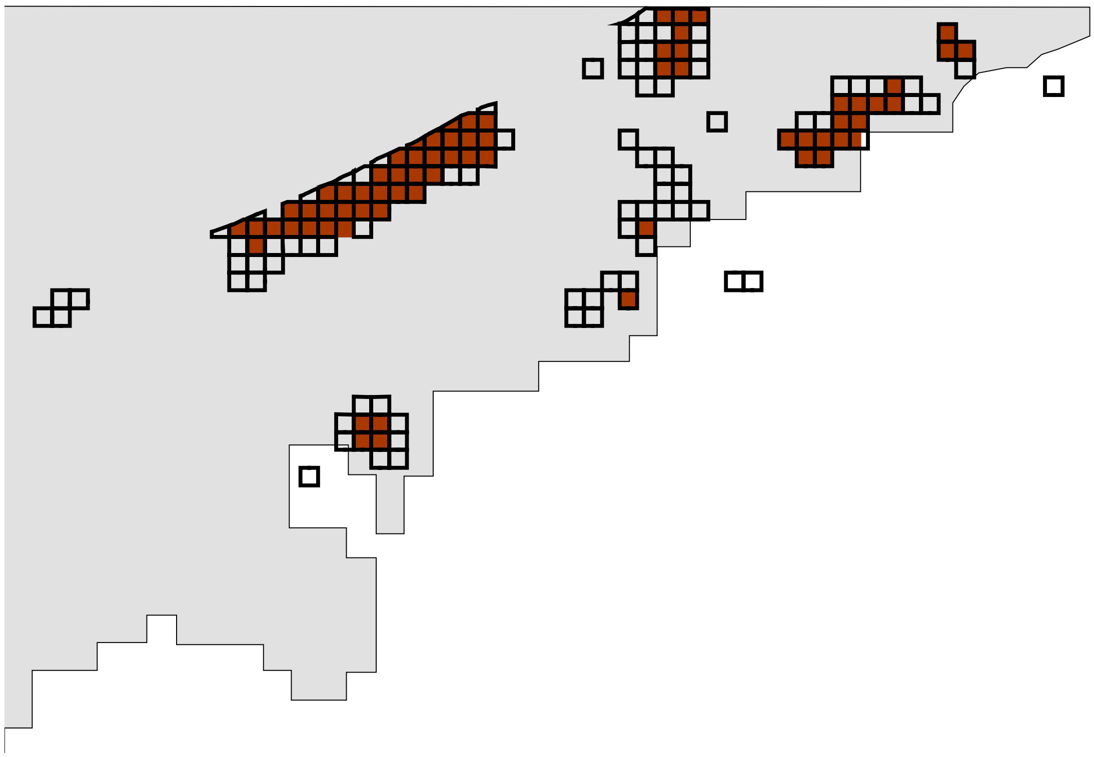


Figure 14. LMCP red-shouldered hawk solution (rust) with original natural region solution (outline).

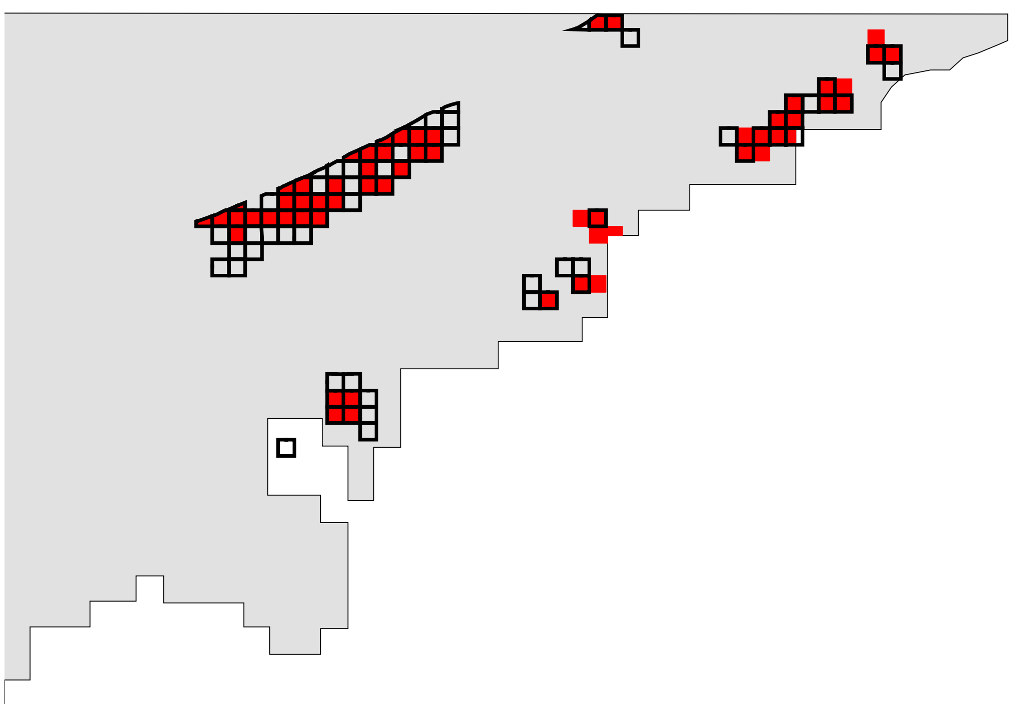


Figure 15. LMCP scarlet tanager solution (red) with original natural region solution (outline).

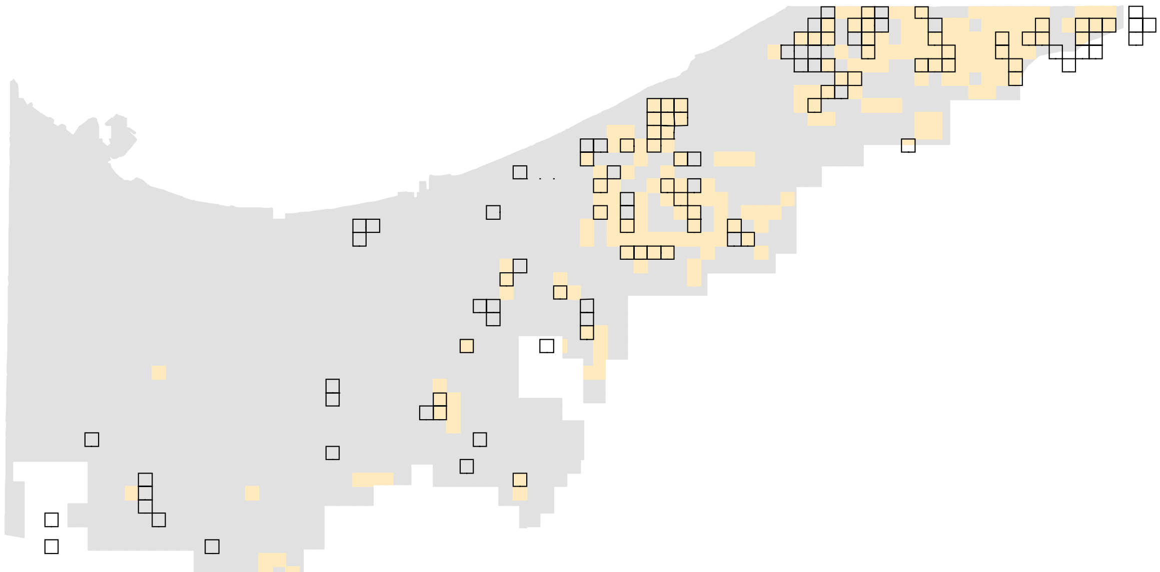


Figure 16. LMCP eastern massasauga solution (brown) with original natural region solution (outline).

