6

Aquatic

The Aquatic Component of Gap Analysis

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Since the very beginning of Gap Analysis, there has been discussion on the need to apply the method to aquatic environments. The effort was officially launched in early September of 1994 with the formation of an advisory group. The group established the goal for the application of GAP methodology to aquatic environments as:

> "To characterize aquatic biodiversity in the U.S. on a landscape scale for the effective management of land and water resources in ways that will preserve this biodiversity."

Dr. Patricia Heglund has been appointed as the coordinator for the aquatic GAP section. She recently moved to Moscow, Idaho from Alaska, where she had spent the past seven years as a research biologist (wetlands and waterfowl) for the U.S. Fish and Wildlife Service - Alaska Fish and Wildlife Research Center (now the National Biological Service - Alaska Science Center). Dr. Heglund currently holds affiliate faculty status in both the Department of Fish and Wildlife Resources and the Department of Biological Sciences at the University of Idaho.

Three prototype projects have been funded for 1995. These projects will be conducted in New York, Washington, and California. These pilot projects are predicated on the same fundamental tenets as the terrestrial component of GAP: 1) to identify places offering the best opportunities to conserve species while they are still common, through the identification of species and their habitats currently under-represented within our conservation network; 2) to provide a baseline for later biogeographic comparison; and 3) to provide landscape level spatial data useful for holistic resource management. These pilot projects will include lacustrine, palustrine, and riverine environments.

Our objectives for these prototype studies include:

1. Acquiring EPA River Reach File III data for use as base maps and catalogs of river basins at a scale of 1:100,000. Base maps will be registered with corresponding terrestrial GAP base maps and corrected for errors in River Reach data sets.
2. Mapping known distributions of fish, macroinvertebrates, amphibians, and reptiles (hereafter referred to as "elements") from museum collection records, agency records, published literature, and other sources.
3. Mapping general predicted ranges of each element from the published literature (e.g. Freshwater Fishes of Canada).
4. Mapping general habitat types, for example, aggregated from National Wetlands Inventory database.
5. Identifying habitat relations models for each element from existing literature.

6. Combining the steps listed above to generate maps for each water body or river reach of known or predicted occurrences of each element.
7. Reviewing predicted occurrences with experts and revising data layers as appropriate.
8. Developing attributes for each river reach, identifying its management status such as:

- county or state shoreline, or riparian management regulations,
- state fisheries management practices (fishing regulations, stocking, pesticide use, motorized/non-motorized boating regulations, etc.),
- state area-specific management designations (e.g., water quality, recreation, water withdrawals, aquatic vegetation management),
- federal designation and regulations (e.g., Wild and Scenic Act, Clean Water Act, navigation considerations, other licenses and permits such as NPDES or FERC, federal structures).

9. Showing relations between, a) species distributions and in-stream management, and b) species distributions and terrestrial land cover between successive watershed sizes (fourth to second order watershed).
10. Determining where the best opportunities are to achieve long-term avoidance of threatened or endangered species status by both in-stream and watershed management.

Analyses will be conducted a second time when adjacent river basins are completed and their information is integrated, allowing for comparisons across larger biogeographic regions.

One of the most exciting aspects in developing the aquatic component of GAP is the construction of data sets compatible with the terrestrial data. Through the GAP process, we will integrate aquatic and terrestrial environments for a variety of analytical applications. For example, the data will show land cover for all second-order watersheds upstream of any given river reach. Although we expect others to find many uses for the data, our current goals are to: 1) conduct an initial screening of large areas from which more specific planning and management options can be developed within a bioregional context, and 2) provide a logical starting point at the landscape scale for conservation problem-solving.

In discussions about both the terrestrial and aquatic components of GAP, the question frequently arises, "What about riparian areas?" Our current position is that although riparian areas are of enormous importance, they cannot be adequately treated by our current level of funding. Adequate treatment of riparian areas requires a level of effort similar to the National Wetlands Inventory program, in that they should be mapped at a scale of at least 1:24,000. Given our funding constraints, we believe it is more productive to focus on landscape elements that can be adequately treated and continue to articulate the needs of those elements that are currently beyond our means.

