Gap Analysis Program

Ohio Aquatic Gap Analysis—An Assessment of the Biodiversity and Conservation Status of Native Aquatic Animal Species

By S. Alex. Covert, Stephanie P. Kula, and Laura A. Simonson

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Conversion Factors

Multiply	By	To obtain
	Length	
inch (in.)	25.4	millimeter (mm)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Area	
square kilometer (km^2)	247.1	acre
square kilometer (km^2)	0.3861	square mile (mi^2)

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:
°C=(°F-32)/1.8

Abbreviations and Acronyms

14-HU	14-Digit Hydrologic Unit
AML	Arc Macro Language
BRD	Biological Resources Discipline
CAD	Computer-Aided Design
DLG	Digital Line Graph
EDU	Ecological Drainage Unit
ESRI	Environmental Systems Research Institute
GAP	Gap Analysis Program
GARP	Genetic Algorithm for Rule-Set Production
GIS	Geographic Information Systems
HU	Hydrologic Unit
NAD	North American Datum
NED	National Elevation Dataset
NGO	Nongovernment organization
NHD	National Hydrography Dataset
NLCD	National Landcover Dataset
NPS	National Park Service
NRCS	National Resources Conservation Service
ODNR	Ohio Department of Natural Resources
ODOT	Ohio Department of Transportation
Ohio EPA	Ohio Environmental Protection Agency
OH-GAP	Ohio Aquatic GAP Project
RTE	Rare, Threatened, or Endangered
STORET	USEPA Storage and Retrieval Database
TNC	The Nature Conservancy
USDoD	U.S. Department of Defense
USEPA	U.S. Environmental Protection Agency
USDA-FS	U.S. Department of Agriculture, Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator
XTRAP	Extrapolation Method

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Executive Summary

The goal of the GAP Analysis Program is to keep common species common by identifying those species and habitats that are not yet adequately represented in the existing matrix of conservation lands. The Gap Analysis Program (GAP) is sponsored by the Biological Resources Discipline of the U.S. Geological Survey (USGS). The gap analysis methods were conceived in the late 1980's and this now National program has traditionally been implemented on a state-by-state project basis with the involvement of people from state agencies and academia. All states except Alaska have completed or are conducting a terrestrial GAP project focusing on vertebrate biodiversity. More recently, GAP efforts have moved towards regional and aquatic projects. The Ohio Aquatic GAP (OH-GAP) is a pilot project that is applying the GAP concept to aquatic—specifically, riverine—data.

The mission of GAP is to provide regional assessments of the conservation status of native animal species and to facilitate the application of this information to land-management activities. OH-GAP accomplished this through

- mapping aquatic habitat types,
- mapping the predicted distributions of fish, crayfish, and bivalves,
- documenting the presence of aquatic species in areas managed for conservation,
- providing GAP results to the public, planners, managers, policy makers, and researchers, and
- building cooperation with multiple organizations to apply GAP results to state and regional management activities.

Gap analysis is a coarse-scale assessment of aquatic biodiversity and conservation; the goal is to identify gaps in the conservation of native aquatic species. It is not a substitute for biological field studies and monitoring programs.

Gap analysis was conducted for the continuously flowing streams in Ohio. Lakes, reservoirs, wetlands, and the Lake Erie islands were not included in this analysis. The streams in Ohio are in the Lake Erie and Ohio River watersheds and pass through six of the level III ecoregions defined by Omernik(1987): the Eastern Corn Belt Plains, Southern Michigan/Northern Indiana Drift Plains, Huron/Erie Lake Plain, Erie Drift Plains, Interior Plateau, and the Western Allegheny Plateau.

Stream Classification and Mapping of Aquatic Habitat Types

To characterize the aquatic habitats available to Ohio fish, crayfish, and bivalves, a classification system needed to be developed and mapped. Classification simplifies, yet attempts to reflect, the complexity of the real world. The process of classification includes delineation of areas of relative homogeneity and labeling these areas using categories defined by the classification system.

To classify Ohio's streams, OH-GAP focused on mapping physical characteristics that endure for decades, if not centuries. Through discussions with Ohio aquatic experts, OH-GAP identified eight separate enduring physical features which, when combined, form the physical habitat type:

- Shreve link (a measure of stream size)
- Downstream Shreve link (a measure of stream connectivity and size)
- Sinuosity
- Gradient
- Bedrock
- Stream temperature
- Character of glacial drift
- Glacial-drift thickness

The variables were linked to the 1:100,000-scale streams of the National Hydrography Dataset of the USGS. OH-GAP's classification scheme consisted of the concatenation of values for each of the eight separate variables into a unique combination of numbers to describe a physical habitat type. The values for the separate variables are maintained in the final habitat type, allowing for the straightforward comparison of two or more physical habitat types. Results of the stream classification reveal 5,269 separate physical habitat types within 65,545 river segments in Ohio. A segment is defined by a change in the value of one or more of the input variables or a topographical break, such as a tributary entering a stream. Based on total length, the top 100 physical habitat types constitute 33 percent of the streams in the state, and the top 300 types classify 54 percent of the streams. This result suggests that although more than 5,000 unique combinations of numbers are defined for Ohio, much of the state can be classified using far fewer habitat types.

Predicted Animal Species Distributions

Potential distribution models were developed for 130 fish, 70 bivalve, and 17 native crayfish species. These models are based on 5,686 fish, 4,469 crayfish, and 2,899 freshwater bivalve (mussels and clams) sampling locations, the variables describing the physical habitat types, and variables indicating the major drainage basins and Omernik's Level III ecoregion. The modeling software package DesktopGarp (Genetic Algorithm for Rule-Set Production) was used in most cases for predicting potential distributions of each species individually.

Using GARP, omission error (the error associated with misclassifying known species habitat locations) was forced to be less than 10 percent for each species. The commission error (the error associated with classifying habitat locations where the species was not found) ranged from 1 to 61 percent for fish, 6 to 70 percent for crayfish, and 1 to 57 percent for bivalves.

The best GARP models (as determined by omission and commission) were combined into one final Geographic Information System (GIS) grid of predicted presence and absence. There is a conscious effort in the GAP process to err on the side of commission. In other words, OH-GAP may predict species as potentially present when they are not. There are two primary reasons for doing so. First, few species have systematic, unbiased known ranges, and science is best served by identifying a greater potential for sampling and investigation than a conservative approach that may miss such opportunities. Second, what appears to be commission error may actually be unsampled locations. In the predictive models, GARP uses known presence points and background points, not known presence points and known absence points. The background points may or may not have been sampled.

A simpler extrapolation method was used for predicting potential distributions when a species had at least one but less than 20 known species-occurrence locations. This method is the product of overlaying or combining GIS layers (OH-GAP physical habitat types) and known biological occurrence points. All stream segments with the same physical habitat type as where the species was sampled were predicted to be potential habitat.

All potential species distributions are displayed and analyzed at the 14-digit hydrologic unit (14-HUs), or subwatershed, level. Mainland Ohio contains 1,749 14-HUs. All statistics and conclusions, as well as spatial data, are discussed and presented in terms of these units.

Land Stewardship and Conservation Status

The Ohio Aquatic Gap Analysis Project compiled a map of public and private conservation lands and OH-GAP classified the lands into four status categories (status 1 through status 4) by the degree of protection offered based on management practices. A status of 1 denotes the highest, most permanent level of maintenance, and status 4 represents the lowest level of biodiversity management, or unknown status. The results of this mapping show that only about 3.7 percent of the state’s land (4.3 percent if lakes and reservoirs are also included) is protected for conservation, either publicly or privately. Of this total, state agencies control about 52 percent, and Federal agencies control about 29 percent. Lands considered status 1 are the most highly protected, and in Ohio The Ohio Department of Natural Resources (ODNR) and The Nature Conservancy manage the bulk of these (43.4 percent and 30.3 percent, respectively). Conservation lands are distributed throughout Ohio in 87 of 88 counties. This is largely due to the presence of ODNR, the largest land steward by area in Ohio, which protects lands in 86 counties (all but Van Wert and Union).

Analysis Based on Stewardship and Conservation Status

Conservation areas that presently protect a portion of Ohio’s aquatic biodiversity were identified through the analysis of the distributions of species and conservation lands on a 14-HU scale. In addition, based on measures of predicted species richness and taxa richness, 75 (out of 504) 14-HUs in the Lake Erie Basin and 67 (out of 1,291) 14-HUs in the Ohio River Basin were identified for their conservation potential.

Results show that 22 fish species and 2 bivalve species had predicted distributions exclusive of conservation lands classified as status 1 or status 2. Nine of these fish species are considered rare, threatened, or endangered in the state. Status 1 and status 2 lands are generally considered by GAP to offer adequate protection.

Results and Conclusions

Fish species richness increases generally from north to south across Ohio. This can be explained by differences in latitude and by climatic and geologic history, among other factors. The primary factor used by OH-GAP for identifying potential high-priority conservation areas was species richness. Because of the known gradient of species diversity, the Lake Erie and Ohio River Basins were analyzed separately for all taxa. Fifteen percent (75 of 504) of the 14-HUs in the Lake Erie Basin were identified by OH-GAP as high potential priorities for conservation. Thirty-seven of them already have some conservation lands located within them. In the Ohio River Basin, 57 of 1,291 14-HUs (4.5 percent) were identified by OH-GAP as potential high-priority conservation areas for conservation using species richness. Of the 57 14-HUs identified as potential high-priority conservation areas, 56 percent already have conservation lands.

In both the Lake Erie and Ohio River Basins, a larger, though not significant, percentage of 14-HUs with existing conservation land were identified by OH-GAP for their potential for high species richness. It is beyond the scope of this report to assess whether high-quality habitats were deliberately protected or whether conservation of habitat has allowed species to thrive. Because only enduring physical characteristics were used in the models, it is likely that these habitats were deliberately protected, and this gap analysis provides further evidence of the habitat quality.

Data Use and Availability

The primary products of the Ohio Aquatic GAP project are geospatial databases for land stewardship, stream-habitat types, and predicted distribution models for native fish, crayfish, and bivalves. Associated OH-GAP geospatial databases include mapped locations of fish, crayfish, and bivalves. These data, along with this report, are available from the USGS through the Internet. The OH-GAP Web page can be accessed at *http://oh.water.usgs.gov/ohgap/ohgap.html*.

1. Introduction

Organization of Report

The organization of this report follows the general chronology of project development, beginning with the production of the individual data layers and concluding with analysis of the data. It diverges from standard scientific reporting by embedding results and discussion sections within individual chapters. This was done to allow the individual data products to stand on their own as testable hypotheses and provide data users with a concise and complete report for each data and analysis product. A glossary of terms and a list of cited literature are at the end of the report to aid the reader.

An overview of the Gap Analysis Program (GAP) mission, concept, and limitations is provided (chapter 1). This is followed by a discussion of habitat-type mapping (chapter 2), prediction of animal-species distribution and species-richness mapping (chapter 3), and land-stewardship mapping and categorization (chapter 4). Data development leads to "Analysis Based on Stewardship and Management Status" (chapter 5), which reports on the status of the native aquatic animal species for Ohio. Finally, conclusions of an "Analysis Based on Aquatic Biodiversity" are described (chapter 6), followed by information on how to acquire and use the data (chapter 7).

Gap Analysis Program Mission

The mission of the Gap Analysis Program is to keep common species common by conducting conservation assessments of native aquatic animal species and facilitating the application of this information to land- and water-management activities. This is accomplished through the following five objectives:

- Mapping aquatic habitat types.
- Mapping the predicted distributions of fish, crayfish, and bivalves.
- Documenting the presence of aquatic species in areas managed for conservation.
- Providing GAP results to the public, planners, managers, policy makers, and researchers.
- Building cooperation with multiple organizations to apply GAP results to state and regional management activities.

To meet these objectives, it is necessary that GAP be operated at the state or regional levels while maintaining consistency with national standards. Within the state, participation by a wide variety of cooperators is necessary and desirable to ensure understanding and acceptance of the data and to forge relationships that will lead to cooperative conservation planning.

Gap Analysis Program Concept

The Gap Analysis Program brings together the problem-solving capabilities of Federal, state, and private scientists to tackle the issues of animal-habitat characterization and mapping and biodiversity conservation assessment at the state, regional, and national levels. The program seeks to facilitate cooperative development and use of information. Throughout the report, the terms "GAP," "OH-GAP," and "gap analysis" are frequently used. "GAP" is used to describe the national program, "OH-GAP" to refer to the Ohio Aquatic GAP Project, and "gap analysis" to refer to the analysis process or methodology. The following paragraphs describe the Gap Analysis Program concept, as carried out by OH-GAP.

The OH-GAP is a pilot project that is applying the GAP concept to aquatic—specifically, riverine—data. The gap analysis process provides an overview of the distribution and conservation status of several components of biodiversity. Though designed and written for terrestrial conservation, the gap analysis processes described below by Scott and others (1993), Davis and others (1995), and Edwards and others (1995) apply to aquatic systems as well.

OH-GAP uses the physical habitat of the rivers and predicted distribution of vertebrate and invertebrate taxa. A Geographic Information System (GIS) is used to identify the habitats of individual species and potentially species-rich areas that are unrepresented or underrepresented in existing conservation-management areas. The relatively coarse scale of gap analysis functions as a preliminary step to the more detailed studies needed to establish actual boundaries for planning and management of biological resources. These gap data and results are made publicly available so that institutions, individual landowners, and managers may become more effective stewards through more complete knowledge of the conservation status of these elements (species or habitat) of diversity. GAP is likely to be both less expensive and more likely to succeed than conservation programs focused on single species or populations (Scott and others, 1993). GAP is not designed to identify and aid protection of elements that are rare or of very restricted distribution; rather, it is designed to help "keep common species common" by identifying risk far in advance of actual population decline.

Biodiversity inventories can be seen as "filters" designed to capture various elements of biodiversity at different spatial scales. The filter concept has been applied by The Nature Conservancy (TNC), which established Natural Heritage Programs in all 50 states. TNC uses a fine filter of rare-species inventory and protection, as well as a coarse filter of community inventory and protection (Jenkins, 1985; Noss, 1987). It is suggested that 85–90 percent of species can be protected through a relatively quick coarse filter inventory such as gap analysis, eliminating the need to inventory or plan reserves for those species individually. However, the spatial scale at which organisms use the environment differs tremendously among species and depends on body size, food habits, mobility, and other factors. Therefore, no coarse filter will be a complete assessment of biodiversity protection status and needs. Coarse-filter protection is a complement to, not a substitute for, protection of individual rare species. To these remaining 10–15 percent of species a fine filter needs to be applied to ensure their protection.

The gap analysis concept as described in this report out can be expanded. The idea of conserving most biodiversity by maintaining examples of all natural community types has never been applied, although numerous approaches to the spatial identification of biodiversity have been described (Kirkpatrick, 1983; Margules and others, 1988; Pressey and Nicholls, 1989; Nicholls and Margules, 1993).

General Limitations of Gap Analysis Program

Limitations must be recognized so that additional studies can be implemented to supplement GAP. The following are general project limitations; specific limitations for the data are described in the respective sections.

1. GAP data are derived from coarse-scale data and modeling to make general assessments about conservation status. Any decisions based on the data must be supported by ground-truthing and more detailed analyses.

2. GAP is not a substitute for threatened and endangered species listing and recovery efforts. A primary argument in favor of gap analysis is that it is proactive: it seeks to recognize sites of high biodiversity value. These sites can then be managed by land stewards for the long-term maintenance of populations of native species and communities before they become critically rare. Thus, it should help to reduce the rate at which species require listing as threatened or endangered. Those species that are already greatly imperiled, however, still require individual efforts to ensure their recovery.

3. GAP data products and assessments represent a snapshot in time generally representing the date of the source data.

4. GAP is not a substitute for a thorough national biological inventory. As a response to rapid habitat loss, gap analysis provides a quick assessment of the distribution of vegetation and associated species before they are lost and provides focus and direction for local, regional, and national efforts to maintain biodiversity. The process of improving knowledge in systematics, taxonomy, and species distributions is lengthy and expensive. That process would need to be continued, however, to obtain the detailed information needed for a comprehensive assessment of our Nation's biodiversity. Vegetation and species distribution maps developed for GAP could be used to make such surveys more cost-effective by stratifying sampling areas according to expected variation in biological attributes.

Ohio Aquatic GAP Study Area

The study area for this project encompasses all of Ohio except the Ohio River and the Lake Erie Islands. The study area can be divided into six of Omernik’s level III ecoregions (1987; see *Appendix A*). Included are the Eastern Corn Belt Plains, Southern Michigan/Northern Indiana Drift Plains, Huron/Erie Lake Plains, Erie/Ontario Drift and Lake Plains, Western Allegheny Plateau, and Interior Plateau; and two major drainage basins: Lake Erie and the Ohio River (fig. 1–1). Watersheds within the Lake Erie Basin include the Maumee, Sandusky, Cuyahoga, and Grand; watersheds within the Ohio River Basin include the Scioto, Muskingum, and Miami.

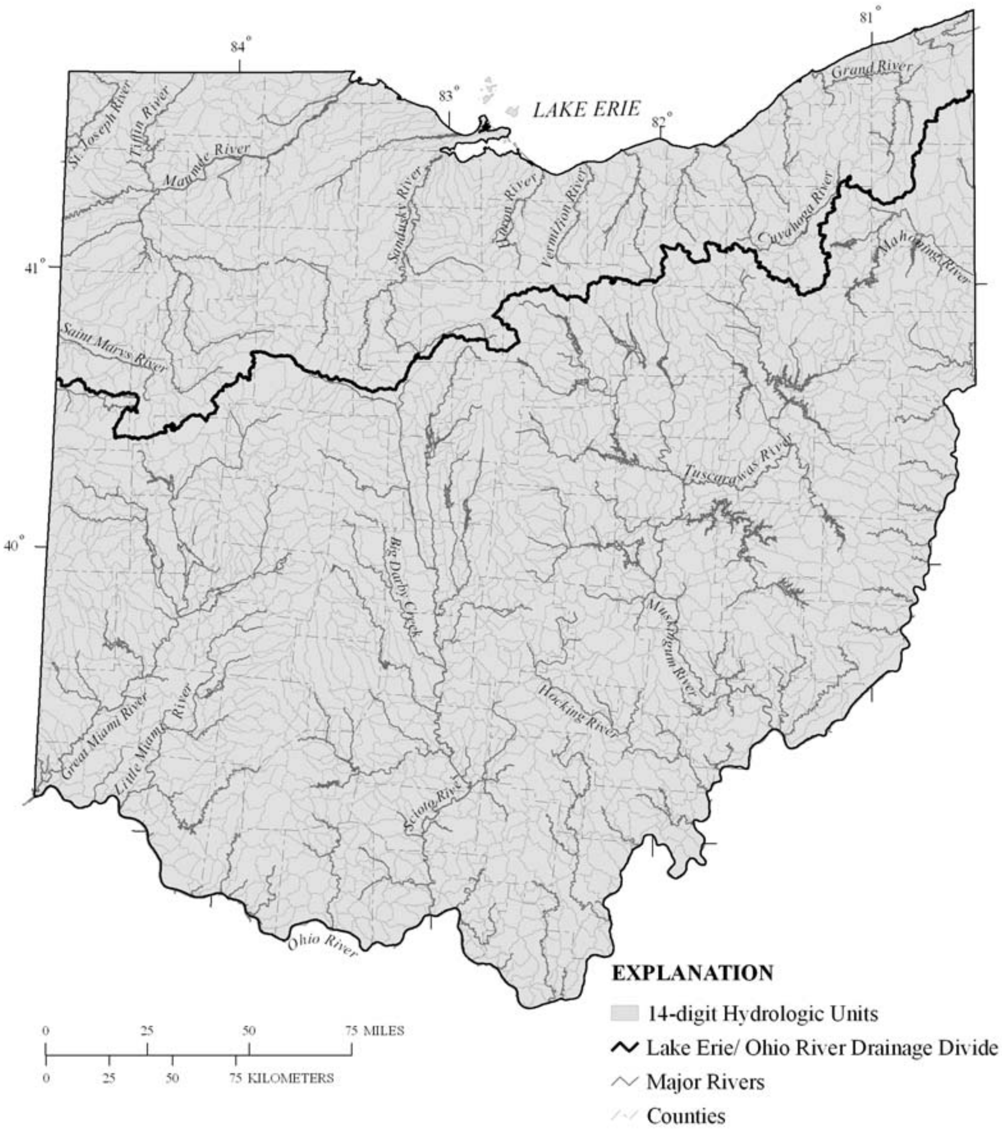

Figure 1–1. Major rivers and drainage basins in Ohio. A solid black line separates the Lake Erie Basin in the north from the Ohio River Basin in the south. Ohio Aquatic GAP Project's assessment units, 14-digit hydrologic units, are shown.

Ohio's present-day landscape and drainage patterns are largely a result of glacial activity and human disturbances. The Eastern Corn Belt Plains, Southern Michigan/Northern Indiana Drift Plains, Huron/Erie Lake Plain, and Erie Drift Plains contain many features molded by the glaciers that were once present. The end moraines, kames, and kettle lakes found in these regions result from glacial activity, and the landscape is much smoother than that of the unglaciated areas in the southeast. Glaciation left behind fertile soils and smoother plains, which support the large amount of agricultural activity now present in these areas (Purdue University, 2004). Underlying bedrock consists of shale, sandstone, limestone, and dolomite. Drainage patterns in these regions were also greatly altered. Glacial ice blocked ancient streams, leaving behind layers of glacial till composed of sand, gravel, and clay (Ohio Department of Natural Resources, 2004). Thus, streams such as the Teays were destroyed, and new drainage patterns emerged when the glaciers receded (Geocities, 2004). Agriculture dominates these regions, but urban, industrial, and recreational developments are also present and have a significant impact on the water quality of streams in these areas (Purdue University, 2004).

The unglaciated regions (Western Allegheny Plateau and parts of the Interior Plateau) feature an uneven landscape of valleys and hills. Where extensive mesophytic and oak forests once grew, agriculture and residential developments are now prevalent. Mining occurs in the sedimentary bedrock found in the Western Allegheny Plateau, as well as in the limestone, chert, sandstone-siltstone, and shale in the Interior Plateau. Streams in these regions drain to the Ohio River and have persisted through glacial activity to the North (Purdue University, 2004).

Ohio has a temperate climate with four seasons. Blizzards, tornados, floods, droughts, hail, wind, sleet, and heat waves can all occur in Ohio. Temperature is fairly regular, ranging from average annual lows of -15 to 5°F in January to average annual highs of 80 to 88°F in July (Sanders and Zimmermann, 2001). Precipitation varies from approximately 30 to 44 in. annually in the form of rain, snow, sleet, and hail and has a statewide average of approximately 38 in. annually (Sanders and Zimmermann, 2001).

Ohio is ranked seventh in the United States in total population with 11,353,140 people inhabiting a land area of 107,044 square kilometers of developed, farmed, and wooded areas (U.S. Census Bureau, 2000). There are about 3,300 named rivers and streams and an equally large number of unnamed smaller branches (Ohio Historical Society, 2004) comprising 70,811 km of continuously flowing streams, along with 974 km^2 of inland water, and 9,062 km^2 of Lake Erie (Covert and others, 2001). However, Ohio also has 182,556 km of highway, giving Ohio more roads per capita than any other state (Covert and others, 2001). Agriculture is the predominant land use (Sanders and Zimmermann, 2001), with approximately 73,000 farms covering 60,703 km^2 (Covert and others, 2001).

2. Stream Classification and Mapping

The mapping of stream habitat can be done by adopting or developing a classification system, delineating areas of relative homogeneity, and labeling these areas using categories defined by the classification system. In its coarse-filter approach to conservation biology (for example, Jenkins, 1985; Noss, 1987), aquatic gap analysis relies solely on the macrohabitat-scale enduring physical characteristics of the streams. This classification system can be used in a hierarchical manner in that the classified river segments can be grouped for a regional study. Alternatively, with the addition of other datasets, the river segments can be further subdivided for a more detailed classification as was done with the predictive species models developed for this project.

The inherent connectivity of aquatic systems presents technical and theoretical challenges in the effort to classify streams. The characteristics of a river segment are directly linked to the upstream rivers and watersheds. The Ohio Aquatic GAP (OH-GAP) classification system is based solely on the physical habitat of the rivers. Although the water quality and vegetation around a stream or in a watershed may change, (depending on the local or upstream land use, for example), the physical characteristics of the river are more enduring. An underlying assumption of OH-GAP is that if the physical habitat is favorable for a species, then that species could potentially exist at that location.

Stream Classification

Stream classifications rely on specified attributes, such as stream temperature, size, or sinuosity, to consistently differentiate categories. The criteria for an aquatic stream classification system for OH-GAP are

- an ability to distinguish areas of different macrohabitat,
- a utility for modeling animal-species habitats,
- a suitability for use within and among biogeographic regions,
- a capability to serve as a baseline habitat for GAP species models, and
- a relative timelessness; that is, a system with attributes that are relatively static from year to year.

Methods

The classification of streams for OH-GAP concentrates on riverine macrohabitats and is roughly based on a combination of approaches including the Aquatic Community Classification System developed by The Nature Conservancy (TNC) (Lammert and others, 1997), the early work of the Missouri Aquatic Gap Project on riverine physical habitat classification (Sowa, 2000), and research on valley segments in Michigan by Seelbach and others (1997).

Mapping Standards and Data Sources

To create a stream-habitat classification system for OH-GAP, a digital map layer was delineated and produced of physical habitat types for Ohio on the basis of streams of the 1:100,000 National Hydrography Dataset (NHD) (U.S. Geological Survey and U.S. Environmental Protection Agency, 2000). Those streams identified as intermittent were eliminated from the physical-habitat type classification and subsequent analyses because they were not likely to contain permanent aquatic communities of interest.

Developing Physical Habitat Types

To classify Ohio's rivers, OH-GAP focused on mapping physical habitats that endure for decades, if not centuries. These physical habitat types are composed of eight separately mapped variables with various source scales and from various sources (table 2–1). Regional variables are

- bedrock
- character of glacial drift
- glacial-drift thickness

Stream-network variables are

- water temperature
- Shreve link
- downstream Shreve link
- gradient
- sinuosity

The eight variables used in the stream classification, as well as additional variables used for the modeling process, are further discussed in this chapter. Nominal-scale variables such as bedrock types were maintained, whereas interval or ratio types of variables (such as stream sinuosity) were put in an ordinal scale. Some variables, such as Shreve link, are composed of both nominal and ordinal categories. The classes were developed for Ohio based on discussion with experts (*Appendix H*) and literature review. The nominal or ordinal classes are listed in *Appendix A*.

Maps of each of these variables were made and then combined into one GIS layer. Confluence-to-confluence segments of the NHD were split into different physical habitat types if the value of any of the eight variables used to create the physical habitat types changed over the course of the confluence-to-confluence segment. This is further discussed in this chapter's "Results" section.

Table 2–1. Sources and scale of Geographic Information System (GIS) data used to create the physical habitat types for OH-GAP.
[m, meters ; *, variables used in the predictive-modeling process but not included in the habitat type classification]

Data layer	Source	Scale	Habitat type variable
National Hydrography Data	U.S. Geological Survey and U.S. Environmental Protection Agency, 2000	1:100,000	Sinuosity (developed through Arc/Info AML); Gradient
River Reach File (RF3)	U.S. Environmental Protection Agency, 1995	1:100,000	Shreve link; Downstream Shreve link (developed through Arc View scripts)
Level III Ecoregions	Omernik (U.S. Environmental Protection Agency), 1987	1:7,500,000	*
National Elevation Data	U.S. Geological Survey, 1999	30m (1:100,000)	Gradient
Bedrock geology	Ohio Department of Natural Resources, 1981	1:500,000	Bedrock
Glacial sediment thickness and character	Ohio Department of Natural Resources, 2000	1:24,000	Thickness of glacial drift; character of glacial drift
Preglacial drainage	Stout and others, 1943; Tight, 1903; Pavey and others, 1999	> 1:1,000,000	*

Regional Variables

Bedrock

A digital map of bedrock was obtained from the Ohio Department of Natural Resources (ODNR). In Ohio, bedrock at the surface is entirely sedimentary and consists of combinations of shale, sandstone, limestone, and coal. The bedrock is covered by glacial deposits in much of the state. Because of the coarse scale of the data (1:500,000), the bedrock layer maps all of the bedrock, not just the topmost layer at a particular location. These data were the best available at the time, but their use implies that there may be error in coding the segments, especially where different types of bedrock border each other.

Glacial Character and Drift Thickness of Glacial Material

Digital maps of glacial character and drift thickness were obtained from ODNR. Glacial-character classes were till, fine-grained stratified, and coarse-grained stratified. Drift thickness values were shallow (0–100 ft) and deep (> 100 ft). These variables are not applicable in many of the smaller streams of the unglaciated southeastern 30 percent of Ohio.

Stream-network variables

Water Temperature

Point-specific temperature data were obtained from the U.S. Environmental Protection Agency (USEPA) Storage and Retrieval (STORET) database. More than 4,000 measured temperature points throughout the state were used. The assignment of temperature classes to unsampled reaches was somewhat arbitrary. Most of the streams in Ohio are classified as warm-temperature streams and so, by default, all streams not classified as cold or transition were classified as warmwater. To determine which streams could be classified as cold or transition, statistical regressions were used to identify a day in mid-July as having the highest temperature for a year. If a stream was cold or transition on that day, it was considered to be a cold-water or transition stream. The temperature ranges used to define cold, transition, and warm were defined for Ohio by aquatic experts (*Appendix H*). Because the data were point specific, the streams were manually assigned a temperature value. Reaches at or immediately upstream from a cold or transition temperature reading were assigned cold or transition; otherwise, they were assigned to the warm-water class. Specifically, if a cold or transition point was on a first- or second-order stream and there were no other temperature points upstream, all of the reaches upstream also were classified as cold or transition. If the point was on a third- or larger order stream, it was assigned cold or transition only for that reach.

Stream size and connectivity

Stream size and connectivity of flow were mapped using TNC's Tools for Macroinvertebrate Habitat Classification (The Nature Conservancy, 2000). These tools were run using the USEPA River Reach File 3 (RF3) data and then cross-walked with the NHD for OH-GAP. Stream size was measured using Strahler stream order and stream Shreve link, the number of first-order streams upstream from a current reach. The downstream link, the link number of the stream downstream from a current reach, was used as a measure of flow connectivity. Classes for link and downstream link (as well as all of the ordinal and categorical variables) can be found in *Appendix A*. The maps were manually reviewed once classes had been programmatically assigned.

Gradient

Gradient was measured for each section of stream, as defined by its Strahler stream order, so that the full length of a second-order stream, for example, would have the same gradient value. Gradient was based on the range of elevations on that Strahler-stream-order-defined section of stream. Elevation data were obtained from the USGS National Elevation Dataset (NED) (U.S. Geological Survey, 1999).

Sinuosity

Sinuosity was measured using an Arc Macro Language (AML) program in ArcInfo (Arya, 1999), and sinuosity classes were defined on the basis of the work of Rosgen (1994). Because of the prevalence of pseudo nodes from the removal of intermittent streams, the AML tended to assign sinuosity values over short lengths of the river. The map was manually checked after the program, and the three classes of sinuosity were assigned to achieve consistency along a stream.

Additional Variables used in the Predictive Models

Ecological drainage units (EDUs), ecoregions, and major drainage areas are regional variables that were used in the predictive models but were not used as part of the physical-habitat classification of the streams. Ecological sections and major drainage areas typically correspond to significant differences in aquatic assemblages (Pflieger, 1989; Rabeni and Doisy, 2000).

Seven major drainage areas were identified in Ohio corresponding to the state's four large river basins (Maumee, Scioto, Muskingum, Miami) and aggregations of the other smaller river systems. (See map in *Appendix B*.) These seven areas were based on the combination of several eight-digit hydrologic units (HUs). HUs are hierarchical divisions and subdivisions of a watershed. The combined HUs used here are all true watersheds, meaning that the full upstream portion of the stream network is encompassed within each of the areas defined as a watershed.

Methodology for mapping EDUs was adapted from TNC's Aquatic Classification Framework (Lammert and others, 1997). The EDUs are a combination of modern major drainage (Ohio River or Lake Erie), evolutionary significant drainages, glacial history, and ecoregion. The goal while compiling this map was to consider key ecological and evolutionary processes taking place in Ohio that would provide relevant assessments and directly correspond to the conservation of common species. Modern ecoregions commonly serve as an assessment unit for ecologically meaningful processes. Omernik's level III ecoregion map (1987) was used because it was designed for aquatic and terrestrial applications. The regions are based on factors including land use, land-surface form, potential natural vegetation, and soils (*Appendix B*). Historic drainage patterns and processes influence the modern distribution of aquatic species. The Evolutionary Significant Drainage map (*Appendix B*) is a compilation of three previously existing maps describing the preglacial Teays drainage, preglacial hydrographic basins of the Upper Ohio Valley, and the line of furthest glacial advance (Stout and others, 1943; Tight, 1903; Pavey and others, 1999).

Accuracy Assessment

The habitat-type classification data were not ground-truthed; error in the input maps would lead to error in the classification.

Additionally, different levels of precision and tolerance levels were used during the habitat-type delineation. This led to a slight shift in the lines when compared to the original NHD data. This shift is well within National Map Accuracy Standards for 1:100,000-scale maps.

Furthermore, because of technical limitations, unfamiliarity with the (then new) NHD, and cross-walking of attributes from one digital river dataset (RF3) to the NHD, some small portions of river segments were attributed with different habitat types than the larger, surrounding river along that same confluence-to-confluence reach. Although attempts were made to combine the small segments into the larger segment, many persist, and their effect on the dataset remains. Because of the design of ArcInfo's "Eliminate" command, the attributes of some small river segments were assigned to the larger arcs when the small and large arcs were merged together, instead of the smaller arc taking on the attributes of the larger arc, as was intended in order to minimize the error in the attribute values. No estimate of the magnitude of this error was performed, though it is likely that many of the errors were caught when maps of Shreve link, downstream Shreve link, Strahler stream order, sinuosity, and gradient were manually examined. (Due to the order in which the variables were assigned, these would have been the variables most affected by the tiny slivers.) Small river segments (correctly) created from the intersection of the river linework with the finer scale maps of glacial thickness and glacial character could have also been affected by the use of the "Eliminate" command.

Results

OH-GAP's classification used "smart coding" that consisted of the concatenation of values for each of the eight separate variables into a physical habitat type code. The values for the separate variables are maintained in the final habitat type, allowing for the straightforward comparison of two or more physical habitat types. The order of the variables in the physical habitat code is

1. Shreve link
2. downstream Shreve link
3. sinuosity
4. gradient
5. bedrock
6. stream temperature
7. glacial thickness
8. glacial character

By way of example, a physical habitat type code of "4 6 2 2 2 3 1 3" has the same habitat as a code of "4 6 2 2 5 3 1 3", except for the bedrock type Shale/sandstone/coal (5) instead of shale/limestone (2). (See *Appendix A* for category descriptions.)

As the number of variables and categories of each variable increase, the theoretical number of physical habitat types increases exponentially. For example, there are three categories for temperature and 10 categories for downstream Shreve link. Effort was made to have enough classes of each variable to be meaningful but not too many to be overwhelming, especially when dealing with this macrohabitat, coarse scale. Classifying a stream requires simplification of a complex natural system. If there are too many groups, this goal may not be achieved. On the other hand, an oversimplified classification may not adequately describe the rivers, leading to misapplication (Juracek and Fitzpatrick, 2003). For this reason, in the classification deliberation between "clumping" together and "splitting" apart, OH-GAP tended towards "splitting," both in defining the classes of habitat types and in the actual splitting of the river segments when the river crossed a class. This resulted in many small river segments and many habitat types. When possible, river segments less than 51 m were eliminated because of National Map Accuracy Standards for 1:100,000-scale data. Table 2–2 is a partial list of Ohio's physical habitat types; the complete list, along with data listing whether a habitat type has been sampled for fish, crayfish, and bivalves, is in *Appendix C*.

Table 2–2. Top physical habitat types in Ohio, by total length.
[See *Appendix A* for descriptions of each physical habitat type category. Parenthesis () shown around double-digit categories for clarity; km, kilometer]

Physical habitat type	Number of segments	Total length (km)	Percent of Ohio's rivers
1 1 4 1 4 3 3 4	558	766.3	1.4
4 3 1 3 2 3 1 3	660	666.1	1.2
6 (13) 1 1 2 3 1 2	436	564.0	1.0
4 3 1 3 4 3 1 3	509	547.3	1.0
6 (13) 2 1 2 3 1 2	428	481.8	0.9
4 3 1 3 1 3 1 3	519	417.3	0.8
3 2 2 3 4 3 3 4	419	400.1	0.7
1 1 3 1 4 3 3 4	226	362.2	0.7
1 1 4 1 5 3 3 4	275	340.6	0.6
4 3 1 1 1 3 1 3	385	324.5	0.6
2 1 4 1 4 3 3 4	306	317.5	0.6
2 1 2 2 2 3 1 2	268	309.6	0.6
6 (13) 1 1 2 3 1 3	274	286.0	0.5
4 3 2 3 2 3 2 1	190	280.4	0.5
Others	60,092	48,802.4	89.0

Results of the stream classification reveal 5,269 separate physical habitat types over 65,545 river segments in Ohio. Lakes, reservoirs, and wetlands, were not classified. The average stream segment length is 0.8 km; the average length of a physical habitat type is likely longer, because some physical habitat types can span several consecutive river segments. The top 100 physical habitat types by length constitute 33 percent of the streams in the state, and the top 300 types classify 54 percent of the streams; this result suggests that although more than 5,000 different habitat types are defined for Ohio, much of the state can be classified using far fewer habitat types (table 2–3). The large number of physical habitat types for Ohio, including many of the smaller habitat types by length and total number, persist in the dataset because of the factors discussed in the "Accuracy Assessment" section of this chapter.

Table 2–3. Cumulative percentage of rivers that can be classified by the addition of physical habitat types.

Number of physical habitat types (sorted by length)	Percent of Ohio's total stream length represented
1	1.4
100	33
200	46
300	54
400	61
500	65
800	75
1,000	80
2,000	98
All 5,269	100

The habitat type with the greatest combined length (766.3 km, 1.4 percent of the state's streams) is also the second most abundant physical habitat type in number of segments, 558. This habitat type (1 1 4 1 4 3 3 4) is a small stream (1) that flows into a small stream (1) and has a high gradient (4) and low sinuosity (1); bedrock is composed of layers of shale, sandstone, limestone, and coal (4); stream temperature is warm (3) and the thickness and character of glacial drift are not applicable (3)(4) in these smaller unglaciated streams of southeastern Ohio. The 9th-ranked habitat type in total length (340.6 km, 0.7 percent of state's rivers) and 14th-ranked in number of segments (275 segments) has the same habitat as this longest one, only without limestone layers in the bedrock.

Three of the top four physical habitat types by number of segments (660, 519, and 509 segments) differ only by their underlying bedrock. These types also rank second, fourth, and sixth in total length (666.1 km, 547.3 km, and 417.3 km, corresponding to 2.97 percent of the total length of streams in Ohio). As might be expected, these segments (4 3 1 3 x 3 1 3) are all large rivers flowing into large rivers, have a very low gradient, high sinuosity, warm water temperature, shallow drift thickness, and fine-grained stratified glacial deposits. These segments are in several parts of the state but are predominantly along the Sandusky and Maumee Rivers of northwestern Ohio, the Grand River of northeastern Ohio, and Raccoon and Symmes Creeks of southern Ohio.

The segment types ranking third and fifth in total length (564.0 km, 481.8 km, 1.91 percent of Ohio rivers) and fifth and sixth in number of segments (436 and 428 segments) are ditches/channels flowing into other ditches/channels with low sinuosity, underlain by shale, sandstone, and limestone; and having warm stream temperatures, shallow drift thickness, and till. Gradient varies from low to very low (code 6 (12) x 1 2 3 1 2). These areas are exclusively in the Maumee and Portage River watersheds of northwest Ohio. Although ditches are certainly not natural, their grid-like design, ambiguous flow pattern, and abundance in northwest Ohio warranted separate link and downstream-link categories.

Limitations and Discussion

The purpose of developing the physical habitat types was for use in the potential species-distribution models. Like any stream classification, this classification is a simplification of a complex, dynamic natural system (Juracek and Fitzpatrick, 2003). The physical habitat types are based on data from various scales (table 2–1); and because the resulting physical habitat types may appear to be fine scale because of their size (average of 0.84 km, though many are less), these data were designed for regional, coarse-scale gap analysis. A more straightforward approach to developing the physical habitats may have been to maintain the full confluence-to-confluence reach, because then the scale of the data would be more obvious to the user.

