

ACQUATIC

Applications of a Broad-Spectrum Tool for Conservation and Fisheries Analysis: Aquatic Gap Analysis

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Introduction

Natural resources support all of our social and economic activities, as well as our biological existence. Humans have little control over most of the physical, biological, and sociological conditions dictating the status and capacity of natural resources in any particular area. However, the most rapid and threatening influences on natural resources typically are anthropogenic overuse and degradation. In addition, living natural resources (i.e., organisms) do not respect political boundaries, but are aware of their optimal habitat and environmental conditions. Most organisms have wider spatial ranges than the jurisdictional boundaries of environmental agencies that deal with them; even within those jurisdictions, information is patchy and disconnected. Planning and projecting effects of ecological management are difficult, because many organisms, habitat conditions, and interactions are involved. Conservation and responsible resource use involves wise management and manipulation of the aspects of the environment and biological communities that can be effectively changed. Tools and data sets that provide new insights and analysis capabilities can enhance the ability of resource managers to make wise decisions and plan effective, long-term management strategies. Aquatic gap analysis has been developed to provide those benefits.

Gap analysis is more than just the assessment of the match or mis-match (i.e., gaps) between habitats of ecological value and areas with an appropriate level of environmental protection (e.g., refuges, parks, preserves), as the name suggests. Rather, a Gap Analysis project is a process which leads to an organized database of georeferenced information and previously available tools to examine conservation and

other ecological issues; it provides a geographic analysis platform that serves as a foundation for aquatic ecological studies. This analytical tool box allows one to conduct assessments of all habitat elements within an area of interest.

Aquatic gap analysis naturally focuses on aquatic habitats. The analytical tools are largely based on specification of the species-habitat relations for the system and organism group of interest (Morrison et al. 2003; McKenna et al. 2006; Steen et al. 2006; Sowa et al. 2007). The Great Lakes Regional Aquatic Gap Analysis (GLGap) project focuses primarily on lotic habitat of the U.S. Great Lakes drainage basin and associated states and has been developed to address fish and fisheries issues. These tools are unique because they allow us to address problems at a range of scales from the region to the stream segment and include the ability to predict species-specific occurrence or abundance for most of the fish species in the study area. The results and types of questions that can be addressed provide better global understanding of the ecological context within which specific natural resources fit (e.g., neighboring environments and resources, and large and small scale processes). The geographic analysis platform consists of broad and flexible geospatial tools (and associated data) with many potential applications.

The objectives of this article are to provide a brief overview of GLGap methods and analysis tools, and demonstrate conservation and planning applications of those data and tools. Although there are many potential applications, we will highlight just three: (1) support for the Eastern Brook Trout Joint Venture (EBTJV), (2) Aquatic Life classification in Wisconsin, and (3) an educational tool that makes use of Google Earth (use of trade or product names does not imply endorsement by the U.S. Government) and Internet accessibility.

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General Method

The basic development of an aquatic gap “analysis platform” follows the process of (1) data collection and organization, (2) identification and characterization of species-habitat relations, (3) predictive model construction, and (4) application of predictions to each stream reach within each drainage. GLGap is designed for evaluation of habitat condition influence on potential fish distributions at the Aquatic Ecological System (Sowa et al. 2007) (~8- or 10-digit Hydrologic Unit Code (HUC) or combination) or larger scale, but model predictions are made at the stream segment level (confluence-to-confluence). The empirical models designed to represent the species-habitat relations are a significant advancement of our ability to predict where stream conditions should be appropriate for support of various fish species. More than 100 species models have been developed for Great Lakes Basin stream habitats; most are highly reliable, explaining more than 75 percent of variation in the model development data (McKenna et al. 2006; Steen et al. 2006; J. Lyons, Wisconsin Department of Natural Resources, written commun. 2008). The drainage-wide projections provide a map of fish distribution patterns (and data-permitting abundances) and associated habitat conditions. Model predictions and the organized databases provide the analytical platform needed to address many questions about sampling distributions, habitat conditions and suitability, and biodiversity potential at large and small spatial scales. Applications of our model projections have already provided a wide range of benefits to natural resource management agencies, conservation groups, and scientific investigators.