As with terrestrial GAP, the aquatic component is starting with no generally accepted community- based habitat classification system. As with the land cover mapping effort, we hope the aquatic projects will spur a consensus about the structure and substance for a national classification system and how the system can be maintained over time.

In Pursuit of the Aquatic Component of Gap Analysis

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While GAP has made huge strides in developing information on the biogeography of terrestrial environments for conservation assessments, much less has been accomplished for aquatic environments. The program's initial focus on terrestrial vertebrates and vegetation types was a choice based on what was achievable at that early time in our history. The issue is not which components of biodiversity we might specialize in, rather, how to pragmatically implement gap analysis. In principle, GAP is committed to developing biogeographic information for all species and habitats. How else could we claim to be in the business of assessing the conservation status of biodiversity?

The need to apply the GAP methodology to aquatic environments is now, more than ever, crucial to the survival of many aquatic species. The Nature Conservancy (TNC 1966) estimates that 68 percent of all freshwater mussel species, 51 percent of crayfish species, 40 percent of amphibian species, and 39 percent of freshwater fish species are either vulnerable, imperiled, critically imperiled, or presumed extinct. These numbers of endangerment for aquatic organisms eclipse comparable figures for terrestrial taxa (about 15 percent of mammals and birds combined are endangered). Yet, the information required to relate species distributions to biodiversity management is still poorly organized for most states.

Determining gaps in the management of aquatic biodiversity begins by integrating the GAP terrestrial data, such as land cover and land management, with the following suite of aquatic data sets:

(a) the National Hydrography Dataset (includes the EPA River Reach File; see http://nhd.fgdc.gov/nhdpgs/), which is the spatial framework for aquatic features;
(b) distributions of species by river reach;
(c) the bundle of management scenarios for each river reach, such as county zoning set-back requirements, sport fish stocking, or state water quality regulations;
(d) the distributions of aquatic habitat types by river reach.

One of the most significant contributing factors to the continued demise of aquatic biodiversity is that terrestrial and aquatic environments have been, and still are, managed as separate entities. An important opportunity in developing the aquatic component of Gap Analysis is in creating seamless land-water data sets. As demonstrated by GAP products for terrestrial environments, the combined terrestrial and aquatic data sets will not only be used to identify aquatic biodiversity conservation gaps, they will also be used iterative in everyday land and water management choices as well as opportunistically in ways we have not thought of.

The need for developing the aquatic component of GAP was recognized as early as 1993, when the funds needed to support the effort were allocated by Congress. Those funds, however, were rescinded by the 1994 Congress. GAP still managed to initiate development of an aquatic component of the program in 1995 with the start of a pilot project in the upper Allegheny River Basin in Western New York. This project succeeded in providing a fully developed and practical working example of GAP methodologies applied to aquatic habitats at the river basin scale. For more information, go to the aquatic link on the GAP home page (http://www.dnr.cornell.edu/hydro2/Aquagap.htm) or contact Mark Bain <mbb1@cornell.edu>.

In 1996, in partnership with the Missouri Resources Assessment Partnership (MoRAP) and the USGS National Water Quality Assessment program (NAWQA), a statewide pilot was initiated in Missouri. Recently, the Department of Defense has joined with the BRD in supporting this project. The Missouri project is assessing aquatic biodiversity at the regional, watershed, and "valley-segment" (Lammert et al. 1997) scales. A major emphasis is on identifying opportunities and techniques for integrating conservation assessments conducted separately for terrestrial and aquatic environments, as well as integrating the foundation data sets for combined analyses. For more information on this project see MoRAP Projects at <http://www.msc.nbs.gov/morap/projects/projects.html#marp>, or go to the MoRAP web site by clicking on Missouri from GAP's State Project Information page, or contact Scott Sowa <scott_sowa@usgs.gov>.