A further limitation of these data is that they are based only on the enduring physical characteristics of the rivers; there is no way to account for land use, land cover, water quality, the effect of dams, sedimentation, or any number of natural or human-induced local or upstream stressors that may occur at the catchment or watershed level. The ditches in northwest Ohio were assigned link and downstream-link values to set them apart from natural streams, but no other stream modifications such as dams, levees, modified channels, among others, were given such consideration. Though these factors likely affect fish, crayfish, and bivalve distributions, these factors were undocumented at the time of this analysis and therefore could not be considered in the predictive models presented. Lastly, treating the landscape in a simple manner—that is, classifying 54,865 km of streams on the basis of only eight categorical variables—has implications for the omission and commission error of our models. This is further discussed in the following chapter on species-distribution modeling.

3. Predicted Animal Species Distributions and Species Richness

All species-range maps are predictions of the occurrence of those species within a particular area (Csuti, 1994). Traditionally, the predicted occurrences of most species begin with samples from collections made at individual point locations. Most species range maps are small scale (for example, >1:10,000,000) and derived primarily from point data to construct field guides which are suitable, at best, for approximating distribution at the county or regional level. The purpose of the Ohio Aquatic GAP (OH-GAP) species maps is to provide more precise information about the current predicted distributions of individual native species according to actual habitat characteristics within their general ranges and to allow calculation of the predicted area of distributions to specific habitat characteristics.

Gap analysis uses the predicted distributions of animal species to evaluate their conservation status relative to existing land management (Scott and others, 1993). However, the maps of species distributions may be used to answer a wide variety of management, planning, and research questions relating to individual species or groups of species. In addition to the maps, utility may be found in the consolidated specimen-collection records and literature that are assembled into databases used to produce the maps. Perhaps most importantly, as a first effort in developing such detailed distributions, such maps should be viewed as testable hypotheses to be confirmed or refuted in the field. Biologists and naturalists are encouraged to conduct tests and to report their findings in the appropriate literature and to the Gap Analysis Program (GAP) so that new data may improve information and Gap Analysis tools.

Ordinary species—that is, those not threatened with extinction or not managed as game animals—are generally not given sufficient consideration in land-use decisions in the context of large geographic regions or in relation to their actual habitats. Simply creating a consistent spatial framework for storing, retrieving, manipulating, analyzing, and updating the totality of our knowledge about the status of each animal species is a necessary and basic element for preventing the further degradation of biological resources.

Mapping Standards

Data Sources

A stream-habitat classification system for OH-GAP was created by delineating a digital map layer of habitat types for Ohio based on the streams of the 1:100,000 National Hydrography Dataset (NHD) and eight physical characteristics: stream link, downstream link, gradient, sinuosity, bedrock, stream temperature, thickness of glacial drift, and character of glacial drift. (For further explanation of variables, see “Methods” section of chapter 2 and *Appendix A*.) The scale and sources of these data are listed in table 2–1. For modeled species distributions, the physical-habitat-type data were converted to 200-m grid cells and, thus, are the minimum mapping unit. (For a more detailed description of the derivation of the physical habitat types, see chapter 2.)

OH-GAP compiled databases of fish, crayfish, and freshwater bivalves collected from Ohio streams during the periods 1978–2001, 1920–2003, and 1850–2001, respectively. Crayfish and freshwater bivalve species were modeled only if historical records were accompanied by recent records (1978–2003) in order to prevent extirpated species from skewing the analysis.

The available biological data were collected by a number of sources and represent the wide diversity of stream sizes and types found within Ohio. Collecting agencies for fish include the Ohio Environmental Protection Agency (Ohio EPA), Ohio Department of Natural Resources (ODNR), Ohio Department of Transportation (ODOT), and U.S. Geological Survey (USGS). A database of known crayfish records was compiled for the OH-GAP by Roger F. Thoma, Ohio crayfish expert, while he was working for Ohio EPA. Sources of available crayfish data include the Cleveland Museum of Natural History, The Ohio State University Museum of Biological Diversity, Ohio EPA, and personal collections from Roger F. Thoma. The available freshwater bivalve database was obtained from The Ohio State University Museum of Biological Diversity, Division of Mollusks, under the direction of Thomas Watters. The bivalve collectors in the database are too numerous to list here (*Appendix D*).

Mapping Range Extent

Available biological distribution data were digitally mapped by displaying points where each species was collected. Predicted distributions are available for all native species in which a collection revealed its presence within Ohio perennial streams where physical-habitat data were available. Streams crossing Ohio's border were clipped at the state boundary.

Fundamentally, GAP assumes that habitat types directly influence animal distributions. OH-GAP selected the biological sampling points to represent Ohio's diversity of stream sizes and habitat types. Stream sizes were split into three classes: streams on the 1:100,000-scale National Hydrography Dataset with a Strahler stream order of 1 were classified as a 1, Strahler stream orders of 2 and 3 were classified as a 2, and all larger streams were classified as a 3. Size classes were established to account for known differences in biological communities of differing stream sizes. Table 3–1 shows a data gap in the smallest streams. OH-GAP stream-size class 1 streams make up 29.4 percent of all streams by length in Ohio yet contain less than 10 percent of all biological data collected.

Table 3–1. Percentage of sampling points collected from each OH-GAP stream size class for fish, crayfish, bivalves, and all taxa combined. The last column shows the percentage of Ohio's streams by length in each of the OH-GAP stream size classes.

	Fish	Crayfish	Bivalves	All Taxa	Ohio Streams
Size class 1	5.0	7.9	2.1	6.6	29.4
Size class 2	42.4	49.6	23.4	44.4	40.6
Size class 3	52.6	42.5	74.5	49.0	30.0

The top 100 physical habitat types (by total stream length rather than individual stream reaches) represent 33 percent of the total stream length in the state. Nearly all (96 of 100) of these habitat types have been sampled (*Appendix C*). Examined further, 60 of these top 100 habitat types have had all three taxa sampled, 82 have been sampled for fish, 91 have been sampled for crayfish, and 67 have been sampled for bivalves.

Of all 5,269 physical habitat types, 1,757 (33 percent of the habitat types in Ohio) have been sampled for at least one of these taxa, and 383 (7 percent) have been sampled for all three. Considered further, 1,176 (22 percent) of the habitat types have fish samples, 1,324 (25 percent) have crayfish samples, and 659 (13 percent) have bivalve samples.

Analyzed differently, habitats that collectively represent 34 percent of the total length of perennial streams in the state (54,865 km) have been sampled for all three taxa, 59 percent for two or more, and 75 percent for at least one.

For the predictive modeling, this implies that an adequate number of species points (available data) are distributed throughout the 33 percent of the state represented by the 100 different habitat types and throughout the entire state, for at least one taxon. This holds true when performing analysis on the basis of total number of habitat types and the total length of streams that these habitat types represent. It may seem that the 7 percent of the physical habitat types sampled for all three taxa is not very much. However, these habitat types represent 34 percent of all the stream kilometers in the state and, as such, constitute reasonable coverage for modeling purposes. This is especially true because the predictive models were based on the individual variables in the physical habitat types, not the types themselves.

So that each biological sampling point could be associated with a set of physical-habitat data, OH-GAP spatially joined the two datasets. Available biological sampling points were the basis for, and are henceforth referred to as, “known species distributions.” Excluded from the known species distributions were all collection points from reservoirs, lakes, and the Ohio River. The biological sampling points did not fall directly on the river network because of (1) different spatial scales, (2) difficulty with intersecting geospatial points and lines, inclusively, at all scales, and (3) true sampling-location mismatch; that is, the spatial data were collected from a field adjacent to the stream. In an effort to match the sampling points to the streams from where the fish, crayfish, and freshwater bivalves were collected, an accuracy assessment was completed. (See “Accuracy Assessment” section.) As a result of the accuracy assessment, some known distribution points were excluded because they could not satisfactorily be linked to the stream reach of collection. The data resulting from this accuracy assessment were used to produce the known species distributions.

Methods

Species Known Occurrences

OH-GAP predicted potential distributions for 130, 17, and 70 native species of fish, crayfish, and freshwater bivalves, respectively, on the basis of known occurrences and habitat. (See tables 3–2 through 3–4 for a complete species list.) The locations of species' known occurrences were checked to ensure spatial accuracy.

The reasons for including or excluding biological sampling points are shown in the flowchart of figure 3–1 and described here. All biological sampling points that were excluded from OH-GAP were assigned a code, Exclusion ID, to explain the reason for excluding them. All biological sampling points that were kept for use in OH-GAP were assigned a code, Inclusion ID, to explain the reason for keeping them. This process was completed separately for each of the three aquatic taxa: fish, crayfish, and freshwater bivalves.

All biological sampling points collected in Lake Erie, the Ohio River, reservoirs, lakes, or aquatic nonriverine habitats were assigned Exclusion IDs of 1, 2, 3, 3, or 4, respectively. The remaining biological sampling points were spatially joined to the National Hydrography Dataset (NHD) of permanent and intermittent streams. Biological sampling points located on unconnected stream segments were assigned an Exclusion ID of 5. Biological sampling points that were closest to an intermittent stream were tagged as potentially intermittent but were not deleted. Biological sampling points were then spatially joined with the permanent-only streams.

The biological sampling points did not fall directly on the NHD river network. In an effort to match biological sampling points to the precise stream reach from which they were collected, the following accuracy assessment was completed. In general, all deleted biological sampling points could not be positively matched with the precise stream reach.

The distance from the stream centerline to each biological sampling point was calculated. A query for all distances greater than 100 m was performed. The results of this query were excluded and given an Exclusion ID of 6, because the biological sampling points were too far to assign it to a physical habitat type reach-ID. The stream names from the remaining biological sampling points and the NHD were compared one on one. If the two stream names were the same or similar, an Inclusion ID of 1 was assigned. If the stream names were different, then the biological sampling sites were manually checked. If more than one biological sampling site with the same stream name fell on the same stream, then it was assigned an Inclusion ID of 2. It was assumed that the stream name given by the collectors of the biological data and the stream name of the NHD were different but that the physical locality was the same. If the biological sampling point stream name was not found in the NHD stream names and it matched "Tributary to… ," then an Inclusion ID of 3 was assigned. There was only one instance when this occurred. If neither of these situations was true, an Exclusion ID of 7 was assigned.

Some of the named streams where biological sampling points were found spatially matched NHD streams with no names present. These biological sampling points were queried based on whether the stream name of the biological sampling point was found anywhere among the stream names of the NHD. If the biological sampling-point stream name was found in the NHD and if more than one biological sampling site with the same stream name fell on the river, then those sites were assigned an Inclusion ID of 4. This specifically addresses those biological sampling sites matched to streams without names in the NHD.

Similarly, if the biological sampling point stream name was not found in the NHD, was a permanent stream, had more than one biological sampling site with the same stream name, and fell on the same NHD stream, then Inclusion ID was assigned a 5. Here, the NHD had no record of the biological sampling site stream name. This does not mean that biological sampling sites were misplaced. Also, some biological sampling sites, where stream names were not found in the NHD and were permanent, matched NHD stream names of "Tributary to …" or "unnamed site." These were assigned an Inclusion ID of 6.

If the biological sampling point stream name was found in the NHD but only one sampling site with the same stream name fell on the stream, then those sites were assigned an Exclusion ID of 8.

If the biological sampling point was found in an unnamed, intermittent stream, then Exclusion ID was assigned a 9. Here, the NHD has no record of the biological sampling site stream name.

Digital and hardcopy versions of the biological known occurrence maps were produced. Experts reviewed the species distribution data for locational errors. Fish data were reviewed by Ohio fish experts (1) Randall E. Sanders, Environmental Administrator for the Ohio Department of Natural Resources, Division of Real Estate and Land Management, and (2) Roger Thoma, Fisheries Biologist for the Ohio Environmental Protection Agency, Division of Surface Water. Crayfish data were reviewed by crayfish experts (1) Thomas Simon, Ph.D., Biologist, U.S. Fish and Wildlife Service, and (2) Horton H. Hobbs III, Ph.D., Professor of Biology, Wittenberg University. Bivalve data were reviewed by Ohio bivalve experts (1) Michael A. Hoggarth, Ph.D., Otterbein University, Associate Professor & Chairperson, Dept. Life & Earth Sciences, and (2) G. Thomas Watters, Ph.D., Curator of Molluscs, Museum of Biological Diversity, Department of Evolution, Ecology & Organismal Biology, The Ohio State University.

As a result of the expert review process, some points that had been deleted (that is, given Exclusion ID codes) were added back into the OH-GAP database. These were assigned an Inclusion ID of 7.

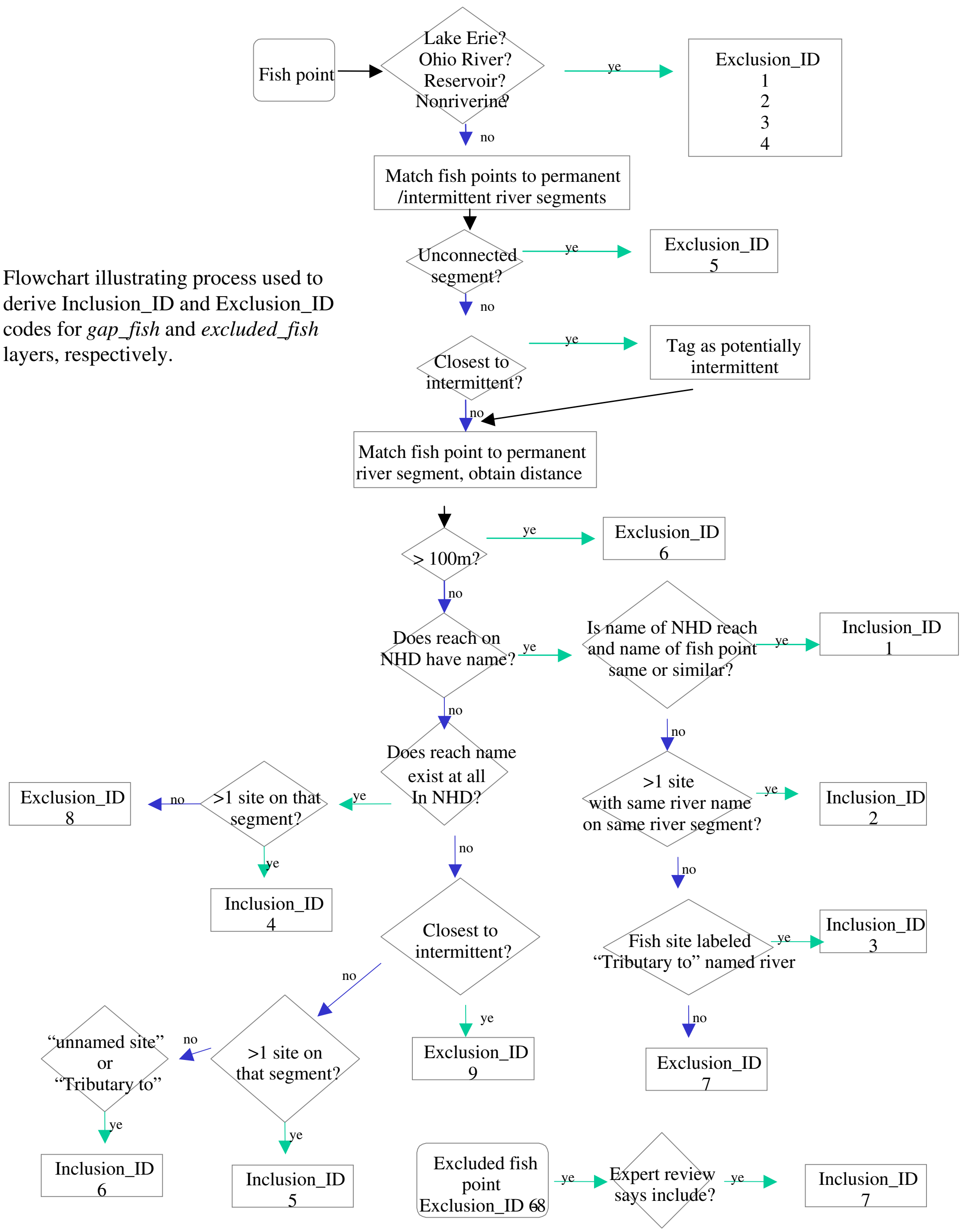

Figure 3–1. Process used to derive the Ohio Aquatic GAP (OH-GAP) biological database. (m, meters; NHD, National Hydrography Dataset.)

Species Habitat

The habitat used in the fish, crayfish, and bivalve models was assumed to be a combination of physical characteristics of the river where the species were collected. (See table 2–1 in the previous "Stream Classification and Mapping" chapter for a list of GIS data layers and sources used in the animal species modeling process. Refer to the metadata accompanying the digital data for more complete descriptions.)

OH-GAP used perennial streams, excluding the Ohio River, when predicting species distributions. DesktopGarp software was used in most cases for predicting potential distributions (Scachetti-Pereira, 2002). This modeling software package uses the Genetic Algorithm for Rule-Set Production (GARP) originally developed by David Stockwell at the Environmental Resources Information Network Unit of Environment Australia and by Ricardo Scachetti-Pereira through the University of Kansas Biodiversity Research Center. Using GARP, omission error was forced to be less than 10 percent for each species, whereas commission error associated with any one species ranged from 1–61 percent for fish, 6–70 percent for crayfish, and 1–57 percent for freshwater bivalves. A simpler extrapolation method was used for predicting potential distributions when a species had less than 20 known species occurrence points. When there were less than 20 known points, GARP tended to overfit the model to the datapoints, resulting in very limited distributions.

The resulting output of GARP was a set of GIS grids or maps showing potential distributions for a biological species. Each species had at least 1,000 models representing its potential distribution. The error associated with any one model varied. OH-GAP, therefore, combined models to limit the total omission error while matching the commission error with the particular species' extent of distribution. In other words, a species with a narrow distribution in two medium-sized streams would be expected to have lower commission error than a species that is found evenly throughout Ohio. Commission errors are predictions of a species existence in stream reaches in which none of that species were found in the observed occurrence data. Intrinsic omission errors occurred when known occurrence points used to build the model were not found on the predicted stream reaches. Extrinsic omission errors occurred when those known occurrence points used to test the model were not found on the predicted stream reaches. Tables 3–2 through 3–4 show various error values associated with each species model.

Distribution Modeling

Predicting Potential Biological Distributions

Presence-only points were used with the physical habitat type classifications of Ohio perennial streams to produce potential distributions for fish, crayfish, and freshwater bivalves using DesktopGarp. Spatial data of the environmental variables are entered along with the known biological occurrence data. The spatial data were entered into DesktopGarp as 200-m grid cells.

The algorithms used in GARP were developed by artificial intelligence experts to structure the data and direct the procedures using four different rule types: atomic, logistic regression, bioclimatic envelope, and negated bioclimatic envelope. Using these rules, GARP iteratively identifies nonrandom correlations between species presence/absence and environmental parameter values.

The DesktopGarp software allowed OH-GAP to choose the percentage of known biological data points to hold back for independent testing of the models. OH-GAP chose to model potential biological species distributions using 78 percent of the known occurrence points, thus leaving 22 percent for testing of the models (Fielding, 2002). This ratio allowed for the maximum number of data points to be used in building the models, while accounting for number of predictor variables.

For purposes of cross-validation, the number of runs per experiment was also entered. A minimum of 1,000 runs were performed for each species to ensure an adequate number of high-quality models. The number of runs was increased up to 3,000 in order to achieve satisfactory models for ubiquitous species.

Two methods for influencing the behavior of GARP include setting the convergence limit and the number of maximum iterations. The convergence limit sets the value at which GARP algorithms will stop running. A convergence limit of zero will result in GARP's running until every possible combination is extinguished. The maximum iteration number is the value at which GARP will stop running regardless of whether the convergence limit is reached. The convergence limit was set to 0.01, and the maximum number of iterations was set to 1,000. (This maximum was never reached for OH-GAP potential distributions, meaning that the convergence limit was always reached.)

Selecting Subsets of GARP Outputs

To achieve the goal of combining models and thus lessening omission error, many methods were tested by OH-GAP. Final distributions were mapped by selecting the models with extrinsic and intrinsic omission error values less than 10 percent. Of all the methods of combining models, this was found to produce the best results for the most species. Depending on the species, the range of omission error associated with the models varied; models with less than 5, 10, and 15 percent error were considered. However, it was found that using less than 10 percent omission error offered the best compromise between omission and commission error values. All models achieving less than 10 percent extrinsic and intrinsic omission error were selected for further inspection.

Although the primary criterion for model selection was to limit the omission error, the next step was to select models with the lowest commission error from the previously selected models. OH-GAP placed more value on known occurrence points, thus minimizing omission error, than on potential occurrences or commission error which may or may not be accurate. Commission error (real or perceived) is a useful tool. When using point occurrence data, commission error can indicate error in the model, as well as locations that may not have been adequately sampled or not sampled at all. Additionally, factors not included in an ecological niche model—including historical factors such as speciation, limited colonization ability, extinction, and competition—all contribute to the commission error (Peterson and others, 2000). In order to limit the models to more probable, though still potential, distributions, the 20 models with the lowest commission error were combined to make the predictive model for each species. In general, it was found that by adding more models together (up to a certain point), the predicted area could be limited. This is because more models predicting occurrence in different areas decrease the chance of agreement when all are combined. The result of this step is a final predictive distribution with limited commission error.

By producing all of the species predictive models with the same method, equal weight can be placed on each species' value; thus, a GAP analysis of groups of fish, crayfish, and freshwater bivalves can be completed. It should be noted that for species with very few, as well as with numerous, known occurrence points, the above method could not be used. For species with a very limited range, sometimes the highest intrinsic or extrinsic omission rate was less than 10 percent. Alternatively, in widely distributed species, the lowest omission error may have been greater than 10 percent. To deal with this, 10 percent was added to the lowest omission-error value, and models that had an omission error under this value were used. In other cases of widely distributed species, there were <20 models with omission less than 10 percent. Here, an omission error was used that would identify at least 20 models. The actual omission percentage used is identified in the *forced omission error* column of tables 3–2 through 3–4.

True omission error was determined for the combined models representing the final distributions. This step was necessary because the models combined each contained individual error values. After the 20 models were combined, the predicted area where 20, 19, 18, and so on, models agreed was created. To decrease omission error, those stream reaches in which 19 of 20 models agreed were combined with the previous output of where 20 of 20 models agreed. In doing this, more known occurrence points may have been added, thus, decreasing the total omission error. Models were added in this fashion until at least 90 percent of the known occurrence points were included in our predicted distributions, corresponding to a 10-percent omission level. (See *number of models used* column on tables 3–2 through 3–4 for actual number of GARP models combined for each species.)

Alternative Method for Predicting Potential Biological Distributions

GARP was used to predict only those species that had 20 or more occurrence points. In those instances when a species had fewer than 20 points, an alternative means of predicting potential species distributions, the extrapolation method, was used. It is a simple model that has been used by other aquatic GAP projects (South Dakota Cooperative Fish and Wildlife Research Unit, 2001). This method is the product of overlaying or combining GIS layers (OH-GAP physical habitat types) and known biological location points. The unique physical habitat type(s) where a species was collected was assumed to indicate the preferred habitat for that species. Therefore, all stream reaches with the same physical habitat type(s) were predicted to be potential habitat for that species. Because each occurrence point, and its underlying habitat type, is extrapolated individually, there was no reason or benefit to using a minimum number of occurrence points in the extrapolation method. A species with 15 occurrence points could be associated with only one or 15 different physical habitat types, all of which would be extrapolated.

Table 3–2. Native fish species that the Ohio Aquatic GAP Project modeled. GARP was used to model 111 of 130 native fish species, whereas the remaining 19 fish species were modeled by the extrapolation method.

[(a) Defines the method used to predict potential distributions; GARP, Genetic Algorithm for Rule-Set Production, or XTRAP, extrapolation method. (b) Omission error used to select the best 20 GARP models as a subset. (c) Number of verified presence points used to predict potential distributions; if GARP was the method used, then value represents the number of occurrence points (200-meter grid cells were used; some points were merged, could result in summarized number less than 20). (d) Range of commission error of the best 20 GARP models used to produce the final potential distributions. (e) After the best 20 GARP models were combined, this value represents the minimum number of models that, when summed, agreed to produce less than 10 percent (%) omission error.]

	Common name	Scientific name	(a) Method	(b) Forced omission error (%) for GARP	(c) Number of points (summarized for GARP)	(d) Commission range of 20 models (%)	(e) Number of models used (out of 20) to achieve less than 10 % omission error
1.	American brook lamprey	*Lampetra appendix*	GARP	10	82	16 to 32	15
2.	American eel	*Anguilla rostrata*	XTRAP	N/A	5	N/A	N/A
3.	Banded darter	*Etheostoma zonale*	GARP	10	957	27 to 30	11
4.	Bigeye chub	*Notropis amblops*	GARP	10	91	25 to 35	15
5.	Bigeye shiner	*Notropis boops*	XTRAP	N/A	11	N/A	N/A
6.	Bigmouth buffalo	*Ictiobus cyprinellus*	GARP	10	165	11 to 20	17
7.	Bigmouth shiner	*Notropis dorsalis*	GARP	10	32	4 to 6	20
8.	Black buffalo	*Ictiobus niger*	GARP	10	118	4 to 9	20
9.	Black bullhead	*Ameiurus melas*	GARP	26	666	32 to 42	1
10.	Black crappie	*Pomoxis nigromaculatus*	GARP	10	773	28 to 52	16
11.	Black redhorse	*Moxostoma duquesnei*	GARP	10	856	24 to 30	11
12.	Blacknose dace	*Rhinichthys atratulus*	GARP	12	1369	53 to 66	13
13.	Blackside darter	*Percina maculata*	GARP	21	1037	34 to 42	4
14.	Blackstripe topminnow	*Fundulus notatus*	GARP	11	574	30 to 51	12
15.	Blue sucker	*Cycleptus elongatus*	GARP	10	8	1 to 3	19
16.	Bluebreast darter	*Etheostoma camurum*	GARP	10	59	4 to 7	20
17.	Bluegill	*Lepomis macrochirus*	GARP	21	3209	40 to 47	3
18.	Bluntnose minnow	*Pimephales notatus*	GARP	26	3892	36 to 49	1
19.	Bowfin	*Amia calva*	GARP	10	64	17 to 22	15
20.	Brindled madtom	*Noturus miurus*	GARP	12	203	22 to 40	12
21.	Brook silverside	*Labidesthes sicculus*	GARP	12	433	30 to 37	11
22.	Brook stickleback	*Culaea inconstans*	GARP	10	111	20 to 28	16
23.	Brook trout	*Salvelinus fontinalis*	XTRAP	N/A	1	N/A	N/A

	Common name	Scientific name	(a) Method	(b) Forced omission error (%) for GARP	(c) Number of points (summarized for GARP)	(d) Commission range of 20 models (%)	(e) Number of models used (out of 20) to achieve less than 10 % omission error
24.	Brown bullhead	*Ameiurus nebulosus*	GARP	15	468	38 to 49	9
25.	Bullhead minnow	*Pimephales vigilax*	GARP	10	192	8 to 10	20
26.	Central mudminnow	*Umbra limi*	GARP	10	254	31 to 41	12
27.	Central stoneroller	*Campostoma anomalum*	GARP	17	3085	45 to 58	6
28.	Channel catfish	*Ictalurus punctatus*	GARP	10	1227	21 to 28	14
29.	Channel darter	*Percina copelandi*	XTRAP	N/A	1	N/A	N/A
30.	Channel shiner	*Notropis wickliffi*	GARP	10	16	5	20
31.	Common shiner	*Luxilus cornutus*	GARP	10	588	30 to 34	13
32.	Creek chub	*Semotilus atromaculatus*	GARP	22	3102	44 to 61	3
33.	Creek chubsucker	*Erimyzon oblongus*	GARP	10	60	16 to 19	12
34.	Dusky darter	*Percina sciera*	GARP	10	117	12 to 16	13
35.	Eastern sand darter	*Ammocrypta pellucida*	GARP	10	37	8 to 14	19
36.	Emerald shiner	*Notropis atherinoides*	GARP	10	819	37 to 48	14
37.	Fantail darter	*Etheostoma flabellare*	GARP	17	1527	43 to 61	10
38.	Fathead minnow	*Pimephales promelas*	GARP	12	1048	51 to 64	15
39.	Flathead catfish	*Pylodictis olivaris*	GARP	10	418	10 to 12	17
40.	Freshwater drum	*Aplodinotus grunniens*	GARP	10	754	19 to 30	14
41.	Ghost shiner	*Notropis buchanani*	GARP	10	70	15 to 37	15
42.	Gizzard shad	*Dorosoma cepedianum*	GARP	11	1781	32 to 44	12
43.	Golden redhorse	*Moxostoma erythrurum*	GARP	13	2055	32 to 46	8
44.	Golden shiner	*Notemigonus crysoleucas*	GARP	21	828	32 to 44	7
45.	Goldeye	*Hiodon alosoides*	XTRAP	N/A	3	N/A	N/A
46.	Grass pickerel	*Esox americanus v.*	GARP	14	842	37 to 49	8
47.	Gravel chub	*Erimystax x-punctatus*	GARP	10	171	6 to 9	20
48.	Greater redhorse	*Moxostoma valenciennesi*	GARP	10	41	5 to 6	20
49.	Green sunfish	*Lepomis cyanellus*	GARP	22	3637	38 to 50	2
50.	Greenside darter	*Etheostoma blennioides*	GARP	19	2155	36 to 47	5
51.	Highfin carpsucker	*Carpiodes velifer*	GARP	10	209	8 to 10	20
52.	Hornyhead chub	*Nocomis biguttatus*	GARP	10	214	31 to 36	17
53.	Iowa darter	*Etheostoma exile*	XTRAP	N/A	2	N/A	N/A

	Common name	Scientific name	(a) Method	(b) Forced omission error (%) for GARP	(c) Number of points (summarized for GARP)	(d) Commission range of 20 models (%)	(e) Number of models used (out of 20) to achieve less than 10 % omission error
54.	Johnny darter	*Etheostoma nigrum*	GARP	24	2308	37 to 48	2
55.	Lake chubsucker	*Erimyzon sucetta*	XTRAP	N/A	2	N/A	N/A
56.	Largemouth bass	*Micropterus salmoides*	GARP	21	2625	36 to 47	2
57.	Least brook lamprey	*Lampetra aepyptera*	GARP	10	140	25 to 28	12
58.	Least darter	*Etheostoma microperca*	GARP	10	23	10 to 12	20
59.	Logperch	*Percina caprodes*	GARP	12	1377	35 to 49	12
60.	Longear sunfish	*Lepomis megalotis*	GARP	12	1762	30 to 46	13
61.	Longnose dace	*Rhinichthys cataractae*	GARP	10	11	12 to 14	20
62.	Longnose gar	*Lepisosteus osseus*	GARP	10	317	15 to 27	14
63.	Mimic shiner	*Notropis volucellus*	GARP	10	319	25 to 34	17
64.	Mississippi silvery minnow	*Hybognathus nuchalis*	XTRAP	N/A	1	N/A	N/A
65.	Mooneye	*Hiodon tergisus*	GARP	10	62	7 to 9	20
66.	Mottled sculpin	*Cottus bairdi*	GARP	10	656	38 to 47	16
67.	Mountain brook lamprey	*Ichthyomyzon greeleyi*	XTRAP	N/A	3	N/A	N/A
68.	Mountain madtom	*Noturus eleutherus*	GARP	10	13	3 to 6	20
69.	Muskellunge	*Esox masquinongy*	GARP	10	31	15 to 30	17
70.	Northern brook lamprey	*Ichthyomyzon fossor*	XTRAP	N/A	1	N/A	N/A
71.	Northern hogsucker	*Hypentelium nigricans*	GARP	14	2459	41 to 62	14
72.	Northern madtom	*Noturus stigmosus*	XTRAP	N/A	6	N/A	N/A
73.	Northern pike	*Esox lucius*	GARP	10	177	21 to 31	12
74.	Ohio lamprey	*Ichthyomyzon bdellium*	XTRAP	N/A	2	N/A	N/A
75.	Oranagespotted sunfish	*Lepomis humilis*	GARP	14	894	25 to 40	10
76.	Orangethroat darter	*Etheostoma spectabile*	GARP	18	504	25 to 28	1
77.	Popeye shiner	*Notropis ariommus*	XTRAP	N/A	7	N/A	N/A
78.	Pumpkinseed	*Lepomis gibbosus*	GARP	17	1006	35 to 50	9
79.	Quillback	*Carpiodes cyprinus*	GARP	10	1116	28 to 32	17
80.	Rainbow darter	*Etheostoma caeruleum*	GARP	21	1683	31 to 48	5
81.	Rainbow smelt	*Osmerus mordax*	XTRAP	N/A	4	N/A	N/A
82.	Redfin shiner	*Lythrurus umbratilis*	GARP	14	612	36 to 51	6
83.	Redside dace	*Clinostomus elongatus*	GARP	10	131	27 to 38	14

	Common name	Scientific name	(a) Method	(b) Forced omission error (%) for GARP	(c) Number of points (summarized for GARP)	(d) Commission range of 20 models (%)	(e) Number of models used (out of 20) to achieve less than 10 % omission error
84.	River carpsucker	*Carpiodes carpio*	GARP	10	338	8 to 10	18
85.	River chub	*Nocomis micropogon*	GARP	10	396	32 to 36	16
86.	River darter	*Percina shumardi*	XTRAP	N/A	5	N/A	N/A
87.	River redhorse	*Moxostoma carinatum*	GARP	10	226	11 to 13	19
88.	River shiner	*Notropis blennius*	GARP	10	17	7 to 9	20
89.	Rockbass	*Ambloplites rupestris*	GARP	12	2438	41 to 51	11
90.	Rosefin shiner	*Lythrurus ardens*	GARP	10	641	20 to 27	14
91.	Rosyface shiner	*Notropis rubellus*	GARP	14	597	30 to 42	11
92.	Rosyside dace	*Clinostomus funduloides*	GARP	10	17	2 to 4	20
93.	Sand shiner (2000 runs)	*Notropis stramineus*	GARP	13	1684	39 to 49	10
94.	Sauger	*Stizostedion canadense*	GARP	10	297	9 to 12	15
95.	Shorthead redhorse	*Moxostoma macrolepidotum*	GARP	10	748	13 to 26	14
96.	Shortnose gar	*Lepisosteus platostomus*	XTRAP	N/A	6	N/A	N/A
97.	Silver chub	*Macrhybopsis storeriana*	GARP	10	33	7 to 14	16
98.	Silver lamprey	*Ichthyomyzon unicuspis*	GARP	10	48	7 to 12	20
99.	Silver redhorse (2000 runs)	*Moxostoma anisurum*	GARP	10	891	22 to 26	12
100.	Silver shiner	*Notropis photogenis*	GARP	10	948	28 to 33	12
101.	Silverjaw minnow	*Notropis buccatus*	GARP	19	1328	47 to 53	6
102.	Skipjack herring	*Alosa chrysochloris*	GARP	19	74	5 to 6	20
103.	Slenderhead darter	*Percina phoxocephala*	GARP	10	121	8 to 9	19
104.	Smallmouth bass	*Micropterus dolomieui*	GARP	12	2081	38 to 54	13
105.	Smallmouth buffalo	*Ictiobus bubalus*	GARP	10	287	12 to 15	16
106.	Southern redbelly dace	*Phoxinus erythrogaster*	GARP	10	294	46 to 64	16
107.	Spotfin shiner (3000 runs)	*Cyprinella spiloptera*	GARP	14	2335	31 to 42	8
108.	Spottail shiner	*Notropis hudsonius*	GARP	10	92	6 to 10	18
109.	Spotted bass	*Micropterus punctulatus*	GARP	10	682	21 to 26	13
110.	Spotted darter	*Etheostoma maculatum*	XTRAP	N/A	6	N/A	N/A
111.	Spotted sucker	*Minytrema melanops*	GARP	15	765	27 to 46	12
112.	Steelcolor shiner	*Cyprinella whipplei*	GARP	10	305	13 to 18	15
113.	Stonecat madtom	*Noturus flavus*	GARP	12	649	30 to 42	14

	Common name	Scientific name	(a) Method	(b) Forced omission error (%) for GARP	(c) Number of points (summarized for GARP)	(d) Commission range of 20 models (%)	(e) Number of models used (out of 20) to achieve less than 10 % omission error
114.	Streamline chub	*Erimystax dissimilis*	GARP	10	67	2 to 4	20
115.	Striped shiner	*Luxilus chrysocephalus*	GARP	19	2435	40 to 55	11
116.	Suckermouth minnow	*Phenacobius mirabilis*	GARP	15	824	33 to 39	8
117.	Tadpole madtom	*Noturus gyrinus*	GARP	10	174	19 to 24	10
118.	Threadfin shad	*Dorosoma petenense*	XTRAP	N/A	2	N/A	N/A
119.	Tippecanoe darter	*Etheostoma tippecanoe*	GARP	10	47	2 to 3	20
120.	Tonguetied minnow	*Exoglossum laurae*	GARP	10	39	5 to 8	20
121.	Trout-perch	*Percopsis omiscomaycus*	GARP	13	284	32 to 55	15
122.	Variegate darter	*Etheostoma variatum*	GARP	10	172	16 to 23	15
123.	Walleye	*Stizostedion vitreum v.*	GARP	10	204	13 to 17	18
124.	Warmouth	*Lepomis gulosus*	GARP	13	376	24 to 48	13
125.	Western banded killifish	*Fundulus diaphanus menona*	XTRAP	N/A	5	N/A	N/A
126.	White bass	*Morone chrysops*	GARP	10	429	13 to 22	12
127.	White crappie	*Pomoxis annularis*	GARP	15	1228	31 to 43	6
128.	White sucker	*Catostomus commersoni*	GARP	25	3401	41 to 50	2
129.	Yellow bullhead	*Ameiurus natalis*	GARP	27	2260	36 to 50	1
130.	Yellow perch	*Perca flavescens*	GARP	12	353	30 to 42	13

Table 3–3. Native crayfish species that the Ohio Aquatic GAP Project modeled. GARP was used to model 14 of 17 native crayfish species, whereas the remaining 3 crayfish species were modeled by the extrapolation method.

[(a) defines the method used to predict potential distributions; GARP, Genetic Algorithm for Rule-Set Production, or XTRAP, extrapolation method. (b) Omission error used to select the best 20 GARP models as a subset. (c) Number of verified presence points used to predict potential distributions; if GARP was the method used, then value represents the number of occurrence points (200-meter grid cells were used; some points were merged, could result in summarized number less than 20). (d) Range of commission error of the best 20 GARP models used to produce the final potential distributions. (e) After the best 20 GARP models were combined, this value represents the minimum number of models that, when summed, agreed to produce less than 10 percent (%) omission error.]

	Common name	Scientific name	(a) Method	(b) Forced omission error (%) for GARP	(c) Number of points (summarized for GARP)	(d) Commission range of 20 models (%)	(e) Number of models used (out of 20) to achieve less than 10% omission error
1.	Allegheny crayfish	*Orconectes obscurus*	GARP	10	211	7 to 17	20
2.	Big water crayfish	*Cambarus robustus*	GARP	10	329	36 to 43	14
3.	Devil crayfish	*Cambarus diogenes*	XTRAP	N/A	13	N/A	N/A
4.	Digger crayfish	*Fallicambarus fodiens*	XTRAP	N/A	10	N/A	N/A
5.	Little brown mudbug	*Cambarus thomai*	GARP	11	88	41 to 59	13
6.	Northern clearwater crayfish	*Orconectes propinquus*	GARP	10	221	9 to 12	20
7.	Ohio crawfish	*Cambarus species A*	GARP	10	240	56 to 70	15
8.	Ortmann’s mudbug	*Cambarus ortmanni*	XTRAP	N/A	17	N/A	N/A
9.	Paintedhand mudbug	*Cambarus species B*	GARP	10	65	24 to 44	14
10.	Papershell crayfish	*Orconectes immunis*	GARP	19	194	30 to 38	1
11.	Rock crawfish	*Cambarus carinirostris*	GARP	10	60	17 to 23	13
12.	Rusty crayfish	*Orconectes rusticus*	GARP	22	2201	28 to 45	3
13.	Sanborn’s crayfish	*Orconectes sanbornii*	GARP	10	1210	40 to 51	15
14.	Sloan’s crayfish	*Orconectes sloanii*	GARP	10	61	6 to 10	20
15.	Spiney stream crayfish	*Orconectes cristavarius*	GARP	10	61	13 to 20	15
16.	Teays River crayfish	*Cambarus sciotensis*	GARP	10	157	11 to 14	19
17.	White River crayfish	*Procambarus acutus*	GARP	10	60	25 to 33	13

Table 3–4. Native freshwater bivalve species that the Ohio Aquatic GAP Project modeled. GARP was used to model 51 of 70 native bivalve species, whereas the remaining 19 bivalve species were modeled by the extrapolation method.