Example Applications

Eastern Brook Trout Joint Venture

The Eastern Brook Trout Joint Venture is a coalition of agencies and organizations attempting to evaluate the status of brook trout (*Salvelinus fontinalis*) throughout its entire native range (EBTJV 2007). The EBTJV is a scientifically-based effort to provide a comprehensive range-wide conservation and education strategy that will assist all partners in effectively addressing common large-scale threats to brook trout and their habitat. Published work, available data, and expert knowledge were used to: (1) estimate the presence of brook trout in major drainage units of the eastern U.S., (2) determine the extant range of heritage strains of brook trout, and (3) identify those populations most in need of conservation (e.g., protection, rehabilitation, and reintroduction). Several specific EBTJV

partner objectives are ideally accomplished by use of aquatic gap analysis tools and data, particularly assessing the status, trends, and changes in distribution of brook trout populations and identifying data needed to facilitate species conservation and management. GLGap also may be used to identify threats and potential solutions, assist resource managers in action prioritization based on indices of need, and share information and successes with partners and others. GLGap predictions also provide a reasonable benchmark of habitat potential (to support a particular fish species) with which future changes (restoration-induced or other) may be compared for monitoring and reporting purposes.

EBTJV efforts have been successful from Maine to Georgia. However, knowledge and information gaps remain. Even the most knowledgeable experts were unsure of the presence or status of brook trout within parts of their jurisdictions. For example, within the New York Department of Environmental Conservation (NYDEC) Region 7 (which includes the U.S. Route 81 corridor from Binghamton, NY to Syracuse, NY), there are about 11,000 km of stream habitat, divided into 6,348 stream reaches (defined as confluence-to-confluence based on 1:100,000 scale National Hydrography Data [NHD]). Extensive survey effort has provided samples of fish assemblage composition and brook trout occurrence and abundance from 8 percent of total stream length, within 86 percent of the Region 7 watersheds; brook trout status remains unknown in 14 percent of the watersheds (Figure 1).

The NYDEC and EBTJV are interested in filling those knowledge gaps for brook trout in the most effective way. GLGap’s multiscale model predictions provide both relatively fine- and coarse-scale indices of potential occurrence and relative abundance of brook trout within any stream segment. The GLGap model for brook trout in Central New York accounts for more than 90 percent of variation in brook trout data from the NYDEC Statewide Fisheries Database (McKenna et al. 2006). Preliminary evaluation of those predictions by comparison with field collections and expert review indicate a good correspondence with knowledge of brook trout habitat in selected areas of Central New York. Based on model predictions, past field collections are being evaluated with regard to locations of expected optimal brook trout habitat. The predictions also are being used to allocate field sampling effort, within the “known” regions. Results of field collections will be used to improve the EBTJV assessments and the GLGap brook trout model. GLGap predictions and new information can be used to help the EBTJV develop a Conservation Strategy that identifies current threats to eastern brook trout, propose a general strategy to deal with these threats, monitor improvements, identify priority needs, and outline potential solutions.