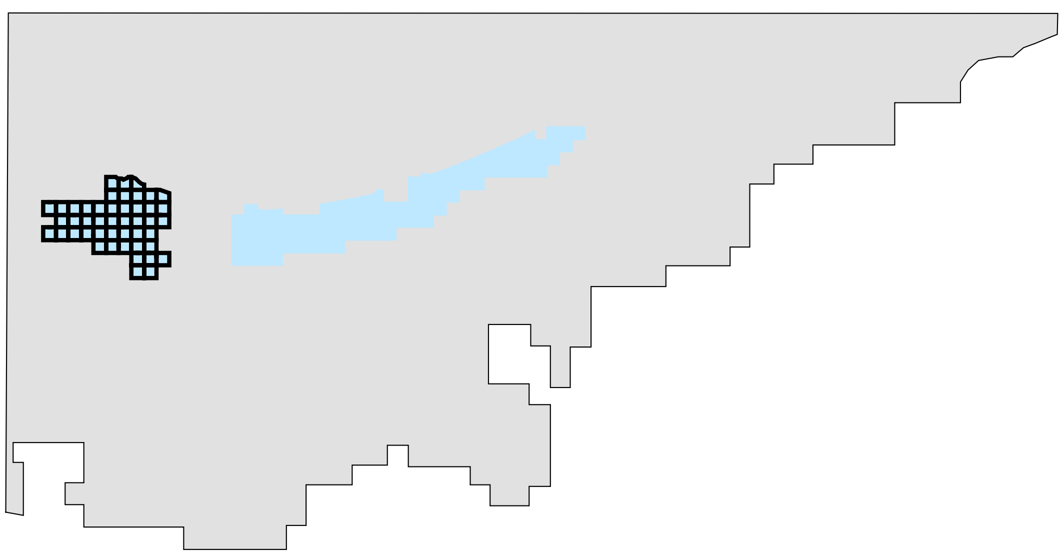


Figure 17. LMCP Karner blue butterfly solution (blue) with original natural region solution (outline). Changes here are not the result of modeling but only of more complete communication with species specialists to obtain the full set of conservation areas.

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.

Trials and triumphs

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 chosen in the rerun, and the new cells identified in the rerun would be identified on the basis of incompletely updated information. We were able to check aerial photos to make a general assessment of all new cells, which improved our confidence in our results. But we would have appreciated a chance to make another round of ground-truthing. Of course, if cells were eliminated during the update, that would have led to further runs, and the need for additional ground-truthing ... But the process is finite. Local teams could do the work relatively easily, which also confirms our confidence in the general practicality of the approach.

The 2003 aerial photos were generally of high quality, and a significant proportion of the habitat checking could be done by inspection of the photos. Wetland habitat types were more difficult to distinguish, as was shrubland, and pasture and rowcrops also not always separable. Ground-truthing of these habitats was very helpful. Blueberry and apple orchards caused minor difficulties initially, although we would recognize them in air photos more easily now. We had no method of defining them in the shapefile so they would not to be selected as habitats, other than listing them as some variety of urban landcover (which we did not do). Fortunately, their overall area was minor, relative to the LMCP area.

Problems of software continuity were far worse than we could have predicted. C-Plan, the software basis for Phase 1, is supported from Australia and responsibility for it, and websites supporting it were in flux when we sought to reactivate our licenses. The animal modeling software for Phase 2 was designed specifically for the natural regions, and all base data sets had to be reworked to simulate the usual IBI natural region datasets so that the package would accept LMCP boundaries. In some cases, fine details about animal models took time to trace (the original Northwest Moraine models were complete about 2 years ago by employees who have long since gone on to other positions). Our own level of responsibility in maintaining careful documentation, always a concern in any ongoing database operation, was made even more apparent than it already was.

Ongoing documentation of species habitat needs should modify animal models over time, as occurred during our reruns. Although this causes a break from the original methods, the changes follow the intent of the IBI process. Such adaptive changes are in the best interests of good conservation, but make the results a moving target (an unavoidable aspect of changing landscapes in any event).

Conversations with the CELP members have provided the strongest possible confirmation that a group of conservation-minded people knowledgeable about their area can think critically and creatively about IBI outputs. Participants readily saw the strengths and shortcomings of the products and quickly suggested additional data that might be used in concert with IBI outputs to best design conservation strategies. Trail maps, Important Bird Areas and several other potential GIS layers were quickly identified, along with possible sources for such information. We developed IBI hoping for just such cooperative local application, and watching it happen is a pleasure and a privilege.

Assessing Biodiversity and Threats to Biodiversity in Aquatic Habitats

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 foundation of data than a terrestrial IBI. Under this contract, we have reviewed the currently available literature concerning biodiversity assessment in aquatic habitats in order to understand what methods are in use. We first describe existing efforts to map aquatic biodiversity through GAP-like analysis. We conclude by describing how such an effort might proceed in Indiana and for the LMCP.

Discussions to develop Aquatic GAP analysis methods began in the mid 1990s. The United States Geological Survey working with the Nature Conservancy launched several statewide and basin wide pilot projects to develop aquatic GAP methodology. Prominent pilots include upper Allegheny River watershed in New York, the Ohio GAP analysis, Missouri GAP analysis, and the Great Lakes Aquatic GAP analysis. New York started the first pilot project in 1995 on the upper Allegheny River watershed (Sowa et al. 2004).

The first statewide project to integrate aquatic habitats and taxa was an effort started in 1997 by the Missouri Research Assessment Partnership (MoRAP) (Sowa et al. 2004). MoRAP used a hierarchical approach to identify unique aquatic habitats as well as locations harboring high biotic diversity. The MoRAP framework incorporates both regional and local influences on aquatic biodiversity in a given system by layering physical and biotic data at several spatial scales.

This initial effort in aquatic GAP analysis differs from terrestrial work due to the relative isolation of different drainage patterns and its strong influence on the development of biodiversity. As a result the MoRAP approach and several similar approaches used by most states so far include both the *watershed* and natural region components into the framework. Although there are differences in the methodology for aquatic and terrestrial gap analysis, Indiana can develop a sound conservation planning tool that includes both aquatic and terrestrial components. The approach would be to first identify key aquatic and terrestrial habitats through separate gap analysis methodology and then layer the information together post analysis.

Since the beginning of the MoRAP pilot project several other states and regional efforts have used similar approaches tweaking portions of the framework to fit geophysical and biotic conditions of the area. Here we outline the common hierarchical approach in aquatic GAP analysis. We provide more detailed information in Appendix 3, highlighting unique features of each state's methods and recent recommendations by The Nature Conservancy. Emphasis is placed on methodology developed by Great Lakes states such as Ohio, Michigan, and Wisconsin because of their proximity to Indiana and similarities in biotic communities.

Aquatic GAP Approach

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 systems, the top levels of the classification system focus on geographic features that influence broad taxonomic differences in species assemblages. The remainder of the classification system, depending on availability of information, is responsible for finer levels of structure and function of aquatic ecosystems and ultimately the composition of species.

In the MoRAP framework levels 1-3 are global and subcontinental land areas based on aquatic zoogeographic maps developed by Maxwell et al. (1995). Levels 1-3 are defined as the Zone, Subzone, and Region respectively. These land regions were identified using quantitative analysis of family level differences in fish distributions across North America. For most projects in aquatic gap these levels would be the same throughout the study area but they can be important in states that include multiple boundaries such as Tennessee, New York, and Pennsylvania or places that straddle the continental divide or major drainage basins (e.g., Mississippi Drainage basin, Great Lakes Drainage basin) (Sowa et al. 2004). These boundaries can represent important differences in biological communities that would have been difficult to identify only examining the landscape at smaller spatial scales.

The fourth level in the Missouri framework is called Aquatic Subregions and is defined by major drainage divides within the region (Figure 18). The purpose of this level is to account for variation in riverine habitat based on major geographic differences which can lead to the development of separate evolutionary histories of aquatic communities.