[(a) defines the method used to predict potential distributions; GARP, Genetic Algorithm for Rule-Set Production, or XTRAP, extrapolation method. (b) Omission error used to select the best 20 GARP models as a subset. (c) Number of verified presence points used to predict potential distributions; if GARP was the method used, then value represents the number of occurrence points (200-meter grid cells were used; some points were merged, could result in summarized number less than 20). (d) Range of commission error of the best 20 GARP models used to produce the final potential distributions. (e) After the best 20 GARP models were combined, this value represents the minimum number of models that, when summed, agreed to produce under 10 percent (%) omission error.]

	Common name	Scientific name	(a) Method	(b) Forced omissionerror (%) for GARP	(c) Number of points (summarized for GARP)	(d) Commission range of 20 models (%)	(e) Number of models used (out of 20) to achieve less than 10% omission error
1.	Black sandshell	*Ligumia recta*	GARP	10	89	10 to 16	13
2.	Butterfly	*Ellipsaria lineolata*	GARP	10	42	4 to 10	20
3.	Clubshell	*Pleurobema clava*	GARP	10	190	13 to 16	16
4.	Creek heelsplitter	*Lasmigona compressa*	GARP	11	221	27 to 54	16
5.	Creeper	*Strophitus undulates*	GARP	13	711	30 to 41	12
6.	Cylindrical papershell	*Anodontoides ferussacianus*	GARP	11	562	48 to 57	12
7.	Deertoe	*Truncilla truncate*	GARP	10	75	9 to 13	15
8.	Eastern pondmussel	*Ligumia nasuta*	XTRAP	N/A	10	N/A	N/A
9.	Elephantear	*Elliptio crassidens*	GARP	10	22	7 to 11	20
10.	Elktoe	*Alasmidonta marginata*	GARP	10	271	13 to 16	18
11.	Fanshell	*Cyprogenia stegaria*	GARP	10	40	6 to 10	20
12.	Fatmucket	*Lampsilis radiata*	GARP	10	1226	34 to 48	15
13.	Fawnsfoot	*Truncilla donaciformis*	GARP	10	158	6 to 10	17
14.	Flat floater	*Anodonta suborbiculata*	XTRAP	N/A	15	N/A	N/A
15.	Fluted shell	*Lasmigona costata*	GARP	10	586	20 to 27	16
16.	Fragile papershell	*Leptodea fragilis*	GARP	10	416	13 to 18	13
17.	Giant floater	*Pyganodon grandis*	GARP	10	956	46 to 52	15
18.	Grooved fingernailclam	*Sphaerium simile*	XTRAP	N/A	16	N/A	N/A
19.	Kidneyshell	*Ptychobranchus fasciolar*	GARP	10	378	18 to 24	10
20.	Lilliput	*Toxolasma parvus*	GARP	10	170	34 to 42	13
21.	Little spectaclecase	*Villosa lienosa*	GARP	10	29	8 to 12	20
22.	Long fingernailclam	*Musculium transversum*	GARP	10	66	23 to 39	12

	Common name	Scientific name	(a) Method	(b) Forced omissionerror (%) for GARP	(c) Number of points (summarized for GARP)	(d) Commission range of 20 models (%)	(e) Number of models used (out of 20) to achieve less than 10% omission error
23.	Long solid	*Fusconaia maculate*	GARP	10	82	7 to 11	20
24.	Mapleleaf	*Quadrula quadrula*	GARP	10	435	11 to 14	13
25.	Monkeyface	*Quadrula metanevra*	GARP	10	26	0 to 2	20
26.	Mucket	*Actinonaias ligamentina*	GARP	10	241	10 to 15	12
27.	Northern riffleshell	*Epioblasma rangiana*	GARP	10	82	4 to 9	17
28.	Ohio pigtoe	*Pleurobema cordatum*	GARP	10	75	5 to 9	20
29.	Paper pondshell	*Utterbackia imbecillis*	GARP	10	202	29 to 38	12
30.	Pimpleback	*Quadrula pustulosa*	GARP	10	241	7 to 10	17
31.	Pink heelsplitter	*Potamilus alatus*	GARP	10	261	14 to 20	19
32.	Pink mucket	*Lampsilis abrupta*	XTRAP	10	16	N/A	N/A
33.	Pink papershell	*Potamilus ohiensis*	GARP	10	128	7 to 9	N/A
34.	Pistolgrip	*Tritogonia verrucosa*	GARP	10	172	8 to 10	20
35.	Plain pocketbook	*Lampsilis ventricosa*	GARP	10	734	21 to 29	16
36.	Pocketbook	*Lampsilis ovata*	GARP	10	46	4 to 8	18
37.	Pond fingernailclam	*Musculium secures*	XTRAP	10	2	N/A	N/A
38.	Pondhorn	*Uniomerus tetralasm*	GARP	10	25	8 to 14	20
39.	Purple catspaw	*Epioblasma obliquata o.*	XTRAP	10	7	N/A	N/A
40.	Purple lilliput	*Toxolasma lividus*	XTRAP	10	9	N/A	N/A
41.	Purple wartyback	*Cyclonaias tuberculata*	GARP	10	134	11 ti 17	16
42.	Pyramid pigtoe	*Pleurobema rubrum*	XTRAP	10	15	N/A	N/A
43.	Rabbitsfoot	*Quadrula cylindrical*	GARP	10	108	7 to 15	16
44.	Rainbowshell	*Villosa iris*	GARP	10	269	22 to 28	13
45.	Rayed bean	*Villosa fabalis*	GARP	10	97	13 to 17	15
46.	Ridgedback peaclam	*Pisidium compressum*	GARP	10	26	10 to 28	12
47.	Ring pink	*Obovaria retusa*	XTRAP	10	3	N/A	N/A
48.	River fingernailclam	*Sphaerium fabale*	XTRAP	10	13	N/A	N/A
49.	River peaclam	*Pisidium fallax*	XTRAP	10	10	N/A	N/A
50.	Rough pigtoe	*Pleurobema plenum*	XTRAP	10	2	N/A	N/A
51.	Round hickorynut	*Obovaria subrotunda*	GARP	10	286	11 to 16	15
52.	Round pigtoe	*Pleurobema sintoxia*	GARP	10	252	12 to 18	13

	Common name	Scientific name	(a) Method	(b) Forced omissionerror (%) for GARP	(c) Number of points (summarized for GARP)	(d) Commission range of 20 models (%)	(e) Number of models used (out of 20) to achieve less than 10% omission error
53.	Salamander mussel	*Simpsonaias ambigua*	GARP	10	45	11 to 15	15
54.	Sheepnose	*Plethobasus cyphyus*	GARP	10	36	8 to 12	20
55.	Slippershell mussel	*Alasmidonta viridis*	GARP	27	306	14 to 17	*
56.	Snuffbox	*Epioblasma triquetra*	GARP	10	198	8 to 14	14
57.	Spike	*Elliptio dilatata*	GARP	10	465	20 to 28	15
58.	Striated fingernailclam	*Sphaerium striatinum*	GARP	12	159	42 to 53	13
59.	Threehorn wartyback	*Obliquaria reflexa*	GARP	10	115	9 to 12	19
60.	Threeridge	*Amblema plicata*	GARP	10	624	16 to 25	16
61.	Tubercled blossom	*Epioblasma torulosa*	XTRAP	10	9	N/A	N/A
62.	Ubiquitous peaclam	*Pisidium casertanum*	XTRAP	10	18	N/A	N/A
63.	Wabash pigtoe	*Fusconaia flava*	GARP	10	646	21 to 29	12
64.	Wartyback	*Quadrula nodulata*	XTRAP	10	3	N/A	N/A
65.	Washboard	*Megalonaias nervosa*	XTRAP	10	17	N/A	N/A
66.	Wavyrayed lampmussel	*Lampsilis fasciola*	GARP	10	240	16 to 24	13
67.	White heelsplitter	*Lasmigona complanata*	GARP	10	498	20 to25	14
68.	White catspaw	*Epioblasma obliquata*	XTRAP	10	11	N/A	N/A
69.	Winged mapleleaf	*Quadrula fragosa*	XTRAP	10	3	N/A	N/A
70.	Yellow sandshell	*Lampsilis teres*	XTRAP	10	8	N/A	N/A

* Slippershell mussel is the only species for which the omission error could not be forced to a value less than 10 percent. There are no locations where less than 18 of 20 models agreed, yet the best omission error that could be obtained was 14 percent.

Assessment Units: 14-Digit Hydrologic Units (14-HUs)

OH-GAP chose to show and analyze all potential species distributions at the 14-digit hydrologic unit (14-HU), or subwatershed, level. Ohio contains 1,750 separate 14-HUs (fig. 3–2), including the Lake Erie Islands (one 14-HU). The 14-HUs are designed to be similar in size; in Ohio they range from about 10 km^2 to about 200 km^2, with most of the smaller ones found along the Ohio border. All statistics, conclusions, and spatial data are discussed and presented in terms of these units. Because they have no perennial rivers, the Lake Erie islands were not included in the assessment.

Figure 3–2. The 1,749 14-digit hydrologic units (14-HUs) in Ohio. A solid black line separates the Lake Erie Basin in the north from the Ohio River Basin in the south.

Results

OH-GAP predicted potential distributions for 130, 17, and 70 native species of fish, crayfish, and freshwater bivalves, respectively. Because of the nature of spatial data, the potential species distributions can be viewed as separate maps for each species (for example, fig. 3–3). The potential distribution maps show stream reaches and 14-HUs. The complete collection of species distribution maps can be viewed in the map files presented separately in this report. Also, tables 3–2 through 3–4 list the OH-GAP-modeled species with statistics that summarize the modeling results.

Species Richness

GAP has often been associated with the mapping of species-rich areas or "hotspots." Richness maps identify where the same numbers of elements co-occur in particular geographic locations (in the case of our data, where numbers of native animal species are mapped for the same grid cells). These are color coded or shaded in intensity from the highest numbers of co-occurrence (richness) to the lowest. Although OH-GAP used this pattern analysis, it is only one measure of these data. The richest areas may or may not indicate the best conservation opportunities. They may occur in already protected areas or may represent mostly protected species or those not at risk. Still, species-rich areas are often a starting point to examine conservation opportunities in combination with other analyses. (See "Introduction" and the chapter "Analysis Based on Stewardship and Management Status.") Species-rich areas may also be used for identifying places of interest for wildlife observation and study.

Potential richness is depicted for all mapped taxa (fig. 3–4) and for taxonomic groups (fig. 3–5 through 3–7). These species-richness values are mapped relative to Ohio. Map production and interpretation are discussed in the chapter "Analysis Based on Stewardship and Management Status."

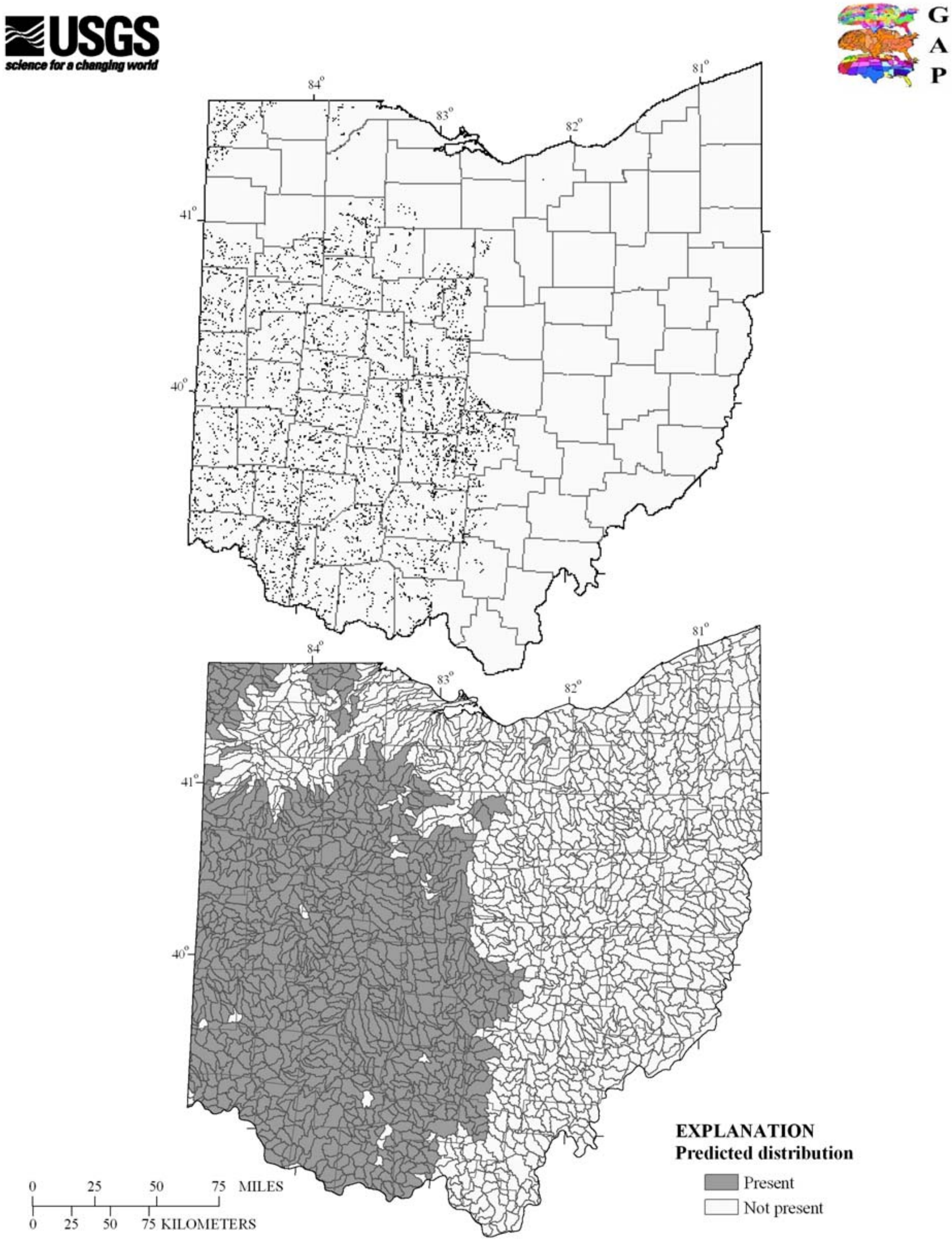

Figure 3–3. Predicted distribution of orangethroat darter, *Etheostoma spectabile*, in Ohio. The top map shows the predicted stream reaches, and the bottom map shows the predicted 14-digit hydrologic units.

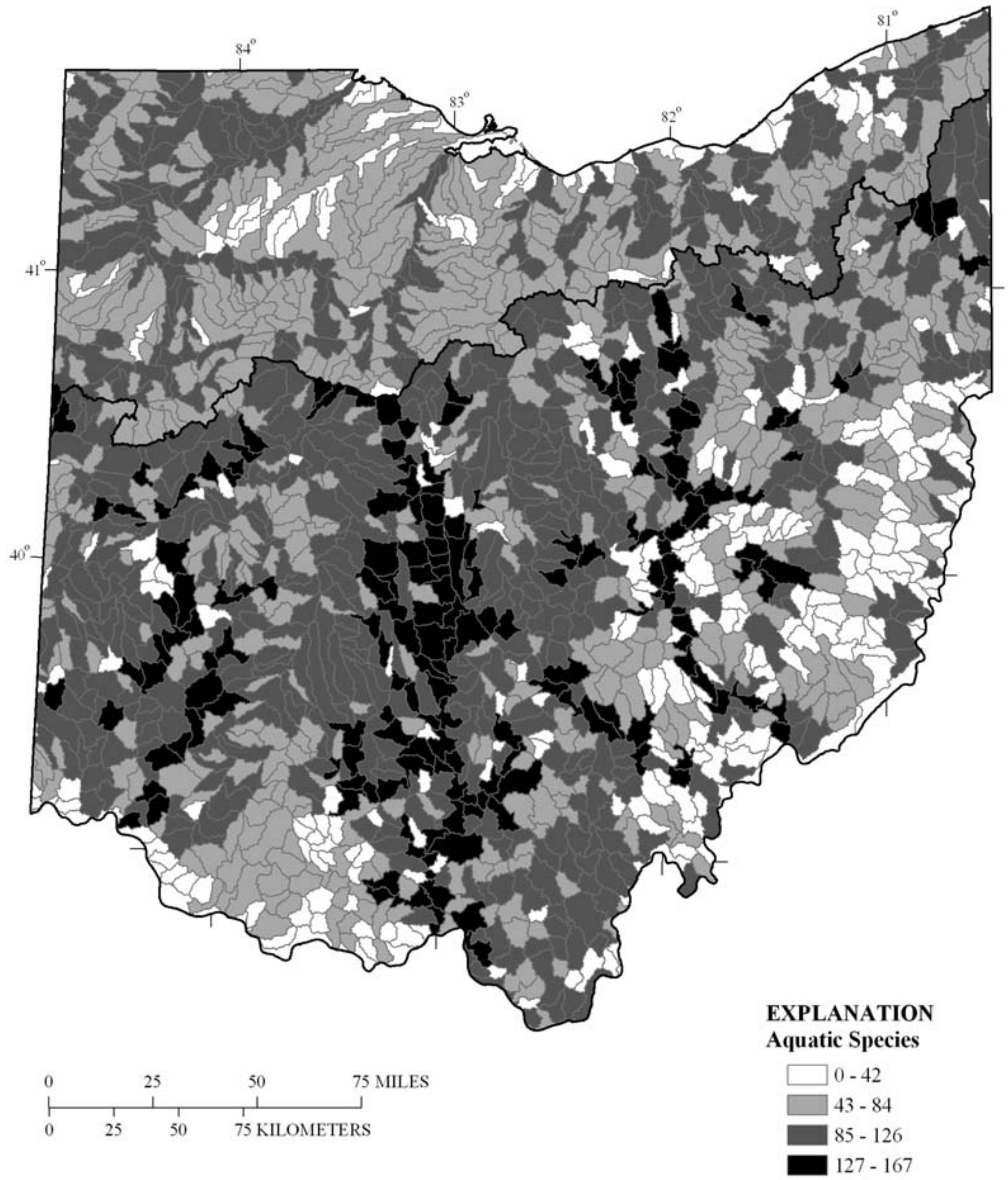

Figure 3–4. Potential species-richness values, by 14-digit hydrologic unit, for fish, crayfish, and bivalves in Ohio. A solid black line separates the Lake Erie Basin in the north from the Ohio River Basin in the south.

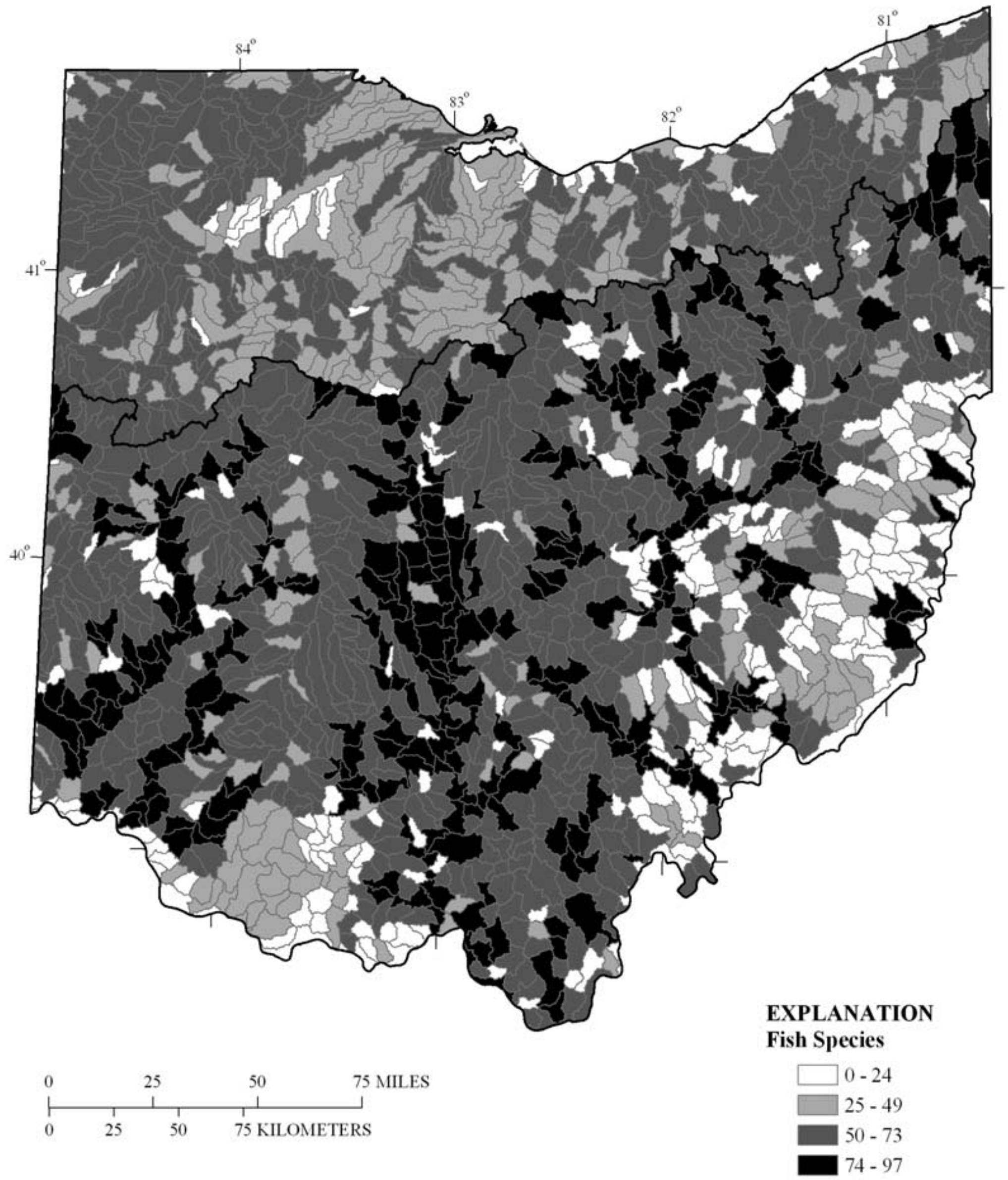

Figure 3–5. Potential species-richness values, by 14-digit hydrologic unit, for fish species in Ohio. A solid black line separates the Lake Erie Basin in the north from the Ohio River Basin in the south.

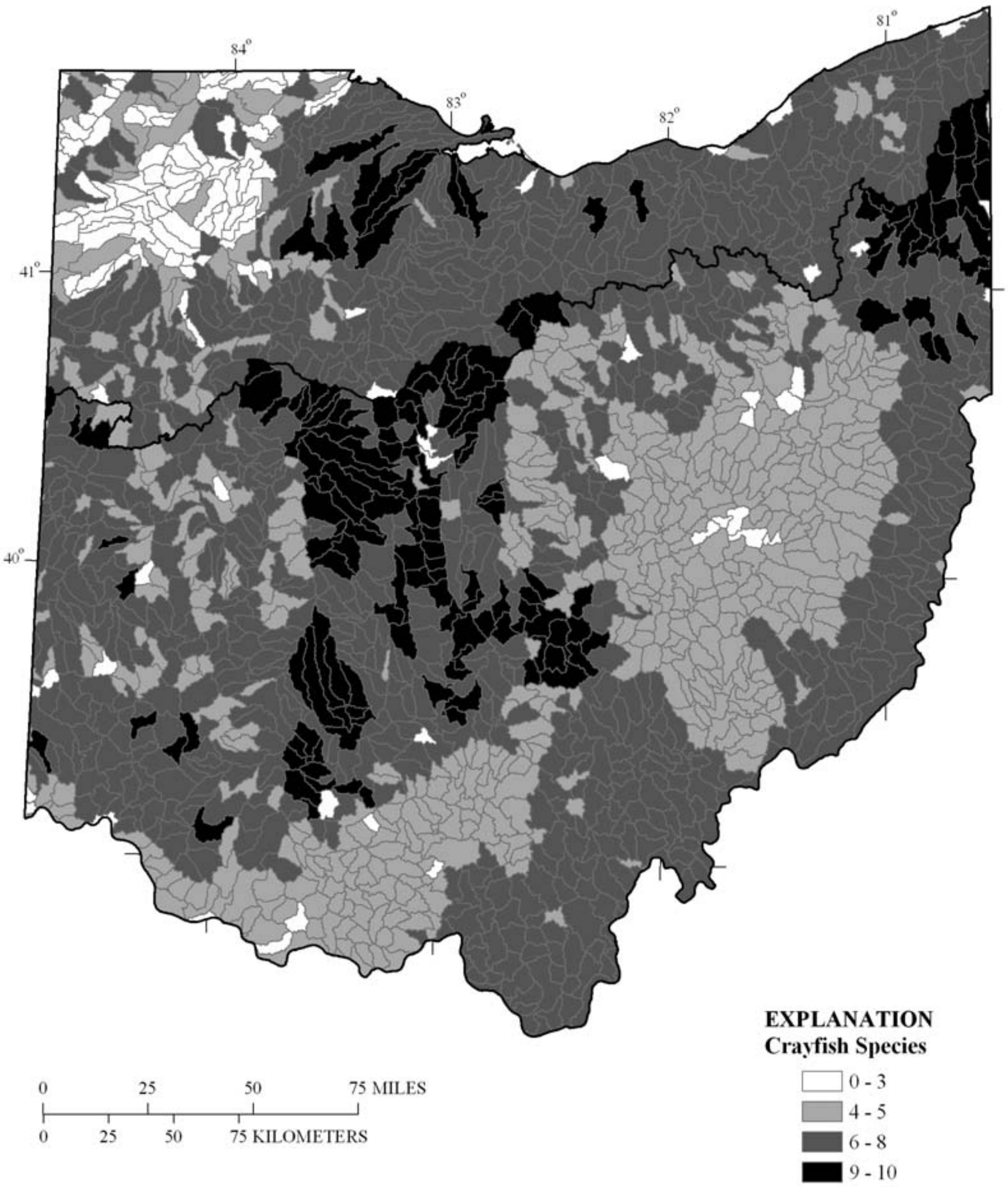

Figure 3–6. Potential species-richness values, by 14-digit hydrologic unit, for crayfish species in Ohio. A solid black line separates the Lake Erie Basin in the north from the Ohio River Basin in the south.

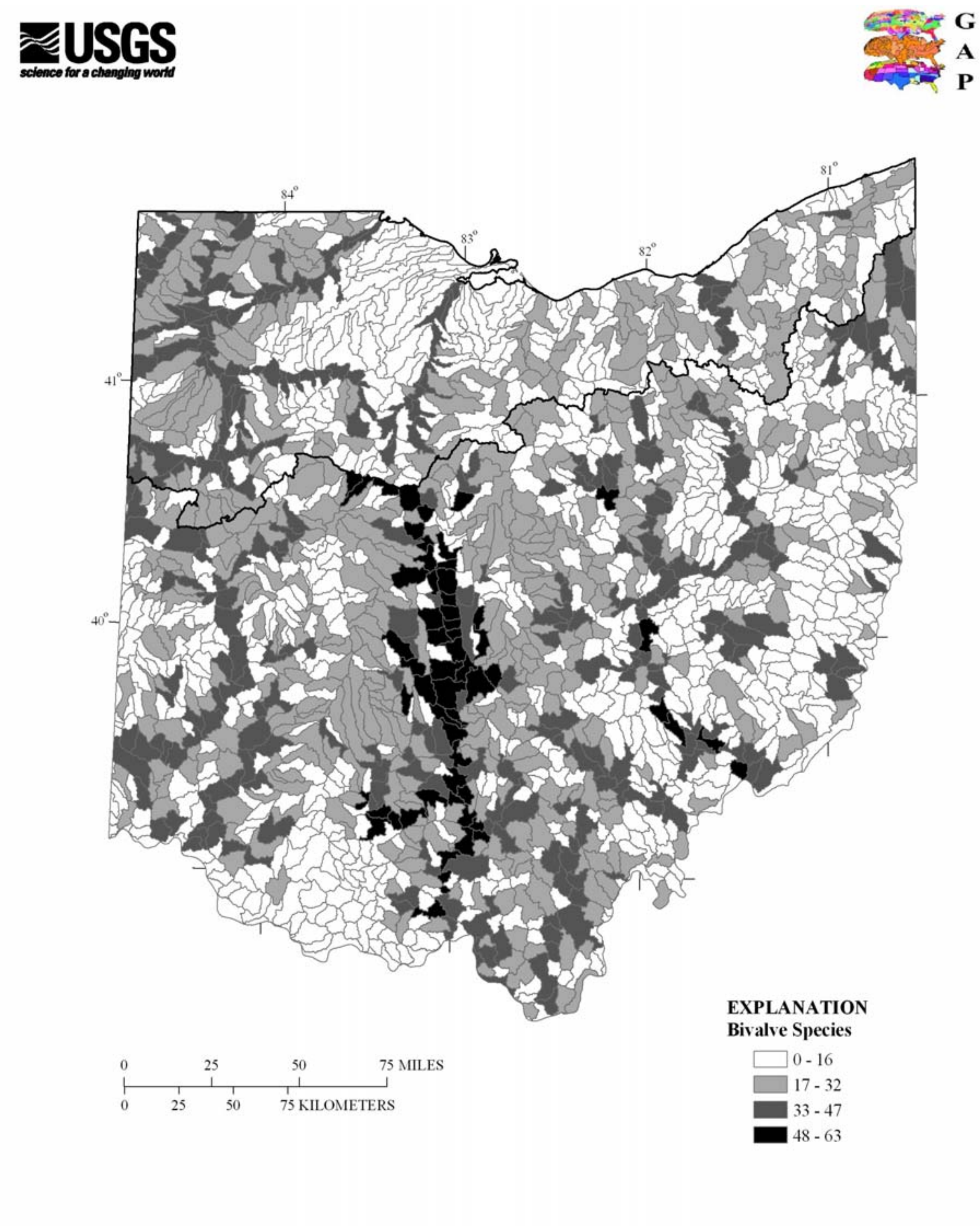

Figure 3–7. Potential species-richness values, by 14-digit hydrologic unit, for bivalve species in Ohio. A solid black line separates the Lake Erie Basin in the north from the Ohio River Basin in the south.

Accuracy Assessment

Assessing the accuracy of the predicted aquatic animal distributions is subject to a host of serious challenges related to both the behavioral aspects of species and the logistics of detecting them. These are described further in the "Background" section of the GAP Handbook on the National GAP Web page (*http://gapanalysis.nbii.gov*). It is, however, necessary to provide some measure of confidence in the results of the gap analysis for species collectively, if not individually or by taxonomic group (comparison to stewardship and management status), and to allow users to judge the suitability of the distribution maps for their own uses. OH-GAP acknowledges that distribution maps are never finished products but are continually updated as new information is gathered. Continuous updates not only allow an improvement of model predictions but also allow for the opportunity to map true changes in species distributions over time.

One of the goals of OH-GAP was to produce maps that show predicted distributions of fish, crayfish, and freshwater bivalves with an accuracy of 90 percent or higher. Failure to achieve this accuracy indicates the need to refine the data sets and models used for predicting distribution. However, there is a conscious effort in the GAP process to err on the side of commission. In other words, OH-GAP may predict species as being potentially present when they are not. There are two primary reasons for doing so: first, few species have systematic, unbiased known-ranges and these distributions provide a greater potential for sampling and investigation than a conservative approach that may miss such opportunities; second, in analyzing conservation representation (see the Analysis Based on Stewardship and Management Status section), labeling a species as having adequate protection and later finding that it does not was deemed less desirable than labeling a species as lacking protection, and later finding that it is adequately protected. Ground-truthing, though not a component of gap analysis, would provide an opportunity to refine the models and remove some of the existing ambiguity. The omission and commission ranges of the aquatic distribution maps are listed in tables 3–2 through 3–4.

Limitations and Discussion

Data Timeframe and Implications

OH-GAP predicted potential species distributions on the basis of enduring physical characteristics of the streams. To achieve this goal, OH-GAP used historical and modern biological records to ensure that species distributions represented their true potential or at least more of a potential than would be shown using recent data only. Use of a smaller set of more recent biological data might fail to accurately predict presence areas. This possibility may result from poor water quality forcing species into their current distributions and thus creating models that show distributions closely approximating known occurrences. This issue may exist at some level for fish because only relatively recent collection points (1978–2001) were available for use. It is probable that species' preferences for habitat were not fully discovered because of land-use changes. (Physical habitat of fish in the 1800s was not used to build the predictive models because no records were found in that habitat using the recent data.) The snapshot seen from the recent data is where fish might be forced to endure (species use the available habitat but do not prefer it). OH-GAP fish models show a subset of preferred or potential habitat. For freshwater mussels and crayfish, GAP used collection points that spanned the past 150 years. This yields a more complete representation of species' preferred habitat based on physical characteristics but may or may not represent modern distributions.

Extrapolation Method of Predicting Potential Distributions

The alternative method for species with 1–20 known occurrence points extrapolates potential distributions from verified presences to areas with the same habitat types. By doing this, one can achieve zero omission error. Every location where a species was collected is included in the predicted distribution. The results can be narrow or broad depending on the physical habitat type(s) from which a species was collected. Some physical habitat types are more numerous than others. In general, however, this method is simple in that it selects stream reaches with the same physical habitat types regardless of proximity to known distributions.

Assessment Units: 14-Digit Hydrologic Units (14-HUs)

The resulting species distributions were illustrated using 200-m grid cells. However, not all of the environmental factors used for modeling were as fine of resolution. This helps explain why a review of the predicted distributions identified areas where short, fragmented distributions were probably not accurate at the stream-reach scale. This supported the decision to show data at a coarser scale, thus creating a buffer in which fish species' occurrence was likely.

OH-GAP chose 14-HUs to analyze species distributions for several reasons. They are easily identifiable and lend themselves to a realistic watershed management approach. The units are similar in area and, although not true watersheds in the sense of encompassing all of the upstream drainage area, they represent meaningful drainage areas (Omernik, 2003). OH-GAP determined that existing familiarity and use of the 14-HU data by conservation managers, academia, developers, and the scientific community was another reason for choosing the 14-HU as the assessment unit.

Additional Abandoned Modeling Methods

OH-GAP was a pilot project. The following techniques were considered but, for reasons described within each technique, not applied to the OH-GAP potential-distribution models. These abandoned modeling methods are discussed for the benefit of future Aquatic GAP or gap-like projects.

Abundance

OH-GAP evaluated several methods of incorporating species catch or abundance data. Abundance bias can be related to sampling bias. The number of individuals can be related to the sampling effort, ease or difficulty of capture, or natural rarity or abundance (Stockwell and Peterson, 2002).

One method was to eliminate all locations where the species was caught an average of one time per sample or not at all. This method controls for number of times sampled. It does not factor in abundance at a particular site compared to the rest of the sites in the state where the species was found, nor does it reflect the relative abundance of that species for that site.

OH-GAP used abundance data to produce potential distributions. Trial results showed that the models were not much improved by eliminating observations on the basis of low abundance numbers. In many cases, the models developed using only the most abundant locations that were able to predict the nonabundant locations as well or almost as well as models developed using all of the location points. Furthermore, the focus of OH-GAP is on potential habitat, not current core habitat. This focus is incongruous with eliminating locations where a species was indeed found.

A second approach focused on the abundance of individuals at a given location compared to the rest of the state. This was accomplished by ranking the number of individuals of a given species per sample compared to other locations in the state where that species was found. The lowest quartile of these abundance locations was tagged and removed from the dataset. This method had the benefit of controlling for number of times sampled, the species' innate ease of capture, and its natural rarity. It does not include relative abundance.

To control for sampling bias, OH-GAP calculated the percentage of individuals of a particular species per site compared to the total number of individuals of all species at that site. Relative abundances were ranked, and locations in the lowest quartile were tagged for possible elimination. The locations were eliminated only if they also met the criteria of having low abundance compared to other locations of that species. This method controls for the most amount of sampling- and abundance-related biases. Eliminating the entire lowest quartile is not a conservative measure, but it has the benefit of examining only what would be considered core locations. Because our tests show that even these liberal location elimination measures had no major effect on the models, OH-GAP concluded that accuracy was not improved by use of abundance data. Because the GARP models were run at least 1,000 times with several internal iterations, it was unlikely that the models were unduly influenced by "outlier" locational observations.

Jackknifing

For producing potential distributions, DesktopGarp software can use all the environmental variables or refine the variable set by use of jackknifing methods (Peterson and Cohoon, 1999). In jackknifing, one variable at a time is left out of the model to determine how important each variable may be to the model. This time-consuming approach was evaluated and discarded by OH-GAP because it did not increase the quality of the models. It would also not be possible to compare the extrapolation models to the GARP models if different variables were used for each.

Land Use as a Surrogate for Water Quality

Early in the project, OH-GAP considered incorporating a measure or surrogate measure of water quality in the GARP predicted distributions. Because all of the physical habitat type variables were relatively unchanging physical characteristics, using land cover as a measure of water quality would have more closely represented present conditions in Ohio, a highly urbanized and agricultural state. OH-GAP examined land use on a 14-HU level. Each 14-HU, which ranged from approximately 10 km^2 to 200 km^2, had a percentage of urban, agriculture, and mining land use associated with it. OH-GAP considered evaluating the upstream watersheds, but technical limitations prevented this analysis.

Later in the project, OH-GAP obtained the software data model ArcHydro, which provided a means to attribute land-cover data from upstream drainage areas to the streams. OH-GAP encountered issues with too many subjective solutions for the allotted timeframe of the project. These included the scale of the new watersheds, developing methods for calculating land-use statistics and transferring them to and from grid and coverage GIS environments (technical issue), locational issue of where on the stream to assign upstream drainage data, and extent of land-use summaries (immediate buffer area or entire upstream land use).

The inclusion of land use as a variable in the potential distributions would improve the accuracy of present-day species distribution maps. The results would be a subset of OH-GAP potential distributions. OH-GAP believes the attempt to exclude areas predicted but not collected despite high sampling effort parallels the areas that would be excluded using land use in the modeling. Including land use could improve the understanding of why certain areas (urban and agricultural) are not associated with known distributions.

Sampling Effort

Early in the project, OH-GAP modified the predicted potential animal distributions by identifying areas (14-HUs) where high sampling effort yielded no detection of a particular species so that commission errors within the predicted distributions could be recognized. Two factors of sampling effort were considered: breadth and depth. Breadth is the number of sampling locations per some given area. Depth is the number of samples per sampling location. Determining which factor should be given the most weight was questionable; for example, one 14-HU had five sampling locations with one sample per location for a total of five samples; another 14-HU had one sampling location with five samples for a total of five samples. The question becomes, “Which 14-HU had the greater sampling effort?” This question, along with complexities such as commission error causation, historical data, and subjective cutoff points for determining sampling effort, led OH-GAP to discard an intensive sampling effort analysis.

4. Land Stewardship

As part of the analytical mission of GAP, it was necessary to compare the mapped distribution of elements of biodiversity with their representation in different categories of land ownership and management. OH-GAP uses the term "stewardship" in place of "ownership" in recognition that legal ownership does not necessarily equate to the entity charged with management of the resource and that the mix of ownership and managing entities is a complex and rapidly changing condition and not suitable for mapping by GAP. At the same time, it is necessary to distinguish between stewardship and management status in that a single category of land stewardship, such as a national forest, may contain several degrees of management for biodiversity.

The purpose of comparing biotic distribution with stewardship is to provide a method by which land stewards can assess their relative amount of responsibility for the management of a species and identify other stewards sharing that responsibility. This information can reveal opportunities for cooperative management of that resource, which directly supports the primary mission of GAP—to provide objective, scientific information to decision makers and managers to make informed decisions regarding biodiversity. It also is possible that a steward that has previously borne the major responsibility for managing a species may, through such analyses, identify a more equitable distribution of that responsibility. OH-GAP, however, identifies private land as a homogeneous category and does not differentiate individual tracts or owners, unless the information was provided voluntarily to recognize a long-term commitment to biodiversity maintenance.