Although a single discrete source of funds for the development of aquatic data sets in each state has not surfaced (and probably will never come as one sum), this year the BRD awarded competitive funds from its Ecosystem Initiative Program to develop a strategy for making the transition from the pilot project phase to a nationwide program, and to develop the broad-based support needed. This effort will begin with a series of regional workshops to assess the information needs of state and federal agencies, nongovernment organizations, and the academic community. The outcome of these workshops will be to establish a network of communications and support and a series of guidance documents (i.e., a GAP Handbook Chapter for aquatic environments). Stay tuned for a workshop near you in 1998. For more information about this activity contact Tom Muir <tmuir@usgs.gov>.

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Making Gap Analysis Work for New York Waters: A State Perspective on Aquatic GAP

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A review of the New York Aquatic GAP pilot project ("Making GAP Analysis Work for New York Waters" workshop) was held in December 1997 with natural resource agencies in New York. The workshop was attended by representatives of many bureaus and offices of the New York Department of Environmental Conservation (NYDEC): Hudson Valley region, marine resources, habitat protection, fisheries, bioassessment and monitoring, and water resources. Representatives of the New York offices of the U.S. Fish and Wildlife Service, The Nature Conservancy, and the U.S. Geological Survey also participated. Our aim was to present the methods developed in the pilot project for the aquatic component of GAP in New York to a select group of agency representatives, to recommend actions, and to obtain their thoughts and ideas for applying gap analysis to all New York waters. The event worked well because the attendees were interested in and enthusiastic about the application of GAP methods to aquatic environments. They readily contributed ideas on how to enhance the GIS models, enhance the pilot project to better meet their agency's needs, and apply GAP to real management issues in New York. The workshop discussions also posed some challenges to making "aquatic" GAP a highly state-relevant technology.

An encompassing notion that emerged was that national programs and within-state perspectives often contrast. The National GAP Program seeks to develop standardized methods to be applied broadly and consistently across the nation for the purpose of identifying biodiversity conservation priorities—this purpose requires methods that are general, broad-scale, and oriented to diversity of species. NYDEC and other state agencies see the greatest gain in GIS efforts aimed at specific kinds of problems (e.g., streamside buffers, bank erosion, vegetation beds), fish species and life stages, and assessing threats of a site-specific nature. Further, it was noted that the GAP Program counts geographic coverage as a measure of accomplishment, and the workshop attendees recommended that the geographic scope of future work be either halted or reduced. The top priority of workshop attendees was to see the GAP models tested and perfected in a limited area using data that is already assembled and detailed, targeted field surveys. Consequently, some hard thinking by workshop attendees was needed to see a way to closely mesh state and federal interests in this program.

In the interest of integrating GAP technology with state needs and priorities, three general themes were raised in the many comments offered during the review. First, the GAP Program's focus on high species diversity as a measure of management priority was not seen as central in the issues or approach of New York agencies. Agency representatives were largely interested in fish species and often just one life stage (e.g., spawning) of some species. This species-oriented perspective would call for model development aimed at very specific habitats, which differs from the GAP approach of mapping habitats associated with species and communities. Some means of addressing diversity and communities while retaining predictive power for species and life stages of economically important species will be needed to blend national and state-level needs.

A second issue was the scale of GAP technology development and application. The GAP Program aims at developing broad-scale habitat coverages for states or regions, but this does not match the scale of management issues on the agendas of state agencies. Some way is needed to use a GIS system to simultaneously provide broad spatial coverage and do fine-scale applications. Finally, the GAP Program's development approach is to complete statewide habitat coverages and learn how to best use those for identifying conservation "gaps." The workshop attendees strongly favored model development, testing, and refinement in a limited area before moving to statewide coverages. Some sort of dual development approach is needed to balance model refinement and validation with expanding spatial coverage.