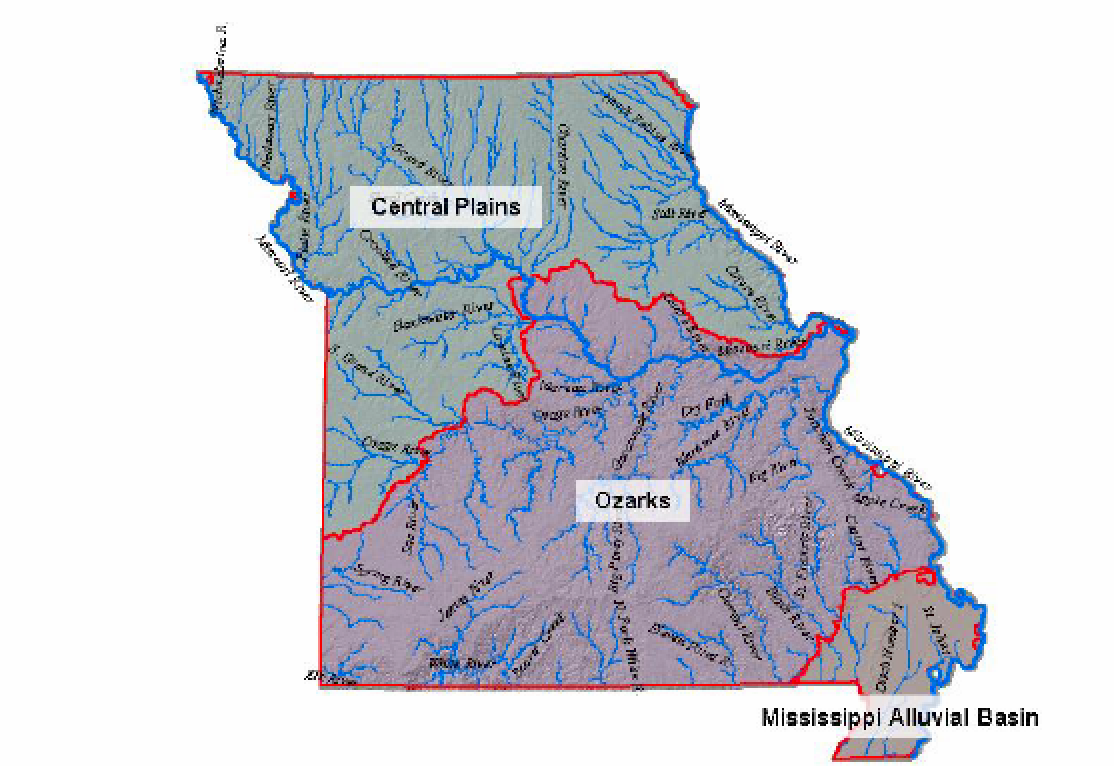


Figure 18. Map showing aquatic subregions of Missouri (Sowa et al. 2004).

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 zoogeographic unit is the overall planning unit for a particular project and does not necessarily follow political boundaries. Its purpose is to distinguish biological communities at regional scales.

The finer scale levels in the MoRAP and Nature Conservancy frameworks are similar. The next classification level in both frameworks is the Ecological Drainage Unit (Figure 19). This level further distinguishes taxonomic differences caused by geographic variation within an aquatic subregion. To get and idea of size, draft Ecological Drainage Units in the Missouri pilot approximately followed USGS 8-digit hydrologic units (Sowa et al. 2004).

The next level in both the Missouri Pilot project and the Nature Conservancy are Aquatic Ecological systems. This level examines finer variation in physiogeography of an area and its influence ecological composition at a more local scale. Unlike the previous framework levels, Aquatic Ecological systems include only abiotic differences that distinguish watersheds or subwatersheds (drainage areas of 100 to 600 mi^2) from each other (Higgins et al. 2005; Sowa et al. 2004). These attributes include water body size, temperature, chemistry, position in drainage network, elevation, and gradient.

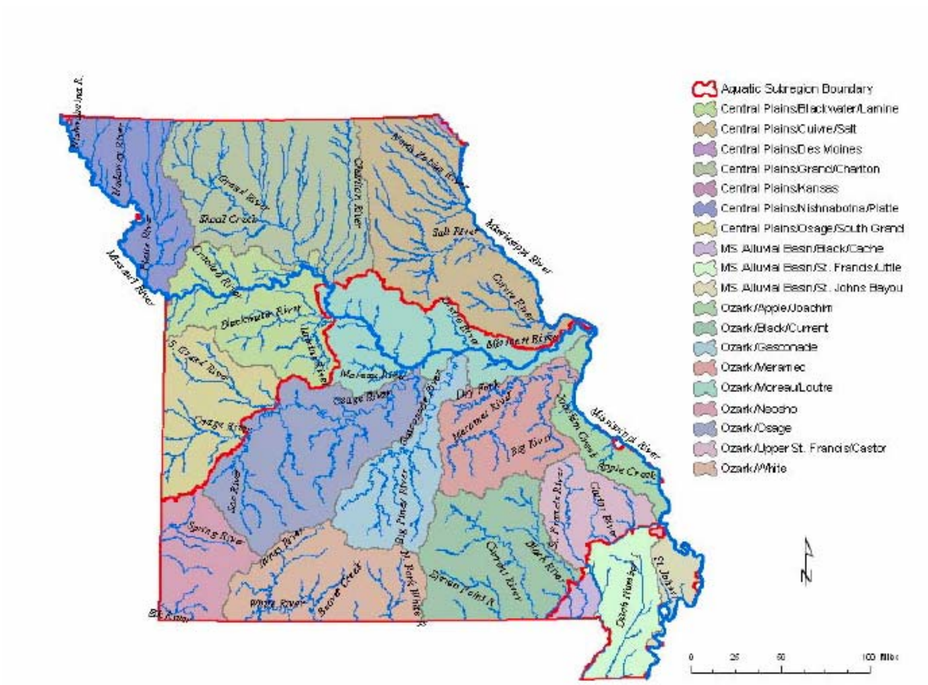


Figure 19. Ecological Drainage Units in Missouri (Sowa et al. 2004). Note that these units are substrata of Aquatic Subregions.

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 was classified by a unique combination of temperature and geology attributes that have been linked to differences in species assemblages (Table 7). Level 8 in the MoRAP framework involves finer habitat features such as riffle run sequences and other information that would likely require field observations. The lowest level in the Nature Conservancy framework is the Macrohabitat and is derived in a similar fashion to Valley Segment Types.

One of the main focuses in the Nature Conservancy Framework is practicality and the organization recognizes limitations in available data. Additional layers, as described in the MoRAP project, might provide a more complete picture of an ecosystem, however, four layers are sufficient to get a good idea of aquatic habitat variation across a landscape.

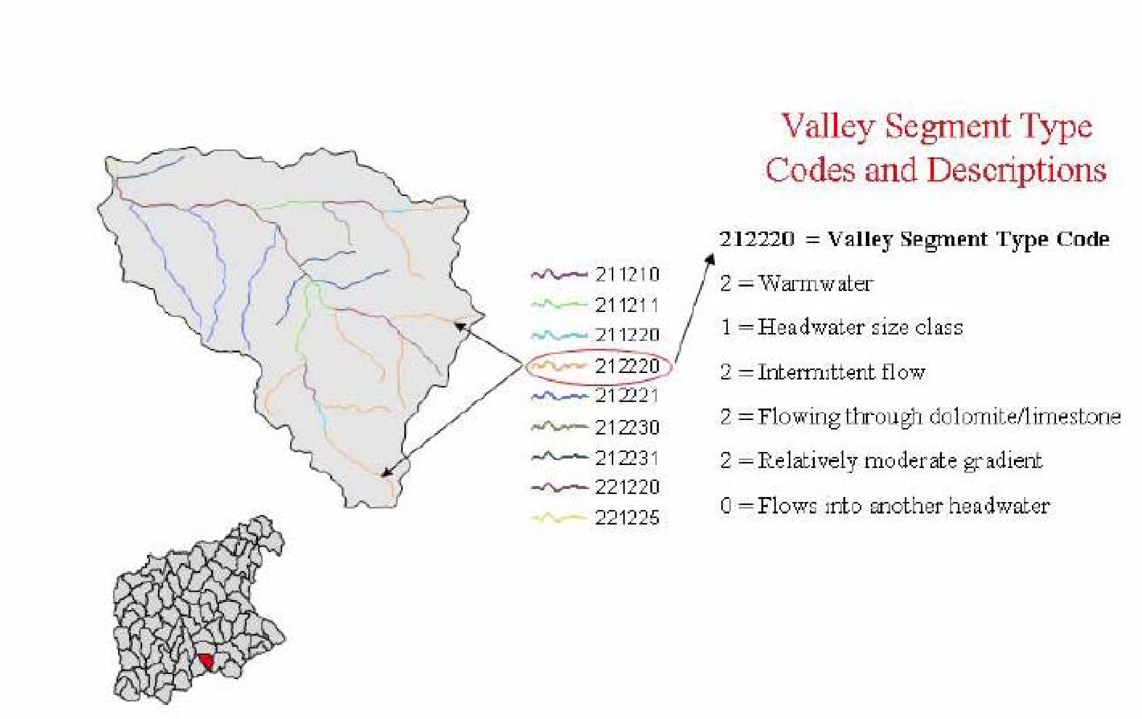


Figure 20. An example of Valley Segment Types within an Ecological Drainage Unit (Sowa et al. 2004).