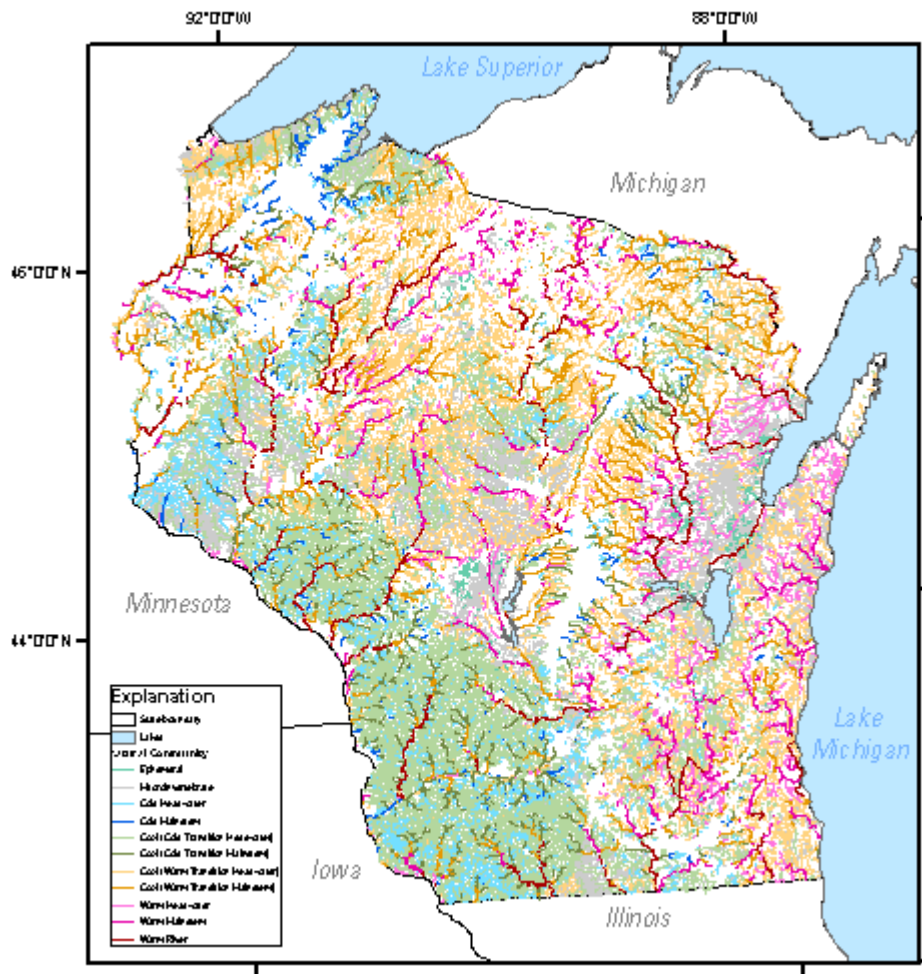


Figure 1. Part of south-central New York within the New York Department of Environmental Conservation, Management Region 7. Shaded polygon areas indicate known brook trout status (e.g., yellow areas are “Present Reduced”) based on expert knowledge. Black lines bound 8-digit hydrologic units with unknown brook trout status (white background). Colored lines within those areas indicate GLGap predicted potential brook trout abundance within each stream segment. The greatest potential for good brook trout habitat is in the red and orange reaches.

Aquatic Life Indices for Wisconsin Waters

Wisconsin streams range from icy spring-fed headwaters to the mighty Mississippi River, with an associated diversity of distinctive aquatic communities. In the absence of major human impacts, the occurrence and abundance of fishes and invertebrates in Wisconsin streams (and probably other Great Lakes systems) is determined largely by streamflow and water temperature (Lyons et al. 1988; Lyons 1989, 1996; Wang et al. 2003), particularly minimum summer streamflow and maximum daily water temperature.

Biotic classification can be built on these habitat conditions. However, until recently, broad use of the stream classification has been hampered by the lack of data on stream temperatures and flows for the vast majority of streams in Wisconsin and throughout the Great Lakes Basin. The geographic information system (GIS)-framework (Brenden et al. 2006) and associated water temperature and flow models created for Wisconsin as part of a joint effort between the GLGap Project and the Wisconsin Department of Natural Resources (in conjunction with the Michigan and Illinois Departments of Natural Resources) provide an ideal mechanism to apply the classification to all of the streams in the state. This framework divides all Wisconsin streams into approximately 36,000 discrete confluence-to-confluence reaches. Landscape variables (including geology, topography, channel connectivity, climate, and land cover/use) are associated with each reach at the channel, riparian, and watershed scales. Artificial neural network and multiple regression models were developed from these variables to predict maximum daily mean stream water temperature (Stewart et al. 2006) and annual 90 percent exceedence flow (L. Hinz, Illinois DNR, oral commun. 2006) for each reach. The temperature and flow models are about 67 percent and 70 percent accurate in validation tests, respectively.

The biotic community-habitat relationship was then used to develop a Wisconsin streams classification framework (Table 1). Preliminary trials indicate that this classification is useful for explaining variation in fisheries potential and biotic integrity, designing and implementing field monitoring, and guiding habitat and water-quality management (J. Lyons, Wisconsin DNR, written commun. 2006) (Figure 2). This natural community classification has nine primary classes and two major subdivisions of Coolwater (Cold-Transition and Warm-Transition), providing appropriate precision for fisheries management and other applications.