Despite the differences in perspectives, almost everyone at the workshop realized the utility and potential applications of predicting biota from remotely sensed data and mapped habitats. This is the basic philosophy of GAP, and no suggestions were made to abandon it. Also, there was no sentiment for the apparent alternative GIS development mode of consolidating aquatic biosurvey data to map known species distributions. New York agencies have extensive biological survey data, there are established programs maintaining this information, and most of it is in computer databases. The inconsistencies identified in the workshop dealt only with the level of biological predictions (diversity vs. species), the scale of development (statewide vs. limited area), and the initial development approach (statewide coverage construction vs. validated protocol refinement).

The leadership of the NYDEC is committed to seeing aquatic GAP continue in the state, and it has made a commitment to shared support of GAP. With the workshop results in mind, a joint USGS (NY Coop Unit) and NYDEC proposal was formed for the continued development of aquatic GAP in New York. Some changes in the methods of our pilot project were identified to make aquatic GAP serve a diversity of needs while retaining the basic attributes of the National GAP Program. Building greater prediction flexibility into the GAP protocol would bridge the need to address species diversity and species-specific mapping. Unlike terrestrial GAP that largely relies on satellite data, aquatic GAP used a variety of data that we mapped in categorical form, such as shaded or open canopy cover, high or low gradient, and stressful or suitable water quality. The use of continuous data (e.g., gradient in m/km rather than high and low slope) on a variety of parameters (canopy cover, water quality, channel structure, etc.) would greatly enhance the capability of GAP models to deal with varied prediction needs. We already developed GIS tools to automate the acquisition of continuous form data for GIS modeling. Prediction algorithms would differ for species and diversity, and a subset of variables with optimized weighting could be developed for each use. The workshop promoted a staged approach to developing GAP coverages in New York; that is, expand state-level coverage by developing coverages basin by basin across the state. This approach allows both expanded GAP coverage while working in watersheds with extensive data useful in model testing and refinement.

The proposed USGS/NYDEC Aquatic GAP Project would develop the GIS software and protocols for implementing an automated system and developing prediction equations. The national aquatic GAP methods, developed over time with experiences in several states, would include a set of GIS data layers to develop and how (the GIS structure), a set of classification equations for national-scale syntheses (National GAP classification rules), and a protocol for developing study and species-specific predictions (habitat classification optimization). If the mathematical formats were standardized, a wide variety of uses could be accommodated depending on user interests without separate development efforts. The "Making GAP Work for New York Waters" workshop raised tough questions about the basic aquatic GAP approach. The new ideas presented in the joint USGS/NYDEC proposal could not have been developed without the input of the New York agencies.

Applying Gap Analysis Towards the Protection of an Endangered Species of Minnow (Notropis topeka) in South Dakota

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Introduction

The Topeka shiner (Notropis topeka) is a minnow (family Cyprin- idae) found in low-order streams in six Great Plains states (Iowa, Kansas, Minnesota, Missouri, Nebraska, South Dakota). The U.S. Fish and Wildlife Service listed the species as endangered in 1999 (Tabor 1998). The species has declined because of habitat deterio- ration and predation by stocked fish.

We are applying GAP procedures (Scott et al. 1993) to aid resource managers in protecting the Topeka shiner. Since the South Dakota GAP project began in 1997, we have completed digital maps of mammal distributions, land cover (eastern South Dakota), and stew- ardship. We are expanding the GAP study to include aquatic eco- systems, using the Topeka shiner study as a pilot project. We report here our progress after one field season.

The goal of our study is to analyze the habitat at locations where the Topeka shiner has been historically found, and use the data to predict river reaches where the species may be present or absent. Specific objectives are to:

1. Measure local habitat and landscape features at Topeka shiner sites.2. Compare Topeka shiner habitat features to maps of these fea- tures available in GIS databases.3. Conduct fish sampling in areas suggested by mapping.