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

Model Development

The development of species distribution models varies based on the availability of aquatic community data. Some states develop their models relative to segment valley or ecological drainage unit based solely on fish distribution information while other states have attempted to model a combination of various organisms. The Missouri project reported better regression models using fish data only than a combination of fish, mussel, and macroinvertebrate data. Both model attempts displayed positive correlations to habitat classifications. In Appendix 3, species model information, if available, was listed by state to display the variation in model approaches. Researchers in Iowa published an article in the GAP Analysis Bulletin that describes their approach to acquiring relevant species distribution information in the state.

Protected Areas and Threat Assessment

Identifying areas where habitats are already protected or habitats at risk is mostly similar to terrestrial gap analysis. Some states, such as Alabama, are working to include water quality information in threats assessment.

Proceeding with an Indiana or LMCP aquatic biodiversity and threats assessment

Mapping areas of high known or potential biodiversity.

Implementing a GIS-based aquatic biodiversity assessment project presents different challenges than those involved in producing the Indiana Biodiversity Initiative (IBI) Regional Assessments, which are essentially terrestrial. First, we must determine what to include in an assessment of aquatic biodiversity, recognizing that a continuum exists from aquatic to terrestrial systems.

The IBI Regional Assessments include palustrine wetlands (by definition >2 meters deep), and NWI categories including ponds. An aquatic biodiversity assessment project would presumably be complementary, focusing on rivers, streams, and lakes and their associated wetlands. As with the terrestrial assessment, we would have to decide on how to address human-altered systems, in this case, reservoirs, and channelized, dammed, or leveed rivers and streams.

Units of analysis. The landscape units for aquatic assessment would differ from those used in the terrestrial assessment. The IBI Regional Assessments, as the name implies, used a modified version of Indiana's natural regions (Homoya et al.1985) as the unit of analysis. In various discussions among those involved in terrestrial biodiversity assessment within IBI and among those involved in Aquatic Gap Analysis, there has been a consensus that terrestrial subdivisions are not appropriate for aquatic assessment. As the preceding discussion of aquatic biodiversity notes, most current aquatic-GAP-like approaches use natural regions, but secondarily; abiotic features are the primary factors in the higher levels of the hierarchical classification of aquatic units.

Because aquatic speciation is generally a within-drainage process, watershed-based regions are the most obvious choice for landscape units. We suggest that an appropriate unit of analysis for aquatic biodiversity may be some level of watershed based on the United States Geological Survey and USDA Natural Resources Conservation Service Hydrological Unit system. Hydrologic Units from 8-digit to 14-digit (major river watersheds to sub-watersheds) are available in digital form for Indiana. MoRAP's aquatic subregions and TNC's aquatic zoogeographic units useful examples of the kinds of watershed divisions that might be used for natural aquatic regions in Indiana.

Smaller units must be defined, within whatever main divisions are chosen, to serve as the basic unit of analysis - analogous to the square kilometers of the terrestrial IBI models. The idea of fixed area or length may be less useful for aquatic systems: both MoRAP and TNC develop a hierarchical series of subdivisions. TNC's system pragmatically recognizes the possibility of data gaps, and may serve as an easier starting point for Indiana. Ideally, Indiana's system would be flexible enough to add additional refinements as new kinds of data become available and as existing data sets become more complete.

Available information and its use. Both the MoRAP and TNC initial hierarchical classifications are based solely on abiotic information. Relevant data include water body size, temperature, chemistry, position in drainage network, elevation and gradient. For Indiana, slope can be quantified from digital elevation models (DEMs), stream order can be determined from digital line graphs (DLGs) of streams, and polygon and raster maps of land cover show lakes, ponds, and (less well) associated wetland habitats and their area. Stream flow measurements are available for some permanent streams, and at least coarse bathymetry is available for larger lakes, and maximum depth for most smaller lakes. Surficial hydrology and soils maps provide basic information on bedrock and substrate and basic water chemistry parameters provide simple water quality measures.

This initial classification stage of an aquatic assessment is similar to Phase I of the terrestrial IBI in that it assesses habitat using rather general information. Terrestrial IBI uses rare-species information in the first phase, and umbrella-species information in the second phases, whereas the aquatic biodiversity work to date seems to approach hydrogeochemical information first, and then proceed to biological information. Because aquatic habitats are strongly structured by these physical factors, such an approach is reasonable, although it fails to consider the structural contributions of vegetation in determining basic habitat types. Algal beds and emergent riparian wetlands can be considered structural categories just as much as riffles and runs can be.

The second step of the aquatic GAP approach, like Phase II of IBI, is to develop species models ranging from simple maps of species distributions to statistical models to along the lines of habitat suitability models. However, GAP approaches generally map or model distribution for all species of interest, an approach that is immensely time consuming and expensive. IBI Phase II, in contrast, uses an umbrella species approach in order to protect many species while modeling only a few. In theory the umbrella-species approach can be used in any ecosystem so long as data are available to select appropriate species.

In conducting an aquatic biodiversity assessment using an umbrella-species approach, one would not have the many single-species models that GAP approaches combine to find areas of high biodiversity. The Heritage observations of rare species can serve as a surrogate for the GAP 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 Indiana Biodiversity Initiative acronym]). *IBI* data are designed to rank aquatic habitat quality using hydrogeochemical as well as biological information. Here, it is useful to note the potential distinction between high biodiversity and high habitat quality. Although high quality habitats often support high biodiversity (absent other factors such as overharvest), it is also possible to have at least somewhat high biodiversity in degraded conditions. In terrestrial systems, this might occur with a high number of invasive plant species in a "waste" area at the edge of an industrial project. In aquatic systems, it might be a relatively high number of species associated with anoxic waters and soft bottoms. An assessment based entirely on species richness might consider these to be relatively "good" areas. However, *IBI* data would integrate water quality and habitat structure data, and would downgrade these potentially less desirable and generally less threatened species assemblages, due to the lower quality of their surroundings.

In Regional Assessments, we generally excluded urban areas (including industrial areas) from analysis *a priori*, even though some native species can persist in urban environments. The goal of Regional Assessments is to find areas of known or potentially high (native) biodiversity, and urban areas do not support that goal. A similar exclusion, perhaps based on water quality parameters, might be useful in an aquatic biodiversity assessment. However, whereas urban areas rarely revert to high-quality habitat, stream reaches can be restored and pollution sources controlled. Even poor quality stream reaches probably should not be permanent excluded from an aquatic biodiversity assessment unless permanent anthropogenic modifications are in places (e.g., channelization and armoring).

Pilot work for an aquatic biodiversity assessment should use both index data and rare-species data. Actual practice is the best determinant of when and how they will be used. But thought will need to be given to the method for integrating physical data, rare species data, index data, and the umbrella-species models. If C-Plan can be used with aquatic systems, then rare species information can be used together with the physically-based habitat classifications and index data, as well as information about what areas are already being conserved, in order to indicate what additional areas should be conserved in order to meet conservation targets.