After comparison to stewardship, it is also necessary to compare biotic occurrence to categories of management status. The purpose of this comparison is to identify the need for change in management status for the distribution of individual elements or areas containing high degrees of diversity. Such changes can be accomplished in many ways that do not affect the stewardship status. Although it will eventually be desirable to identify specific management practices for each tract and whether they are beneficial or harmful to each element, OH-GAP uses a scale of 1 to 4 to denote relative degree of maintenance of biodiversity for each tract. A status of 1 denotes the highest, most permanent level of maintenance, and status 4 represents the lowest level of biodiversity management, or unknown status. This is a highly subjective area, and there are a variety of limitations in this approach, although certain principles in assigning the status level are maintained. The first principle is that land ownership is not the primary determinant in assigning status. The second principle is that, although data are imperfect and all land is subject to changes in ownership and management, the intent of a land steward as evidenced by legal and institutional factors can be used to assign status. In other words, if a land steward institutes a program backed by legal and institutional arrangements that are intended for permanent biodiversity maintenance, then that is used as the guide for assigning status.

The characteristics used to determine status are as follows:

- Permanence of protection from conversion of natural land cover to unnatural (human-induced barren, exotic-dominated, arrested-succession) land cover.
- Relative amount of the tract managed for natural cover.
- Inclusiveness of the management; for example, single feature or species versus all biota.
- Type of management and degree that it is mandated through legal and institutional arrangements.

The four GAP management status categories can generally be defined as follows (after Scott and others, 1993; Edwards and others, 1995; Crist and others, 1995):

Status 1: An area having permanent protection from conversion of natural land cover and a mandated management plan in operation to maintain a natural state within which disturbance events (of natural type, frequency, and intensity) are allowed to proceed without interference or are mimicked through management.

Status 2: An area having permanent protection from conversion of natural land cover and a mandated management plan in operation to maintain a primarily natural state, but which may receive use or management practices that degrade the quality of existing natural communities.

Status 3: An area having permanent protection from conversion of natural land cover for the majority of the area, but one that is subject to extractive uses of either a broad, low-intensity type or localized intense type. It also confers protection to federally listed endangered and threatened species throughout the area.

Status 4: Lack of irrevocable easement or mandate to prevent conversion of natural habitat types to anthropogenic habitat types. This status allows for intensive use throughout the tract. Also includes those tracts for which the existence of such restrictions or sufficient information to establish a higher status is unknown.

Mapping Standards

Digital data of conservation lands with an estimated cartographic scale of 1:100,000 or finer were obtained from various sources throughout Ohio. In cases where data for a conservation land tract were provided by multiple sources and the boundaries did not completely superimpose, the finer scale data (such as 1:25,000) were used. All data were provided in Computer-Aided Design (CAD), GIS, or USGS Digital Line Graph (DLG) format. Only CAD data that had scale and a projection were included. Data were converted to the GIS and projected into Universal Transverse Mercator (UTM) Zone 17, NAD 83, meters to be compatible with the habitat classification and species data used in OH-GAP. All conservation land tracts, regardless of size, were maintained if they had attribute information associated with them.

Methods

Stewardship Mapping

The patchwork of conservation lands in Ohio is owned and managed by a diverse group of Federal, state, regional, and local agencies and private organizations. Although state and Federal lands make up more than 80 percent of the conservation area in the state, the map would be incomplete without considering other sources. Through regular stakeholder meetings, Internet searches, and conversations with land managers, a list of conservation land stewards in the state was generated (table 4–1); OH-GAP requested GIS data from these stewards. With one exception, where DLG lines were used to delineate Muskingum Watershed Conservancy District lands, no new GIS datasets were created for the map. Unfortunately, some counties and regions may be underrepresented in their mapped conservation lands from lack of available or usable GIS data. Nonetheless, by way of the 19 GIS sources ultimately used (table 4–2), conservation lands in 87 out of 88 counties in the state are represented, encompassing Federal, state, regional, local, and private land tracts.

Table 4–1. Conservation land stewards in Ohio.

Land steward
Federal
U.S. Department of Agriculture, Forest Service (USDA-FS)
U.S. Fish and Wildlife Service (USFWS)
U.S. Department of Defense (USDoD)
National Park Service (NPS)
State
Ohio Department of Natural Resources (ODNR)
Division of Parks and Recreation
Division of Wildlife
Division of Natural Areas and Preserves (DNAP)
Ohio Historical Society
Ohio University
Kent State University
Regional/County/Local
Clermont County Parks District
Cleveland Metroparks
Clinton County Park Board
Columbus and Franklin County Metroparks
Five Rivers Metroparks
Geauga County Park District
Greene County Park District
Hamilton County Park District
Metroparks serving Summit County
Metroparks of the Toledo Area
Lorain County Metroparks
Portage County Park District
Stark County Park District
Watershed Conservancy Districts
Townships, cities, and others
Private
Audubon Society
Holden Arboretum
The Nature Conservancy
Local land conservancies
Local conservation easements, trusts

Table 4–2. Sources of GIS data used to develop the statewide conservation stewardship dataset.

Data sources
Army Corps of Engineers, Buffalo District
Cleveland Metroparks
Clinton County Park District
Columbus and Franklin County Metroparks
Cuyahoga County Planning Commission
Delaware County Auditors Office
U.S. Environmental Protection Agency
Geauga County Park District
Green County Park District
Hamilton County Park District
Lucas County Auditors Office
Mahoning County GIS Department
National Park Service
Muskingum Watershed Conservancy District maps
Ohio Department of Natural Resources, Division of Real Estate and Land Management
Ohio Department of Natural Resources, Division of Forestry
Metroparks of the Toledo Area
Wayne National Forest
U.S. Geological Survey

New attributes were created for each GIS data layer containing information about the managing agency, the type of property, source of the GIS, and the assigned GAP status code. Once all layers had common attributes, the individual layers were merged into a single GIS layer for Ohio. Details of the map production methods are included in the metadata of the Stewardship GIS dataset.

The land stewardship map was combined with the 1:100,000-scale National Hydrography Dataset (NHD) to identify conservation areas that are lakes and reservoirs. These were tagged as "water" but remained in the dataset. For purposes of this chapter on Stewardship, no calculations or analyses were done on any polygon labeled as "water." The metadata that accompany the stewardship GIS layer contain detailed information on the individual GIS processing steps taken to create this map.

Management Status Categorization

A dichotomous key provided in the GAP handbook (Gap Analysis Program, 2000) (*Appendix E* and *Appendix F*) was used by OH-GAP and (or) provided to land managers for categorization of biodiversity management status of land units. In using the terms "permanent" and "legally enforceable," OH-GAP recognizes that all conditions are subject to change, even in preserves and national parks, but the intent is for the condition to be long term. The use of a dichotomous key helped ensure a less subjective assessment of lands, although room for interpretation persists. For example, to be classified as status 1, the lands needed to have at least 95 percent natural land cover and allow for natural disturbance events. This percentage was estimated by the land managers; land-cover maps were not used. Additionally, after conversations with land managers, the challenge of defining a natural disturbance became evident. Nevertheless, use of the keys helped with the classification of the conservation lands of Ohio.

When the GIS data were available, sections within a property were delineated (for example, preserves within a metropark). Telephone conversations, as well as the Internet, management plans, and other written sources, were explored to familiarize OH-GAP with a particular land tract or managing organization. (See *Appendix F* and the stewardship layer's metadata for more information.)

In some cases, such as in the Wayne National Forest, management plans for each land area were examined by OH-GAP and then coded in consultation with the land stewards. Other stewards such as the Ohio Department of Natural Resources (ODNR)-Division of Natural Areas and Preserves, were able to examine all of their properties separately and assign the gap status for each particular tract. In other cases, all of the tracts under one steward were lumped together and assigned the same status, such as those under the stewardship of the ODNR-Division of Wildlife. In these instances, it is possible that some tracts could have been assigned a higher gap status if they were examined individually.

For use at the state or local level, status 4 lands were separated into subgroups 4a and 4b, in order to identify additional conservation lands. The 4a designation included GIS maps of conservation lands provided to OH-GAP where no written or verbal information on the conservation management plan was found. These include some greenspaces and easements, as well as other types of conservation (and non-conservation) lands. These areas may provide a means to connect Ohio's fragmented conservation lands. Lands classified as 4b include the remaining status 4 lands and include private or developed tracts.

Results

Statewide Assessment

Ohio has very little conservation land in public ownership (figs. 4–1 and 4–2). In a state dominated by agriculture and increasing urban land cover, only about 3.7 percent of the state's land is protected for conservation, either publicly or privately (table 4–3 and fig. 4–3). Of this total, state agencies control about 52 percent and Federal agencies control about 29 percent. The ODNR and The Nature Conservancy manage the bulk (43.4 percent and 30.3 percent, respectively) of the status 1 lands. Status 1 lands, the most highly protected lands, account for 6 percent of the conservation lands and 0.2 percent of the total land area in Ohio (conservation and non-conservation lands).

Conservation lands are distributed throughout Ohio in 87 of 88 counties. This is largely due to ODNR, the largest land steward by area in Ohio (table 4–3 and tables 4–4a and 4–4b), which protects lands in 86 counties (all but Van Wert and Union). These 86 counties include 32 counties, mostly in the northwest, that would otherwise not be represented on the map. A cursory look at the stewardship map shows that the size of the tracts of conservation lands are much smaller and more fragmented in the northwestern quarter of Ohio compared to other parts of the state. Many of these tracts are ODNR Division of Wildlife Habitat Restoration Program areas.

Although Federal and state stewards are responsible for more than 80 percent of the conservation lands in Ohio, regional and local governments also have an important role in Ohio's conservation. The metroparks around sprawling cities such as Columbus and Cincinnati protect and restore lands that otherwise may be converted to suburbs. Regional governments, like metroparks, are the stewards of 10.8 percent of all status 1 lands and 14.3 percent of status 2 lands (fig. 4–3 and tables 4–4a and 4–4b).

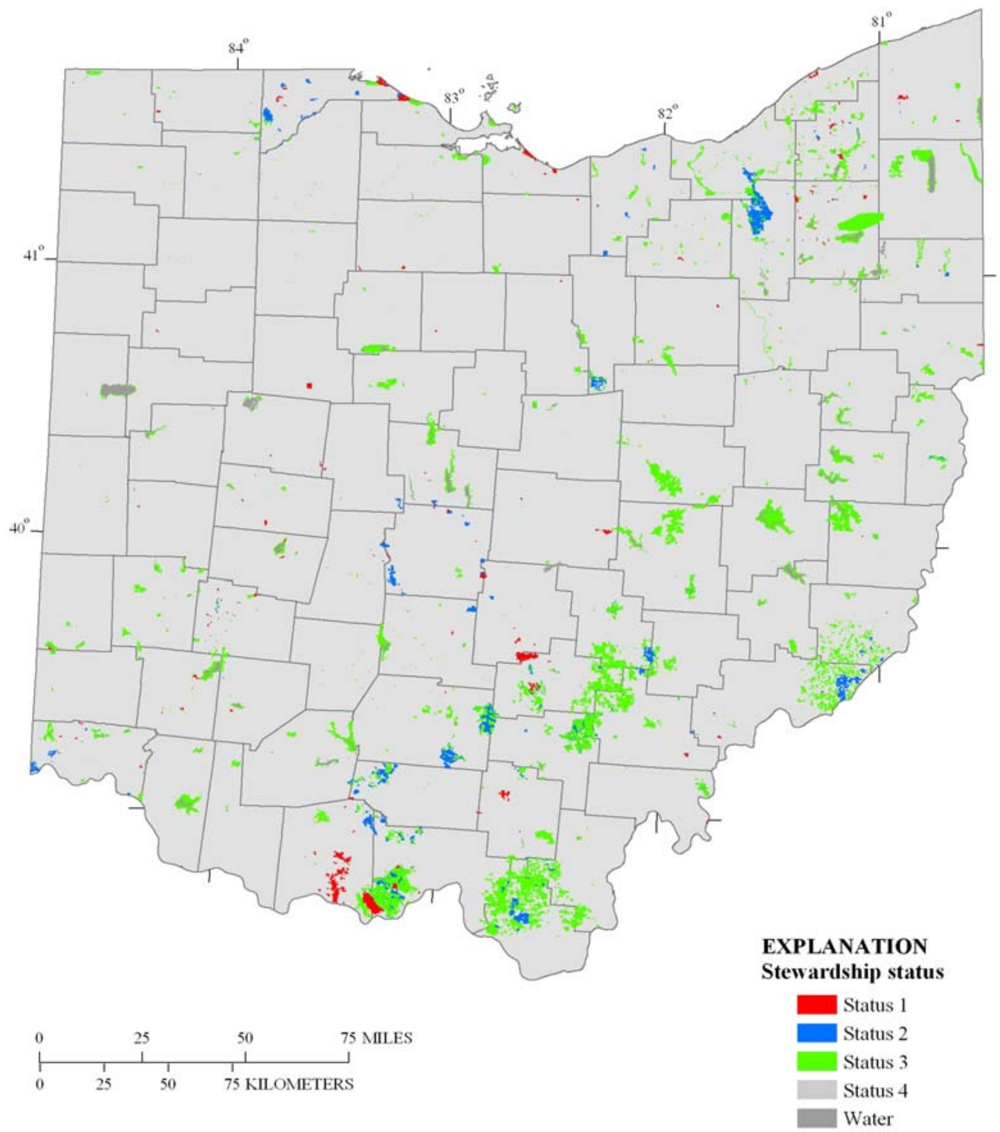

Figure 4-1. Gap Analysis Program (GAP) management status categories for land tracts in Ohio.

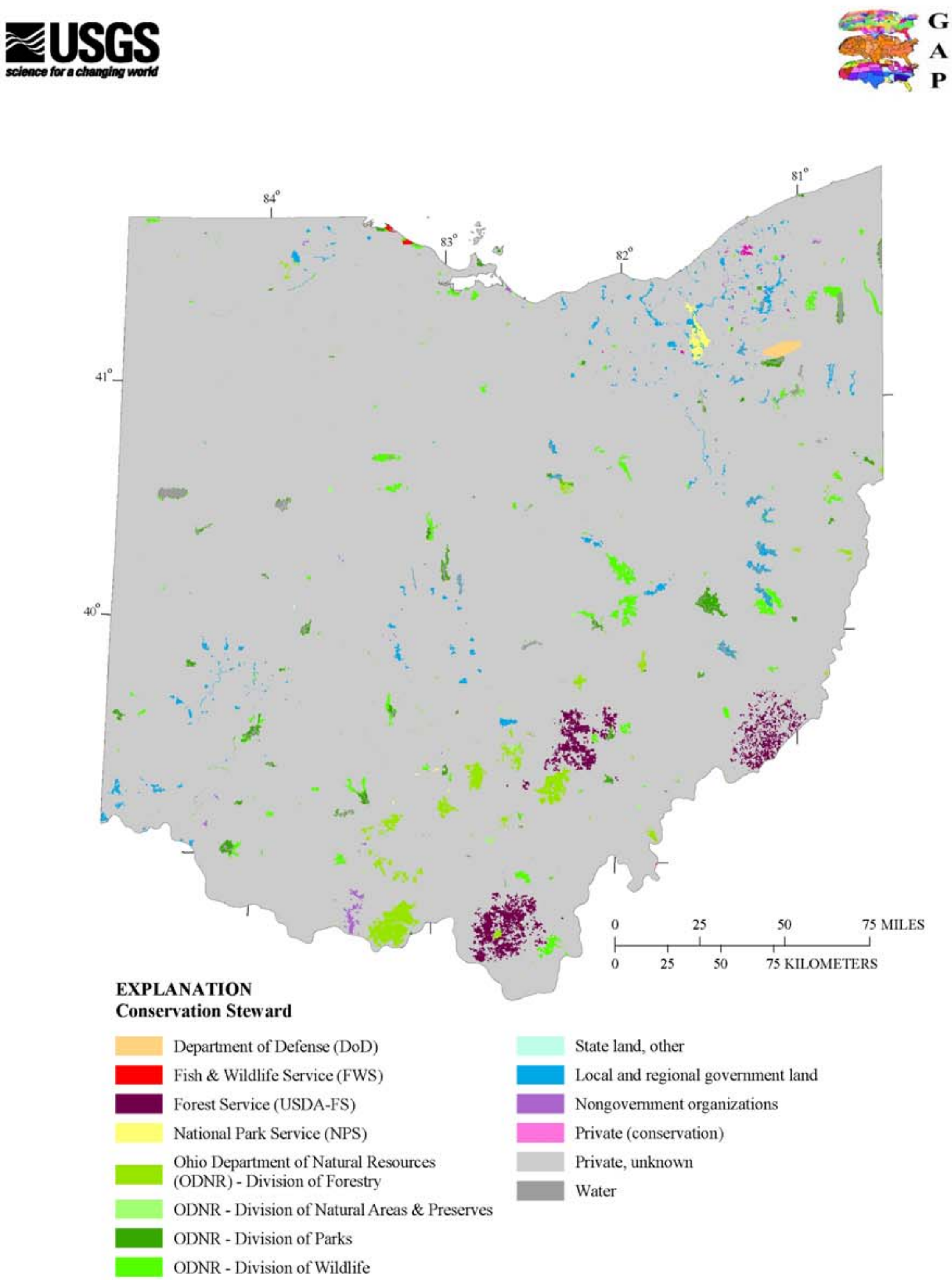

Figure 4-2. Conservation stewards for land tracts in Ohio.

Summary statistics are listed in tables 4–3, 4–4a, and 4–4b. First, a comparison of various stewardship categories in gap management status categories 1, 2, and 3 was made (table 4–3). For example, 74.6 km^2 are owned and managed by The Nature Conservancy, and this is 1.9 percent of all conservation land in the state and 0.1 percent of all Ohio's land area. Tables 4–4a and 4–4b contain information on the proportional makeup of management status categories by stewardship and vice versa, so that land stewards can see the degree their lands generally contribute to biodiversity maintenance. For example, 100 percent of the U.S. Fish and Wildlife service lands are in status 1, and this accounts for 6.3 percent of all the status 1 lands in Ohio. Conservation lands in the state by steward and status are depicted in figure 4–3. (See *Appendix G* for a table listing the documentations for all status 1 and 2 areas in the state.)

Table 4–3. Estimated area in the Ohio Aquatic GAP Project's management status category 1, 2, and 3 lands.

[Area totals exclude water; km^2, square kilometers; <, less than; ODNR, Ohio Department of Natural Resources; NGO, nongovernment organization; TNC, The Nature Conservancy]

GAP manager code	Steward	Area (km^2)	Percent of conservation land	Percent of Ohio
1300	U.S. Fish & Wildlife Service	15.6	0.4	<0.1
1600	National Park Service	105.0	2.6	0.1
1400	U.S. Forest Service	961.6	24.1	0.9
1500	U.S. Dept. of Defense	88.7	2.2	0.1
	ODNR (total)	2,069.6	51.9	1.9
3410-11	ODNR-Parks	396.4	9.9	0.4
3420	ODNR-Preserves	68.8	1.7	0.1
3430-31	ODNR-Wildlife	814.8	20.4	0.8
3440	ODNR-Forestry	789.7	19.8	0.7
3400	Other State Agencies & State Universities	2.9	0.1	<0.1
4000	Regional Government	166.9	4.2	0.2
5000	Local Government	465.7	11.7	0.4
6302	NGO-TNC	74.6	1.9	0.1
6000	NGO-other	18.0	0.5	<0.1
7000	Private/ other conservation	20.2	0.5	<0.1
	TOTAL	3,988.8	100	3.7

Table 4–4a. Proportional makeup of the Ohio Aquatic GAP Project's management status category (1–4) for each steward's land.

[<, less than; ODNR, Ohio Department of Natural Resources; NGO, nongovernment organization; TNC, The Nature Conservancy; >, greater than]

GAP manager code	Steward	Percent in category 1	Percent in category 2	Percent in category 3	Percent in category 4
1300	U.S. Fish & Wildlife Service	100.0			
1600	National Park Service		95.6	4.4	
1400	USDA-Forest Service	<0.1	10.5	89.4	
1500	U.S. Dept. of Defense		96.2	3.8	
	ODNR (total)	5.2	10.0	84.8	
3410-11	ODNR-Parks			100.0	
3420	ODNR-Preserves	99.6	0.4		
3430-31	ODNR-Wildlife		0.5	99.5	
3440	ODNR-Forestry	4.9	25.8	69.3	
3400	Other State	60.0	1.9	36.7	1.4
4000	Regional Government	14.7	41.2	36.5	7.6
5000	Local Government	3.1	7.0	81.2	8.7
6302	NGO-TNC	100.0			
6000	NGO-other	19.8	3.0	54.6	22.6
7000	Private/ other			>99.9	<0.1
	Total all lands	**0.2**	**0.5**	**3.0**	**96.3**

Table 4–4b. Steward's land as a percentage of all the Ohio Aquatic GAP Project's lands, by management status category (1–4).

[ODNR, Ohio Department of Natural Resources; NGO, nongovernment organization; TNC, The Nature Conservancy]

GAP manager code	Steward	Percent of category 1	Percent of category 2	Percent of category 3	Percent of category 4
1300	U.S. Fish & Wildlife Service	6.3			
1600	National Park Service		19.3	0.1	
1400	USDA-Forest Service	0.2	19.4	26.7	
1500	U.S. Dept. of Defense			2.8	
	ODNR (total)	43.4	40.0	54.5	
3410-11	ODNR-Parks			12.3	
3420	ODNR-Preserves	27.8	0.1		
3430-31	ODNR-Wildlife		0.8	25.2	
3440	ODNR-Forestry	15.6	39.1	17.0	
3400	Other State	0.7			<0.1
4000	Regional Government	10.8	14.3	2.0	<0.1
5000	Local Government	6.4	6.9	12.9	<0.1
6302	NGO-TNC	30.3			
6000	NGO-other	1.9	0.1	0.4	<0.1
7000	Private/ other			0.6	99.9
	Total all lands	**100**	**100**	**100**	**100**

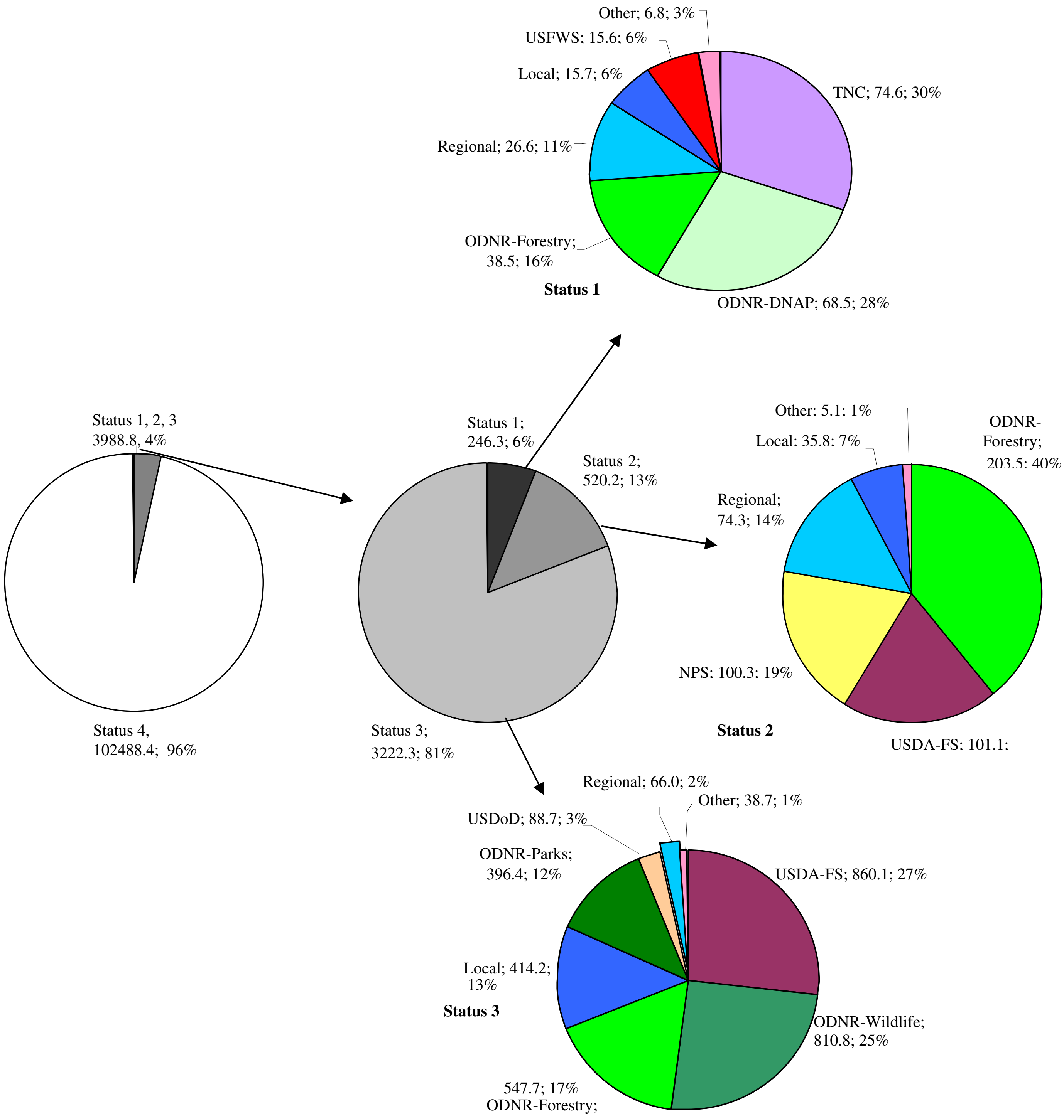

Figure 4–3. Breakdown of land steward for each of the Ohio Aquatic GAP Project's management status category (Gap 1–4). Pies are labeled with manager class, total square kilometers, and percentage of the total for that gap status. Area totals exclude water.

[USFWS, U.S. Fish and Wildlife Service; TNC, The Nature Conservancy; ODNR, Ohio Department of Natural Resources; DNAP, Division of Natural Areas and Preserves; NPS, National Park Service; USDA-FS, U.S. Department of Agriculture, Forest Service; USDoD, U.S. Department of Defense]

Assessment by Ecoregion

One of the goals of this assessment of conservation stewardship is to provide the basis to ultimately achieve a representative stewardship protection of distinct natural communities; therefore, what defines a natural community unit needs to be assessed as well. GAP assesses conservation stewardship on a somewhat arbitrary (to biota) statewide level. Ecoregions are natural spatial units within which to assess conservation stewardship. (See *Appendix B*.) The distribution across level III and level IV ecoregions of different conservation status lands is listed in table 4–5.

The Western Allegheny Plateau of southeastern Ohio contains the second-largest land area (30,669.1 km^2, 28.8 percent of the entire state) out of the six level III ecoregions in Ohio, and it accounts for 61.5 percent of all the conservation land in the state (2,452.3 km^2). The Wayne National Forest (mostly status 3, table 4–4a) is in this ecoregion; the U.S. Department of Agriculture, Forest Service, is the second-largest land steward in Ohio by area. In contrast, the largest ecoregion in Ohio is the Eastern Corn Belt Plains (40,560.9 km^2, roughly 38 percent of the entire state, including much of the western half of Ohio), but it contains only 13.5 percent of the conservation lands in Ohio, including 15.7 percent of the status 1 lands, 9.6 percent of the status 2 lands, and 14.0 percent of the status 3 lands.

A more refined analysis using level IV ecoregions reveals variation even within a level III ecoregion. For example, within the Western Allegheny Plateau, 21.2 percent of the Ohio/Kentucky Carboniferous Plateau is protected (844.9 km^2 out of 5,405.0 km^2), corresponding to 21.2 percent of all the conservation lands in the state. In contrast, only 281.5 km^2 out of 4,324.1 km^2, or 6.5 percent, of the Permian Hills is protected, corresponding to 7.1 percent of all conservation lands in the state. This shows how assessment at different spatial scales leads to different interpretation of the results.

The most poorly conserved ecoregions (level IV) are the Whitewater Interlobate Area of the Eastern Corn Belt Plain level III ecoregion, with no land in conservation, the Paulding Plains of the Huron/Erie Lake Plains Level III ecoregion with only 3.2 km^2/1,451.9 km^2, or 0.2 percent, protected; and the Maumee Lake Plains, also of the Huron/Erie Lake Plains Level III ecoregion, with only 35 km^2/7,053.8 km^2, or 0.5 percent, protected.

The greatest percentages of land in conservation within a level IV ecoregion are the Erie Gorges (183.4 km^2/851.8 km^2, or 21.5 percent) of the Erie/Ontario Drift and Lake Plains level III ecoregion, and the Ohio/Kentucky Carboniferous Plateau (844.9 km^2/5,405.0 km^2, or 15.6 percent) and Knobs-Lower Scioto Dissected Plateau (12.8 percent), both of the Western Allegheny Plateau level III ecoregion.

Examined by level III ecoregion, these differences become less pronounced. The least protected are the Huron/Erie Lake Plains (134.7 km^2/11,693.3 km^2, or 1.2 percent protected) and the Eastern Corn Belt Plains (1.3 percent), which together make up almost the entire western half of Ohio. The best protected are the Southern Michigan/Northern Indiana Drift Plains and Western Allegheny Plateau, both with about 8 percent of the land in conservation. However, the Southern Michigan/Northern Indiana Drift Plains makes up only 0.1 percent of all of Ohio (the northwest tip), so this percentage should not be treated as equal to the 28.8 percent of Ohio contained within the Western Allegheny Plateau.

Table 4–5. Breakdown of Gap Analysis Program (GAP) management status category (columns) within Ohio's six level III ecoregions and 23 level IV ecoregions (rows). [Example, 15.7 percent of all Ohio's status 1 lands are in the Eastern Corn Belt Plains; 13.6 percent of all of Ohio is in the Loamy High Lime Till Plains. Area totals exclude water. km², square kilometers]

Status 1		Status 2		Status 3		Total 1,2,3		Status 4		All of Ohio		Level III ecoregion
km²	percent	km²	percent	km²	percent	km²	percent	km²	percent	km²	percent	Level IV ecoregion
38.7	15.7	49.9	9.6	451.2	14.0	539.8	13.5	40,021.1	39.0	40,560.9	38.1	Eastern Corn Belt Plains
11.1	4.5	4.9	0.9	111.3	3.5	127.3	3.2	16,558.8	16.2	16,686.1	15.7	Clayey High Lime Till Plains
1.6	0.7	18.6	3.6	24.4	0.8	44.6	1.1	2,884.1	2.8	2,928.7	2.8	Darby Plains
16.7	6.8	24.5	4.7	214.2	6.6	255.4	6.4	14,269.4	13.9	14,524.8	13.6	Loamy High Lime Till Plains
4.4	1.8	0	0.0	14.4	0.4	18.8	0.5	1,674.9	1.6	1,693.7	1.6	Mad River Interlobate Area
4.9	2.0	1.9	0.4	86.9	2.7	93.7	2.3	4,449.3	4.3	4,543.0	4.3	Pre-Wisconsinan Drift Plains
0	0.0	0	0.0	0	0.0	0	0.0	184.5	0.2	184.5	0.2	Whitewater Interlobate Area
35.6	14.5	121.6	23.4	617.1	19.1	774.3	19.4	20,951.7	20.4	21,726.0	20.4	Erie/Ontario Drift and Lake Plains
0.9	0.4	97.9	18.8	84.6	2.6	183.4	4.6	668.4	0.7	851.8	0.8	Erie Gorges
6.4	2.6	3.1	0.6	31.1	1.0	40.6	1.0	1,670.0	1.6	1,710.6	1.6	Erie Lake Plain
16.1	6.5	18.6	3.6	301.1	9.3	335.8	8.4	14,971.5	14.6	15,307.3	14.4	Low Lime Drift Plain
6.8	2.8	0.4	0.1	135.7	4.2	142.9	3.6	2,346.2	2.3	2,489.1	2.3	Mosquito Creek/Pymatuning Lowlands
5.4	2.2	1.6	0.3	64.6	2.0	71.6	1.8	1,295.6	1.3	1,367.2	1.3	Summit Interlobate Area
27.8	11.3	32.7	6.3	74.2	2.3	134.7	3.4	11,558.6	11.3	11,693.3	11.0	Huron/Erie Lake Plains
13.7	5.6	1.5	0.3	43.2	1.3	58.4	1.5	2,258.2	2.2	2,316.6	2.2	Marblehead Drift/Limestone Plain
8.4	3.4	9	1.7	17.6	0.5	35	0.9	7,018.8	6.8	7,053.8	6.6	Maumee Lake Plains
4.4	1.8	22.2	4.3	11.5	0.4	38.1	1.0	832.9	0.8	871.0	0.8	Oak Openings
1.3	0.5	0	0.0	1.9	0.1	3.2	0.1	1,448.7	1.4	1,451.9	1.4	Paulding Plains
40.2	16.3	15	2.9	23.6	0.7	78.8	2.0	1,637.6	1.6	1,716.4	1.6	Interior Plateau
40.2	16.3	15	2.9	23.6	0.7	78.8	2.0	1,637.6	1.6	1,716.4	1.6	Outer Bluegrass
0.3	0.1	0	0.0	8.7	0.3	9	0.2	102.6	0.1	111.6	0.1	Southern Michigan/Northern Indiana Drift
0.3	0.1	0	0.0	8.7	0.3	9	0.2	102.6	0.1	111.6	0.1	Lake Country
103.8	42.1	301.1	57.9	2,047.4	63.5	2,452.3	61.5	28,216.8	27.5	30,669.1	28.8	Western Allegheny Plateau
84.3	34.2	157.7	30.3	338.2	10.5	580.2	14.5	3,937.3	3.8	4,517.5	4.2	Knobs-Lower Scioto Dissected Plateau
0.4	0.1	3.4	0.6	316	9.8	319.8	8.0	7,564.2	7.4	7,884.0	7.4	Monongahela Transition Zone
8.8	3.6	80.4	15.4	755.7	23.5	844.9	21.2	4,560.1	4.4	5,405.0	5.1	Ohio/Kentucky Carboniferous Plateau
4.9	2.0	47.4	9.1	229.2	7.1	281.5	7.1	4,042.6	3.9	4,324.1	4.1	Permian Hills
1.6	0.7	0.1	0.0	41.6	1.3	43.3	1.1	1,014.9	1.0	1,058.2	1.0	Pittsburgh Low Plateau
3.8	1.5	12.1	2.3	366.7	11.4	382.6	9.6	7,097.8	6.9	7,480.4	7.0	Unglaciated Upper Muskingum Basin
246.4	100	520.3	100	3,222.2	100	3,988.9	100	102,488.4	100	106,477.3	100	Total (km²)

Limitations

The maps of conservation-land stewardship (figs. 4–1 and 4–2) are compilations of ownership maps provided by a variety of sources that are individually responsible for their accuracy. Each map was created solely for the purpose of analyses described in this report and is not suitable for locating boundaries on the ground or determining precise area measurements of individual tracts. OH-GAP is aware that some conservation lands are not included in the map. These include many conservation easements and county- and town-managed public lands; most of these data are not available in a GIS format readily usable for this map at this time.

OH-GAP management status was determined for each land tract in consultation with owners and managers whenever possible. Regardless, some interpretation by land manager and OH-GAP was required to determine status designations. Management status is as complete as possible from the information available during preparation of the data (2002–03). Considerable effort was made to categorize lands in a standardized manner throughout Ohio; however, because many land managers stressed different components of their conservation efforts and because OH-GAP became increasingly familiar with the conservation lands of Ohio during the project, stewardship categories may not be uniformly defined.

The few and fragmented conservation lands in Ohio compared to those of many other states also may have resulted in individual land tracts being assigned a higher status than if those tracts were in another state.

Every effort was made to reduce the error associated with the combination of overlapping spatial datasets, including the elimination of sliver polygons and tagging or eliminating “donut hole” polygons. Reputable data sources and detailed datasets were used, when possible. Errors in the native datasets, including erroneous datum shifts or use of different base data layers, in most cases also persist in this dataset. (See the stewardship GIS layer’s metadata for further information.)

5. Analysis Based on Stewardship and Management Status

This chapter describes the methods and results of the gap analysis as used by the Gap Analysis Program (GAP). As described in the general introduction to this report (chapter 1), the primary objective of GAP is to provide information on the distribution and status of several elements of biological diversity. Although GAP “seeks to identify habitat types and species not adequately represented in the current network of biodiversity management areas” (GAP Handbook, Preface, Version 1, p. I), it is unrealistic to create a standard definition of “adequate representation” for either habitat types or individual species (Noss and others, 1995). A practical solution to this issue is to report both percentages and absolute area of each element in biodiversity management areas and allow the user to determine which types are adequately represented in natural areas. There are many other factors that should be considered in such determinations, including

1. historic loss or gain in distribution,
2. nature of the spatial distribution,
3. immediate and long-term risk, and
4. degree of local adaptation among populations of the biotic elements that are worthy of individual conservation consideration.

Such analyses are beyond the scope of this project; but their application, coupled with field confirmation of the mapped distributions, warrants further consideration.

GAP data may be analyzed to identify the set of areas in which most or all species are predicted to be represented. The use of "complementarity" analysis—that is, an approach that additively identifies a selection of locations that may represent biodiversity rather than "hot spots of species richness"—may prove most effective for guiding biodiversity maintenance efforts. Several quantitative techniques have been developed recently that facilitate this process (Pressey and others, 1993; Williams and others, 1996; Csuti and others, 1997). These areas become candidates for field validation and may be incorporated into a system of areas managed for the long-term maintenance of biological diversity.

Methods

The OH-GAP analysis is accomplished by first producing maps of aquatic habitat types; predicted distributions for fish, crayfish, and bivalve species (Maps section); and land stewardship status (figs. 4–1 and 4–2). Intersecting the land-stewardship map with the distribution maps of the aquatic animal species results in tables that summarize the length of streams and percentage of total mapped distribution of each species in different land stewardship and management categories (tables 5–1 through 5–3). The land-stewardship map is then intersected with the map of physical habitat types to characterize associated habitat protections and needs.

Results

These data are provided in a format that allows users to carry out inquiries about the representation of each aquatic animal species in different land stewardship and management categories as appropriate to their own management objectives. This forms the basis of GAP's mission to provide landowners and managers with the information necessary to make informed decisions on policy, development and planning, and to manage for biodiversity maintenance.

As a coarse indicator of the status of the animal species, a breakdown along five levels of representation (0 to <1 percent, 1 to <10 percent, 10 to <20 percent, 20 to <50 percent, and ≥50 percent) is provided. The <1-percent level indicates those species with essentially none of their distribution in a protected status, whereas levels of 10 percent, 20 percent, and 50 percent have been recommended in the literature as necessary amounts for conservation (Noss and Cooperrider, 1994; Noss, 1991; Odum and Odum, 1972; Specht and others, 1974; Ride, 1975; Miller, 1994).

Predicted Animal Species Distributions Analysis

A summary of the distributions of fish, crayfish, and bivalves, length of streams in kilometers where the species were mapped, distribution by management status and land stewardship, and the percentage of the species' total distribution in each category is listed in tables 5–1 through 5–3. For example, bigmouth shiner, *Notropis dorsalis,* has 16.2 km of potential habitat in state lands that are ranked status 2, which represents 1.12 percent of that species' total distribution. Some generalizations and examples of species results by the various thresholds are further discussed.

Table 5–1. Summary of the length of streams (kilometers) and percentage of total mapped distribution of each fish species in different Gap Analysis Program (GAP) management status categories.