Table 1. Proposed water temperature and flow criteria for defining natural stream biological communities and the estimated total length of each natural community within the 86,897 kilometers of streams in Wisconsin.

[Abbreviations: km, kilometer; °C, degrees Celcius; m³/s, cubic meter per second; <, less than; >, more than]

Natural community	Maximum daily mean water temperature (°C)	Annual 90 percent exceedence flow (m ³ /s)	Estimated length of stream (km)
Ephemeral	Any	0.0	Not estimated
Macroinvertebrate	Any	0.0–0.00085	11,612
Cold headwater	<20.7	0.00085–0.0283	7,020
Cold mainstem	<20.7	>0.0283	1,184
Cool (cold-transition) headwater	20.7–22.5	0.00085–0.085	25,545
Cool (cold-transition) mainstem	20.7–22.5	>0.085	3,499
Cool (warm-transition) headwater	22.6–24.6	0.00085–0.085	19,535
Cool (warm-transition) mainstem	22.6–24.6	>0.085	6,567
Warm headwater	>24.6	0.00085–0.085	4,852
Warm mainstem	>24.6	0.085–3.117	3,789
Warm river	>24.6	>3.117	3,294

With the exception of ephemeral streams, which lack a fully developed aquatic biota, each natural community has a unique aquatic fauna. Only two of the communities, ephemeral and macroinvertebrate, do not consistently support fish. Of the remaining nine, eight apply to wadable streams and one (Warm River) to non-wadable rivers. Trout streams (an existing fish-based stream classification in Wisconsin) fall into six cold or cool, wadable natural communities, and occur from headwater to mainstem habitats. This stream classification system can be used to support Clean Water Act requirements and is being evaluated for implementation and application to Wisconsin natural resource management, as well as Great Lakes issues.

DEC Region 7 -- Brook Trout
Observed and Predicted Abundances and EBTJV Assessemnts

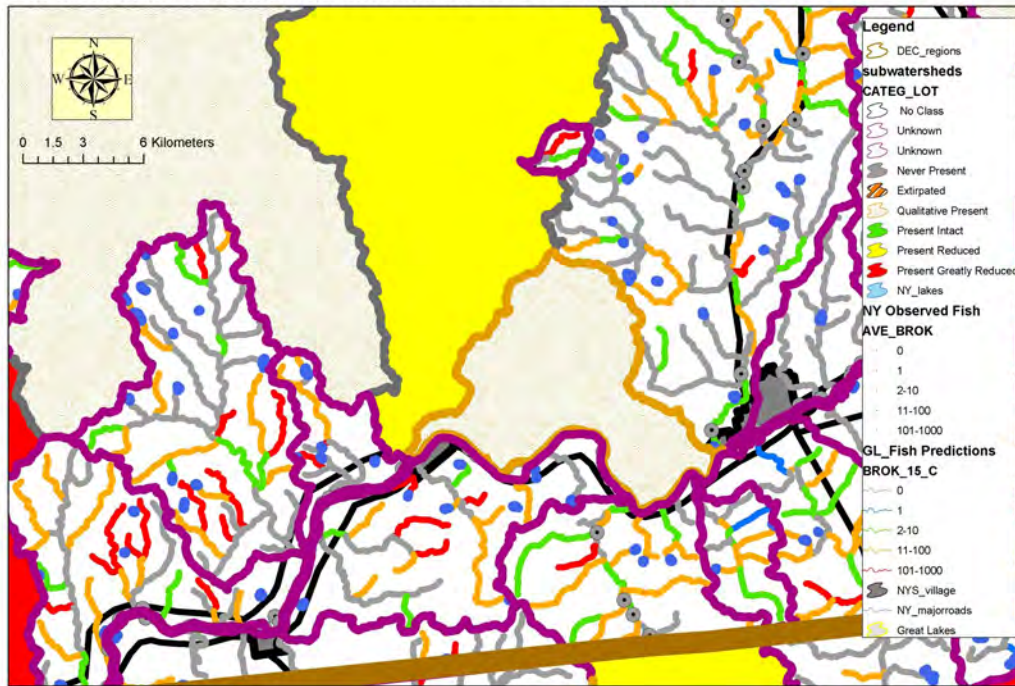


Figure 2. Proposed natural stream biological communities for Wisconsin. The resulting categories are based on predicted maximum daily mean stream temperature and annual 90 percent exceedence streamflow (Stewart et al. 2006; L. Hinz, Illinois DNR, oral commun. 2006). Base from 1:100,000 National Hydrography Data.