Connectivity. In Regional Assessments, Phase III specifically looks at areas that should be conserved or restored to provide connections across a natural region - riparian areas are often suggested for this purpose. For aquatic conservation, once human construction has destroyed connectivity, only additional human construction - fish ladders, fish elevators, etc. can usually restore it. Locks serve as inadvertent improvements to connectivity for some species (where locks occur), but there is great variability in the willingness or ability of aquatic species to enter locks. An aquatic Phase III analysis might focus, not on means of assuring connectivity, but on factors that limit connectivity: dams, segments of extreme toxicity (e.g., stream segments that run through urban areas), etc. Alternatively such factors might become part of a threats assessment.

Spatial optimization. The result of the habitat classification and identification of areas of high observed or potential biodiversity will be a map of suggested targets for conservation. For the Regional Assessments, we used a spatial optimization tool - C-Plan to meet our conservation goals on a small "footprint" of land. Whether C-Plan or something similar can (or should) be used for an aquatic assessment will be an important question. Identifying the most important segments for biodiversity conservation that require the least area would seem to be similarly important in both environments. A corollary to identifying the most important segments is providing for redundancy (e.g., how many segments of stream type x with a rare species complement of 3 does one need in each watershed?).

Ground truthing. The databases that inform an aquatic biodiversity assessment will be limited in their accuracy by their spatial and temporal extents. In some cases, data entry errors may occur. An aquatic biodiversity assessment will reflect whatever obsolescence and error is in the underlying databases. Unfortunately, whereas inspection of air photos and relatively cursory ground visits can detect most errors in land cover classification, ground truthing aquatic data is more time-consuming and expensive. Possibly, the output of an aquatic biodiversity assessment could be compared with the next year's data from IDNR or IDEM to spot check its accuracy.

Aquatic threats assessment.

Once the aquatic assessment is complete, the next logical step is to conduct a threats assessment. Threats to aquatic biodiversity include: 1) Pollution, which would include point source and non-point source contamination of the water column or sediments; 2) Impacts to the physical structure of the habitat, which would include actions like construction of dams, channelization, dredging, riparian clearing or development (lakes and rivers), sand and gravel mining; 3) invasive species, which would include the impacts to the biota and physical environment of lakes and streams by plant and animal invasive species, 4) predicted future development or other future actions that will affect aquatic systems, 5) predicted future harvest or take (mortality) of specific species.

Water quality and aquatic connectivity information may be used in mapping potential targets for conservation of aquatic ecosystems. However, they will need to be considered again in a threats assessment, in concert with other threats. For example, current water quality in a reach bordered primarily by abandoned farms or very low-density housing may be quite good. But a region that is in an urban expansion zone may soon have significantly worse water quality. Or alternatively, an area with deteriorating water quality may still have high biodiversity because adults of many species can persist. But if young individuals cannot survive, biodiversity will eventually decline. Whether these areas are considered “sacrifice zones” that cannot be protected, or are considered sites worthy of increased efforts for conservation, will be up to whoever uses the assessment. But the comparison between current condition and potential future condition should be made in any case.

Much of the data needed for a threats analysis may be readily available. The Indiana Department of Environmental Management (IDEM) and the EPA maintain data sets of point sources of pollution (e.g., outfall pipes). EPA is also working to develop landscape-and-hydrology based metrics to predict non-point source pollution. In the meantime, in-house metrics might be 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 frequently been asked whether aquatic assessments will be produced. Clearly there is interest in such a product within the state.

Appendix 1: GIS Layers, Metadata, and Candidate Project Structure

Layers of the IBI-LCMP GIS Project

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.

12) Porter county color orthophotos flown in 2003, in Mr. Sid II format

13) LaPorte county color orthophotos flown in 2003 in Mr. Sid II format

14) Lake county color orthophotos flown in 2003 in Mr. Sid II format

15) Major cities

16) Pipelines

17) Local roads

18) Highways

19) Urban areas

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 decrease by >250 persons/sq mi - from the Northwest Indiana Regional Planning Commission maps

37) Areas where population is predicted to decrease by 1-250 person/sq mi - from the Northwest Indiana Regional Planning Commission maps

38) Areas where population is predicted to increase by 26-740 persons/sq mi - from the Northwest Indiana Regional Planning Commission maps

39) Areas where population is predicted to increase by >740 persons/sq mi - from the Northwest Indiana Regional Planning Commission maps

A40) Phase 1 solution rerun from updated base data.

A41) Phase 2 solution rerun from updated base data.

A42) American badger solution from Phase 2.

A43) Blanding's turtle solution from Phase 2.

A 44) Blue-spotted salamander solution from Phase 2.

A45) Eastern massasauga solution from Phase 2.

A46) Golden-winged warbler solution from Phase 2.

A47) Karner blue butterfly solution from Phase 2.

A48) Red-shouldered hawk solution from Phase 2.

A49) Scarlet tanager solution from Phase 2.

A50) Overlay grid for updated LMCP data and analyses.

Project Metadata

All layers in this GIS project are in Transverse Mercator projection in UTM zone 16N on the NAD83 datum.

Candidate Project Structure for Included Layers

- Base Map
  - IBI original recommended cells
  - All updated cells
  - Base Vegetation Datasets
    - GAP landcover
    - NWI wetlands
    - Heritage Site
    - ADID wetlands
  - Updated Vegetation Datasets
    - GAP updated
    - NWI updated
    - Heritage updated
  - Base Data
    - LCMP Area
    - LCMP cells - conservation features
    - Areas managed for conservation
    - Color Orthophotos
      - Porter Co. airphoto
      - LaPorte Co. airphoto
      - Lake Co. airphoto

- Infrastructure
  - Major Cities
  - Pipelines
  - Local Road
  - Highway
  - Urban Area
  - Porter Co. outline
  - LaPorte Co. outline
  - Lake Co. outline
- Population Growth & Development
  - Population Change by 2030
  - Anticipated Growth Areas
  - Proposed Transportation Projects by 2030
    - new interchange
    - intersection improvement
    - new road
    - new interstate
    - interchange modification
    - added travel lanes
  - Commited Transportation Projects
    - interchange
    - committed road

Appendix 2: Animal model parameters

American badger (state endangered)

Habitats: 20-ha (or larger) patches of pasture/grassland and terrestrial woodlands on well-drained soils in areas that are not completely flat.

Hostile habitats: areas within 500 m of urban and other developed areas of at least 10 ha.

Buffer distance around primary cell to achieve habitat configuration: 500 m.

Red-shouldered hawk (state species of special concern)

Habitats: terrestrial and palustrine forest together encompassing at least 90 ha, some part of which must be within 300 m of a stream, open wetland, pond, or lake.

Hostile habitats: agricultural areas, or areas within 500 m of urban and other developed areas that are at least 10 ha.

Buffer distance around primary cell to achieve habitat configuration: 500 m.

Golden-winged warbler (state endangered)

Habitats: 10-ha (or larger) patches of terrestrial and palustrine shrubland adjacent to at least 10 ha of woodlands or forest.

Hostile habitats: agricultural areas, or areas within 500 m of urban and other developed areas of at least 10 ha.

Buffer distance around primary cell to achieve habitat configuration: 500 m.

Scarlet tanager

Habitats: mixed and/or deciduous terrestrial forest of at least 45 ha

Hostile habitats: row crop, pasture, areas within 500 m of urban and other developed areas of at least 10 ha.

Buffer distance around primary cell to achieve habitat configuration: 500 m.

Blanding's turtle (state endangered)

Habitats: Marshes of at least ¼ ha within 500 m of patches of pasture, terrestrial shrubland or terrestrial woodland of at least 5 ha and within 1600 m of sandy soils.

Hostile habitats: areas within 1 km of urban and other developed areas.

Buffer distance around primary cell to find initial marshes: 100 m.