Fish species		Status 1		Status 2		Status 3		Status 1, 2, 3		Status 4		All of Ohio
Common name	Scientific name	km	percent	km	percent	km	percent	km	percent	km	percent	km
American brook lamprey	*Lampetra appendix*	23.60	0.27	91.20	1.03	328.40	3.69	443.20	4.98	8,451.20	95.02	8,894
American eel	*Anguilla rostrata*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.00	100.00	10
Banded darter	*Etheostoma zonale*	47.80	0.29	45.80	0.28	463.80	2.84	557.40	3.41	15,787.20	96.59	16,345
Bigeye chub	*Notropis amblops*	44.60	0.39	75.00	0.66	374.00	3.29	493.60	4.34	10,870.80	95.66	11,364
Bigeye shiner	*Notropis boops*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.80	100.00	21
Bigmouth buffalo	*Ictiobus cyprinellus*	24.20	0.39	96.80	1.58	259.20	4.22	380.20	6.19	5,764.00	93.81	6,144
Bigmouth shiner	*Notropis dorsalis*	4.00	0.28	16.20	1.12	170.60	11.76	190.80	13.15	1,259.80	86.85	1,451
Black buffalo	*Ictiobus niger*	13.40	0.64	20.40	0.97	91.60	4.36	125.40	5.96	1,977.20	94.04	2,103
Black bullhead	*Ameiurus melas*	71.60	0.24	152.20	0.50	812.80	2.68	1,036.60	3.42	29,314.00	96.58	30,351
Black crappie	*Pomoxis nigromaculatus*	54.40	0.32	123.20	0.72	647.00	3.80	824.60	4.84	16,204.00	95.16	17,029
Black redhorse	*Moxostoma duquesnei*	54.40	0.39	111.60	0.79	540.60	3.85	706.60	5.03	13,348.60	94.97	14,055
Blacknose dace	*Rhinichthys atratulus*	95.40	0.29	274.40	0.84	1,245.60	3.82	1,615.40	4.95	30,995.60	95.05	32,611
Blackside darter	*Percina maculate*	80.20	0.29	163.60	0.60	912.40	3.33	1,156.20	4.23	26,208.40	95.77	27,365
Blackstripe topminnow	*Fundulus notatus*	21.60	1.02	22.40	1.06	32.60	1.54	76.60	3.62	2,041.40	96.38	2,118
Blue sucker	*Cycleptus elongates*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	33.40	100.00	33
Bluebreast darter	*Etheostoma camurum*	5.60	0.35	18.80	1.18	51.00	3.20	75.40	4.74	1,516.80	95.26	1,592
Bluegill	*Lepomis macrochirus*	102.20	0.33	204.00	0.65	1,027.00	3.27	1,333.20	4.25	30,068.60	95.75	31,402
Bluntnose minnow	*Pimephales notatus*	115.20	0.32	216.20	0.60	1,085.40	3.00	1,416.80	3.91	34,781.80	96.09	36,199
Bowfin	*Amia calva*	22.20	0.36	64.80	1.05	270.40	4.37	357.40	5.77	5,834.00	94.23	6,191
Brindled madtom	*Noturus miurus*	66.20	0.39	116.40	0.69	618.80	3.65	801.40	4.73	16,158.20	95.27	16,960
Brook silverside	*Labidesthes sicculus*	63.20	0.36	125.80	0.71	681.40	3.86	870.40	4.93	16,787.00	95.07	17,657
Brook stickleback	*Culaea inconstans*	27.60	0.31	109.80	1.22	381.40	4.22	518.80	5.75	8,508.60	94.25	9,027
Brook trout	*Salvelinus fontinalis*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.80	100.00	1
Brown bullhead	*Ictalurus nebulosus*	4.00	0.57	20.80	2.99	8.60	1.23	33.40	4.80	663.00	95.20	696
Bullhead minnow	*Pimephales vigilax*	11.60	0.39	20.20	0.69	108.40	3.69	140.20	4.77	2,799.00	95.23	2,939
Central mudminnow	*Umbra limi*	45.20	0.24	233.40	1.23	694.80	3.65	973.40	5.12	18,038.60	94.88	19,012
Central stoneroller	*Campostoma anomalum*	103.80	0.32	194.80	0.61	935.40	2.92	1,234.00	3.85	30,823.60	96.15	32,058
Channel catfish	*Ictalurus punctatus*	53.40	0.46	110.40	0.94	507.60	4.34	671.40	5.74	11,035.60	94.26	11,707
Channel darter	*Percina copelandi*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	100.00	0
Channel shiner	*Notropis wickliffi*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	37.80	100.00	38
Common shiner	*Luxilus cornutus*	39.40	0.24	148.00	0.92	559.20	3.47	746.60	4.63	15,371.80	95.37	16,118

Table 5–1 continued.

Fish species		Status 1		Status 2		Status 3		Status 1, 2, 3		Status 4		All of Ohio
Common name	Scientific name	km	percent	km	percent	km	percent	km	percent	km	percent	km
Creek chub	*Semotilus atromaculatus*	93.00	0.27	226.00	0.65	1,109.40	3.19	1,428.40	4.10	33,370.20	95.90	34,799
Creek chubsucker	*Erimyzon oblongus*	31.40	0.37	31.80	0.37	152.80	1.78	216.00	2.52	8,348.20	97.48	8,564
Dusky darter	*Percina sciera sciera*	9.80	0.16	33.00	0.54	231.00	3.80	273.80	4.51	5,799.40	95.49	6,073
Eastern sand darter	*Ammocrypta pellucida*	5.00	0.17	19.60	0.66	154.20	5.21	178.80	6.04	2,780.80	93.96	2,960
Emerald shiner	*Notropis atherinoides*	66.20	0.33	150.40	0.75	699.80	3.47	916.40	4.54	19,253.40	95.46	20,170
Fantail darter	*Etheostoma flabellare*	86.00	0.29	153.40	0.52	998.60	3.37	1,238.00	4.18	28,357.80	95.82	29,596
Fathead minnow	*Pimephales promelas*	68.60	0.22	152.20	0.49	735.00	2.39	955.80	3.10	29,857.60	96.90	30,813
Flathead catfish	*Pylodictis olivaris*	27.20	0.49	37.60	0.67	231.00	4.13	295.80	5.28	5,302.20	94.72	5,598
Freshwater drum	*Aplodinotus grunniens*	53.00	0.45	117.40	0.99	501.00	4.21	671.40	5.64	11,223.00	94.36	11,894
Ghost shiner	*Notropis buchanani*	26.00	0.31	99.20	1.18	391.60	4.68	516.80	6.17	7,859.40	93.83	8,376
Gizzard shad	*Dorosoma cepedianum*	62.80	0.33	150.60	0.80	693.20	3.67	906.60	4.80	17,980.80	95.20	18,887
Golden redhorse	*Moxostoma erythrurum*	74.40	0.35	160.00	0.75	825.80	3.89	1,060.20	4.99	20,175.00	95.01	21,235
Golden shiner	*Notemigonus crysoleucas*	68.80	0.28	143.40	0.58	731.20	2.93	943.40	3.78	23,986.40	96.22	24,930
Goldeye	*Hiodon alosoides*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.40	100.00	4
Grass pickerel	*Esox americanus v.*	64.00	0.27	139.60	0.59	705.20	2.97	908.80	3.83	22,820.80	96.17	23,730
Gravel chub	*Erimystax x-punctata*	12.80	0.47	20.20	0.75	85.80	3.17	118.80	4.39	2,589.80	95.61	2,709
Greater redhorse	*Moxostoma valenciennesi*	6.60	0.30	24.80	1.12	20.80	0.94	52.20	2.35	2,169.60	97.65	2,222
Green sunfish	*Lepomis cyanellus*	92.20	0.26	168.40	0.48	950.80	2.72	1,211.40	3.46	33,775.20	96.54	34,987
Greenside darter	*Etheostoma blennioides*	80.20	0.29	159.00	0.58	883.20	3.20	1,122.40	4.07	26,459.40	95.93	27,582
Highfin carpsucker	*Carpiodes velifer*	16.00	0.38	23.80	0.57	173.80	4.18	213.60	5.14	3,943.80	94.86	4,157
Hornyhead chub	*Nocomis biguttatus*	50.80	0.35	92.20	0.64	540.60	3.74	683.60	4.73	13,754.60	95.27	14,438
Iowa darter	*Etheostoma exile*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.80	100.00	5
Johnny darter	*Etheostoma nigrum*	86.20	0.27	176.80	0.54	1,003.00	3.09	1,266.00	3.90	31,216.60	96.10	32,483
Lake chubsucker	*Erimyzon sucetta*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.20	100.00	2
Largemouth bass	*Micropterus salmoides*	83.60	0.29	169.80	0.58	883.20	3.01	1,136.60	3.88	28,177.60	96.12	29,314
Least brook lamprey	*Lampetra aepyptera*	32.80	0.23	48.60	0.34	543.40	3.83	624.80	4.40	13,559.60	95.60	14,184
Least darter	*Etheostoma microperca*	6.40	0.22	1.80	0.06	31.20	1.07	39.40	1.36	2,863.80	98.64	2,903
Logperch	*Percina caprodes*	72.80	0.34	131.60	0.62	732.80	3.44	937.20	4.40	20,366.00	95.60	21,303
Longear sunfish	*Lepomis megalotis*	54.80	0.32	62.00	0.36	482.20	2.82	599.00	3.51	16,488.60	96.49	17,088
Longnose dace	*Rhinichthys cataractae*	0.00	0.00	0.00	0.00	0.80	5.97	0.80	5.97	12.60	94.03	13
Longnose gar	*Lepisosteus osseus*	43.60	0.51	103.60	1.21	430.60	5.05	577.80	6.77	7,951.60	93.23	8,529
Mimic shiner	*Notropis volucellus*	61.00	0.41	111.40	0.76	598.80	4.06	771.20	5.23	13,979.20	94.77	14,750
Mississippi silvery minnow	*Hybognathus nuchalis*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.80	100.00	1

Table 5–1 continued.

Fish species		Status 1		Status 2		Status 3		Status 1, 2, 3		Status 4		All of Ohio
Common name	Scientific name	km	percent	km	percent	km	percent	km	percent	km	percent	km
Mooneye	*Hiodon tergisus*	13.40	0.49	20.40	0.75	96.00	3.51	129.80	4.75	2,605.00	95.25	2,735
Mottled sculpin	*Cottus bairdi*	65.60	0.36	123.80	0.67	646.60	3.51	836.00	4.54	17,577.00	95.46	18,413
Mountain brook lamprey	*Ichthyomyzon greeleyi*	0.00	0.00	0.00	0.00	3.40	33.33	3.40	33.33	6.80	66.67	10
Mountain madtom	*Noturus eleutherus*	0.40	1.32	0.00	0.00	0.80	2.65	1.20	3.97	29.00	96.03	30
Muskellunge	*Esox masquinongy oh.*	17.00	0.37	49.20	1.08	258.60	5.67	324.80	7.12	4,236.20	92.88	4,561
Northern brook lamprey	*Ichthyomyzon fossor*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	100.00	1
Northern hog sucker	*Hypentelium nigricans*	76.80	0.29	157.20	0.59	878.60	3.28	1,112.60	4.15	25,680.20	95.85	26,793
Northern madtom	*Noturus stigmosus*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.00	100.00	15
Northern pike	*Esox lucius*	42.60	0.36	110.20	0.93	485.80	4.10	638.60	5.39	11,201.20	94.61	11,840
Ohio lamprey	*Ichthyomyzon bdellium*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	100.00	2
Orangespotted sunfish	*Lepomis humilis*	62.60	0.35	116.20	0.64	573.20	3.16	752.00	4.15	17,369.20	95.85	18,121
Orangethroat darter	*Etheostoma spectabile*	55.20	0.31	51.00	0.28	326.00	1.82	432.20	2.41	17,508.80	97.59	17,941
Popeye shiner	*Notropis ariommus*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.20	100.00	16
Pumpkinseed	*Lepomis gibbosus*	67.20	0.27	179.20	0.73	824.00	3.34	1,070.40	4.34	23,595.60	95.66	24,666
Quillback	*Carpiodes cyprinus*	44.60	0.30	114.60	0.77	540.00	3.61	699.20	4.68	14,253.00	95.32	14,952
Rainbow darter	*Etheostoma caeruleum*	95.00	0.36	171.40	0.65	837.00	3.15	1,103.40	4.16	25,441.80	95.84	26,545
Rainbow smelt	*Osmerus mordax*	0.00	0.00	0.00	0.00	0.80	16.67	0.80	16.67	4.00	83.33	5
Redfin shiner	*Lythrurus umbratilis*	72.00	0.28	149.80	0.58	838.00	3.27	1,059.80	4.14	24,569.40	95.86	25,629
Redside dace	*Clinostomus elongates*	48.00	0.32	106.80	0.71	599.80	3.99	754.60	5.02	14,271.20	94.98	15,026
River carpsucker	*Carpiodes carpio carpio*	16.60	0.38	23.80	0.55	219.40	5.08	259.80	6.02	4,055.20	93.98	4,315
River chub	*Nocomis micropogon*	58.20	0.36	139.40	0.85	721.60	4.41	919.20	5.62	15,430.80	94.38	16,350
River darter	*Percina shumardi*	0.00	0.00	0.00	0.00	0.80	3.70	0.80	3.70	20.80	96.30	22
River redhorse	*Moxostoma carinatum*	21.60	0.38	79.80	1.40	212.80	3.75	314.20	5.53	5,367.60	94.47	5,682
River shiner	*Notropis blennius*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	41.20	100.00	41
Rockbass	*Ambloplites rupestris*	75.20	0.29	156.60	0.60	862.80	3.32	1,094.60	4.21	24,916.00	95.79	26,011
Rosefin shiner	*Lythrurus ardens*	57.20	0.46	49.60	0.40	289.40	2.33	396.20	3.18	12,046.20	96.82	12,442
Rosyface shiner	*Notropis rubellus*	71.00	0.36	141.80	0.71	796.60	4.01	1,009.40	5.08	18,859.40	94.92	19,869
Rosyside dace	*Clinostomus funduloides*	0.00	0.00	0.00	0.00	0.60	2.31	0.60	2.31	25.40	97.69	26
Sand shiner	*Notropis stramineus*	71.60	0.28	141.80	0.56	750.00	2.96	963.40	3.81	24,342.20	96.19	25,306
Sauger	*Stizostedion canadense*	19.80	0.42	25.80	0.55	245.80	5.22	291.40	6.19	4,413.20	93.81	4,705
Shorthead redhorse	*Moxostoma macrolepidotum*	27.00	0.36	89.60	1.19	412.80	5.49	529.40	7.04	6,985.80	92.96	7,515
Shortnose gar	*Lepisosteus platostomus*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.60	100.00	11
Silver chub	*Macrhybopsis storeriana*	10.60	0.30	21.80	0.61	137.20	3.82	169.60	4.73	3,418.20	95.27	3,588

Table 5–1 continued.

Fish species		Status 1		Status 2		Status 3		Status 1, 2, 3		Status 4		All of Ohio
Common name	Scientific name	km	percent	km	percent	km	percent	km	percent	km	percent	km
Silver lamprey	*Ichthyomyzon unicuspis*	8.20	0.25	22.80	0.68	122.20	3.65	153.20	4.58	3,192.60	95.42	3,346
Silver redhorse	*Moxostoma anisurum*	45.00	0.38	99.60	0.84	543.40	4.57	688.00	5.79	11,194.00	94.21	11,882
Silver shiner	*Notropis photogenis*	50.00	0.31	43.80	0.27	445.00	2.73	538.80	3.31	15,759.00	96.69	16,298
Silverjaw minnow	*Notropis buccatus*	93.40	0.31	168.20	0.55	1,019.20	3.33	1,280.80	4.19	29,290.80	95.81	30,572
Skipjack herring	*Alosa chrysochloris*	4.80	0.24	18.80	0.93	58.00	2.86	81.60	4.02	1,948.80	95.98	2,030
Slenderhead darter	*Percina phoxocephala*	28.00	0.87	21.00	0.66	101.80	3.18	150.80	4.71	3,050.40	95.29	3,201
Smallmouth bass	*Micropterus dolomieui*	66.40	0.28	138.60	0.59	756.80	3.25	961.80	4.13	22,342.20	95.87	23,304
Smallmouth buffalo	*Ictiobus bubalus*	24.80	0.40	79.40	1.28	287.00	4.61	391.20	6.28	5,834.80	93.72	6,226
Southern redbelly dace	*Phoxinus erythrogaster*	65.40	0.24	90.60	0.34	821.20	3.08	977.20	3.66	25,722.80	96.34	26,700
Spotfin shiner	*Cyprinella spiloptera*	71.00	0.30	176.80	0.76	850.20	3.64	1,098.00	4.71	22,233.00	95.29	23,331
Spottail shiner	*Notropis hudsonius*	12.80	0.42	66.80	2.20	149.00	4.90	228.60	7.52	2,812.80	92.48	3,041
Spotted bass	*Micropterus punctulatus*	46.80	0.42	40.20	0.36	354.80	3.15	441.80	3.93	10,805.80	96.07	11,248
Spotted darter	*Etheostoma maculatum*	0.00	0.00	0.80	8.33	0.00	0.00	0.80	8.33	8.80	91.67	10
Spotted sucker	*Minytrema melanops*	53.80	0.29	126.80	0.68	623.40	3.33	804.00	4.30	17,898.20	95.70	18,702
Steelcolor shiner	*Cyprinella whipplei*	35.40	0.63	25.60	0.46	197.20	3.52	258.20	4.61	5,343.00	95.39	5,601
Stonecat madtom	*Noturus flavus*	55.60	0.32	123.40	0.70	678.20	3.87	857.20	4.89	16,659.40	95.11	17,517
Streamline chub	*Erimystax dissimilis*	1.80	0.18	12.80	1.27	15.00	1.49	29.60	2.94	975.60	97.06	1,005
Striped shiner	*Luxilus chrysocephalus*	80.00	0.31	133.80	0.52	847.40	3.30	1,061.20	4.13	24,648.20	95.87	25,709
Suckermouth minnow	*Phenacobius mirabilis*	57.20	0.25	127.00	0.56	631.20	2.80	815.40	3.62	21,695.40	96.38	22,511
Tadpole madtom	*Noturus gyrinus*	26.20	0.23	99.80	0.89	273.00	2.42	399.00	3.54	10,872.60	96.46	11,272
Threadfin shad	*Dorosoma petenense*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.80	100.00	2
Tippecanoe darter	*Etheostoma tippecanoe*	2.00	0.40	14.20	2.86	10.00	2.02	26.20	5.28	469.60	94.72	496
Tonguetied minnow	*Exoglossum laurae*	16.20	0.64	4.20	0.16	64.00	2.51	84.40	3.31	2,465.00	96.69	2,549
Trout-perch	*Percopsis omiscomaycus*	55.40	0.32	97.00	0.56	584.80	3.35	737.20	4.23	16,701.40	95.77	17,439
Variegate darter	*Etheostoma variatum*	19.80	0.25	33.00	0.42	271.40	3.45	324.20	4.12	7,537.00	95.88	7,861
Walleye	*Stizostedion vitreum v.*	30.40	0.37	88.80	1.07	417.00	5.04	536.20	6.48	7,734.40	93.52	8,271
Warmouth	*Lepomis gulosus*	46.60	0.32	130.40	0.89	710.60	4.87	887.60	6.09	13,691.60	93.91	14,579
Western banded killifish	*Fundulus diaphanous m.*	0.00	0.00	0.20	1.16	0.00	0.00	0.20	1.16	17.00	98.84	17
White bass	*Morone chrysops*	32.40	0.42	98.20	1.27	394.20	5.09	524.80	6.77	7,222.20	93.23	7,747
White crappie	*Pomoxis annularis*	76.80	0.33	146.20	0.63	767.40	3.32	990.40	4.28	22,148.60	95.72	23,139
White sucker	*Catostomus commersoni*	100.60	0.27	195.60	0.53	1,084.20	2.95	1,380.40	3.76	35,362.40	96.24	36,743
Yellow bullhead	*Ameiurus natalis*	102.40	0.29	240.00	0.69	1,039.20	2.97	1,381.60	3.94	33,645.60	96.06	35,027
Yellow perch	*Perca flavescens*	64.40	0.31	134.40	0.65	699.00	3.38	897.80	4.34	19,790.40	95.66	20,688

Table 5–2. Summary of the length of streams (kilometers) and percentage of total mapped distribution of each crayfish species in different Gap Analysis Program (GAP) management status categories.

Crayfish species		Status 1		Status 2		Status 3		Status 1, 2, 3		Status 4		All of Ohio
Common name	***Scientific name***	**km**	**percent**	**km**	**percent**	**km**	**percent**	**km**	**percent**	**km**	**percent**	**km**
Allegheny crayfish	*Orconectes obscurus*	2.40	0.07	3.20	0.09	146.40	4.30	152.00	4.47	3,250.00	95.53	3,402
Big water crayfish	*Cambarus robustus*	58.40	0.29	266.80	1.34	955.40	4.79	1,280.60	6.43	18,647.40	93.57	19,928
Devil crawfish	*Cambarus diogenes*	0.80	0.06	0.00	0.00	5.20	0.40	6.00	0.47	1,282.80	99.53	1,289
Digger crayfish	*Fallicambarus fodiens*	1.80	0.13	2.80	0.21	19.40	1.42	24.00	1.76	1,338.60	98.24	1,363
Little brown mudbug	*Cambarus thomai*	95.40	0.36	102.80	0.38	940.60	3.50	1,138.80	4.24	25,732.80	95.76	26,872
Northern clearwater crayfish	*Orconectes propinquus*	19.40	0.40	189.20	3.86	402.20	8.21	610.80	12.46	4,289.60	87.54	4,900
Ohio crawfish	*Cambarus sp. A*	110.40	0.31	209.60	0.59	1,382.60	3.88	1,702.60	4.78	33,924.20	95.22	35,627
Ortmann's mudbug	*Cambarus ortmanni*	4.40	0.17	0.40	0.02	23.40	0.91	28.20	1.10	2,530.80	98.90	2,559
Paintedhand mudbug	*Cambarus sp. B*	48.60	0.26	46.40	0.25	319.40	1.73	414.40	2.24	18,080.80	97.76	18,495
Papershell crayfish	*Orconectes immunis*	56.40	0.25	281.00	1.24	668.60	2.95	1,006.00	4.44	21,654.40	95.56	22,660
Rock crawfish	*Cambarus carinirostris*	26.00	0.27	90.80	0.93	778.80	7.97	895.60	9.17	8,873.00	90.83	9,769
Rusty crayfish	*Orconectes rusticus*	77.40	0.29	186.00	0.70	752.20	2.83	1,015.60	3.82	25,594.60	96.18	26,610
Sanborn's crayfish	*Orconectes sanbornii*	64.20	0.28	192.20	0.84	974.60	4.27	1,231.00	5.39	21,593.40	94.61	22,824
Sloan's crayfish	*Orconectes sloanii*	17.20	0.55	4.20	0.13	73.20	2.33	94.60	3.02	3,040.60	96.98	3,135
Spiney stream crayfish	*Orconectes cristavarius*	32.20	0.40	50.60	0.62	398.20	4.89	481.00	5.90	7,670.20	94.10	8,151
Teays river crayfish	*Cambarus sciotensis*	19.80	0.28	46.80	0.67	125.80	1.80	192.40	2.76	6,786.80	97.24	6,979
White river crayfish	*Procambarus acutus*	25.00	0.16	87.00	0.56	329.00	2.11	441.00	2.82	15,173.00	97.18	15,614

Table 5–3. Summary of the length of streams (kilometers) and percentage of total mapped distribution of each bivalve species in different Gap Analysis Program (GAP) land stewardship and management categories.

Bivalve species		Status 1		Status 2		Status 3		Status 1, 2, 3		Status 4		All of Ohio
Common name	Scientific name	km	percent	km	percent	km	percent	km	percent	km	percent	km
Black sandshell	*Ligumia recta*	24.20	0.35	86.60	1.26	358.40	5.20	469.20	6.80	6,426.00	93.20	6,895
Butterfly	*Ellipsaria lineolata*	1.00	0.11	1.80	0.20	33.20	3.60	36.00	3.90	886.00	96.10	922
Clubshell	*Pleurobema clava*	19.60	0.30	45.80	0.70	189.80	2.91	255.20	3.91	6,263.80	96.09	6,519
Creek heelsplitter	*Lasmigona compressa*	64.20	0.31	146.00	0.70	777.20	3.71	987.40	4.71	19,959.20	95.29	20,947
Creeper	*Strophitus undulates*	65.20	0.34	126.00	0.65	690.20	3.58	881.40	4.58	18,374.00	95.42	19,255
Cylindrical papershell	*Anodontiodes ferussacianus*	82.00	0.26	175.80	0.56	959.00	3.08	1,216.80	3.90	29,969.20	96.10	31,186
Deertoe	*Truncilla truncate*	19.40	0.38	35.20	0.69	196.20	3.87	250.80	4.94	4,821.80	95.06	5,073
Eastern pondmussel	*Ligumia nasuta*	3.00	0.80	0.20	0.05	18.20	4.87	21.40	5.73	352.00	94.27	373
Elephantear	*Elliptio crassidens*	7.40	0.24	23.20	0.75	79.00	2.56	109.60	3.55	2,977.00	96.45	3,087
Elktoe	*Alasmidonta marginata*	24.60	0.37	86.20	1.31	318.20	4.84	429.00	6.52	6,146.00	93.48	6,575
Fanshell	*Cyprogenia stegaria*	12.80	0.48	18.60	0.69	83.60	3.10	115.00	4.27	2,579.20	95.73	2,694
Fatmucket	*Lampsilis radiate*	67.80	0.30	149.40	0.67	774.40	3.48	991.60	4.46	21,255.60	95.54	22,247
Fawnsfoot	*Truncilla donaciformis*	21.40	0.58	22.20	0.60	130.80	3.52	174.40	4.69	3,540.60	95.31	3,715
Flat floater	*Anodonta suborbiculata*	4.20	0.60	3.80	0.54	17.80	2.53	25.80	3.67	676.40	96.33	702
Fluted shell	*Lasmigona costata*	46.00	0.41	106.80	0.96	536.20	4.82	689.00	6.20	10,426.60	93.80	11,116
Fragile papershell	*Leptodea fragilis*	31.60	0.44	50.60	0.70	308.40	4.27	390.60	5.41	6,829.60	94.59	7,220
Giant floater	*Pyganodon grandis*	67.80	0.28	137.60	0.57	745.40	3.08	950.80	3.93	23,250.20	96.07	24,201
Grooved fingernailclam	*Sphaerium simile*	4.00	0.57	20.80	2.99	8.60	1.23	33.40	4.80	663.00	95.20	696
Kidneyshell	*Ptychobranchus fasciolar*	38.20	0.33	102.80	0.89	444.00	3.85	585.00	5.08	10,936.60	94.92	11,522
Lilliput	*Toxolasma parvus*	56.40	0.27	112.20	0.54	579.80	2.79	748.40	3.60	20,019.00	96.40	20,767
Little spectaclecase	*Villosa lienosa*	4.80	0.12	25.00	0.61	217.80	5.31	247.60	6.04	3,851.40	93.96	4,099
Long fingernailclam	*Musculium transversum*	48.60	0.26	118.80	0.65	553.40	3.00	720.80	3.91	17,696.20	96.09	18,417
Long solid	*Fusconaia maculate*	6.80	0.21	20.80	0.65	168.20	5.25	195.80	6.11	3,009.00	93.89	3,205
Mapleleaf	*Quadrula quadrula*	28.00	0.46	79.40	1.31	270.80	4.46	378.20	6.23	5,693.60	93.77	6,072
Monkeyface	*Quadrula metanevra*	0.00	0.00	0.00	0.00	0.80	0.27	0.80	0.27	293.60	99.73	294
Mucket	*Actinonaias ligamentina*	20.40	0.32	82.80	1.30	304.60	4.78	407.80	6.40	5,960.00	93.60	6,368
Northern riffleshell	*Epioblasma rangiana*	7.00	0.54	19.20	1.49	64.20	4.97	90.40	7.00	1,200.20	93.00	1,291
Ohio pigtoe	*Pleurobema cordatum*	7.60	0.35	18.00	0.83	61.40	2.82	87.00	3.99	2,093.00	96.01	2,180
Paper pondshell	*Utterbackia imbecillis*	56.20	0.30	117.60	0.63	626.20	3.37	800.00	4.31	17,769.00	95.69	18,569
Pimpleback	*Quadrula pustulosa*	5.80	0.14	29.60	0.73	144.80	3.56	180.20	4.43	3,883.40	95.57	4,064
Pink heelsplitter	*Potamilus alatus*	35.80	0.53	91.80	1.35	289.00	4.24	416.60	6.11	6,399.00	93.89	6,816

Table 5–3 continued.

Bivalve species		Status 1		Status 2		Status 3		Status 1, 2, 3		Status 4		All of Ohio
Common name	Scientific name	km	percent	km	percent	km	percent	km	percent	km	percent	km
Pink mucket	*Lampsilis abrupta*	0.60	0.06	10.60	1.02	41.20	3.96	52.40	5.04	986.80	94.96	1,039
Pink papershell	*Potamilus ohiensis*	18.20	0.47	23.00	0.60	159.80	4.14	201.00	5.21	3,658.00	94.79	3,859
Pistolgrip	*Tritogonia verrucosa*	26.80	0.64	24.80	0.59	165.20	3.95	216.80	5.19	3,963.60	94.81	4,180
Plain pocketbook	*Lampsilis ventricosa*	49.40	0.46	93.80	0.88	482.20	4.51	625.40	5.85	10,064.60	94.15	10,690
Pocketbook	*Lampsilis ovata*	4.60	0.20	19.00	0.82	83.40	3.59	107.00	4.61	2,216.20	95.39	2,323
Pond fingernailclam	*Musculium secures*	0.00	0.00	8.60	14.29	0.60	1.00	9.20	15.28	51.00	84.72	60
Pondhorn	*Uniomerus tetralasm*	8.00	0.27	14.40	0.48	67.40	2.25	89.80	3.00	2,903.60	97.00	2,993
Purple lilliput	*Toxolasma lividus*	5.80	0.43	21.00	1.55	36.20	2.68	63.00	4.66	1,288.20	95.34	1,351
Purple catspaw	*Epioblasma obliquata*	1.00	0.28	0.00	0.00	1.20	0.34	2.20	0.62	351.80	99.38	354
Purple wartyback	*Cyclonaias tuberculata*	22.00	0.35	84.60	1.36	319.00	5.12	425.60	6.84	5,799.20	93.16	6,225
Pyramid pigtoe	*Pleurobema rubrum*	0.80	0.07	2.20	0.20	37.40	3.38	40.40	3.65	1,066.60	96.35	1,107
Rabbitsfoot	*Quadrula cylindrical*	6.20	0.16	19.80	0.52	106.60	2.77	132.60	3.45	3,709.20	96.55	3,842
Rainbowshell	*Villosa iris*	42.20	0.31	111.00	0.80	544.20	3.93	697.40	5.04	13,136.20	94.96	13,834
Rayed bean	*Villosa fabalis*	22.80	0.42	58.00	1.06	160.00	2.93	240.80	4.40	5,227.60	95.60	5,468
Ridged-back peaclam	*Pisidium compressum*	30.80	0.39	42.20	0.53	187.40	2.35	260.40	3.26	7,723.00	96.74	7,983
Ring pink	*Obovaria retusa*	0.00	0.00	2.00	0.25	36.40	4.55	38.40	4.80	761.80	95.20	800
River fingernailclam	*Sphaerium fabale*	4.80	0.85	21.00	3.71	20.80	3.67	46.60	8.23	519.80	91.77	566
River peaclam	*Pisidium fallax*	9.20	0.98	4.00	0.43	14.80	1.58	28.00	2.99	909.00	97.01	937
Rough pigtoe	*Pleurobema plenum*	0.00	0.00	0.00	0.00	0.20	0.30	0.20	0.30	66.60	99.70	67
Round hickorynut	*Obovaria subrotunda*	21.00	0.34	76.60	1.23	278.80	4.47	376.40	6.03	5,865.60	93.97	6,242
Round pigtoe	*Pleurobema sintoxia*	24.00	0.29	100.80	1.21	403.20	4.82	528.00	6.32	7,832.40	93.68	8,360
Salamander mussel	*Simpsonaias ambigua*	23.60	0.42	64.40	1.14	245.00	4.33	333.00	5.89	5,320.20	94.11	5,653
Sheepnose	*Plethobasus cyphyus*	8.60	0.26	23.40	0.71	140.40	4.27	172.40	5.24	3,114.80	94.76	3,287
Slippershell mussel	*Alasmidonta viridis*	148.60	0.27	439.80	0.79	2,022.00	3.61	2,610.40	4.66	53,368.00	95.34	55,978
Snuffbox	*Epioblasma triquetra*	14.00	0.26	22.40	0.41	198.80	3.63	235.20	4.29	5,243.40	95.71	5,479
Spike	*Elliptio dilatata*	39.80	0.36	109.00	0.98	504.40	4.55	653.20	5.89	10,433.20	94.11	11,086
Striated fingernailclam	*Sphaerium striatinum*	75.00	0.29	147.40	0.56	831.80	3.17	1,054.20	4.02	25,156.20	95.98	26,210
Threehorn wartyback	*Obliquaria reflexa*	130.80	0.25	369.80	0.69	1,882.60	3.53	2,383.20	4.47	50,971.40	95.53	53,355
Threeridge	*Amblema plicata*	35.20	0.37	100.80	1.05	442.60	4.60	578.60	6.01	9,049.60	93.99	9,628
Tubercled blossom	*Epioblasma torulosa*	0.00	0.00	12.00	3.80	1.60	0.51	13.60	4.30	302.40	95.70	316
Ubiquitous peaclam	*Pisidium casertanum*	8.00	0.46	18.20	1.05	52.20	3.01	78.40	4.52	1,656.00	95.48	1,734
Wabash pigtoe	*Fusconaia flava*	41.80	0.30	112.20	0.80	549.60	3.92	703.60	5.02	13,317.20	94.98	14,021
Wartyback	*Quadrula nodulata*	1.00	0.45	9.20	4.13	12.20	5.48	22.40	10.06	200.20	89.94	223

Table 5–3 continued.

Bivalve species		Status 1		Status 2		Status 3		Status 1, 2, 3		Status 4		All of Ohio
Common name	Scientific name	km	percent	km	percent	km	percent	km	percent	km	percent	km
Washboard	*Megalonaias nervosa*	3.80	0.27	2.60	0.18	76.40	5.39	82.80	5.84	1,334.00	94.16	1,417
Wavyrayed lampmussel	*Lampsilis fasciola*	29.60	0.34	81.00	0.92	310.20	3.51	420.80	4.77	8,410.20	95.23	8,831
White catspaw	*Epioblasma obliquata*	8.20	0.62	26.80	2.01	73.00	5.48	108.00	8.11	1,223.00	91.89	1,331
White heelsplitter	*Lasmigona complanata*	43.60	0.41	111.60	1.05	507.00	4.76	662.20	6.22	9,982.00	93.78	10,644
Winged mapleleaf	*Quadrula fragosa*	0.00	0.00	8.60	4.41	2.60	1.33	11.20	5.74	183.80	94.26	195
Yellow sandshell	*Lampsilis teres*	2.40	1.25	2.40	1.25	2.00	1.04	6.80	3.54	185.40	96.46	192

Species with distributions predicted to be completely outside of protected areas (status 1 or 2)

Fish

Predicted distributions of 22 fish species (17 percent of fish species modeled) were exclusive of conservation lands classified by OH-GAP as status 1 or 2.

American eel, *Anguilla rostrata*
Bigeye shiner, *Notropis boops*
Blue sucker, *Cycleptus elongates*
Brook trout, *Salvelinus fontinalis*
Channel darter, *Percina copelandi*
Channel shiner, *Notropis wickliffi*
Goldeye, *Hiodon alosoides*
Iowa darter, *Etheostoma exile*
Lake chubsucker, *Erimyzon sucetta*
Longnose dace, *Rhinichthys cataractae*
Mississippi silvery minnow, *Hybognathus nuchalis*
Mountain brook lamprey, *Ichthyomyzon greeleyi*
Northern brook lamprey, *Ichthyomyzon fossor*
Northern madtom, *Noturus stigmosus*
Ohio lamprey, *Ichthyomyzon bdellium*
Popeye shiner, *Notropis ariommus*
Rainbow smelt, *Osmerus mordax*
River darter, *Percina shumardi*
River shiner, *Notropis blennius*
Rosyside dace, *Clinostomus funduloides*
Shortnose gar, *Lepisosteus platostomus*
Threadfin shad, *Dorosoma petenense*

Freshwater Bivalves

Only two bivalve species (3 percent of bivalve species modeled) were unprotected by conservation lands classified by OH-GAP as status 1 or 2.

Monkeyface, *Quadrula metanevra*
Rough pigtoe, *Pleurobema plenum*

Species with >0 to <1 percent of predicted distribution in status 1 or 2

Fish

Forty fish species (31 percent of fish species modeled) had less than 1 percent of their predicted distributions in conservation lands classified by OH-GAP as status 1 or 2. More than half of these species (highlighted below) have very extensive statewide distributions and fall within the top quarter of fish species for total predicted stream kilometers.

Banded darter, *Etheostoma zonale*
Black bullhead, *Ameiurus melas*
Blackside darter, *Percina maculate*
Bluntnose minnow, *Pimephales notatus*
Central stoneroller, *Campostoma anomalum*
Creek chub, *Semotilus atromaculatus*
Creek chubsucker, *Erimyzon oblongus*
Dusky darter, *Percina sciera sciera*
Eastern sand darter, *Ammocrypta pellucida*
Fantail darter, *Etheostoma flabellare*
Fathead minnow, *Pimephales promelas*
Golden shiner, *Notemigonus crysoleucas*
Grass pickerel, *Esox americanus v.*
Green sunfish, *Lepomis cyanellus*
Greenside darter, *Etheostoma blennioides*
Johnny darter, *Etheostoma nigrum*
Largemouth bass, *Micropterus salmoides*
Least brook lamprey, *Lampetra aepyptera*
Least darter, *Etheostoma microperca*
Longear sunfish, *Lepomis megalotis*
Northern hog sucker, *Hypentelium nigricans*
Orangethroat darter, *Etheostoma spectabile*
Redfin shiner, *Lythrurus umbratilis*
River carpsucker, *Carpiodes carpio carpio*
Rockbass, *Ambloplites rupestris*
Rosefin shiner, *Lythrurus ardens*
Sand shiner, *Notropis stramineus*
Silver chub, *Macrhybopsis storeriana*
Silver lamprey, *Ichthyomyzon unicuspis*
Silver shiner, *Notropis photogenis*
Silverjaw minnow, *Notropis buccatus*
Smallmouth bass, *Micropterus dolomieui*
Southern redbelly dace, *Phoxinus erythrogaster*
Spotted bass, *Micropterus punctulatus*
Striped shiner, *Luxilus chrysocephalus*
Suckermouth minnow, *Phenacobius mirabilis*

Tonguetied minnow, *Exoglossum laurae*
Trout-perch, *Percopsis omiscomaycus*
Variegate darter, *Etheostoma variatum*
White sucker, *Catostomus commersoni*

Crayfish

Nine crayfish species (53 percent of crayfish species modeled) had less than 1 percent of their predicted distributions in conservation lands classified by OH-GAP as status 1 or 2.

Allegheny crayfish, *Orconectes obscurus*
Devil crawfish, *Cambarus Diogenes*
Digger crayfish, *Fallicambarus fodiens*
Little brown mudbug, *Cambarus thomai*
Ohio crawfish, *Cambarus sp. A*
Ortmann's mudbug, *Cambarus ortmanni*
Paintedhand mudbug, *Cambarus sp. B*
Sloan's crayfish, *Orconectes sloanii*
White river crayfish, *Procambarus acutus*

Freshwater Bivalves

Nineteen bivalve species (27 percent of bivalve species modeled) had less than 1 percent of their predicted distribution in conservation lands classified by OH-GAP as status 1 or 2. Almost half of these bivalve species (highlighted below) have extensive statewide distributions and fall within the top quarter of bivalve species for predicted stream kilometers.

Butterfly, *Ellipsaria lineolata*
Cylindrical papershell, *Anodontiodes ferussacianus*
Eastern pondmussel, *Ligumia nasuta*
Giant floater, *Pyganodon grandis*
Lilliput, *Toxolasma parvus*
Little spectaclecase, *Villosa lienosa*
Long fingernailclam, *Musculium transversum*
Long solid, *Fusconaia maculate*
Paper pondshell, *Utterbackia imbecillis*
Pimpleback, *Quadrula pustulosa*
Pondhorn, *Uniomerus tetralasm*
Purple catspaw, *Epioblasma obliquata*
Pyramid pigtoe, *Pleurobema rubrum*
Rabbitsfoot, *Quadrula cylindrical*
Ridged-back peaclam, *Pisidium compressum*
Ring pink, *Obovaria retusa*
Snuffbox, *Epioblasma triquetra*
Striated fingernailclam, *Sphaerium striatinum*
Threehorn wartyback, *Obliquaria reflexa*

Species with 1 to <10 percent of predicted distribution in status 1 or 2

Fish

For fish, the spotted darter, *Etheostoma maculatum*, had the highest percentage (8.3 percent) of its distribution in OH-GAP stewardship lands classified as status 1 or 2. Brown bullhead, *Ictalurus nebulosus,* (3.5 percent) and Tippecanoe darter, *Etheostoma tippecanoe* (3.3 percent), had the next two highest percentages for fish. All three of these species had relatively limited predicted distributions (less than 1,000 km). The mean and median percentages of fish species' distributions predicted to occur in streams flowing through OH-GAP stewardship lands classified as 1 and 2 were both 1.0 percent.