Fish in My Back Yard

Our third example demonstrates a means of displaying fish model predictions and informing the public about our tools and analyses. This application extends outreach efforts by using an existing medium (the Internet) and display tool (Google Earth). Google Earth is an interactive map program that allows users to view satellite/aerial imagery projected onto a three dimensional globe <<http://earth.google.com/>>. Given the sharp image, easy-to-use interface, and freeware nature of the program, Google Earth represents an innovative approach for viewing spatial data without the need to develop a specialized stand-alone mapping application. Groups and organizations can build new content (i.e., information about a topic that can be represented geographically) that can be overlain on top of the baseline satellite/aerial images using a simple text-based coding language called keyhole markup language (KML). KML files contain latitude and longitude points so that features can be spatially located onto the globe in Google Earth.

The GLGap Project has used Google Earth to display predicted fish communities linked to the 1:100K NHD stream network on top of satellite-aerial imagery of the Great

Lakes Region. The stream and fish overlays are based on GIS spatial data layers developed as a part of the GLGap Project (Brenden et al. 2006; McKenna et al. 2006; Morrison et al. 2003). Viewing GIS spatial data layers within Google Earth allows a user to clearly see how the stream network falls across the entire landscape. The readily available and viewable satellite-aerial imagery provide a realistic and familiar backdrop that is more informative than viewing individual vector representations (i.e., lines representing the hydrography network, road network, etc.) of the landscape alone. The imagery provides an opportunity to view features of the landscape such as streams, agricultural fields, high density urban development, roads, topographic characteristics, and other landscape or municipal jurisdictions simultaneously in a familiar context. The geographic extent of this pilot study is presently limited to Michigan's Lake Erie watershed. We converted 1:100,000 NHD stream layers to the KML format using a shareware program called Shp2kml <<http://www.zonums.com/shp2kml.html>>. The centroid latitude and longitude was obtained for each confluence-to-confluence stream reach. A Microsoft Excel macro was built that generated KML code based on the centroid position and fish species presence and absence predictions (Steen et al. 2008).

When viewed in Google Earth, this code shows a placemark at each centroid position (Figure 3). Clicking on a placemark will open a popup window that gives a list of the predicted fish species for that particular stream reach, a brief description and picture of the fish species, and links to other websites for

related information (Figure 4). The easy-to-use and realistic interface provided by Google Earth, in conjunction with overlays of predicted fish distributions, can help the public better understand the natural communities that surround them and provide awareness of projects like Aquatic Gap Analysis.