Eastern massasauga (Federal candidate species)

Habitats: palustrine forest and palustrine grassland in patches of at least 1 ha, adjacent to terrestrial shrubland, woodland or forest patches of at least 1 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

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.

Appendix 3: Summary of state efforts in aquatic biodiversity conservation, with recommended reading

Great Lakes Aquatic GAP project
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 regional planning tool of the Great Lakes (Morrison et al. 2003). Each state is using a hierarchical aquatic gap framework similar to the ones developed by the Nature Conservancy and MoRAP. Although the bases of the states' efforts are similar, each framework is tailored to available state data and landform characteristics. The UGSG is currently working on aquatic classification systems for rivers and the coast line of the Great Lakes. The website provides an overview of the efforts, links to state programs, and USGS contact information. Additional information on the Great Lakes Aquatic GAP efforts have been published in the USGS GAP Analysis Bulletin (McKenna et al. 2003).

Wisconsin Aquatic GAP Project
http://wi.water.usgs.gov/public/gap/index.htm

The USGS is working with the Wisconsin Department of Nature Resources on characterizing Valley Segment types throughout the state. Wisconsin is customizing the framework by including attributes such as land use for a 60 m riparian buffer and watershed (Stewart 2003). Rather than storing only categorical data, the state is attempting to insure that interval/ratio data is preserved wherever possible. The state plans to complete their aquatic GAP project by 2006. The following is a summary of attributes for Wisconsin's aquatic classification framework.

Channel Attributes (stored as route on network)

- Hydrography
    - Order (strahler)
    - Link and dlink (Shreve)
    - Sinuosity
    - Elevation (slope)
    - Geology
        - Surficial geology texture
        - Bedrock type
        - Depth to bedrock
        - Soil permeability
        - Climate (annual air temp)

Riparian Attributes (calculated on a 60 m buffer)

- Land cover
- GW potential
- Valley Wall interaction

Catchment Attributes (calculated for catchment of each reach)

- Drainage area and density
- Climate
  - Annual precipitation
  - Growing degree days
  - Evapotranspiration
  - Air temperature (July max, min, mean)
- Geology
  - Surficial texture
  - Bedrock type
  - Depth to bedrock
  - Soil permeability
  - Elevation (slope)
  - Land cover

Michigan

http://www.glsc.usgs.gov/main.php?content=research_GAP_michigan&title=Aquatic%20GAP0&menu=research_NCE_GAP

Great Lakes Science Center
1451 Green Road
Ann Arbor, Michigan 48105
Phone: (734) 994-3331
Fax: (734) 994-8780

Information on the Michigan program is housed at the USGS Great Lakes Science Center website. The site provides an outline of Michigan's approach with a timeline for anticipated completion habitat classification, models, and public outreach. Agencies involved in the Michigan aquatic GAP analysis project include the Michigan Department of Natural Resources and the USGS.

Ohio

http://oh.water.usgs.gov/ohgap/ohgap.html
Stephanie Kula
spkula@usgs.gov
614-430-7739

The USGS is working with The Ohio State University and the Ohio Division of Wildlife on terrestrial and aquatic components of GAP analysis for the state. The state has classified their stream systems by Valley Segment Type and Ecological Drainage Units (Kula and Covert 2003).

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.

New York

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).

Alabama

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 Resources (GADNR) is developing decision support tools to assist agencies in sampling, monitoring, and protection decisions (Erwin et al. 2002).

Oregon

http://oregonstate.edu/ornhic/aquatic_class.pdf
http://oregonstate.edu/ornhic/gap-aquatic.html

The Oregon Natural Heritage Information Center, a collaborative organization of federal, state, and university representatives, is working on classifying aquatic habitats throughout the state. The state is using anadromous fish distribution data from another project, aquatic habitats, and other indicators of diversity to identify regions in need of protection. The Oregon project is following the classification framework established by the Nature Conservancy and USGS. The website provides a general synopsis of the project and a list of contacts.

Virginia

http://www.cmiweb.org/gis/vagap.html (mostly terrestrial)

Upper Tennessee River Aquatic Gap Analysis
http://www.cmiweb.org/gis/tngap.html
Dr. Paul L. Angermeier, Associate Professor, Assistant Leader, Cooperative Research Unit
Dr. Paul L. Angermeier
Scott D. Klopfer, Conservation Management Institute
Scott D. Klopfer

Researchers from Virginia Tech and the USGS are currently working on developing models to identify species distribution and threats to major taxa in the Upper Tennessee watershed. Goals of the project include identify potential threats, test model reliability and develop a QA/QC protocol for model development in the region.

The website providing information on the methodology is sparse.

Iowa

http://www.gis.iastate.edu/gisday04/PostersTalks/AgapPoster_04.pdf

http://www.gap.uidaho.edu/Bulletins/12/IowaAquaticGap.htm

Iowa State University researchers are following the MoRAP methodology to develop GAP analysis projects for aquatic systems in the state. An article published in the GAP Analysis Bulletin provides information on how Iowa gathered fishery data throughout the state to develop species distribution models which might be helpful for future Indiana projects (Loan-Wilsey et al. 2003). This information includes how the databases were construction, sources of information, and a summary of current Iowa information.

http://www.iowagap.iastate.edu/

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

Kansas

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 classification attributes include temperature, stream size, permanence of flow, gradient, geology, and floodplain reach. At this time, most of the habitat datasets for the Lower Colorado have been identified and researchers are working on compiling fish data from museum records.

South Dakota

http://wfs.sdstate.edu/sdgap/aquaticgap.htm

South Dakota researchers are also following the methodology developed by MoRAP. Currently researchers are compiling fish data and are seeking to create models that relay information on habitat type affinity for particular species and occurrence throughout the state. Segment Valley Characteristics include:

- Temperature (warm vs. cool)
- Stream size (headwater, creek, small river, and larger river)
- Geology (13 values based on parent material of soils
- Ground water potential (amount of percolation present)
- Relative gradient (average change in elevation in meters)
- Size Discrepancy (difference in stream size from one reach to another)
- Floodplain reach

Pennsylvania

http://www.orser.psu.edu/PAGAP/PA_GAP_final_report_toc.htm
Dr. Wayne Myers
Professor of Forest Biometrics
Co-director, Office for Remote Sensing of Earth Resources
Penn State Institutes of the Environment
124 Land and Water Research Building
Pennsylvania State University
University Park, PA 16802

Telephone: (814) 863-0002
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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.

Recommended Reading

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.

Appendix 4. Annotated bibliography for aquatic biodiversity and threat assessment

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 dimensional gap analysis: a tool for efficient conservation planning and biodiversity policy implementation. Ambio 32(8): 527-534.

Bennetti, A. and R. Mac-Nally. 2004. "dentifying priority areas for conservation action in agricultural landscapes. Pacific Conservation Biology 10(2-3):106-123.

Abstract:
Farming for food, fibre and other products for human consumption is a dominant land-use throughout the world. Rural landscapes are also critical to the conservation of flora and fauna, and the maintenance of ecological processes on which all of life depends. In Australia, excessive clearing of native vegetation in the most productive agricultural landscapes has had profound environmental and social consequences. Restoration of these landscapes is an enormous challenge that offers the opportunity to shape the future of Australia, environmentally, socially and economically. In this paper we address the issue of identifying priority areas for conservation in agricultural landscapes. The spatial location of conservation actions in rural landscapes is important because it affects the degree of representation of the biota, the level of protection for rare and threatened species, the adequacy of habitats for species and communities and their future viability, the maintenance of ecological processes, and the integrity of habitats. However, because most land in agricultural regions is privately owned, effective implementation of restoration goals in preferred locations requires understanding of social processes, recognition of pragmatic issues in land management and financial commitment by the wider Australian society. We briefly review the strengths and limitations of some current approaches to determining priority locations for conservation action, including the use of general principles, species-based approaches, quantitative approaches for assessing representativeness, and "bottom-up" approaches based on landholder action. There is no single "best" solution: the most effective approach or combination of approaches depends on the objectives for restoration and the circumstances in the area where restoration will occur. An important consideration is the quality of the data available for the area, particularly detailed vegetation maps and knowledge of the status and habitat requirements of species that occur there. We summarize five stages that form a logical sequence in restoration programmes and highlight some of the issues at each stage. As the outcomes of the present continent-wide experiment in restoration cannot be fully evaluated for many decades, it is prudent that a range of alternatives are trialed and monitored for their effectiveness and success.