Crayfish

The northern clear water crayfish, *Orconectes propinquus*, had the highest percentage (4.3 percent) of its distribution in OH-GAP stewardship lands classified as 1 and 2. This crayfish species was predicted to occur in about 4,900 km of Ohio streams. The big water crayfish, *Cambarus robustus* (1.6 percent), and papershell crayfish, *Orconectes immunis* (1.5 percent), had the next two highest percentages for crayfish. Both of these species had relatively large predicted distributions with both being greater than 19,900 stream kilometers. The mean and median percentages of crayfish species' distributions predicted to occur in streams flowing through OH-GAP stewardship lands classified as 1 and 2 were 1.0 and 0.9 percent, respectively.

Freshwater Bivalves

The wartyback, *Quadrula nodulata* (4.6 percent), and river fingernailclam, *Sphaerium fabale* (4.6 percent), had the second and third highest percentages for bivalves predicted in OH-GAP stewardship lands classified as 1 or 2. Both bivalve species' distributions were relatively limited (less than 1,000 km) and within the lowest 10 species for total predicted stream-length occurrences. The average percentage of bivalve species' distributions predicted in OH-GAP stewardship lands classified as 1 and 2 was 1.5, whereas the median was 1.1 percent.

Species with 10 to <20 percent of predicted distribution in status 1 or 2

Freshwater Bivalves

The pond fingernail clam, *Musculium secures*, was the aquatic species with the highest percentage (14.3 percent) of its distribution in OH-GAP stewardship lands classified as 1 and 2.

The analysis of aquatic animals in OH-GAP conservation lands revealed that no one species of fish, crayfish, or bivalves was found in greater than 14.3 percent of the combined land-steward classes of 1 and 2.

Analysis of Ohio Rare, Threatened, or Endangered Species

Fish

OH-GAP predicted the occurrences of 12 native rare, threatened, or endangered fish species (9 percent of fish species modeled). Nine of these 12 fish species (75 percent) had predicted distributions exclusive of conservation lands classified by OH-GAP as 1 or 2. Conversely, the spotted darter, *Etheostoma maculatum*, has the greatest amount of predicted distribution contained within class 1 and 2 conservation lands of any fish species.

Blue sucker, *Cycleptus elongates*
Goldeye, *Hiodon alosoides*
Mississippi silvery minnow, *Hybognathus nuchalis*
Mountain brook lamprey, *Ichthyomyzon greeleyi*
Mountain madtom, *Noturus eleutherus*
Northern brook lamprey, *Ichthyomyzon fossor*
Northern madtom, *Noturus stigmosus*
Ohio lamprey, *Ichthyomyzon bdellium*
Popeye shiner, *Notropis ariommus*
Shortnose gar, *Lepisosteus platostomus*
Spotted darter, *Etheostoma maculatum*
Western banded killifish, *Fundulus diaphanous m.*

Crayfish

One crayfish species, Sloan's crayfish, *Orconectes sloanii*, is considered threatened in Ohio. It is predicted to occur in 0.68 percent of conservation lands classified by OH-GAP as 1 or 2.

Freshwater Bivalves

Twenty-two native bivalve species (31 percent) are considered rare, threatened, or endangered in Ohio. Ten of these bivalve species (45 percent of rare, threatened or endangered bivalve species modeled) have less than 1 percent of their predicted distributions in conservation lands classified by OH-GAP as 1 or 2.

Butterfly, *Ellipsaria lineolata*
Clubshell, *Pleurobema clava*
Eastern pondmussel, *Ligumia nasuta*
Elephantear, *Elliptio crassidens*
Fanshell, *Cyprogenia stegaria*
Little spectaclecase, *Villosa lienosa*
Long solid, *Fusconaia maculate*
Monkeyface, *Quadrula metanevra*
Northern riffleshell, *Epioblasma rangiana*
Ohio pigtoe, *Pleurobema cordatum*
Pink mucket, *Lampsilis abrupta*
Purple catspaw, *Epioblasma obliquata*

Purple lilliput, *Toxolasma lividus*
Pyramid pigtoe, *Pleurobema rubrum*
Rabbitsfoot, *Quadrula cylindrical*
Rayed bean, *Villosa fabalis*
Sheepnose, *Plethobasus cyphyus*
Snuffbox, *Epioblasma triquetra*
Wartyback, *Quadrula nodulata*
Washboard, *Megalonaias nervosa*
White catspaw, *Epioblasma obliquata*
Yellow sandshell, *Lampsilis teres*

Physical Habitat Type Analysis

The most abundant physical habitat types (by total length) for all stream sizes in the Lake Erie and Ohio River Basins are listed in table 5–4. In the Lake Erie Basin, the streams classified with the most extensive (spatially) physical habitat types are predominantly in the Blanchard, Portage, and Sandusky River watersheds. In the Ohio River Basin, the most abundant physical habitat types are in southeastern Ohio.

Table 5–4. Percentage of physical habitat type in the Ohio Gap Analysis Project's land stewardship classes for the most abundant physical habitat type (by total length) for each OH-GAP stream-size class.
[km, kilometers]

Size class	Physical habitat type	Status 1 (percent)	Status 2 (percent)	Status 3 (percent)	Status 4 (percent)	Number of segments	Total length (km)
Lake Erie							
Small	6 (13) 1 1 2 3 1 2	0	0	0.07	99.93	406	532
Medium	2 1 2 2 2 3 1 2	0	0	1.33	97.1	114	167
Large	4 3 1 3 2 3 1 3	1.63	0.54	0.12	97.68	606	628
Ohio River							
Small	1 1 4 1 4 3 3 4	0.18	1.31	14.43	85.85	558	766
Medium	2 1 4 1 4 3 3 4	0.07	0.3	6.56	93.5	305	316
Large	4 3 1 3 4 3 1 3	0	0.58	5.14	94.28	509	547

Limitations and Discussion

When applying the results of the OH-GAP analyses, it is critical that the following limitations be considered: (1) the limitations described for each of the component parts (physical-habitat classification and mapping, animal-species mapping, stewardship mapping) of the analyses; (2) the spatial and thematic map accuracy of the components; and (3) the suitability of the results for the intended application. (See "Appropriate and Inappropriate Use" section.)

6. Analysis Based on Aquatic Biodiversity

Methods

Priorities for conservation are developed on the basis of objectives and goals of the individual agencies and organizations involved with conservation. Some efforts focus on individual species or taxa, others on unique physical habitats. High priority may be given to streams and land in danger of encroachment, whereas similar places in less developed parts of the state (or in other states) may not be considered as high a conservation priority. Similarly, a habitat type in one part of the state may be seen as unique to that region and, therefore, a conservation priority for that region only. Landscape-scale conservation efforts aimed at connecting landscapes and habitats would have different criteria than the site-specific-scale conservation of an isolated land tract. With this understanding, OH-GAP developed an analysis of the biodiversity in the state of Ohio robust enough for different approaches to conservation of aquatic resources. This approach is a coarse-filtered approach, looking at the landscape at a macro scale; a need for assessment at other spatial scales persists.

Species Richness

Species richness (number of species within a given area) represents biodiversity in a geographic area. Identifying areas with high species richness values supports the National GAP goal of keeping common species common. Research over the last two decades has shown the importance of biodiversity conservation at all spatial scales (Poiani, and others, 2000; Noss, 1990; Christensen and others, 1996). Previous efforts that focused solely on hotspots or endangered species resulted in the creation of small, fragmented nature preserves. These conservation areas are extremely important, but as fragmented islands, are insufficient for long-term preservation of biological diversity in and outside of the preserve (Harris, 1984). OH-GAP calculated species richness for each taxon of aquatic animals at the 14-HU scale. This encompassing areal assessment unit allows for the coarse-scale comparison of riverine habitat. At the simplest level of analysis, each 14-HU in the state could be compared to the other 14-HUs on the basis of total native species richness. However, in recognition of the importance of streams of different sizes and relative diversity, OH-GAP examined the 14-HUs by major drainage basin, Omernik's III ecoregions (1987), and stream size.

Major Drainage Basins

Fish species richness increases generally from north to south across Ohio. This can be explained by the differences in latitude as well as the climatic and geologic history, among other factors. As a result, the streams and 14-HUs in the Lake Erie Basin are not identified as being species rich when viewed at the state level (fig. 6–1). Relative differences in species richness among the Lake Erie 14-HUs are also masked by the larger relative differences in the Ohio River 14-HUs. Therefore, for purposes of highlighting Lake Erie stream heterogeneity, OH-GAP mapped species richness values relative to the Lake Erie and Ohio River Basins separately (fig. 6–2).

Ecoregions

Ecoregions represent watersheds with a set of relatively homogeneous terrestrial variables including land-surface form, soils, potential natural vegetation, and land use. Ohio contains parts of six ecoregions. (See "Ohio Aquatic GAP Study Area" in chapter 1 for general descriptions.) The Ohio Environmental Protection Agency (Ohio EPA) (1987) uses ecoregions in the development of biological criteria for water-quality assessments. The Ohio EPA chooses regional reference sites from ecoregions with which all aquatic biological data are compared, ultimately, to determine the attainment of aquatic life-use designations. This approach helps explain variability in the data and defines what is attainable.

OH-GAP also used Omernik's Level III ecoregions (1987) to identifying potential conservation-priority areas. (See *Appendix B* for map.) The assessment of potential conservation-priority areas by ecoregions was produced with the same methods as the major drainage basins analysis. However, because ecoregion boundaries split watersheds, 14-HUs were assigned to an ecoregion if most of the area and all of the streams lay inside the ecoregion boundary. A new category was created to include 14-HUs that were split by the ecoregion boundaries. With this methodology, the small part of Ohio in the Southern Michigan/Northern Indiana Drift Plains ecoregion was dissolved into the newly formed transition category.

Stream Size

Species richness values increase with increasing drainage areas (Ohio Environmental Protection Agency, 1987). The GIS grid representing Ohio's stream network was, therefore, divided into three stream-size classes: small (first order), medium (second and third order), and large (fourth order and up). To ensure that smaller streams were not masked by larger streams, OH-GAP mapped species-richness values relative to stream size (figs. 6–3 through 6–5).

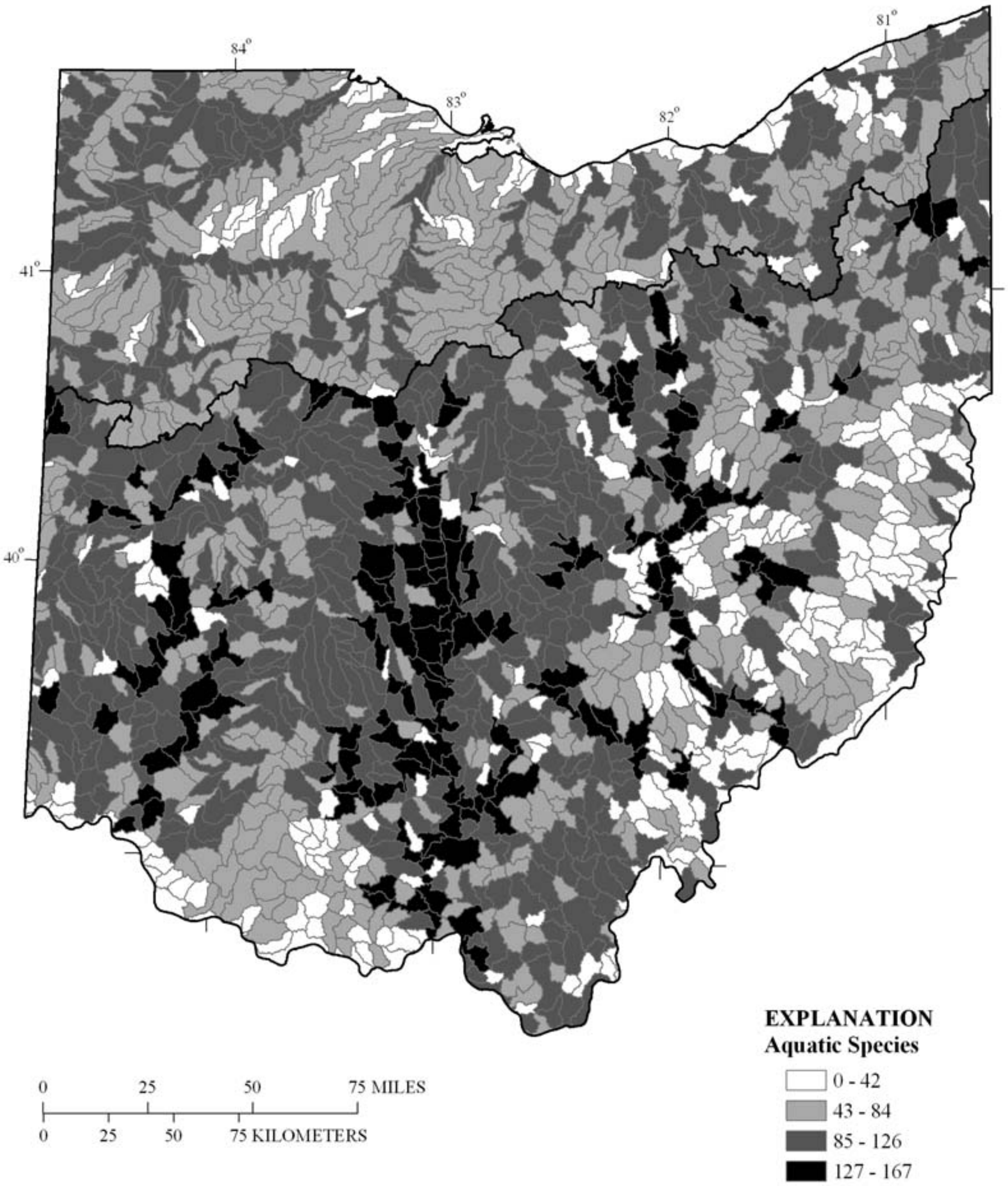

Figure 6–1. Predicted number of fish, crayfish, and bivalve species, by 14-digit hydrologic unit. A solid black line separates the Lake Erie Basin in the north from the Ohio River Basin in the south.

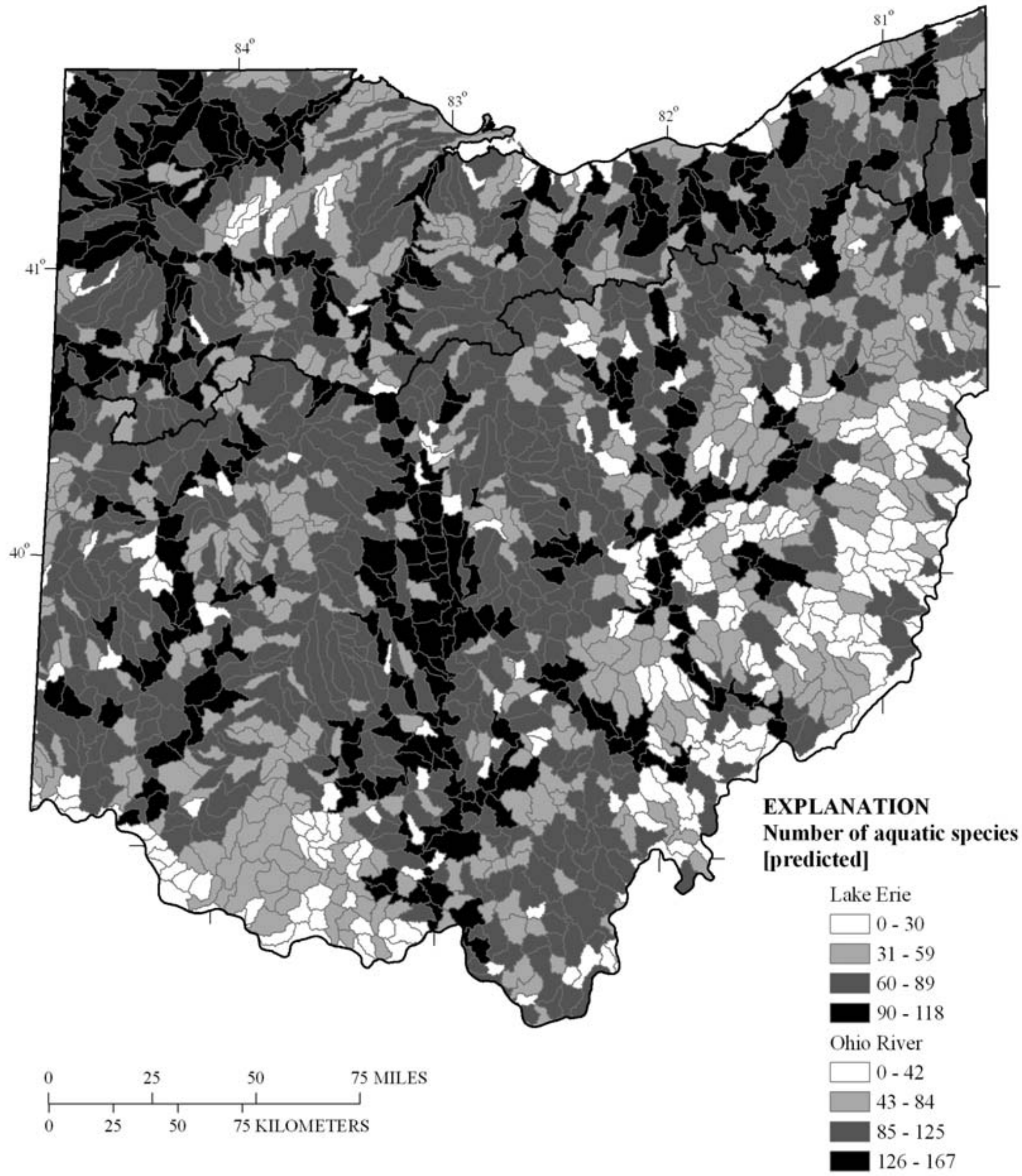

Figure 6–2. Predicted number of fish, crayfish, and bivalve species, by 14-digit hydrologic unit, relative to major drainage (Lake Erie and Ohio River). A solid black line separates the Lake Erie Basin in the north from the Ohio River Basin in the south.

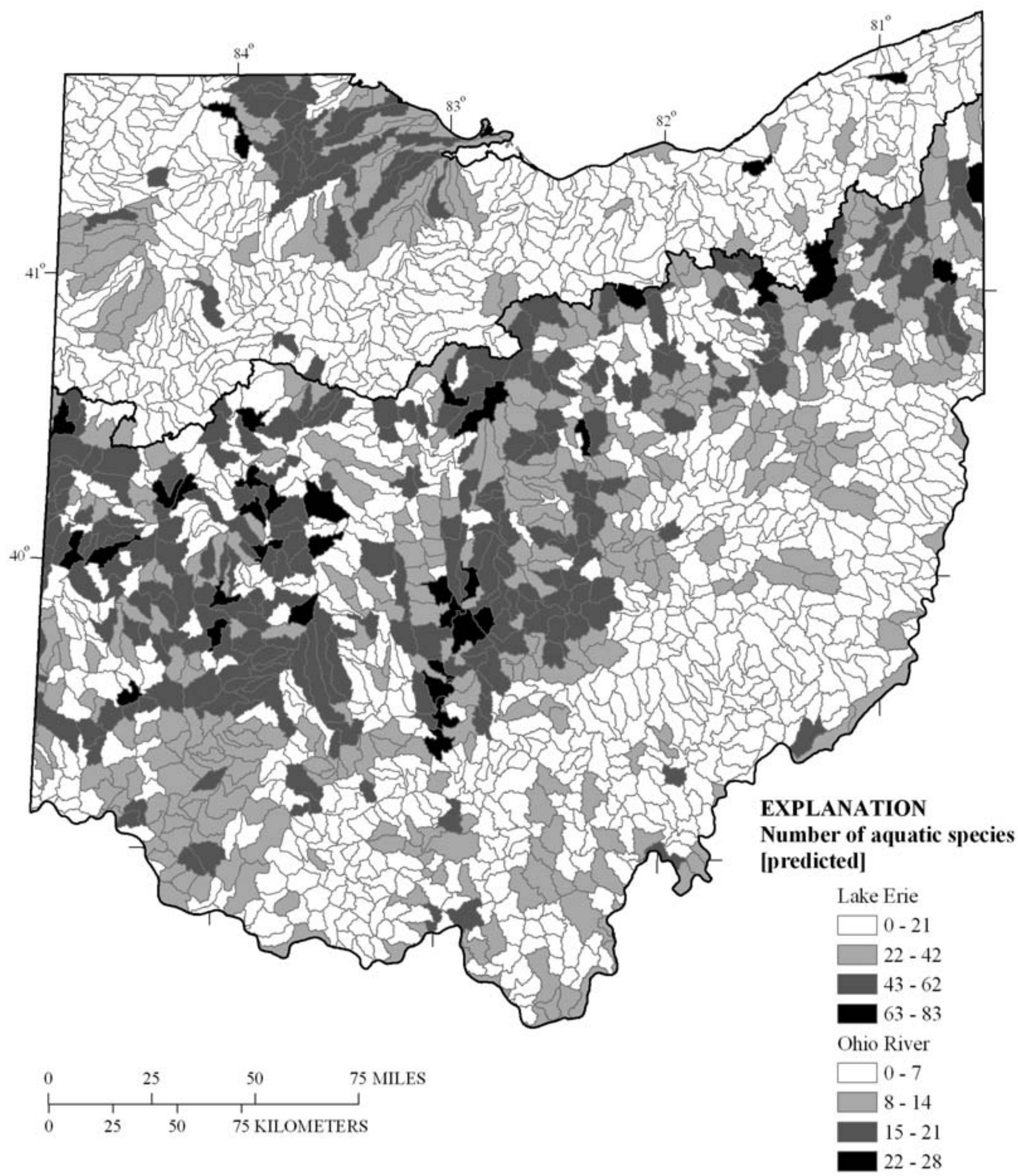

Figure 6–3. Predicted number of fish, crayfish, and bivalve species, by 14-digit hydrologic unit, for first-order (small) streams. A solid black line separates the Lake Erie Basin in the north from the Ohio River Basin in the south.

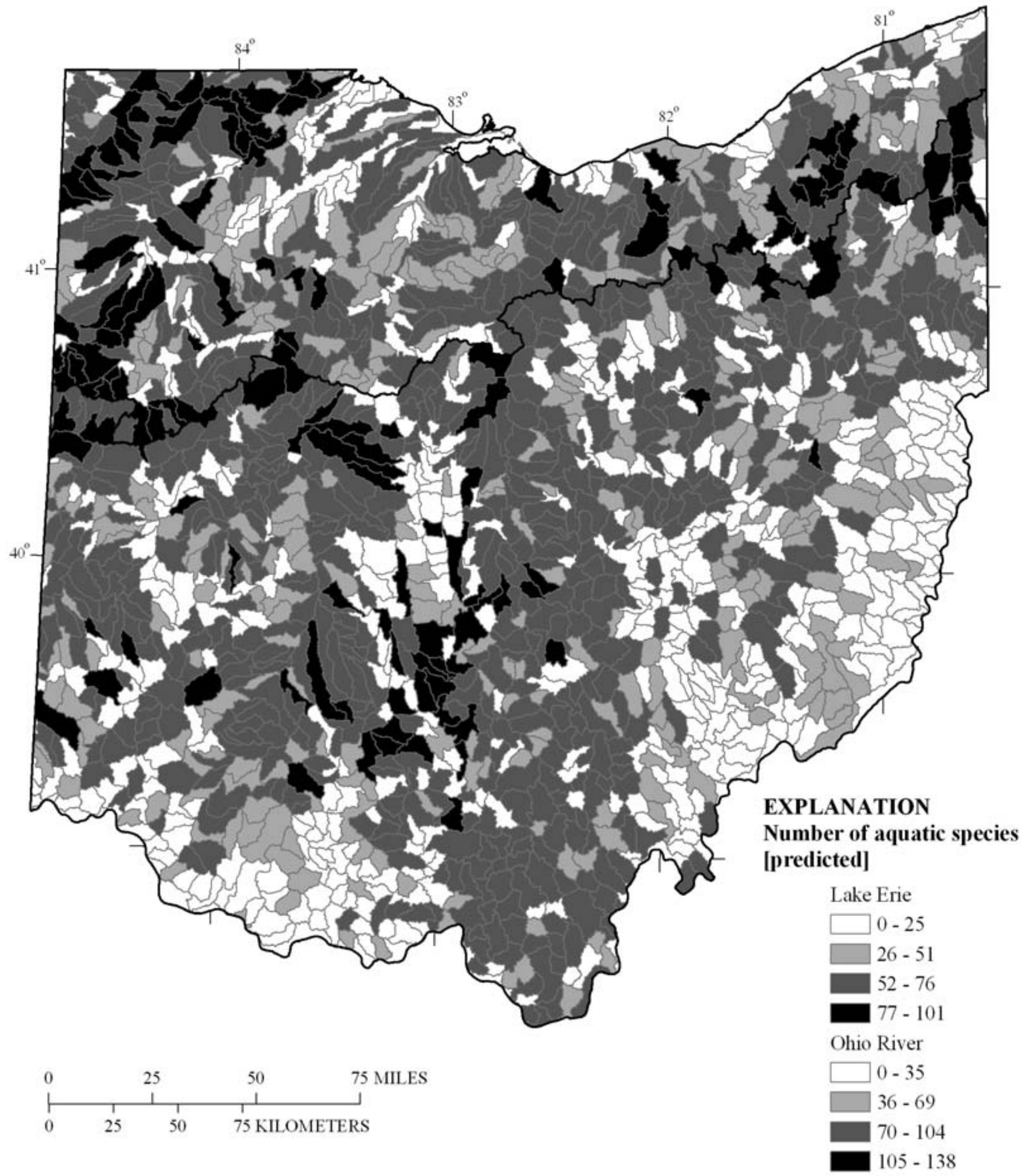

Figure 6–4. Predicted number of fish, crayfish, and bivalve species, by 14-digit hydrologic unit, for the second- and third-order (medium) streams. A solid black line separates the Lake Erie Basin in the north from the Ohio River Basin in the south.

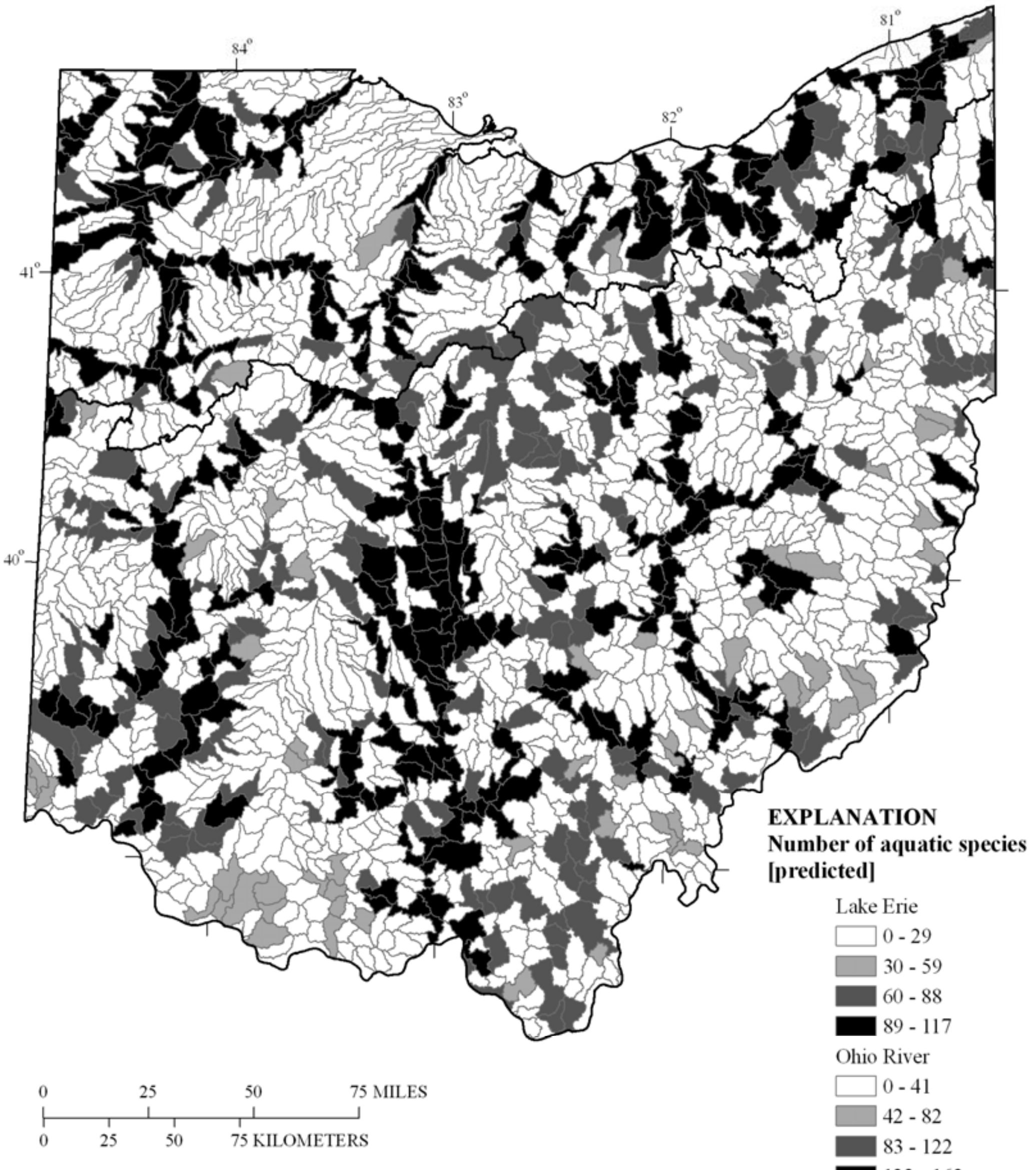

Figure 6–5. Predicted number of fish, crayfish, and bivalve species, by 14-digit hydrologic unit, for streams of fourth and higher order (large). A solid black line separates the Lake Erie Basin in the north from the Ohio River Basin in the south.

Setting Species Richness Criteria

To help identify 14-HUs as potential conservation-priority areas, OH-GAP used percentages of summed potential species-richness values. For example, the numbers of native fish species predicted in streams of OH-GAP size class 2 were summed for each 14-HU. The 14-HU with the largest number of fish species from streams of OH-GAP size class 2 was identified for each major drainage basin, the Lake Erie Basin and Ohio River Basin. This species number was then used to set upper percentile criteria. For example, the 14-HU in the Ohio River Basin with the highest number of species predicted in streams of OH-GAP size class 2 had a value of 86. Multiplied by the desired percentage and rounded up to the nearest whole number, this value represents the lowest value of which each 14-HU must surpass in order to be identified as an important 14-HU for fish in size class 2 streams in the Ohio River Basin. OH-GAP used three percentages to set criteria: 75th, 90th, and 95th percentiles. In the example, 14-HUs in the Ohio River Basin would be highlighted for each percentile criterion if the summed fish species from OH-GAP size class 2 streams was greater than 65, 78, and 82.

The 14-HUs meeting the 95th-percentile criterion for a taxon were kept regardless of attainment of other criteria. These 14-HUs represent the highest in potential species richness for each taxon in each major drainage basin. 14-HUs meeting the 90th-percentile criterion were kept if two or more taxa, such as fish and bivalves, overlapped for this criterion. Lastly, 14-HUs meeting the 75th-percentile criterion were kept only if all three taxa agreed at the 75th-percentile level (or higher). The three criteria were used together to identify areas with different aquatic assemblages or groups of animals. OH-GAP did not give one individual criterion more weight than another. OH-GAP did give more weight to 14-HUs meeting an increasing number of criteria. For example, a 14-HU that met the 75th percentile for crayfish, the 90th percentile for bivalves, and the 95th percentile for fish would be given more weight when considering conservation priorities than a 14-HU that only met the 95th percentile for fish.

Figure 6–6 shows species richness values for fish, crayfish, and bivalves at the 14-HU scale relative to major drainage basin and stream size. This map shows the OH-GAP high-priority areas based on predicted potential species richness.

EXPLANATION
Aquatic species richness
[predicted]

Lake Erie drainage basin

Small streams (1st order)

- fish (95%)
- fish (95%) bivalves (95%)

Small AND medium streams (1st, 2nd, 3rd order)

- fish (95%)
- crayfish (95%)

Medium streams (2nd and 3rd order)

- fish (95%)
- crayfish (95%)
- fish (90%) bivalves (95%)

Large streams (4th order and larger)

- fish (95%)
- crayfish/bivalves (75%) fish (95%)
- crayfish (95%)
- fish (90%) crayfish (95%)
- fish (95%) crayfish (95%)
- fish/crayfish/bivalves (75%)
- fish/bivalves (90%)
- bivalves (90%) fish (95%)
- fish (90%) bivalves (95%)
- fish (95%) bivalves (95%)
- crayfish (75%) fish (95%) bivalves (95%)

Ohio River drainage basin

Small streams (1st order)

- fish (95%)
- crayfish (95%)
- bivalves (95%)

Medium streams (2nd and 3rd order)

- bivalves (75%) crayfish (90%) fish (95%)
- fish/crayfish/bivalves (75%)
- fish (95%)
- bivalves (75%) fish (90%) crayfish (95%)
- bivalves (75%) fish/crayfish (90%)
- crayfish (95%)
- fish (95%) and bivalves (95%)

Large streams (4th order and larger)

- fish/crayfish/bivalves (75%)
- fish (95%)
- crayfish/bivalves (75%) fish (95%)
- bivalves (75%) fish/crayfish (90%)
- crayfish (95%)
- fish/bivalves (90%)
- bivalves (90%) fish (95%)
- crayfish (75%) fish/bivalves (90%)
- crayfish (75%) bivalves (90%) fish (95%)
- crayfish (75%) fish (95%) and bivalves (95%)

Cold water streams

- cold water
- cold water and crayfish (95%)

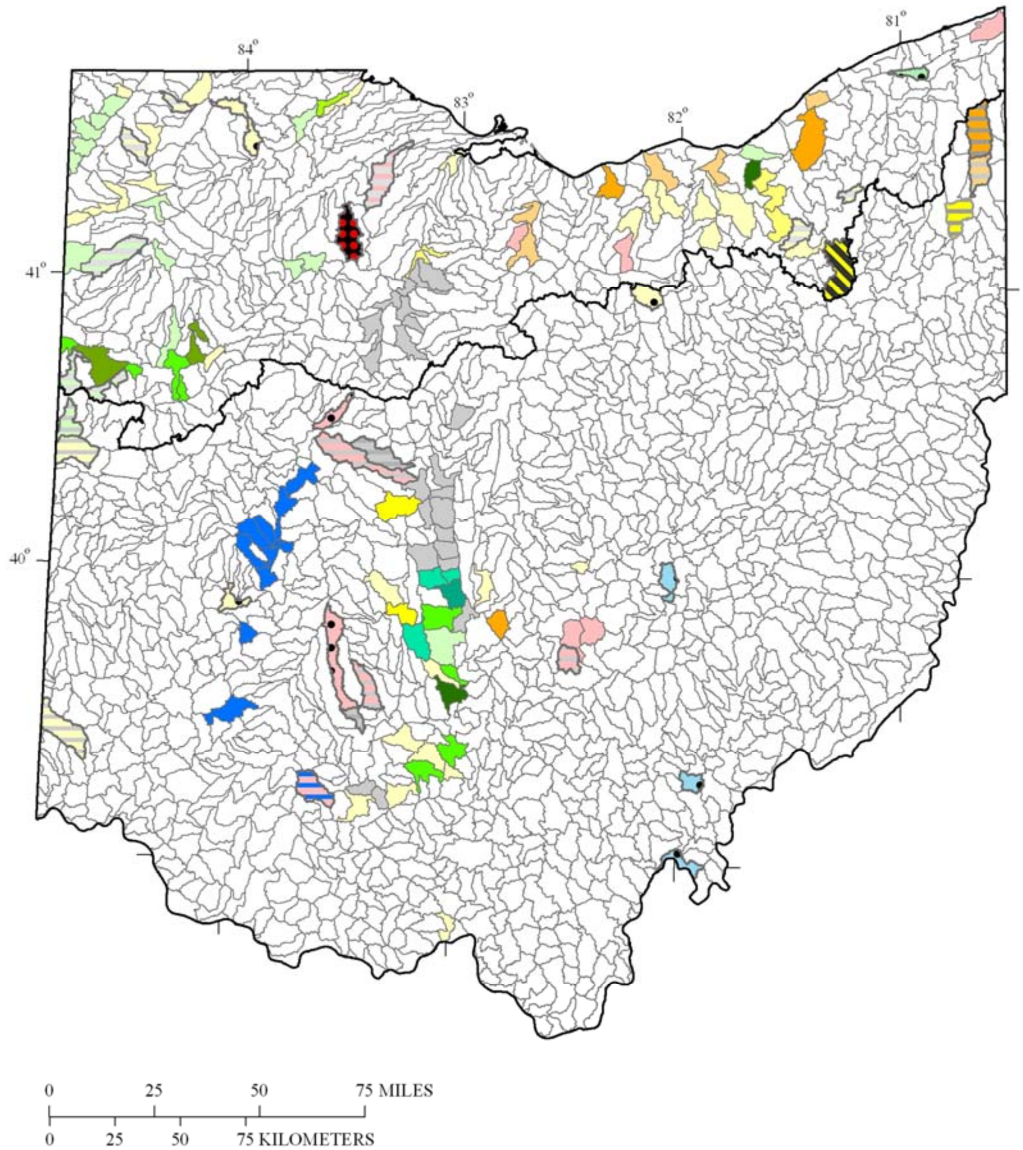

Figure 6–6. Species richness of fish, crayfish, and bivalve species, by 14-digit hydrologic unit (14-HU), relative to major drainage basin and stream size. Number in parenthesis (75%, 90%, 95%) indicates the highest percentile criteria achieved. These 14-HUs represent areas of potentially high conservation priority. A solid black line separates the Lake Erie Basin in the north from the Ohio River Basin in the south.

Rare, Threatened, or Endangered (RTE)

Despite the National GAP emphasis on keeping common species common, OH-GAP wanted to identify areas with high predicted species richness-values that also contained predicted rare, threatened, or endangered species to further help in prioritizing potential conservation areas. OH-GAP used state lists to identify species classified as rare, threatened, or endangered. State lists included species listed federally but also contained species of regional concern. Of the 24 fish species listed by the Ohio Department of Natural Resources as being rare, threatened, or endangered, 12 species were used in the OH-GAP analysis. Some listed species were not used by OH-GAP for the following reasons: some species were predominantly lake rather than riverine fish; some species were not represented in the data because of their rarity and were, therefore, not modeled; and some species' predicted distributions contained less than 1,000 m, which OH-GAP disregarded. Rare, threatened, or endangered aquatic species were mapped per taxon (figs. 6–7 through 6–9). The maximum number of these RTE fish species predicted in one 14-HU was two, so all 14-HUs containing a rare, endangered, or threatened fish species were highlighted. Of the 17 crayfish species modeled by OH-GAP, only 1, Sloan's crayfish, is listed as rare, endangered, or threatened. Again, all 14-HUs containing Sloan's crayfish were highlighted. In the Lake Erie Basin, the maximum number of predicted rare, threatened, or endangered bivalves was seven species, in the Ohio River Basin the maximum number was 16.