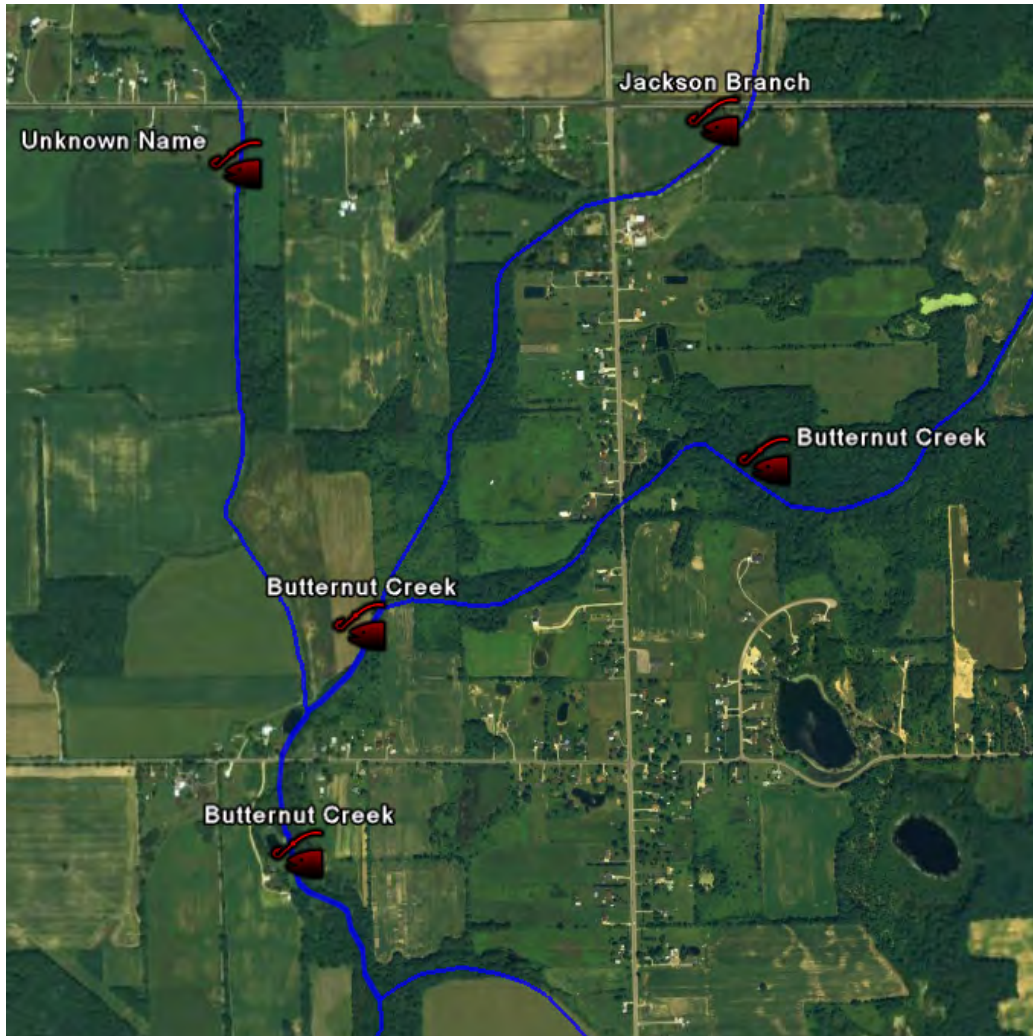

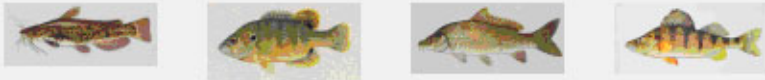


Figure 3. Screen capture from Google Earth over southeastern Michigan landscape, overlaid with 1:100,000 NHD stream network. The fish icons represent placemarks that can be queried. This map displays the utility of combining GIS vector data with satellite/aerial imagery to provide stream ecosystems with high definition and context from their surrounding landscape.

Stony Creek



Fish in My Backyard



Potential Fish Community:






Black Bullhead	The black bullhead tolerates severe environments.	Fish Information	Fish Model	 US Fish and Wildlife
Brook Silverside	Most species of silversides are marine, although this one is not. They have been seen leaping out of the water as if playing.	Fish Information	Fish Model	 James Ford Bell Museum of Natural History U of Minnesota
Brook Stickleback	Five sharp dorsal spines distinguish this species!	Fish Information	Fish Model	 James Ford Bell Museum of Natural History U of Minnesota
Central Mudminnow	This fish was once observed living in a dry horse pasture in the standing water left in footprints! They are tough.	Fish Information	Fish Model	 James Ford Bell Museum of Natural History U of Minnesota
Central Stoneroller	A vegetarian, its mouth is	Fish Information	Fish Model	

Figure 4. Popup window that provides information on the predicted fish community for a particular stream reach, including a picture, species descriptions, a link to more detailed species information, and a link to information about the predictive fish model used.

Conclusions

We present only a small sample of the potential applications of aquatic gap analysis data and tools. This basic analysis platform greatly extends our ability to examine large-scale ecological conditions in aquatic systems and provides coarse-scale filter and an opportunity to estimate fine-scale (1–10 km) conditions throughout the U.S. Great Lakes Basin. This platform of analytical tools and associated data represent a critical stepping stone to the next generation of data and analytical tools that will allow integration of spatial and temporal dynamics. This system provides the capability to address many real-time and long-term problems natural resource managers face every day.

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