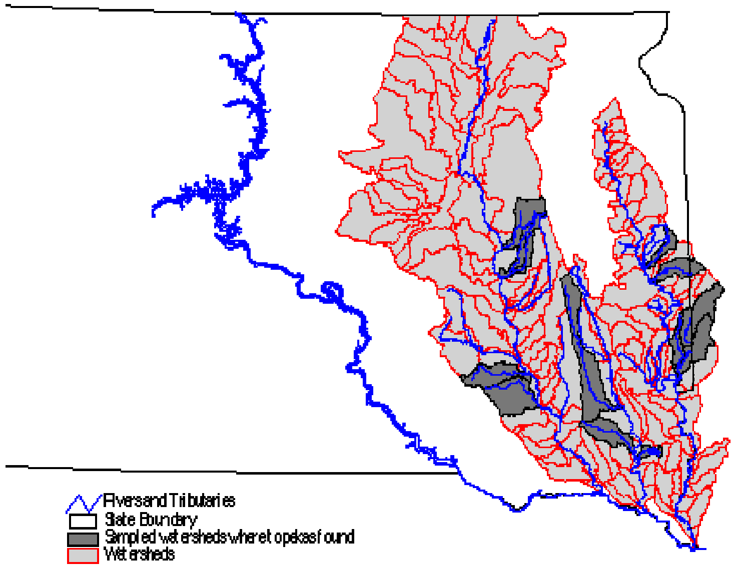

Figure 1. Watersheds where Topeka shiners were found during 1999 field season.

Life History of the Topeka Shiner

The ecology of the Topeka shiner is not well known. Oldest indi- viduals are usually three years of age and have grown to about 7 cm long. Topeka shiners prey on benthic invertebrates and spawn over silt-free substrates in spring. A striking characteristic of the spe- cies is the bright reddish-orange coloration of the breeding male. In South Dakota, the shiner has been found in tributaries of the James, Vermillion, and Big Sioux rivers east of the Missouri River (Figure 1). Topeka shiners also have been recorded from down- stream portions of tributaries to the Missouri River (e.g., Grand River) in western South Dakota (Beckman and Elrod 1971).

The preferred habitat of Topeka shiners has not been definitively determined, but the species may prefer prairie streams with good water quality (Tabor 1998). Topeka shiners have been found in pool habitats that are maintained by perennial flows or groundwa- ter seepage (Pflieger 1975, Cross and Collins 1995). Stream bot- toms range from silt to cobble (Tabor 1998).

Prairie streams of eastern South Dakota typically have highly vari- able flow rates, and some streams are intermittent (Poff and Ward 1989). Fish communities in such streams are largely affected by abiotic factors (Poff and Ward 1989), which may be systemic (e.g., climate) or local (e.g., channel shape). The methods below de- scribe how we plan to apply GAP procedures, using systemic and local variables that affect fish distribution, to determine the habitat requirements of Topeka shiners and the probable distribution of the species.

Methods and Progress

The study can be divided into two parts (Figure 2). One part in- volves the collection and analysis of field data to measure local habitat and landscape features at locations where the Topeka shiner has been recently found (Braaten 1993, Cunningham 1999). The second part involves GIS analysis to predict streams where Topeka shiners might be found.

Field Methodology - A total of 31 historical sites were sampled during the 1999 field season. At each site physical stream habitat, hydrology, water quality conditions, and landscape features were measured (see Simonson et al. 1993 and Platts et al. 1983 for meth- odology). Fish were collected by seining. The abiotic and biotic variables will be analyzed to determine the habitat affinities and the fish community associations of the Topeka shiner. A similar study was conducted by Matthews (1985) to classify sites inhab- ited by eight common midwestern stream fishes. The habitat af- finities will be incorporated into a model to predict