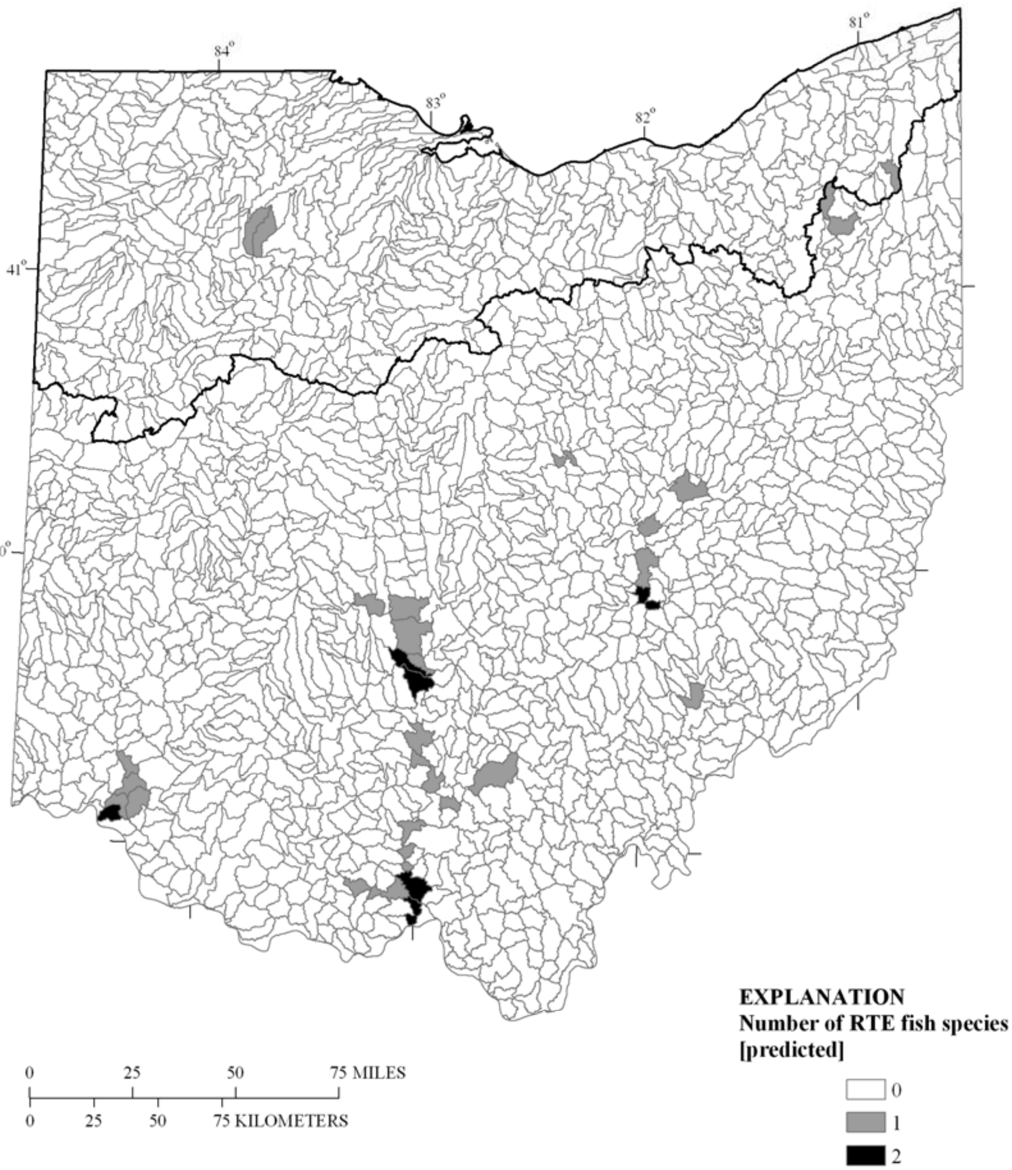

Figure 6–7. Predicted number of rare, threatened, or endangered (RTE) fish species, by 14-digit hydrologic unit. A solid black line separates the Lake Erie Basin in the north from the Ohio River Basin in the south.

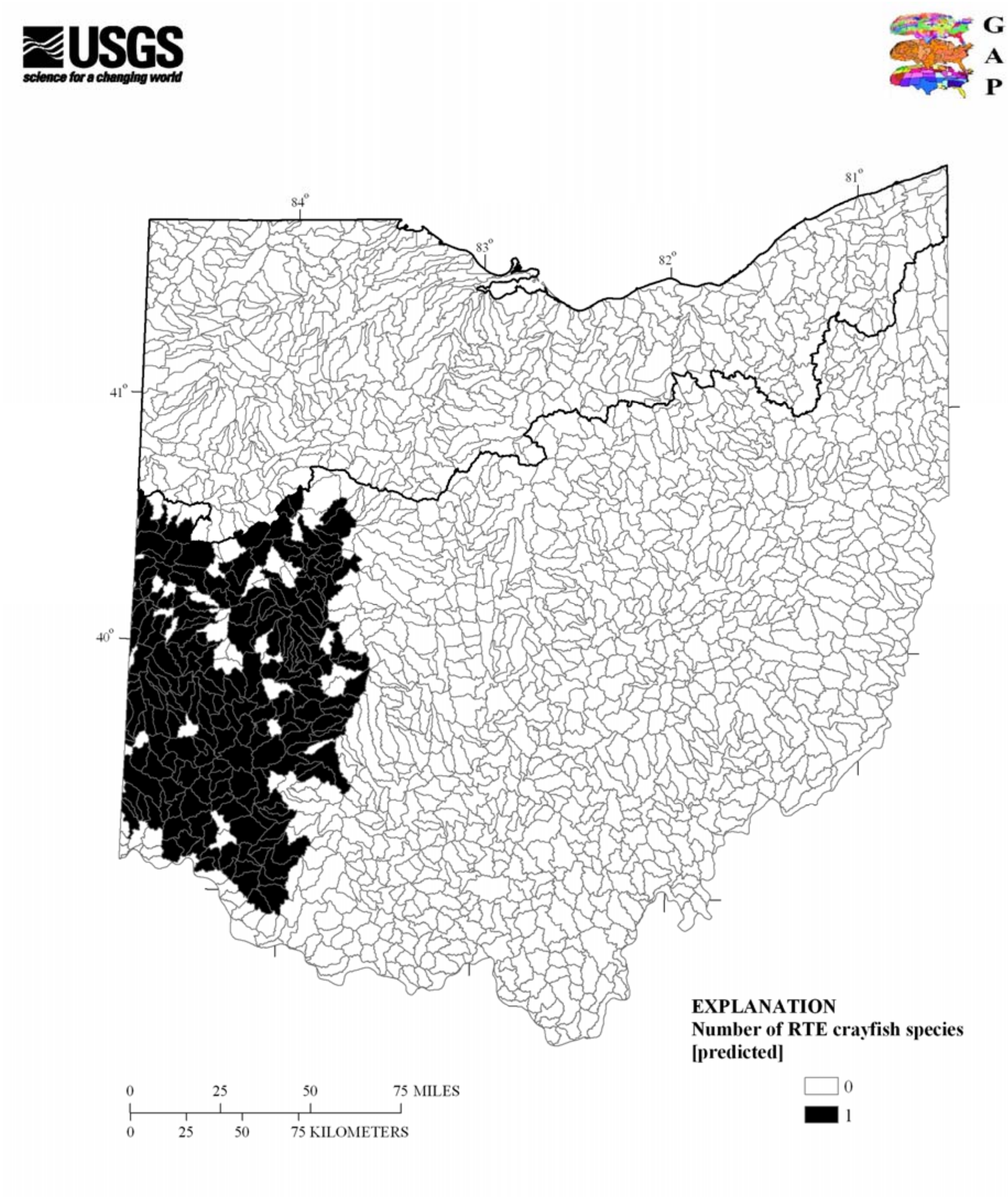

Figure 6–8. Predicted number of rare, threatened, or endangered (RTE) crayfish species, by 14-digit hydrologic unit. A solid black line separates the Lake Erie Basin in the north from the Ohio River Basin in the south.

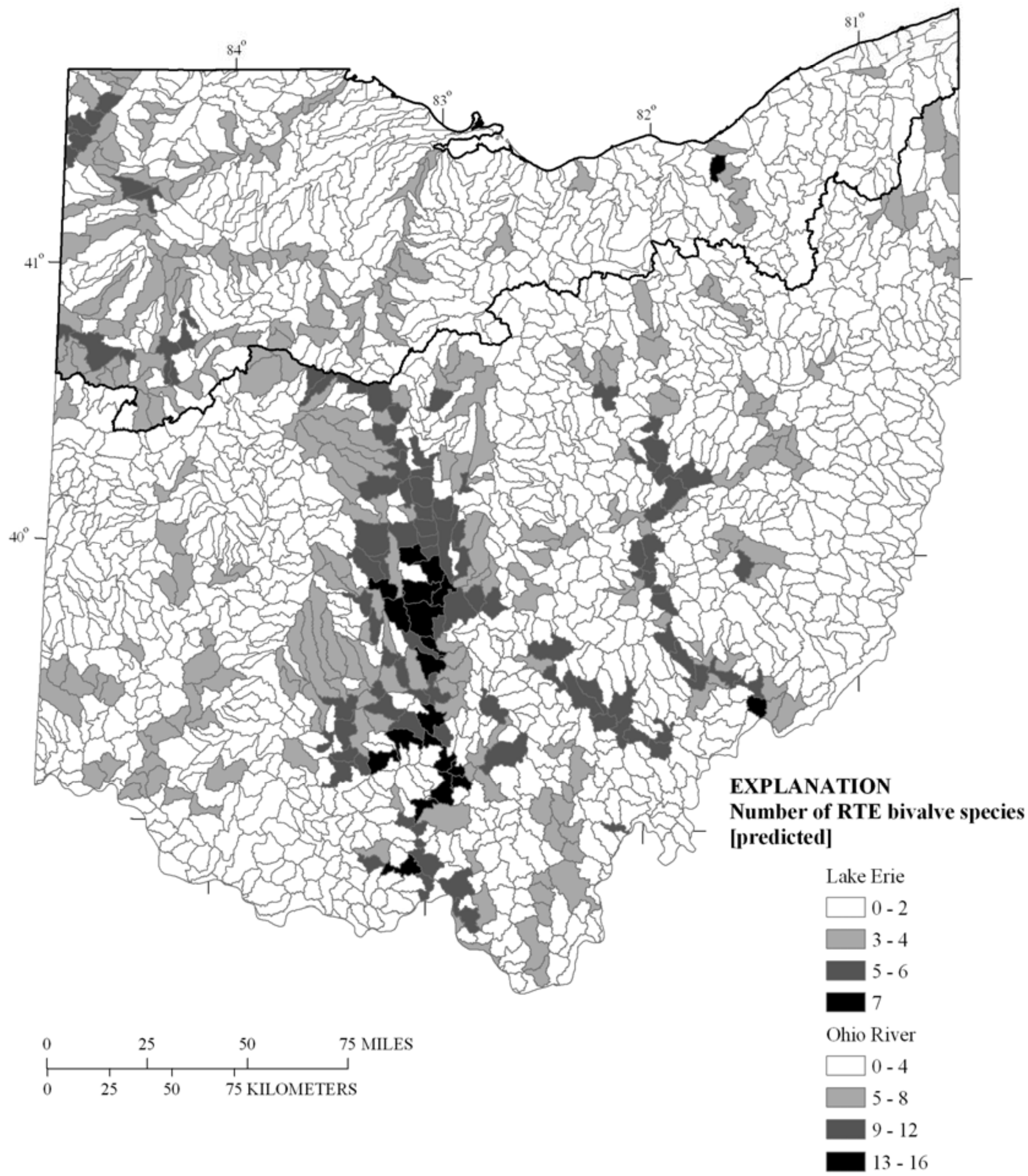

Figure 6–9. Predicted number of rare, threatened, or endangered (RTE) bivalve species, by 14-digit hydrologic unit relative to major drainage basin. A solid black line separates the Lake Erie Basin in the north from the Ohio River Basin in the south.

Coldwater Assemblages

OH-GAP included areas containing coldwater species assemblages, which are also identified as having high species richness values. Coldwater species assemblages are present in a few areas in Ohio and do not usually contain high numbers of species. Coldwater assemblages do, however, represent one of Ohio's conservation goals as evidenced by the Ohio EPA's separate aquatic life use designation, Coldwater Habitat, specifically developed for coldwater species (Ohio Environmental Protection Agency, 1987).

The Ohio EPA identifies six fish species that along with select macroinvertebrate and plant species are indicative of cool and coldwater habitats in Ohio (Ohio Environmental Protection Agency, 1987). Two of the Ohio EPA listed fish species were not included by OH-GAP because they are not native to Ohio: brown trout and rainbow trout. The overlap of the other four fish species' distributions, both known and predicted, was more extensive than the known coldwater streams in Ohio. This may suggest that each of the four species use habitats with differing ranges of water temperature. OH-GAP decided to represent coldwater assemblages by identifying 14-HU where the water temperature data revealed a coldwater habitat type.

Results and Discussion

The primary factor for identifying high conservation-priority areas was species richness. Species richness was classified relative to stream size using three increasing percentile criteria for each of fish, crayfish, and bivalve taxon. Areas that attained more than one criterion are considered to have a greater conservation value. Each stream class is treated independently, but 14-HUs that are identified for more than one stream class are considered to have a higher conservation value, all else being equal. Additionally, although a 14-HU identified for fish and bivalves may be considered to have higher conservation priority than a 14-HU with fish only, OH-GAP cannot state that fish are better than bivalves, or that the combination of fish and crayfish is considered to have a higher conservation priority than fish and bivalves, for example. This type of taxa comparison would depend on the purpose of the comparison and is beyond the scope of OH-GAP. Other factors such as the presence of rare, threatened, or endangered species, existing conservation lands, coldwater habitat streams, and prior sampling efforts further helped decide high conservation-priority areas. The 14-HUs in the Lake Erie and Ohio River Basins identified as having high conservation-priority areas on the basis of species richness are listed in tables 6–1 and 6–2. The 14-HUs identified as having high conservation-priority areas on the basis of species richness by ecoregion are listed in tables 6–3 through 6–8.

Table 6–1. The 75 14-digit hydrologic units (14-HU) in the Lake Erie Basin identified by the Ohio Aquatic GAP Project as having a high priority based on fish, crayfish, and bivalve species-richness values relative to stream size
[1st, 2nd, or 3rd refer to OH-GAP stream size class]

14-HU	14-HU Site name	Rare, threatened, or endangered	Highest criterion attainment
04100003-030-010	St. Joseph River below West Branch to above Nettle Creek	None	3rd fish (95%)
04100003-030-030	St. Joseph River below Nettle Creek to above Eagle Creek	Bivalves	3rd fish/bivalves (90%)
04100003-030-050	St. Joseph River below Eagle Creek to above Bear Creek	Bivalves	3rd fish/bivalves (90%)
04100003-060-010	St. Joseph River below Bear Creek to above Fish Creek	Bivalves	3rd fish/bivalves (90%)
04100003-060-020	St. Joseph River below Fish Creek to above Big Run	Bivalves	3rd fish/bivalves (90%)
04100003-060-050	St. Joseph River below Big Run to above Buck Creek (Indiana)	Bivalves	3rd fish/bivalves (90%)
04100004-020-030	St. Marys River below Hussey Creek to above Twelvemile Creek [except Eightmile Creek]	None	3rd fish (90%) bivalves (95%)
04100004-020-050	Twelvemile Creek [except Blierdofer Ditch]	None	2nd fish (90%) bivalves (95%)
04100004-030-010	St. Marys River below Twelvemile Creek to above Black Creek	None	3rd fish/bivalves (95%)
04100004-030-020	Black Creek [except Little Black Creek]	None	2nd fish (90%) bivalves (95%)
04100004-030-040	St. Marys River below Black Creek to above Twentyseven Mile Creek [except Duck Creek]	None	3rd fish (90%) bivalves (95%)
04100005-020-010	Maumee River below Hamm Ditch (Indiana) to above Zuber Cutoff	None	3rd fish (95%)
04100005-020-030	Maumee River below Zuber Cutoff to above Gordon Creek [except Marie Delarme Creek]	None	3rd fish (95%)
04100005-020-060	Maumee River below Gordon Creek to below Sulphur Creek [except Platter Creek]	None	3rd fish (95%)
04100006-020-040	Old Bean Creek	None	3rd fish (95%)
04100006-030-010	Tiffin River below Mill Creek to above Bates Creek	None	2nd fish (95%)
04100006-040-010	Tiffin River below Leatherwood Creek to above Brush Creek [except Beaver Creek]	None	3rd fish (95%)
04100006-050-030	Prairie Creek	None	2nd fish (95%)
04100006-060-050	Tiffin River below Lick Creek to Maumee River [except Mud Creek and Webb Run]	None	3rd fish (95%)
04100007-020-010	Auglaize River below Pusheta Creek to above Two Mile Creek	None	3rd fish (90%) bivalves (95%)
04100007-020-030	Auglaize River below Two Mile Creek to near Spencerville	None	3rd fish (90%) bivalves (95%)
04100007-020-040	Auglaize River from near Spencerville to above Jennings Creek	None	3rd fish/bivalves (90%)
04100007-030-080	Ottawa River below Lost Creek to above Little Ottawa River	None	3rd fish (95%)
04100007-040-020	Ottawa River below Little Ottawa River to above Dug Run	None	3rd fish/bivalves (95%)
04100007-040-050	Ottawa River below Dug Run to above Pike Run [except Honey Run]	None	3rd fish/bivalves (95%)
04100007-060-080	Auglaize River below Blanchard River to above Little Auglaize River [except Prairie Creek]	None	3rd fish/bivalves (90%)
04100007-100-040	Blue Creek below Upper Prairie Creek to Auglaize River	None	2nd fish (90%) bivalves (95%)
04100007-120-050	Flatrock Creek below Hoffman Creek (Indiana) to below Payne, Ohio	None	3rd fish/bivalves (90%)
04100007-120-050	Flatrock Creek below Hoffman Creek (Indiana) to below Payne, Ohio	None	3rd fish/bivalves (90%)
04100007-120-100	Auglaize River below Auglaize Reservoir to Maumee River [except Powell Creek]	None	3rd fish/bivalves (90%)

Table 6–1, continued.

14-HU	14-HU Site name	Rare, threatened, or endangered	Highest criterion attainment
04100008-030-030	Blanchard River below Eagle Creek to above Aurand Run	None	3rd fish/bivalves (90%)
04100008-030-050	Blanchard River below Aurand Run to above Ottawa Creek	None	3rd fish/bivalves (90%)
04100009-040-020	Bad Creek below South Branch Bad Creek to Maumee River	None	1st fish (95%)
04100009-080-030	Swan Creek below Blue Creek to above Wolf Creek	None	3rd fish/bivalves (90%)
04100009-080-050	Swan Creek below Wolf Creek to Maumee River	None	3rd bivalves (90%) fish (95%)
04100009-090-040	Maumee River below Grassy Creek to Lake Erie [except Swan Creek]	None	3rd fish (95%)
04100010-040-030	South Branch Portage River headwaters to above East Branch Portage River	None	1st AND 2nd crayfish (95%)
04100010-060-020	Sugar Creek	None	2nd crayfish (95%)
04100011-040-010	Sandusky River below Broken Sword Creek to above Rock Run [except Little Sandusky River]	None	3rd fish/crayfish/bivalves (75%)
04100011-040-040	Sandusky River below Rock Run to above Negro Run	None	3rd fish/crayfish/bivalves (75%)
04100011-040-060	Sandusky River below Negro Run to above Tymochtee Creek	None	3rd fish/crayfish/bivalves (75%)
04100011-050-090	Tymochtee Creek below Little Tymochtee Creek (1) to above Warpole Creek	None	3rd fish/crayfish/bivalves (75%)
04100011-060-010	Tymochtee Creek below Warpole Creek to above Lick Run [except Oak Run]	None	3rd fish/crayfish/bivalves (75%)
04100011-060-040	Tymochtee Creek below Lick Run to Sandusky River [except Little Tymochtee Creek (2) and Spring Run]	None	3rd fish/crayfish/bivalves (75%)
04100011-070-010	Sandusky River below Tymochtee Creek to above Sycamore Creek [except Thorn Run and Taylor Run]	None	3rd fish/crayfish/bivalves (75%)
04100011-070-050	Sandusky River below Sycamore Creek to above Honey Creek	None	3rd fish/crayfish/bivalves (75%)
04100011-080-060	Honey Creek below Silver Creek to Sandusky River	None	3rd fish/crayfish/bivalves (75%)
04100011-090-010	Sandusky River below Honey Creek to above Morrison Creek [except Rock Creek]	None	3rd crayfish/bivalves (75%) fish (95%)
04100011-120-040	Sandusky River below Muskellunge Creek to Sandusky Bay [except Bark Creek]	None	3rd fish (95%)
04100012-010-050	West Branch Huron River from near Willard to above Slate Run [except Holliday Lake drainage]	None	3rd fish (90%) crayfish (95%)
04100012-020-030	Slate Run below Mud Run to West Branch Huron River	None	3rd crayfish (95%)
04100012-020-050	West Branch Huron River below Slate Run to Huron River [except Frink Run, Seymour Creek, & Unnamed Creek "C"]	None	3rd fish (90%) crayfish (95%)
04100012-060-040	Vermilion River below East Fork. Vermilion River to Lake Erie	None	3rd fish/crayfish (95%)
04110001-020-030	Charlemont Creek	None	3rd crayfish (95%)
04110001-020-040	West Branch Black River below Charlemont Creek to above Wellington Creek	None	3rd fish (95%)
04110001-020-080	West Branch Black River below Plum Creek to above East Branch	None	3rd fish (95%)
04110001-040-020	East Branch Black River from Grafton to above West Branch [except Willow Creek]	None	3rd fish (95%)
04110001-050-010	Black River below confluence of East Branch and West Branch to Lake Erie [except French Creek]	None	3rd fish (90%) crayfish (95%)
04110001-060-050	West Branch Rocky River below North Branch to above Mallet Creek	None	3rd fish (95%)
04110001-060-080	West Branch Rocky River from Valley City to Westview	None	3rd fish (95%)
04110001-070-020	East Branch Rocky River [except Baldwin Creek]	None	3rd fish (95%)
04110001-070-040	Rocky River below East Branch Rocky River to Lake Erie	None	3rd fish (90%) crayfish (95%)
04110002-010-070	Black Brook	None	2nd fish (95%)
04110002-020-020	Breakneck Creek	None	1st AND 2nd fish (95%)
04110002-030-010	Cuyahoga River below Breakneck Creek to above Little Cuyahoga River [except Plum Creek and Fish Creek]	None	3rd fish (95%)

Table 6–1, continued.

14-HU	14-HU Site name	Rare, threatened, or endangered	Highest criterion attainment
04110002-040-020	Mud Brook	None	2nd fish (95%)
04110002-040-040	Cuyahoga River below Yellow Creek to above Brandywine Creek [except Furnace Run]	None	3rd crayfish/bivalves (75%) fish (95%)
04110002-050-010	Cuyahoga River below Brandywine Creek to above Tinkers Creek [except Chippewa Creek]	None	3rd crayfish/bivalves (75%) fish (95%)
04110002-060-010	Cuyahoga River below Tinkers Creek to above Mill Creek	None	3rd crayfish/bivalves (75%) fish (95%)
04110002-060-030	Cuyahoga River below Mill Creek to above Big Creek	Bivalves	3rd crayfish (75%) fish/bivalves (95%)
04110002-060-050	Cuyahoga River below Big Creek to Lake Erie	None	3rd fish/bivalves (90%)
04110003-030-010	Chagrin River below Aurora Branch to above East Branch	None	3rd fish/crayfish (95%)
04110003-030-030	Chagrin River below East Branch to Lake Erie	None	3rd fish (90%) crayfish (95%)
04110004-060-020	Grand River below Coffee Creek to above Mill Creek (3)	None	1st fish/bivalves (95%)
04120101-010-300	Conneaut Creek from Pennsylvania border to Lake Erie	None	3rd crayfish (95%)

Table 6–2. The 67 14-digit hydrologic units (14-HU) in the Ohio River Basin identified by the Ohio Aquatic GAP Project as having a high priority based on fish, crayfish, and bivalve species-richness values relative to stream size.
[1st, 2nd, or 3rd refer to OH-GAP stream size class]

14-HU	14-HU Site name	Rare, threatened, or endangered	Highest criterion attainment
05030102-030-285	Pymatuning Creek above Clear Creek	None	2nd bivalves (75%) fish (90%) crayfish (95%)
05030102-030-290	Pymatuning Creek above Clear Creek to below Sugar Creek	None	2nd bivalves (75%) fish/crayfish (90%)
05030103-060-040	Mosquito Creek below Mosquito Creek Lake Dam to Mahoning River	None	2nd bivalves (75%) crayfish (90%) fish (95%)
05030202-170-040	Ohio River Tribs. below Yellow Brush Creek to above Leading Creek	None	1st bivalve (95%)
05030204-030-010	Little Rush Creek headwaters to near Rushville	None	3rd crayfish (95%)
05030204-030-020	Little Rush Creek near Rushville to Rush Creek	None	3rd crayfish (95%)
05030204-030-030	Raccoon Run	None	2nd crayfish (95%)
05030204-100-030	Hocking River below Willow Creek to above Federal Creek	None	1st bivalve (95%)
05040002-060-010	Muddy Fork headwaters above Interstate 71	None	1st fish (95%)
05040006-040-100	South Fork Licking River below Ramp Creek to above North Fork Licking River [except Dutch Fork]	None	3rd fish (95%)
05040006-060-040	Licking River below Dillon Reservoir Dam to Muskingum River [except Timber Run]	None	1st bivalve (95%)
05060001-030-030	Panther Creek	None	1st crayfish (95%)
05060001-050-070	Fulton Creek	None	2nd fish/crayfish/bivalves (75%)
05060001-060-010	Bokes Creek	None	2nd crayfish (95%)
05060001-060-020	Scioto River below Bokes Creek to above Mill Creek	None	3rd fish/crayfish/bivalves (75%)
05060001-070-030	Mill Creek below New Dover to Scioto River [except Blues Creek]	Bivalve	3rd crayfish/bivalves (75%) fish (95%)
05060001-080-010	Scioto River below Mill Creek to O'Shaughnessy Dam [except Eversole Run]	Bivalve	3rd fish/crayfish/bivalves (75%)
05060001-080-050	Scioto River below Indian Run to Griggs Dam	Bivalve	3rd fish/crayfish/bivalves (75%)
05060001-080-060	Scioto River from Griggs Dam to above Olentangy River	Bivalve	3rd crayfish (75%) fish/bivalves (90%)
05060001-110-020	Olentangy River below gaging station at Claridon to above Grave Creek	None	3rd fish/crayfish/bivalves (75%)
05060001-110-090	Olentangy River from Delaware Dam to below Horseshoe Run [except Houseshoe Run and Delaware Run]	None	3rd fish/crayfish/bivalves (75%)
05060001-120-010	Olentangy River below Horseshoe Run to below Delaware Run	None	3rd fish/crayfish/bivalves (75%)
05060001-120-020	Olentangy River near Powell	None	3rd fish/crayfish/bivalves (75%)
05060001-120-030	Olentangy River near Worthington	None	3rd fish/crayfish/bivalves (75%)
05060001-120-040	Olentangy River from near Worthington to gaging station at Henderson Road	None	3rd fish/crayfish/bivalves (75%)
05060001-120-050	Olentangy River from gaging station at Henderson Road to Dodridge Street	None	3rd fish/crayfish/bivalves (75%)

Table 6–2, continued.

14-HU	14-HU Site name	Rare, threatened, or endangered	Highest criterion attainment
05060001-120-060	Olentangy River from Dodridge Street to Scioto River	Bivalve	3rd crayfish (75%) fish/bivalves (90%)
05060001-140-030	Big Walnut Creek below Rocky Fork Creek to above Blacklick Creek [except Mason Run]	Bivalve	3rd fish (95%)
05060001-160-030	Big Walnut Creek below Alum Creek to Scioto River	Bivalve	3rd fish/crayfish/bivalves (75%)
05060001-180-010	Walnut Creek below Sycamore Creek to above Georges Creek	Bivalve	3rd bivalves (75%) fish/crayfish (90%)
05060001-210-070	Little Darby Creek below Spring Fork to Big Darby Creek	None	3rd fish (95%)
05060001-220-020	Big Darby Creek below Little Darby Creek to above Hellbranch Run	Fish/Bivalves	3rd crayfish/bivalves (75%) fish (95%)
05060001-220-030	Big Darby Creek below Hellbranch Run to Darbyville	Bivalve	3rd crayfish (75%) fish/bivalves (90%)
05060001-220-040	Big Darby Creek from Darbyville to Scioto River	Fish/Bivalves	3rd fish (95%)
05060001-230-010	Scioto River below Olentangy River to above Big Run	Bivalve	3rd crayfish (75%) fish (90%) bivalves (95%)
05060001-230-030	Scioto River below Scioto Big Run to above Big Walnut Creek	Fish/Bivalves	3rd bivalves (90%) fish (95%)
05060001-230-040	Scioto River below Big Walnut Creek to above Walnut Creek	Fish/Bivalves	3rd fish/bivalves (90%)
05060001-230-050	Scioto River below Walnut Creek to above Big Darby Creek [except Dry Run]	Fish/Bivalves	3rd bivalves (90%) fish (95%)
05060002-010-010	Scioto River below Big Darby Creek to above Yellowbud Creek[except Hargus Creek]	Fish/Bivalves	3rd crayfish (75%) fish/bivalves (95%)
05060002-050-020	Scioto River below Kinnikinnick Creek to Chillicothe [except Dry Run]	Fish/Bivalves	3rd bivalves (90%) fish (95%)
05060002-160-070	Scioto River below Scioto Brush Creek to Ohio River [except Pond Creek]	Fish	3rd fish (95%)
05060003-010-010	Paint Creek above East Fork Paint Creek	None	1st crayfish (95%)
05060003-050-010	Paint Creek below East Fork Paint Creek to above Sugar Creek	None	2nd fish/crayfish/bivalves (75%)
05060003-050-040	Paint Creek below Rattlesnake Creek to above Rocky Fork	Bivalve	3rd fish/crayfish/bivalves (75%)
05060003-060-040	Clear Creek	None	2nd crayfish (95%) AND COLD
05060003-060-060	Rocky Fork below Rocky Fork Lake to Paint Creek	Bivalve	3rd fish (95%)
05060003-070-010	Paint Creek below Rocky Fork to above Buckskin Creek	Bivalve	3rd fish/crayfish/bivalves (75%)
05060003-070-030	Paint Creek below Buckskin Creek to above Lower Twin Creek [except Buckskin Creek & Upper Twin Creek]	Bivalve	3rd fish (95%)
05060003-080-040	Compton Creek above Crooked Creek	None	2nd crayfish (95%)
05060003-090-030	North Fork Paint Creek below Herrod Creek to above Little Creek	None	3rd fish (95%)
05060003-090-050	North Fork Paint Creek below Little Creek to Paint Creek	None	3rd fish (95%)
05060003-100-010	Paint Creek below Lower Twin Creek to above North Fork Paint Creek [except Black Run & Ralston Run]	Bivalve	3rd bivalves (90%) fish (95%)
05060003-100-040	Paint Creek below North Fork Paint Creek to Scioto River	Fish/Bivalves	3rd fish (95%)
05080001-150-020	Mad River below State Route 33 to above Machochee Creek	Crayfish	COLD
05080001-150-040	Mad River below Machochee Creek to above Kings Creek [except Glady Creek]	Crayfish	COLD
05080001-160-010	Mad River below Kings Creek to above Nettle Creek [except Muddy Creek and Dugan Run]	Crayfish	COLD
05080001-160-040	Nettle Creek [except Anderson Creek]	Crayfish	COLD

Table 6–2, continued.

14-HU	14-HU Site name	Rare, threatened, or endangered	Highest criterion attainment
05080001-160-050	Anderson Creek	Crayfish	COLD
05080001-160-060	Mad River below Nettle Creek to above Chapman Creek [except Storms Creek]	Crayfish	COLD
05080001-160-080	Chapman Creek	Crayfish	COLD
05080001-180-010	Mad River below Chapman Creek to above Buck Creek [except Moore Run]	Crayfish	COLD
05080001-180-080	Mad River below Donnels Creek to above Mud Creek [except Jackson Creek]	Crayfish	1st fish (95%)
05080002-080-030	Indian Creek below Brandywine Creek (Indiana) to Great Miami River	Crayfish	2nd fish (95%)
05090202-010-050	Little Miami River below Yellow Springs Creek to above Massies Creek	Crayfish	COLD
05090202-050-050	Caesar Creek below Anderson Fork to Little Miami River [except Flat Fork]	Crayfish	COLD
05120101-010-020	Wabash River below Bear Creek to below Stony Creek (Simison Creek in Indiana)	Crayfish	2nd fish (95%)
05120101-010-030	Wabash River below Stony Creek to above Beaver Creek	Crayfish	2nd fish/bivalves (95%)

Lake Erie Drainage Basin

Fifteen percent (75 of 504) of the 14-HUs in the Lake Erie Basin were identified by OH-GAP as priorities for conservation (table 6-1). Thirty-seven of them (including four of the 14-HUs that include the Cuyahoga Valley National Park) already have conservation lands within them. The other half do not. Currently, the two most protected high-priority 14-HUs are 04110002-040-040, including the Cuyahoga River below Yellow Creek to above Brandywine Creek (excluding Furnace Run) and 04110002-050-010, including the Cuyahoga River below Brandywine Creek to above Tinkers Creek (except Chippewa Creek). These adjacent 14-HUs, identified for the 95th percentile of predicted fish and 75th percentile for crayfish and bivalves in large streams, are almost completely covered by the Cuyahoga Valley National Park. Of the 14-HUs identified as high conservation-priority areas, 49 percent already have conservation lands (37/75), as compared to 43 percent (185/429) of the remaining 14-HUs. It is beyond the scope of this report to assess whether the high-quality habitats were deliberately protected or whether the conservation of habitat has allowed species to thrive. Because only enduring physical characteristics were used in the models, it is likely that these habitats were deliberately protected, and this gap analysis provides further evidence of the habitat quality.

Small Streams

There are four 14-HUs identified as important for the small stream class size. None of the 14-HUs in the Lake Erie basin were identified as containing RTE species of fish, crayfish, or bivalves in small streams. There were no 14-HUs identified for all three taxa and one 14-HU identified for two taxa. That 14-HU is in the Grand River watershed (04110004-060-020) and meets the 95th-percentile criterion for fish and the 95th-percentile criterion for bivalves.

There were three 14-HUs identified for small and medium-sized streams for fish or crayfish. This suggests that, although there may not be as much richness when considering all three taxa, there is species richness for particular taxa in different places within the 14-HU. The 14-HU (04100010-040-030) was identified for meeting the 95th percentile for crayfish in both small and medium streams. This 14-HU is in the South Branch of the Portage River watershed. The 14-HUs to the west and east of this 14-HU are composed of mostly ditches, but this 14-HU has predominantly natural streams flowing through it. The last two14-HUs are identified as meeting the 95th percentile for fish in both small and medium streams. One (04110002-020-020) is in Cuyahoga River watershed, and one in the Maumee River watershed (04100009-040-020).

Of the 14-HUs identified as important for the small stream class size, the 14-HUs in the Cuyahoga River watershed and Grand River watershed have a small amount of conservation land, some of which is along the streams.

Medium streams

In addition to the three 14-HUs that are identified as priorities for conservation for small and medium-sized streams, eight 14-HUs meet the 95th-percentile criteria for medium-sized streams. There were no 14-HUs identified for endangered fish, crayfish, or bivalves in medium sized streams. The 14-HUs identified include four 14-HUs for fish, one for crayfish, and three for both fish and bivalves. The 14-HU identified for crayfish is along Sugar Creek (04100010-060-020) (west of Sandusky River, east of Portage River). There is a tiny (0.19 km^2) ODNR wildlife restoration program land tract in this 14-HU.

For the 95th percentile of fish, two of the 14-HUs are along the Tiffin River, which flows into the Maumee River, and two are along tributaries of the Cuyahoga River. Watershed conservancy land for the City of Akron is contained in one of the Cuyahoga River 14-HUs (04110002-010-070).

Fish and bivalves at the 95th percentile are found in three 14-HUs in the Maumee watershed of western Ohio. Twelvemile Creek (04100004-020-050) and Black Creek (04100004-030-020) flow into St. Marys River, which flows into the Maumee River. Blue Creek (04100007-100-040) flows into the Auglaize River, which also flows into the Maumee River. None of these 14-HUs have conservation land.

Large streams

A total of 63 14-HUs, including 11 different combinations of criteria attainment, have been identified as potential priorities for conservation for large streams. With the exception of the Grand and Sandusky Rivers, all major rivers in the Lake Erie Basin have at least one 14-HU identified as a priority for conservation. Six of the 63 14-HUs also have six or seven RTE bivalve species predicted within the 14-HU.

Of the 63 14-HUs identified for large streams, fish are present in all but one of the criteria, corresponding to 60 of the 63 14-HUs. The fish are at the 95th percentile for 28 14-HUs, distributed throughout the large rivers of the Lake Erie Basin. These 28 14-HUs are considered to be highly species rich for fish (and maybe bivalves and crayfish, at lesser, but still high, levels). These may be good areas to target for conservation of fish. Examining the data another way, there are 14 14-HUs that meet at least the 75th percentile for all three taxa groups and are clustered along the main branches of the Sandusky River, including the Tymochtee Creek and Honey Creek tributaries and the Cuyahoga River. Although these regions still meet the criteria for at least the 75th percentile, they may not be as fish-rich as other parts of the Lake Erie Basin. However, because crayfish and bivalves are also present at these 14-HUs at the 75th percentile level, this region could be targeted for conservation of a variety of taxa and species.

A total of 24 14-HUs met some criteria for crayfish. Only 10 14-HUs include crayfish at the most stringent criterion, the 95th percentile. These 10 14-HUs are along the main stems of the rivers of central and eastern Ohio, including the Huron, Vermilion, Black, and Rocky Rivers and Conneaut Creek. Many of these 14-HUs at or near the mouths of the river, where the river flows into Lake Erie, have conservation lands. Examples include the Mill Hollow-Bacon Woods Park along the Vermilion River, the Black River Reservation along the Black River, the Rocky River Reservation along the Rocky River, and the Chagrin River Land Conservancy and the North Chagrin Property along the Chagrin River, to name a few.

Seven of the criteria attainment combinations include bivalves, for a total of 35 14-HUs. There were no 14-HUs identified for bivalves only, suggesting that the requirements for bivalves are also those for fish or crayfish. The 14-HUs identified occur in continuous swaths along the Sandusky River and main tributaries (10 14-HUs in total) and the Cuyahoga River (five 14-HUs). The 14-HU along the Cuyahoga River below Mill Creek (04110002-060-030) is identified as being at the 95th percentile for bivalves as well as meeting one or more of the criteria for crayfish and fish. This 14-HU was also identified for having the physical habitat for seven species of endangered bivalves and contains the Ohio and Erie Canal Reservation Metropark.

The 20 remaining 14-HUs are in the Maumee River watershed, clustered primarily along parts of the St. Joseph, St. Marys, Auglaize, and Maumee Rivers. Seven of these 14-HUs in the Maumee River watershed (along the Auglaize, St. Marys, and Ottawa Rivers) were identified as being in the 95th percentile for bivalves as well as meeting one or more of the criteria for crayfish and fish. Five of the six contiguous 14-HUs along the St. Joseph River (04100003-030-010, 04100003-030-050, 04100003-060-010, 04100003-060-020, 04100003-030-050) meet the 90th percentile for bivalves (and fish) and are tagged as potentially containing six species of rare, threatened, or endangered bivalves. The small, 0.2 km^2 Fish Creek Wildlife Area is in two of these 14-HUs, by the confluence of Fish Creek and the St. Joseph River. This is the only conservation area along the main stem of the St. Joseph River.

Four additional 14-HUs were identified as having the physical habitat to support endangered species, although they were not identified for their species richness. One of these, identified for potentially containing six species of rare, endangered, or threatened bivalves, is where Fish Creek flows into the St. Joseph River and is contiguous with the other identified 14-HUs along the St. Joseph River. The other three 14-HU are more isolated and were identified for potentially containing RTE.

Ohio River Drainage Basin

There were 57 of 1,291 14-HUs (4.5 percent) in the Ohio River Basin identified by OH-GAP as potential high-priority conservation areas using species richness (table 6–2). These areas were concentrated in the Scioto River watershed (fig. 6–6). No spatial trends emerged, as is evident from the location of other highlighted 14-HUs (either isolated or accompanied by one or two other adjoining basins). Of the 57 14-HUs identified as high potential conservation-priority areas, 56 percent already have conservation lands (32 of 57), as compared to 48 percent (588 of 1,234) of the remaining 14-HUs. It is interesting that in both the Lake Erie and Ohio River Basins, a larger percentage of 14-HUs with existing conservation land were identified by OH-GAP for their potential for high species richness.