[1] This bibliography contains a mixture of sources that might be worthwhile. These are from literature searches conducted through Indiana University Library databases or literature cited in relevant papers.

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, in developing countries where priorities other than environmental conservation exist, the threat of eutrophication, acidification and contamination by toxic substances is predicted to continue to increase. Although the future of biodiversity in lakes and ponds is seriously threatened, growing concern for environmental problems, implementation of new environmental strategies and administrations, and international agreements, are positive signs of changes that should improve the ability to manage old as well as new, yet undiscovered, threats.

Cushman, S.A. and K. McGarigal. 2002. Hierarchical, multi-scale decomposition of species-environment relationships. Landscape Ecology 17:637-646.

Hawkins, C.P., R.H. Norris, J. Gerritsen, R.M. Hughes, R.M. Jackson, S.K. Johnson., R.K. Stevenson and R. Jan. 2000. Evaluation of the use of landscape classifications for the prediction of freshwater biota: synthesis and recommendations. Journal of the North American Benthological Society 19:541-556.

Abstract.
This paper summarizes and synthesizes the collective results that emerged from the series of papers published in this issue of J-NABS, and places these results in the context of previously published literature describing variation in aquatic biota at landscape spatial scales. Classifications based on landscape spatial scales are used or are being evaluated for use in several countries for aquatic bioassessment programs. Evaluation of the strength of classification of different approaches should provide insight for refinement of existing bioassessment programs and expedite the development of new programs. The papers in this series specifically addressed the degree to which descriptions and classification of landscape

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 composition of freshwater fauna. One potential approach entails use of landscape classifications as a means of refining or augmenting classifications based on local habitat features, which appear to account for substantially more biotic variation than larger-scale environmental features. These results have significant implications for how assessment and monitoring programs at local, state/province, and national levels should be designed.

Heino, J. 2002. Concordance of species richness patterns among multiple freshwater taxa, a regional perspective. Biodiversity and Conservation 11(1):137-147.

Abstract:
Geographical gradients in species richness and the degree to which different taxa show congruent patterns remain unknown for many taxonomic groups. Here, I examined broad-scale species richness patterns in five groups of freshwater organisms; macrophytes, dragonflies, stoneflies, aquatic beetles and fishes. The analyses were based on provincial distribution records in Denmark, Norway, Sweden and Finland. In general, variation in species richness across provinces was concordant among the groups, but stoneflies showed weaker negative relationships with the other taxonomic groups. Species richness in most groups decreased with increasing latitude and altitude, and a considerable part of the variation was explained by mean July temperature. However, stoneflies showed a reversed pattern, with species richness correlating positively, albeit more weakly, with mean provincial altitude. Nevertheless, combined species richness of all five taxa showed a strong relationship with mean July temperature, accounting for 74% of variation in provincial species richness alone. Such temperature-controlled patterns suggest that regional

Hitt, N.P. and C.A. Frissell. 2004. A case study of surrogate species in aquatic conservation planning. Aquatic Conservation 14(6):625-633.

Abstract:
1.The use of surrogate species (i.e. keystones, indicators, umbrellas) has been advocated for the conservation of target taxa and communities.
2.A recent Habitat Conservation Plan, which provided conservation measures intended to protect multiple aquatic species of concern over a large area, established an important precedent for surrogate species in aquatic conservation pursuant to the US Endangered Species Act.
3.The Habitat Conservation Plan's application of federally threatened bull trout was evaluated as an umbrella species for westslope cutthroat trout, which is in decline but not listed under the

Act. Approximately 75% of known westslope cutthroat trout strongholds are not captured within bull trout strongholds west of the continental divide. The Habitat Conservation Plan failed to evaluate the suitability of this umbrella species and consequently failed to cover important priority areas for westslope cutthroat trout conservation.
4.This case study highlights the feasibility and importance of formally validating assumptions of surrogate species utility in multi-species conservation planning.

Higgins, J.M., M. Lammert, M.T. Bryer, M. DePhilip, and D. Grossman. 1998. Freshwater conservation in the Great Lakes Basins: development and application of an aquatic community classification framework. The Nature Conservancy, Chicago.
http://conserveonline.org/docs/2000/12/glreppub.zip

Higgins, J.V. 2003. Maintaining the ebbs and flows of the landscape- conservation planning for freshwater ecosystems. Pages 291-318 in C.R. Groves, editor. Drafting a conservation blueprint: a practioner's guide to regional planning for biodiversity. Island Press, Washington, DC.

Hoctor, T.S., M.H. Carr and P.D. Zwick. 2000. Identifying a linked reserve system using a regional landscape approach: The Florida Ecological Network. Conservation Biology 14(4):984-1000.

Hudson, P.L., R.W. Griffiths, and T.J. Wheaton. 1992. Review of habitat classification schemes appropriate to streams, rivers, and connecting channels in the Great Lakes drainage basin. Pages 73-107 in W.D.N. Busch and PG. Sly, editors. The development of aquatic habitat classification system for lakes. CRC Press, Boca Raton, FL.

Jennings, M.D. 2000, Gap analysis: concepts, methods, and recent results: Landscape Ecology. 15:5–20.

Joy, M.K. and R.D. Death. 2004. Predictive modeling and spatial mapping of freshwater fish and decapod assemblages using GIS and neural networks. Freshwater Biology 49(8):1036-1052.

Abstract:
1. *We used stream fish and decapod spatial occurrence data extracted from a national database and recent surveys with geospatial landuse data, geomorphologic, climatic, and spatial data in a geographical information system (GIS) to model fish and decapod occurrence in the Wellington Region, New Zealand.*
2. *2. To predict the occurrence of each species at a site from a common set of predictor variables we used a multi-response, artificial neural network (ANN), to produce a single model that predicted the entire fish and decapod assemblage in one procedure.*
3. *3. The predictions from the ANN using this landscape scale data proved very accurate based on evaluation metrics that are independent of species abundance or probability thresholds. The important variables contributing to the predictions included the latitudinal and elevational position of the site reach, catchment area, average air temperature, the vegetation type, landuse proportions of the catchment, and catchment geology.*

4. *4. Geospatial data available for the entire regional river network were then used to create a habitat-suitability map for all 14 species over the regional river network using a GIS. This prediction map has many potential uses including: monitoring and predicting temporal changes in fish communities caused by human activities and shifts in climate, identifying areas in need of protection, biodiversity hotspots, and areas suitable for the reintroduction of endangered or rare species.*

Leach, J.H. and R.C. Herron. 1992. A review of lake habitat classification. Pages 27-57 in W.D.N. Busch and P.G. Sly, editors. The development of an aquatic habitat classification system for lakes. CRC Press, Boca Raton, FL.

Lawler, J.J., D. White and L.L. Master. 2003. Integrating representation and vulnerability: two approaches for prioritizing areas for conservation. Ecological Applications 13(6): 1762-1772.

Abstract:
Reserves protect biodiversity by ameliorating the threats to the persistence of populations. Methods for efficient, systematic reserve selection have generally been designed to maximize the protection of biodiversity while minimizing the costs of reserves. These techniques have not directly addressed the factors threatening species at specific sites. By incorporating measures of site vulnerability into reserve selection procedures, conservation planners can prioritize sites based on both representing biodiversity and the immediacy of factors threatening it. Here we develop two complementary approaches for identifying areas for conservation based on species composition and potential threats facing the species. These approaches build on two established methods of systematic reserve selection. The first approach involves mapping irreplaceability (a statistic derived from reserve selection theory that measures the potential importance of a site for protecting all species) and the degree to which the area is vulnerable to threats from three basic anthropogenic factors (the percentages of a site devoted to agriculture, to urban and suburban development, and to open mines). We classified areas with respect to both irreplaceability and the three indicators of vulnerability, producing a continuous ranking of all sites based on these factors. Our second approach was to incorporate site vulnerability into a reserve selection algorithm. This approach allowed us to locate those sets of sites that protected all species and were most likely to be threatened by human activities. These two analyses can provide regional-scale guidance for conservation in the Mid-Atlantic region of the United States, and they demonstrate two potential tools for solving complex conservation-planning problems.