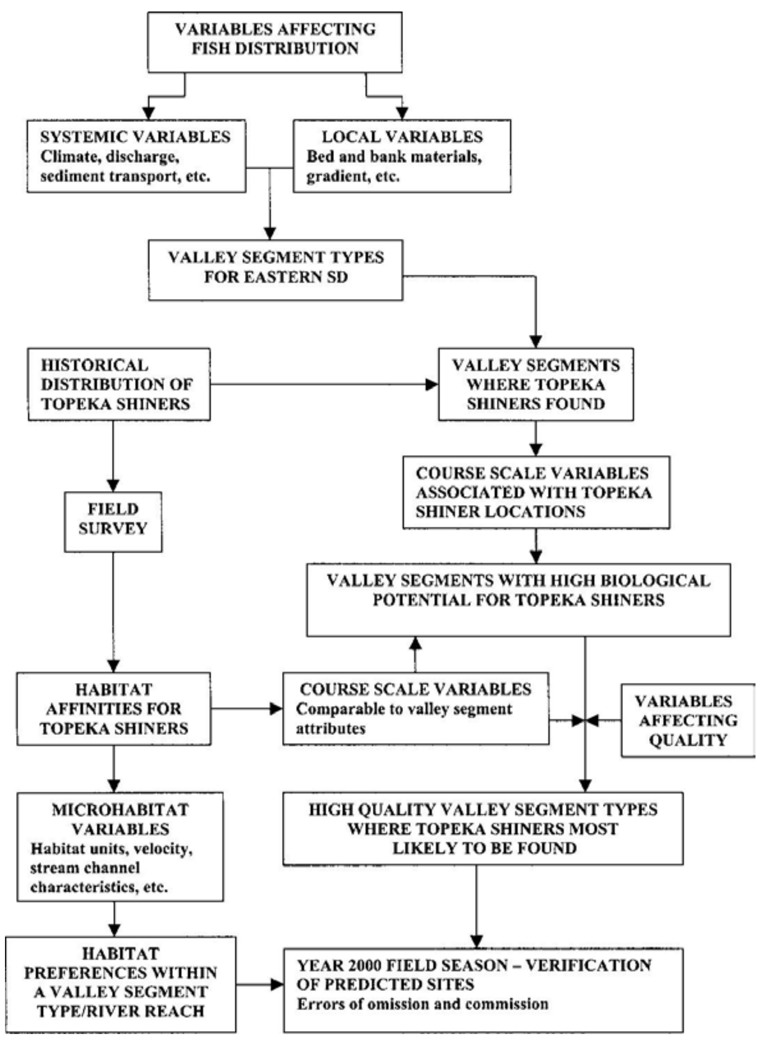

Figure 2. Diagram showing the methods to be used for modeling the distribution of Topeka shiners.

Table 1. Fish community found in watersheds where Topeka shiners were present.

	JAMES RIVER BASIN						VERMILLION RIVER BASIN			BIG SIOUX RIVER BASIN			
	Mid. Pearl	Shue	Pearl	Enemy	Twelve Mile	Firesteel	W. Fork Vermillion	Turkey Ridge	Blind	Six Mile	W. Pipestone	Pipestone	Split Rock
Topeka shiner	x	x	x	x	x	x	x	x	x	x	x	x	x
Plains topminnow					x								
Black bullhead	x	x	x	x	x	x	x	x	x	x		x	x
Tadpole madtom		x	x			x	x	x		x		x	
Channel catfish						x						x	
Stonecat												x	
Orange-spotted sunfish	x	x	x	x	x	x	x	x	x	x		x	x
Green sunfish	x		x			x	x	x	x	x		x	
Largemouth bass							x		x		x		
Bluegill									x				
Black crappie						x							
White crappie						x							
Northern pike							x	x				x	x
Blacknose dace										x			
Longnose dace				x									
Johnny darter	x				x		x	x		x			x
Blackside darter												x	
Red shiner	x	x	x	x	x	x	x	x	x	x	x	x	x
Common shiner	x		x	x	x		x		x	x	x	x	x
Sand shiner	x	x	x	x	x	x	x	x	x	x	x	x	x
Bigmouth shiner	x		x	x	x	x	x		x	x	x	x	
Emerald shiner								x					
Fathead minnow	x	x	x	x	x	x	x	x	x	x		x	x
Bluntnose minnow			x								x	x	x
Brassy minnow	x	x	x		x			x	x	x			
Plains minnow				x									
Creek chub	x	x	x	x	x	x	x		x	x	x	x	x
White sucker	x	x	x	x	x	x	x	x	x	x	x	x	x
Shorthead redhorse						x	x			x			x
Common carp		x		x	x		x	x	x		x	x	x
River carpsucker													x
Central stoneroller	x	x	x	x	x				x	x			