Lyons, J. 1996. Patterns in species composition of fish assemblages among Wisconsin streams. Environmental Biology of Fishes 43:329-341.

Margules, C.R. and R.L. Pressey. 2000. Systematic conservation planning. Nature 405:243–253.

Moyle, P.B. and R.M. Yoshiyama. 1994. Protection of aquatic biodiversity in California: a five-tiered approach. Fisheries 19:6-18.

Olivera, S.V. and R.M.V. Cortes. 2005. A biologically relevant habitat condition index for streams in Northern Portugal. Aquatic Conservation 15(2):189-210.

Abstract:

1.This study describes the development of an index for assessing stream habitats in northern Portugal at a variety of spatial scales and levels of perturbation. In developing the index, 86 environmental variables, including regional and local ones, were used to reflect the geomorphological characteristics, riverine habitat, and human activities occurring in each basin.
2.Collections of benthic invertebrates were made at each sample site. To reflect the observed variation in assemblages, the streams were separated into two categories: the North-west catchments and the Douro catchments.
3.Multivariate analysis techniques applied to the physical and biological data sets allowed the determination of the relative importance of local and regional environmental descriptors in the discrimination of the invertebrate assemblages.
4.Successive statistical refinement procedures yielded 10 variables, all at the local scale. Variation along disturbance gradients allowed the development of a habitat index through scoring criteria that separated reference sites from stressed sites.
5.The results indicate the reduced impact of catchment factors by a buffering influence probably resulting from the presence of a riparian corridor.

Poff, N.L. 1997. Landscape features and species traits: towards mechanistic understanding and prediction in stream ecology; Journal of the North American Benthological Society 16:391-409.

Poff, N.L. and J.D. Allan. 1995. Functional organization of stream fish assemblages in relation to hydrologic variability. Ecology 76:606-627.

Pusey, B.J. and A.H. Arthington. 2003. Importance of the riparian zone to the conservation and management of freshwater fish: a review. Marine and Freshwater Research 54(1):1-16.

Abstract:
The relationship between freshwater fish and the integrity of the riparian zone is reviewed with special emphasis on the fauna of northern Australia. Linkages between freshwater fish and riparian zone processes are diverse and important. The riparian zone occurs at the interface between terrestrial and aquatic ecosystems and it may, therefore, regulate the transfer of energy and material between these systems, as well as regulating the transmission of solar energy into the aquatic ecosystem. Riparian influences on light quantity, quality and shade in streams are discussed and predictions are made about the likely impacts associated with changes in light quality. Increased rates of transfer of thermal energy between the atmosphere and the aquatic environment in the absence of an intact riparian zone may potentially disrupt reproduction by desynchronizing the thermal regimen from regional factors, such as the flow regimen, as well as having direct effects on mortality rates, body morphology, disease resistance and metabolic rates. Impacts associated with changes in light quality range from increased egg and larval mortality due to increased ultraviolet (UV) B irradiation and a decreased ability to discriminate between potential mates to increased conspicuousness to predators. Increased insolation and

proliferation of exotic pasture grasses, an increasing threat in northern Australia, are shown to have a range of impacts, including changes in habitat structure, food-web structure and the facilitation of invasion by exotic fish species. The interception of terrestrial sediments and nutrients by the riparian zone has important consequences for stream fish, maintaining habitat structure, water clarity and food-web structure. Coarse organic matter donated to the aquatic environment by the riparian zones has a large range of influences on stream habitat, which, in turn, affect biodiversity and a range of process, such as fish reproduction and predation. Terrestrial matter is also consumed directly by fish and may be a very important source of energy in some Australian systems and under certain circumstances. Attention to the linkages between fish and riparian systems is essential in efforts to rehabilitate degraded stream environments and to prevent further deterioration in freshwater fish populations in northern Australia.

Rabeni, C.F. and K.E. Doisey. 2000. Correspondence of stream benthic invertebrate assemblages to regional classification schemes in Missouri. Journal of the North American Benthological Society 19:419-428.

Roff, J.C. and M.E. Taylor. 2000. National frameworks for marine conservation: a hierarchical geophysical approach. Aquatic Conservation 10(3):209-223.

Abstract:
1. Development of environmental protected areas has been driven 'more by opportunity than design, scenery rather than science' (Hackman A. 1993. Preface. A protected areas gap analysis methodology: planning for the conservation of biodiversity. World Wildlife Fund Canada Discussion Paper; i-ii). If marine environments are to be protected from the adverse effects of human activities, then identification of types of marine habitats and delineation of their boundaries in a consistent classification is required. Without such a classification system, the extent and significance of representative or distinctive habitats cannot be recognized. Such recognition is a fundamental prerequisite to the determination of location and size of marine areas to be protected.
2. A hierarchical classification has been developed based on enduring/recurrent geophysical (oceanographic and physiographic) features of the marine environment, which identifies habitat types that reflect changes in biological composition. Important oceanographic features include temperature, stratification and exposure; physiographic features include bottom relief and substrate type.
3. Classifications based only on biological data are generally prohibited at larger scales, due to lack of information. Therefore, we are generally obliged to classify habitat types as surrogates for community types. The data necessary for this classification are available from mapped sources and from remote sensing. It is believed they can be used to identify representative and distinctive marine habitats supporting different communities, and will provide an ecological framework for marine conservation planning at the national level. Copyright © 2000 John Wiley & Sons, Ltd.

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 Biology 16(1):30-41.

Abstract:

Freshwater species and habitats are among the most threatened in the world. One way in which this growing conservation concern can be addressed is the creation of freshwater protected areas. Here, we present three strategies for freshwater protected-area design and management: whole-catchment management, natural-flow maintenance, and exclusion of non-native species. These strategies are based on the three primary threats to fresh waters: land-use disturbances, altered hydrologies, and introduction of non-native species. Each strategy draws from research in limnology and river and wetland ecology. Ideally, freshwater protected areas should be located in intact catchments, should have natural hydrological regimes, and should contain no non-native species. Because optimal conservation conditions are often difficult to attain, we also suggest alternative management strategies, including multiple-use modules, use of the river continuum concept, vegetated buffer strips, partial water discharges, and eradication of exotic species. Under some circumstances it may be possible to focus freshwater conservation efforts on two key zones: adjacent terrestrial areas and headwaters.

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

Literature Cited For All Sections

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 Project. GAP Analysis Bulletin 7:21-22.

Meixler, M.S. and M.B. Bain. 1999. Application of GAP analysis to aquatic biodiversity Conservation: A pilot study by the New York Cooperative Fish and Wildlife Research Unit. Final project report by the New York Cooperative Fish and Wildlife Research Unit, Cornell University, Ithaca, NY to the U. S. Geological Survey, GAP Analysis Program.

Morrison, S.S., D.R. Passino-Reader, D.N. Myers, J.E. McKenna, J. Stewart, B.C. Scudder, K. Lohman. 2003. FACT SHEET: Great Lakes Regional Aquatic GAP Analysis - Preserving Biodiversity in the Great Lakes Basin. Great Lakes Science Center Fact Sheet 2003-1. 6 pp.

Myers, W., J. Bishop, D. Argent, R. Brooks, T. O'Connell, J. Stauffer, R. Carline. 2000. Landscape indicators of aquatic habitat and ordination by habitat availability. Pennsylvania State University, University Park, PA. Research Powerpoint presentation http://www.orser.psu.edu/PAGAP/publications/powerpoints/aquatic_habitat_files/frame.htm. Presented at National GAP 2000.

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.