the distribution of Topeka shiners.

We found Topeka shiners at 60% of the historic sites visited in 1999. Sample size of Topeka shiners ranged from 1 to 95 per site. Topeka shiners were found with 9 to 17 other fish species (Table 1). The fish community was dominated by cyprinids (minnows). Red shin- ers and sand shiners were present in large numbers at all sites where we found Topeka shiners. Predators were not commonly associ- ated with Topeka shiners, with the exception of orange-spotted sun- fish and green sunfish, which may provide silt-free gravel for To- peka shiner spawning (Pflieger 1975).

GIS Analysis –

Field data will be combined with climatic and hydrogeomorphic variables for GIS analysis. The procedures we are using closely follow those proposed by Sowa (1999a) for aquatic gap analysis. The first step involves determining what attributes or driving variables are most important for shaping the distribution of aquatic communities (Higgins et al. 1999) in eastern South Dakota. Expert opinion indicated that these variables were hydrology, to- pography, geology, climate, and landscape.

The next step involves identifying an assessment element. The as- sessment element that will be used in our study is valley segment type (Sowa 1999a), which will be delineated using The Nature Conservancy's hierarchical classification system (Lammert et al. 1996). Valley segment types will be delineated by combining hy- drological, topographical, geological, and climatic variables in a GIS environment to predict the potential biological community of each specific stream segment for eastern South Dakota.

Once the valley segment types are delineated, the next step involves selecting valley segments that might contain suitable Topeka shiner habitat. A list of habitat affinities for the Topeka shiner will be generated from the associated attributes found in the field and through GIS analysis of valley segments where Topeka shiners are present. Valley segments that match the habitat affinities of Topeka shiners will be queried out and classified as having high, moderate, or low potential for Topeka shiners.

The next step involves determining which of these valley segments classified as potential Topeka shiner habitat are in areas that are considered "high quality." The quality of an area will be deter- mined by comparing landscape features such as land cover, land use, stewardship, water quality, and physical modifications with valley segments using GIS analysis (Sowa 1999b).

Future Plans

Once we identify valley segments that might have Topeka shiner habitat, a field survey will be performed to verify the predictive power of the model and detect any errors of omission or commis- sion. GIS analysis will continue by comparing the location of streams and watersheds that could potentially contain Topeka shin- ers with land stewardship maps to identify any "gaps" in the pro- tection of the shiner.

Conclusion Sparse collections of a rare animal can hamper a study, so we were happy to find that Topeka shiners were fairly common and wide- spread. We expect that applying gap analysis techniques to the

Topeka shiner data will be fruitful. However, the flat topography and lack of some basic geologic, hydrologic, and water quality data may make aquatic gap analysis difficult. Federal and state agen- cies have specific needs that can be met by GAP products. The identification of streams and watersheds that contain high-quality Topeka shiner habitat will help determine critical habitat and fur- ther determine the distribution of the shiner. The recognition of "gaps" in land/water use management will enable agencies to de- cide where best to implement conservation priorities to effectively protect the Topeka shiner. Finally, maps classifying streams as high-, moderate-, or low-quality habitat for Topeka shiners will allow agencies to streamline the endangered species consultation process.

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