Small Streams

The 14-HUs identified as priorities for conservation for the smallest stream class size met only the 95th-percentile criterion for each taxon individually and were spread out across the Ohio River Basin. Three 14-HUs in the Muskingum River watershed (Hocking River, 05030204-100-030, Ohio River tributaries, 05030202-170-040, and Licking River below Dillon Dam to Muskingum River, 05040006-060-040) met the 95th-percentile criterion for bivalves. The 14-HUs identified as potential priorities for conservation for crayfish were in two watersheds within the Scioto River drainage (Panther Creek, 05060001-030-030 and Paint Creek above East Fork Paint Creek, 05060003-010-010), whereas those identified for fish were in two major watersheds all together (Mad River, 05080001-180-080 and Muddy Fork, 05040002-060-010). This may suggest that fish, crayfish, and bivalves use the smallest streams in different ways.

Only one of the potential high-priority conservation areas identified using species richness for the smallest streams (Mad River, 05080001-180-080) coincided with rare, threatened, or endangered species. The basin, however, was tagged as a priority for conservation for fish, and the overlapping threatened species was from the crayfish taxon: Sloan's crayfish, *Orconectes sloanii*. Fourteen percent of streams in seven 14-HUs identified as priorities for conservation for the smallest stream size class contained conservation lands, but none of the lands were near streams of this size class.

Medium Streams

The medium stream class size was represented by many combinations of criteria attainment for fish, crayfish, and bivalves and by about half the major watersheds in the Ohio River Basin. In the northeast, three adjacent 14-HUs surrounding Pymatuning Creek (Pymatuning Creek, 05030102-030-285, Pymatuning Creek, 05030102-030-290, and Mosquito Creek, 05030103-060-040) were highlighted for all taxa at the 75th percentile, as well as for fish and crayfish at the 90th percentile. Two conservation lands, Pymatuning Creek Wetlands Nature Preserve and Shenango Wildlife Area, encompass parts of Pymatuning Creek in the 14-HUs in this area.

One 14-HU (Wabash River, 05120101-010-030) was identified as being a potential priority for conservation of fish and bivalves and was also found to overlap with an endangered species; again, Sloan's crayfish, *Orconectes sloanii*, in the Great Miami River watershed. One 14-HU in the Scioto River watershed (Compton Creek, 05060003-080-040) was identified as a priority for conservation for crayfish and also contained coldwater streams, the only 14-HU where coldwater habitat coincided with a species-rich area. Total conservation land acreage was small within the highlighted 14-HUs for OH-GAP medium stream sizes despite the presence of conservation lands within 14-HUs identified as priority conservation areas (5 of 12; 42 percent).

Large Streams

For the largest stream size class, 17 of 25 drainages (68 percent) identified as high conservation-priority areas using species richness were in the Scioto River watershed. Again, many combinations of criteria for fish, crayfish, and bivalves were represented for 37 highlighted 14-HUs. Large areas of the Scioto River main stem were identified as potential conservation-priority areas. Of these 14-HUs selected as conservation priorities, at least one of the three criteria were met for fish. The entire Big Darby watershed (05060001-220-020, 05060001-220-030, 05060001-220-040, and 05060001-210-070) was highlighted, as well as the 14-HU it flows into (Scioto River, 05060002-010-010) which met the most criteria. Also of note is the Paint Creek watershed, containing eight conservation-priority 14-HUs.

Twenty-four of 37 14-HUs (65 percent) identified as conservation-priority areas were also tagged as potentially containing rare, threatened, or endangered species of fish and (or) bivalves. These areas represent drainages that are species rich but have the potential to lose some of Ohio's rarer species as well. Twenty-three of 37 (62 percent) 14-HUs for the largest stream class size identified as high conservation-priority areas contained conservation lands. The largest streams in the Scioto River watershed flow through a number of conservation lands including Highbanks Metropark, Prairie Oaks Metropark, Batelle-Darby Creek Metropark, Three Creeks Metropark, and Paint Creek State Park. Of note is the fact that Columbus is situated in the middle of the clustered 14-HUs identified by OH-GAP for their conservation priority.

Ecoregions

In general, when comparing conservation priority on an ecoregion scale instead of by major drainage basin, there was a total net gain of 77 14-HUs identified as being potential conservation-priority areas (134 gained and 57 lost). This gain in the number of watersheds was expected because of the increase of number of assessment units (six ecoregion categories versus two major drainage basins). Because aquatic biological communities differ from ecoregion to ecoregion, this gain in 14-HUs identified as potential conservation-priority areas may offer more diverse aquatic communities and, thus, more choices for conservation managers. There were 85 14-HUs that were identified for their conservation-priority potential in both the major drainage basin and ecoregional analyses (19 Lake Erie watersheds and 66 Ohio River watersheds, including the coldwater 14-HUs).

Tables 6–3 through 6–8 show the 14-HUs identified as potential conservation-priority areas for each ecoregion. A figure was not included because of the complexity and numerous combinations of criteria that were met. This merits notice because analysis of the Lake Erie and Ohio River watersheds resulted in 14-HUs identified as potential conservation-priority areas almost exclusively for each individual stream size class. In other words, each watershed was found to be favorable for only one stream size class; 1, 2, or 3. The fact that more than one stream size class met the criteria for a 14-HU using ecoregions as the assessment unit may suggest and support a higher priority for conservation when taking into account the interconnectedness of streams and a watershed-based approach to aquatic biota conservation.

Table 6–3. The 57 14-digit hydrologic units (14-HUs) in the Eastern Cornbelt Plains ecoregion identified by the Ohio Aquatic GAP Project (OH-GAP) as having a high priority on the basis of fish, crayfish, and bivalve species-richness values relative to stream size.

[1st, 2nd, or 3rd refer to OH-GAP stream size class. Gray-shaded records indicate a 14-HU not identified by the major drainage basin analysis; %, percentile]

14-HU	14-HU Site name	Highest criterion attainment
04100007-030-020	Hog Creek above Fitzhugh Ditch to above Grass Creek	3rd fish (95%)
04100008-010-010	Blanchard River headwaters to above Cessna Creek	3rd crayfish (75%) fish (95%) bivalves (95%)
05060001-030-010	Scioto River below Taylor Creek to above Wolf Creek	3rd fish/crayfish/bivalves (75%)
05060001-030-020	Scioto River above Wolf Creek to above Panther Creek	3rd fish/crayfish/bivalves (75%)
05060001-030-030	Panther Creek	3rd crayfish (95%)
05060001-030-040	Scioto River below Panther Creek to above Rush Creek (except Wildcat Creek)	3rd fish/crayfish/bivalves (75%)
05060001-030-060	Scioto River below Rush Creek to below Green Camp	3rd fish/crayfish/bivalves (75%)
05060001-040-030	Little Scioto River below Rock Fork to near Marion	3rd crayfish (95%)
05060001-040-040	Little Scioto River near Marion to Greencamp	3rd crayfish (95%)
05060001-050-010	Scioto River below Little Scioto River to above Patton Run	3rd fish/crayfish/bivalves (75%)
05060001-050-030	Scioto River below Patton Run to above Kebler Run [except Battle Run]	3rd fish/crayfish/bivalves (75%)
05060001-050-060	Scioto River below Kebler Run to above Bokes Creek [except Fulton Creek]	3rd fish/crayfish/bivalves (75%)
05060001-050-070	Fulton Creek	2nd fish/crayfish/bivalves (75%)
05060001-060-010	Bokes Creek	2nd crayfish (95%)
05060001-060-020	Scioto River below Bokes Creek to above Mill Creek	3rd fish/crayfish/bivalves (75%)
05060001-070-030	Mill Creek below New Dover to Scioto River [except Blues Creek]	3rd crayfish/bivalves (75%) fish (95%)
05060001-080-010	Scioto River below Mill Creek to O'Shaughnessy Dam [except Eversole Run]	3rd fish/crayfish/bivalves (75%)
05060001-080-050	Scioto River below Indian Run to Griggs Dam	3rd fish/crayfish/bivalves (75%)
05060001-080-060	Scioto River from Griggs Dam to above Olentangy River	3rd crayfish (75%) fish/bivalves (90%)
05060001-090-010	Olentangy River headwaters to near New Winchester	3rd crayfish (95%)
05060001-090-020	Olentangy River near New Winchester to above Flat Run [except Mud Run]	3rd crayfish (95%)
05060001-110-020	Olentangy River below gaging station at Claridon to above Grave Creek	3rd fish/crayfish/bivalves (75%)
05060001-110-090	Olentangy River from Delaware Res. Dam to below Horseshoe Run [except Houseshoe Run and Delaware Run]	3rd fish/crayfish/bivalves (75%)
05060001-120-010	Olentangy River below Horseshoe Run to below Delaware Run	3rd fish/crayfish/bivalves (75%)
05060001-120-020	Olentangy River near Powell	3rd fish/crayfish/bivalves (75%)
05060001-120-030	Olentangy River near Worthington	3rd fish/crayfish/bivalves (75%)
05060001-120-040	Olentangy River from near Worthington to gaging station at Henderson Road	3rd fish/crayfish/bivalves (75%)
05060001-120-050	Olentangy River from gaging station at Henderson Road to Dodridge Street	3rd fish/crayfish/bivalves (75%)
05060001-120-060	Olentangy River from Dodridge Street to Scioto River	3rd crayfish (75%) fish/bivalves (90%)

Table 6–3, continued.

14-HU	14-HU Site name	Highest criterion attainment
05060001-140-010	Big Walnut Creek below Hoover Reservoir Dam to above Rocky Fork Creek	3rd fish/crayfish/bivalves (75%)
05060001-140-030	Big Walnut Creek below Rocky Fork Creek to above Blacklick Creek [except Mason Run]	3rd crayfish/bivalves (75%) fish (95%)
05060001-160-030	Big Walnut Creek below Alum Creek to Scioto River	3rd fish/crayfish/bivalves (75%)
05060001-180-010	Walnut Creek below Sycamore Creek to above Georges Creek	3rd bivalves (75%) fish (90%) crayfish (95%)
05060001-180-030	Walnut Creek below Georges Creek to above Little Walnut Creek	3rd fish/crayfish/bivalves (75%)
05060001-210-070	Little Darby Creek below Spring Fork to Big Darby Creek	3rd crayfish/bivalves (75%) fish (95%)
05060001-220-020	Big Darby Creek below Little Darby Creek to above Hellbranch Run	3rd crayfish/bivalves (75%) fish (95%)
05060001-220-030	Big Darby Creek below Hellbranch Run to Darbyville	3rd crayfish (75%) fish/bivalves (90%)
05060001-220-040	Big Darby Creek from Darbyville to Scioto River	3rd crayfish/bivalves (75%) fish (95%)
05060001-230-010	Scioto River below Olentangy River to above Big Run	3rd crayfish (75%) bivalves (90%) fish (95%)
05060001-230-030	Scioto River below Scioto Big Run to above Big Walnut Creek	3rd crayfish (75%) bivalves (90%) fish (95%)
05060001-230-040	Scioto River below Big Walnut Creek to above Walnut Creek	3rd crayfish (75%) fish/bivalves (90%)
05060001-230-050	Scioto River below Walnut Creek to above Big Darby Creek [except Dry Run]	3rd crayfish (75%) bivalves (90%) fish (95%)
05060002-010-010	Scioto River below Big Darby Creek to above Yellowbud Creek [except Hargus Creek]	3rd crayfish (75%) fish/bivalves (95%)
05060002-010-040	Scioto River below Yellowbud Creek to above Kinnikinnick Creek [except Scippo Creek and Deer Creek]	3rd fish/crayfish/bivalves (75%)
05060002-030-040	Deer Creek above Opossum Run to above Duffs Fork [except Opossum Run]	3rd fish/crayfish/bivalves (75%)
05060002-050-020	Scioto River below Kinnikinnick Creek to Chillicothe [except Dry Run]	3rd crayfish (75%) bivalves (90%) fish (95%)
05060003-010-010	Paint Creek above East Fork Paint Creek	3rd crayfish (95%)
05060003-040-050	Rattlesnake Creek below Lees Creek to above Fall Creek [except Walnut Creek and Hardin Creek]	3rd fish/crayfish/bivalves (75%)
05060003-050-010	Paint Creek below East Fork Paint Creek to above Sugar Creek	2nd fish/crayfish/bivalves (75%)
05060003-050-040	Paint Creek below Rattlesnake Creek to above Rocky Fork	3rd fish/crayfish/bivalves (75%)
05060003-060-040	Clear Creek	2nd crayfish (95%)
05060003-060-060	Rocky Fork below Rocky Fork Lake to Paint Creek	3rd crayfish/bivalves (75%) fish (95%)
05060003-080-040	Compton Creek above Crooked Creek	2nd crayfish (95%)
05060003-090-030	North Fork Paint Creek below Herrod Creek to above Little Creek	3rd fish (95%)
05080002-080-030	Indian Creek below Brandywine Creek (Indiana) to Great Miami River	2nd fish (95%)
05120101-010-020	Wabash River below Bear Creek to below Stony Creek (Simison Creek in Indiana)	2nd fish (95%)
05120101-010-030	Wabash River below Stony Creek to above Beaver Creek	2nd fish/bivalves (95%)

Table 6–4. The 34 14-digit hydrologic units (14-HUs) in the Erie/Ontario Lake and Drift Plains ecoregion identified by the Ohio Aquatic GAP Project (OH-GAP) as having a high priority based on fish, crayfish, and bivalve species-richness values relative to stream size.
[1st, 2nd, or 3rd refer to OH-GAP stream size class. Gray-shaded records indicate a 14-HU not identified by the major drainage basin analysis; %, percentile]

14-HU	14-HU Site name	Highest criterion attainment
04110001-010-030	Beaver Creek below Squires Schramm Ditch to Lake Erie	1st crayfish (95%)
04110002-020-020	Breakneck Creek	1st fish/crayfish (95%)
04110002-060-020	Mill Creek	1st crayfish (95%)
04110002-060-030	Cuyahoga River below Mill Creek to above Big Creek	3rd bivalves (95%)
04110003-010-020	Euclid Creek	1st crayfish (95%)
04110004-060-020	Grand River below Coffee Creek to above Mill Creek (3)	1st fish/crayfish/bivalves (95%)
05030102-030-285	Pymatuning Creek above Clear Creek	2nd fish/crayfish/bivalves (95%)
05030102-030-290	Pymatuning Creek above Clear Creek to below Sugar Creek	2nd fish/crayfish/bivalves (95%)
05030102-030-295	Pymatuning Creek below Sugar Creek to below Stratton Creek	3rd fish/bivalves (75%) crayfish (95%)
05030102-030-300	Pymatuning Creek below Stratton Creek to below Shanango Reservoir	3rd fish/crayfish/bivalves (75%)
05030102-050-220	Yankee Run	2nd fish/crayfish (90%)
05030103-030-010	Mahoning River below Berlin Reservoir to above West Branch [except Kale Creek]	3rd fish/crayfish/bivalves (75%)
05030103-040-050	Eagle Creek below South Fork to Mahoning River [except Tinkers Creek]	3rd fish/bivalves (75%) crayfish (95%)
05030103-040-060	Mahoning River below West Branch to above Duck Creek [except Eagle Creek]	3rd fish/crayfish (75%) bivalves (95%)
05030103-050-020	Mahoning River below Duck Creek to above Mosquito Creek [except Mud Creek]	3rd fish/crayfish/bivalves (75%)
05030103-060-030	Mosquito Creek below headwaters to Mosquito Creek Lake Dam [except Walnut Creek]	2nd fish/crayfish (90%)
05030103-060-040	Mosquito Creek below Mosquito Creek Lake Dam to Mahoning River	2nd fish/crayfish/bivalves (95%)
05030103-070-040	Mahoning River below Mosquito Creek to above Mill Creek [except Meander Creek and Squaw Creek]	3rd fish/crayfish/bivalves (75%)
05030103-080-050	Mahoning River below Mill Creek to above Yellow Creek [except Crab Creek]	3rd fish/crayfish (75%) bivalves (95%)
05030103-080-240	Mahoning River below Yellow Creek to Beaver Creek [except Hickory Run]	3rd fish/crayfish/bivalves (75%)
05040001-020-080	Chippewa Creek below Red Run to Tuscarawas River	3rd fish (90%) bivalves (95%)
05040001-030-020	Tuscarawas River below Chippewa Creek to above Fox Run [except Nimisila Creek]	3rd fish/bivalves (90%)
05040001-030-060	Tuscarawas River below Fox Run to above Sippo C. [except Mudbrook C., Newman C. & W. Sippo C.]	3rd fish/bivalves (90%)
05040002-020-030	Black Fork Mohican River below Charles Mill Lake Dam to above Rocky Fork	3rd fish/bivalves (90%)
05040002-060-010	Muddy Fork headwaters above Interstate 71	1st crayfish (95%)
05040002-070-010	Lake Fork below Muddy Fork/Jerome Fork confluence to above Odell Lake Outlet	3rd fish/bivalves (90%)
05040002-070-030	Lake Fork below Odell Lake Outlet to Mohican River	3rd bivalves (75%) fish (90%) crayfish (95%)
05040002-080-010	Black Fork below Rocky Fork to above Honey Creek	3rd fish (90%) bivalves (95%)
05040002-080-030	Black Fork below Honey Creek to above Clear Fork	3rd fish (90%) bivalves (95%)
05040003-050-050	Killbuck Creek below Little Killbuck Creek (1) to above Little Killbuck Creek (2)	2nd crayfish (75%) bivalves (90%) fish (95%)
05040003-050-080	Killbuck Creek below Clear Little Killbuck Creek(2) to above Apple Creek [except Clear Creek]	3rd fish/bivalves (90%)
05040003-060-030	Killbuck Creek below Apple Creek to above Shreve Creek	3rd fish/bivalves (90%)

Table 6–4, continued.

14-HU	14-HU Site name	Highest criterion attainment
05040003-070-030	Killbuck Creek below Salt Creek to above Millersburg [except Paint Creek and Martins Creek]	3rd fish/bivalves (95%)
05040006-040-100	South Fork Licking River below Ramp Creek to above North Fork Licking River [except Dutch Fork]	3rd fish/bivalves (95%)

Table 6–5. The 42 14-digit hydrologic units (14-HUs) in the Huron/Erie Lake Plains ecoregion identified by the Ohio Aquatic GAP Project (OH-GAP) as having a high priority based on fish, crayfish, and bivalve species-richness values relative to stream size.

[1st, 2nd, or 3rd refer to OH-GAP stream size class. Gray-shaded records indicate a 14-HU that was not identified by the major drainage basin analysis; %, percentile]

14-HU	14-HU Site name	Highest criterion attainment
04100001-020-150	Tenmile Creek below Prairie Ditch to above North Branch Tenmile	2nd fish (95%)
04100005-020-010	Maumee River below Hamm Ditch(Indiana) to above Zuber Cutoff	3rd fish (95%)
04100005-020-030	Maumee River below Zuber Cutoff to above Gordon Creek [except Marie Delarme Creek]	3rd fish (95%)
04100005-020-060	Maumee River below Gordon Creek to below Sulphur Creek [except Platter Creek]	3rd fish (95%)
04100005-020-080	Maumee River below Sulphur Creek to above Tiffin River	3rd bivalves (95%)
04100006-030-040	Flat Run	2nd fish (95%)
04100006-050-040	Lick Creek below Little Lick Creek to Tiffin River [except Prairie Creek]	3rd crayfish (75%) fish/bivalves (90%)
04100006-060-050	Tiffin River below Lick Creek to Maumee River [except Mud Creek and Webb Run]	3rd fish (95%)
04100007-040-080	Ottawa River below Pike Run to above Sugar Run [except Leatherwood Ditch]	3rd fish/bivalves (95%)
04100007-050-030	Ottawa River below Sugar Creek to Auglaize River [except Plum Creek]	3rd bivalves (95%)
04100007-060-060	Auglaize River below Jennings Creek to above Ottawa River	3rd bivalves (95%)
04100007-060-070	Auglaize River below Ottawa River to above Blanchard River	3rd bivalves (95%)
04100007-060-080	Auglaize River below Blanchard River to above Little Auglaize River [except Prairie Creek]	3rd crayfish (75%) fish (90%) bivalves (95%)
04100007-090-060	Little Auglaize River below Dog Creek to Auglaize River [except Middle Creek]	3rd bivalves (95%)
04100007-100-040	Blue Creek below Upper Prairie Creek to Auglaize River	2nd fish/bivalves (95%)
04100007-120-050	Flatrock Creek below Hoffman Creek(Indiana) to below Payne, Ohio	3rd bivalves (95%)
04100007-120-100	Auglaize River below Auglaize Reservoir to Maumee River [except Powell Creek]	3rd bivalves (95%)
04100008-030-050	Blanchard River below Aurand Run to above Ottawa Creek	3rd crayfish (75%) fish (90%) bivalves (95%)
04100008-040-030	Blanchard River below Ottawa Creek to above Moffitt Ditch	2nd fish (95%) and 3rd fish (90%) bivalves (95%)
04100008-040-050	Blanchard River below Moffitt Ditch to above Dutch Run [except Dukes Run]	3rd bivalves (95%)
04100008-040-080	Blanchard River below Dutch Run to above Riley Creek	3rd bivalves (95%)
04100008-060-010	Blanchard River below Riley Creek to above Cranberry Creek	3rd bivalves (95%)
04100008-060-030	Blanchard River below Cranberry Creek to above Deer Creek [except Miller City Cutoff and Bear Creek]	3rd bivalves (95%)
04100008-060-070	Blanchard River below Deer Creek to Auglaize River	3rd bivalves (95%)
04100009-010-020	Maumee River below Independence Dam to above Benien Creek [except Wade Creek]	3rd bivalves (95%)
04100009-010-050	Maumee River below Benien Creek to above Oberhaus Creek [except Garret Creek]	3rd bivalves (95%)
04100009-020-040	School Creek	2nd fish/bivalves (90%)
04100009-030-010	North Turkeyfoot Creek	3rd fish/crayfish/bivalves (75%)
04100009-030-020	Maumee River below North Turkeyfoot Creek to above Bad Creek	2nd fish (90%) bivalves (95%)
04100009-040-020	Bad Creek below South Branch Bad Creek to Maumee River	1st fish/bivalves (95%) 2nd fish (95%)
04100009-060-010	Maumee River below Beaver C. to above Tontogany C. (includes Sugar C., Sister C. & Kettle C.)	3rd bivalves (95%)
04100009-080-010	Blue Creek headwaters to above Harris Ditch	2nd fish (95%)

Table 6–5, continued.

14-HU	14-HU Site name	Highest criterion attainment
04100009-080-030	Swan Creek below Blue Creek to above Wolf Creek	3rd bivalves (95%)
04100009-080-050	Swan Creek below Wolf Creek to Maumee River	3rd fish/bivalves (95%)
04100009-090-040	Maumee River below Grassy Creek to Lake Erie [except Swan Creek]	3rd fish/bivalves (95%)
04100010-060-020	Sugar Creek	1st crayfish (95%) and 2nd crayfish (95%)
04100011-090-040	Sandusky River below Morrison Creek to above Wolf Creek [except Spicer Creek and Sugar Creek]	3rd fish/bivalves (75%) crayfish (95%)
04100011-100-040	East Branch of Wolf Creek below East Branch of East Branch of Wolf Creek to Sandusky River	3rd crayfish (95%)
04100011-120-010	Sandusky River below Wolf Creek to above Muskellunge Creek [except Indian Creek]	3rd fish/bivalves (75%) crayfish (95%)
04100011-120-030	Muskellunge Creek	1st crayfish (95%)
04100011-120-040	Sandusky River below Muskellunge Creek to Sandusky Bay [except Bark Creek]	3rd bivalves (75%) fish/crayfish (95%)
04100011-120-050	Bark Creek	3rd fish/bivalves (75%) crayfish (95%)

Table 6–6. The 17 14-digit hydrologic units (14-HUs) in the Interior Plateau ecoregion identified by the Ohio Aquatic GAP Project (OH-GAP) as having a high priority based on fish, crayfish, and bivalve species-richness values relative to stream size.

[1st, 2nd, or 3rd refer to OH-GAP stream size class. Gray-shaded records indicate a 14-HU that was not identified by the major drainage basin analysis; %, percentile]

14-HU	14-HU Site name	Highest criterion attainment
05080002-090-060	Great Miami River below Paddys Run to above Whitewater River [except Taylor Creek]	1st crayfish/bivalves (95%) and 3rd crayfish (75%) fish/bivalves (95%)
05080002-090-070	Taylor Creek	1st crayfish/bivalves (95%) and 2nd fish/bivalves (95%)
05080003-080-120	Whitewater River below Johnson Fork (Indiana) to above Dry Fork	3rd crayfish (75%) bivalves (90%) fish (95%)
05090201-100-010	Ohio Brush Creek headwaters above Lost Fork	1st crayfish/bivalves (95%)
05090201-100-040	Elk Run	2nd crayfish (95%)
05090201-100-060	Middle Fork Ohio Brush Creek	2nd crayfish (95%)
05090201-110-010	Crooked Creek	2nd bivalves (95%)
05090201-110-030	Little East Fork	2nd bivalves (95%)
05090201-110-040	Ohio Brush Creek below West Fork to above Lick Fork	1st crayfish/bivalves (95%)
05090201-160-010	Ohio River Tribs. between Ohio Brush Creek and Big Threemile Creek	1st fish (75%) crayfish/bivalves (95%)
05090201-200-050	Eagle Creek below East Fork to Ohio River	1st bivalves (95%)
05090201-270-030	Whiteoak Creek below Georgetown to Ohio River	3rd crayfish (95%)
05090201-400-030	Ohio River tributaries between Indian Creek and Twelvemile Creek	1st crayfish/bivalves (95%)
05090201-400-060	Ohio River tributaries between Tenmile Creek and Little Miami River	1st crayfish/bivalves (95%)
05090203-020-010	Ohio River drainage between Little Miami River and Mill Creek	1st fish/bivalves (95%)
05090203-020-020	Ohio River drainage between Mill Creek and Muddy Creek and between Muddy Creek and Great Miami River	1st crayfish/bivalves (95%)
05090203-020-030	Muddy Creek	1st crayfish/bivalves (95%)

Table 6–7. The 44 14-digit hydrologic units (14-HUs) in the Western Allegheny Plateau ecoregion identified by the Ohio Aquatic GAP Project (OH-GAP) as having a high priority based on fish, crayfish, and bivalve species-richness values relative to stream size.

[1st, 2nd, or 3rd refer to OH-GAP stream size class. Gray-shaded records indicate a 14-HU that was not identified by the major drainage basin analysis; %, percentile]

14-HU	14-HU Site name	Highest criterion attainment
05030101-070-070	Middle Fork Little Beaver Creek below Elk Run to above West Fork	1st crayfish (95%)
05030101-080-030	Brush Creek	1st crayfish (95%)
05030101-080-040	West Fork Little Beaver Creek below Cold Run to above Middle Fork [except Brush Creek]	1st crayfish (95%)
05030101-090-300	North Fork Little Beaver Creek below Bull Creek to Little Beaver Creek	1st crayfish (95%)
05030101-170-030	Ohio River drainage between Yellow Creek and Island Creek	1st crayfish (95%)
05030106-040-080	Short Creek below Piney Fork to Ohio River [except Little Short Creek]	1st crayfish (95%)
05030106-070-010	Ohio River tributaries south of Short Creek and north of Wheeling Creek	1st crayfish (95%)
05030106-200-090	Captina Creek above Cat Run to Ohio River	1st crayfish (95%)
05030201-010-050	Sunfish Creek below Piney Fork to Ohio River	1st crayfish (95%)
05030201-240-040	Duck Creek from Stanleyville to Ohio River including Ohio River direct drainage between L. Muskingum and Muskingum Rivers	3rd crayfish (95%)
05030202-100-010	Ohio River tributaries between Hocking River and Shade River	2nd fish/crayfish (90%)
05030202-170-040	Ohio River tributaries below Yellow Brush Creek to above Leading Creek	1st fish/crayfish (75%) bivalves (95%)
05030204-050-060	Hocking River below Fivemile Creek to above Monday Creek	3rd fish/crayfish/bivalves (75%)
05030204-060-030	Monday Creek below Little Monday Creek to Hocking River [except Snow Fork]	3rd fish/crayfish/bivalves (75%)
05030204-090-090	Federal Creek below McDougall Branch to Hocking River [except Sharps Fork, Marietta Run, and Big Run]	3rd fish/crayfish/bivalves (75%)
05030204-100-030	Hocking River below Willow Creek to above Federal Creek	1st fish/crayfish (75%) bivalves (95%)
05040001-160-050	Little Stillwater Creek near Dennison to Stillwater Creek	2nd bivalves (90%) fish (95%)
05040001-190-050	Tuscarawas River below Evans Creek to confluence with Walhonding River [except White Eyes Creek]	3rd fish (95%)
05040003-080-010	Killbuck Creek below Black Creek to above Doughty Creek [except Wolf Creek and Big Run]	3rd fish (95%)
05040003-080-060	Killbuck Creek below Doughty Creek to Walhonding River	3rd fish (95%)
05040003-090-010	Walhonding River below Kokosing and Mohican River to above Mohawk Creek	3rd fish (95%)
05040003-090-050	Walhonding River below Mohawk Creek to above Killbuck Creek [except Beaver Run and Simmons Run]	3rd fish (95%)
05040003-090-060	Walhonding River below Killbuck Creek to confluence with Tuscarawas River [except Mill Creek]	3rd fish (95%)
05040004-010-010	Muskingum River below Walhonding and Tuscarawas confluence to above Wills Creek	3rd fish (95%)
05040004-010-020	Muskingum River below Wills Creek to above Wakatomika Creek	1st fish (95%) and 3rd fish (95%)
05040004-010-030	Muskingum River below Wakatomika Creek to above Symmes Creek	3rd fish (95%)
05040004-030-040	Wakatomika Creek below Black Run to Muskingum River [except Little Wakatomika Creek]	3rd fish (95%)
05040006-060-040	Licking River below Dillon Reservoir Dam to Muskingum River [except Timber Run]	1st bivalves (95%)
05060002-050-040	Scioto River at Chillicothe to above Paint Creek	3rd fish (95%)
05060002-060-010	Scioto River below Paint Creek to below Stoney Creek [except Indian Creek and Dry Run]	3rd fish (95%)
05060002-060-020	Indian Creek	2nd fish (95%)
05060002-060-030	Dry Run	2nd fish (95%)

Table 6–7, continued.

14-HU	14-HU Site name	Highest criterion attainment
05060002-060-040	Scioto River below Stoney Creek to above Salt Creek [except Walnut Creek]	3rd fish (95%)
05060002-100-100	Salt Creek below Little Salt Creek to Scioto River	3rd fish (95%)
05060002-110-010	Scioto River below Salt Creek to above Carrs Run	3rd fish (95%)
05060002-110-030	Scioto River below Carrs Run to above Pee Pee Creek	1st fish (95%) and 2nd fish (95%) and 3rd fish/bivalves (95%)
05060002-120-010	Scioto River below Pee Pee Creek to above Sunfish Creek [except No Name Creek and Big Beaver Creek]	1st fish (95%) and 2nd fish (95%) and 3rd fish/bivalves (95%)
05060002-150-060	Scioto Brush Creek below South Fork Scioto Brush Creek to Scioto River [except Bear Creek and McCullough Creek]	3rd fish (95%)
05060002-160-010	Scioto River below Sunfish Creek to above Bear Creek [except Big Run and Camp Creek]	3rd fish (95%)
05060002-160-050	Scioto River below Bear Creek to above Scioto Brush Creek [except Miller Run]	3rd fish (95%)
05060002-160-070	Scioto River below Scioto Brush Creek to Ohio River [except Pond Creek]	1st fish (95%) and 3rd fish (95%)
05060003-100-040	Paint Creek below North Fork Paint Creek to Scioto River	1st fish (95%) and 2nd fish (95%) and 3rd bivalves (90%) fish (95%)
05090103-050-050	Ginat Creek	2nd fish/crayfish (90%)
05090103-080-050	Little Scioto River below Rocky Fork to Ohio River [except Frederick Creek] and 1172 acres of Ohio River drainage between Pine Creek and Little Scioto River	1st fish/crayfish/bivalves (75%) and 3rd fish/crayfish/bivalves (75%)

Table 6–8. The 15 14-digit hydrologic units (14-HUs) in the transitional ecoregion category identified by the Ohio Aquatic GAP Project (OH-GAP) as having a high priority based on fish, crayfish, and bivalve species-richness values relative to stream size.

[1st, 2nd, or 3rd refer to OH-GAP stream size class. Gray-shaded records indicate a 14-HU that was not identified by the major drainage basin analysis; %, percentile]

14-HU	14-HU Site name	Highest criterion attainment
04100006-050-030	Prairie Creek	2nd bivalves (95%)
05030204-030-010	Little Rush Creek headwaters to near Rushville	3rd crayfish (95%)
05030204-030-020	Little Rush Creek near Rushville to Rush Creek	3rd crayfish (95%)
05030204-030-030	Raccoon Run	2nd bivalves (75%) fish/crayfish (95%)
05030204-030-040	Rush Creek below Little Rush Creek to Hocking River [except Raccoon Run]	3rd fish/crayfish/bivalves (75%)
05040001-120-040	Sugar Creek below Middle Fork Sugar Creek to Beach City Reservoir [except South Fork Sugar Creek]	2nd fish (95%)
05040003-070-040	Killbuck Creek above Millersburg to above Black Creek [except Shrimplin Creek]	2nd fish (95%)
05040006-020-060	North Fork Licking River below Clear Fork to above South Fork [except Dry Creek]	2nd fish (95%)
05040006-040-060	South Fork Licking River below Buckeye Lake Feeder to below Buckeye Lake	2nd crayfish (90%) fish (95%)
05040006-040-070	South Fork Licking River below Buckeye Lake to above Ramp Creek	3rd fish (95%)
05060001-100-010	Whetstone Creek headwaters to above Shaw Creek	2nd fish (95%)
05060003-070-010	Paint Creek below Rocky Fork to above Buckskin Creek	3rd crayfish (75%) fish/bivalves (90%)
05060003-070-030	Paint C. below Buckskin C. to above Lower Twin C. [except Buckskin C. & Upper Twin C.]	3rd bivalves (90%) fish (95%)
05060003-090-050	North Fork Paint Creek below Little Creek to Paint Creek	2nd bivalves (90%) fish (95%) and 3rd fish (95%)
05060003-100-010	Paint Creek below Lower Twin Creek to above North Fork Paint Creek [except Black Run & Ralston Run]	3rd fish/bivalves (95%)

Sampling Effort

Fourteen-digit hydrologic units (14-HUs) were investigated by use of known aquatic taxa data to identify areas with no prior sampling effort. This analysis can help guide future sampling efforts by highlighting 14-HUs that have never been sampled. Table 6–9 identifies 14-HUs already highlighted for high species-richness values that have never been sampled.

Table 6–9. High-species-rich 14-digit hydrologic units (14-HUs) that have never been sampled.
[Three 14-HUs shaded in gray were identified as potential conservation-priority areas for two taxa.]

14-HU	Site name	Taxa	Major drainage basin
04100003-030-010	St. Joseph River below West Branch to above Nettle Creek	fish	Lake Erie
04100003-030-030	St. Joseph River below Nettle Creek to above Eagle Creek	fish	Lake Erie
04100003-060-050	St. Joseph River below Big Run to above Buck Creek (Indiana)	fish	Lake Erie
04100004-020-030	St. Marys River below Hussey Creek to above Twelvemile Creek [except Eightmile Creek]	bivalves	Lake Erie
04100004-030-020	Black Creek [except Little Black Creek]	bivalves	Lake Erie
04100004-030-040	St. Marys River below Black Creek to above Twentyseven Mile Creek [except Duck Creek]	fish	Lake Erie
04100007-120-050	Flatrock Creek below Hoffman Creek(Indiana) to below Payne, Ohio	bivalves/fish	Lake Erie
04100008-030-030	Blanchard River below Eagle Creek to above Aurand Run	bivalves	Lake Erie
04100008-030-050	Blanchard River below Aurand Run to above Ottawa Creek	bivalves	Lake Erie
04100011-040-040	Sandusky River below Rock Run to above Negro Run	crayfish/fish	Lake Erie
04100011-060-010	Tymochtee Creek below Warpole Creek to above Lick Run [except Oak Run]	fish	Lake Erie
04100011-070-010	Sandusky River below Tymochtee Creek to above Sycamore Creek [except Thorn Run & Taylor Run]	fish	Lake Erie
04100012-020-030	Slate Run below Mud Run to West Branch Huron River	crayfish	Lake Erie
04110002-010-070	Black Brook	fish	Lake Erie
04110002-060-030	Cuyahoga River below Mill Creek to above Big Creek	bivalves	Lake Erie
05030102-030-290	Pymatuning Creek above Clear Creek to below Sugar Creek	bivalves	Ohio River
05030103-060-040	Mosquito Creek below Mosquito Creek Lake Dam to Mahoning River	bivalves	Ohio River
05030202-170-040	Ohio River Tribs. below Yellow Brush Creek to above Leading Creek	bivalves	Ohio River
05030204-030-010	Little Rush Creek headwaters to near Rushville	crayfish	Ohio River
05030204-030-030	Raccoon Run	crayfish	Ohio River
05060001-080-010	Scioto River below Mill Creek to O'Shaughnessy Dam [except Eversole Run]	crayfish	Ohio River
05060001-110-020	Olentangy River below gaging station at Claridon to above Grave Creek	crayfish/fish	Ohio River

Land Use

OH-GAP analyzed the land use for 14-HUs identified as having high species richness values. Land use was determined by use of the National Land Cover Dataset (NLCD) (1992). OH-GAP produced new classes that combined existing NLCD groups: developed (21–Low Intensity Residential; 22–High Intensity Residential; 23–Commercial/Industrial/Transportation), forested (41–Deciduous Forest; 42–Evergreen Forest; 43–Mixed Forest; 51–Shrubland), agricultural (81–Pasture/Hay; 82–Row Crops;

83–Small Grains; 84–Fallow), and wetlands (91–Woody Wetlands; 92–Emergent Herbaceous Wetlands).

OH-GAP created potential aquatic species-richness maps that do not take present-day water quality into account. Land-use thresholds were found that represent potential negative impacts to aquatic ecosystems. Potential species rich areas were then identified as having the likelihood of attaining such a designation. Tom Fitzhugh (2005) reports research findings that show thresholds of urban land use greater than 20 to 50 percent as having a negative effect on fish communities. OH-GAP chose the lesser to highlight areas with more natural landscapes that could be acquired for conservation. Fitzhugh also states an agriculture threshold of greater than 50 percent as having a negative effect on fish.

In the Lake Erie Basin, the 14-HUs identified as conservation priorities are spread out across northeast Ohio. The easternmost 14-HU holds Conneaut Creek (04120101-010-300), which is surrounded by a high percentage of riverine wetlands (12 percent of 14-HU) and also has a high potential for crayfish. Another 14-HU (04110004-060-020) contains small streams draining to the Grand River that have a high potential for fish and bivalves. The land use in this 14-HU is primarily divided between forest and agriculture with the streams being heavily buffered by forests. It appears that land use does not fully explain or predict species richness at the 14-HU level.

There are 128 14-HUs identified as having high potential species-richness values that exceeded both the forest and agriculture thresholds, leaving 14 14-HUs below the thresholds (7 in each major drainage). In the Ohio River Basin, four contiguous 14-HUs (05060003-070-010, 05060003-070-030, 05060003-100-010, and 05060003-100-040) were identified in the Paint Creek watershed. The 14-HUs contain a range of 36 to 58 percent forested land that lies mostly beyond the agriculture buffering the streams. These basins show high potential for fish and bivalves. The southernmost 14-HU on the Scioto River (05060002-160-070), just north of Portsmouth, Ohio, has a high potential for fish and contains 36 percent forested land. The last two 14-HUs (Hocking River, 05030204-100-030 and Ohio River tributaries, 05030202-170-040) have a high potential for bivalves in the smallest stream size class.

7. Product Use and Availability

How to Obtain the Products

It is the goal of the Gap Analysis Program (GAP) and the U.S. Geological Survey (USGS) to make the GAP data and associated information as widely available as possible. Use of the data requires specialized software called geographic information systems (GIS) and substantial computing power. Additional information on how to use the data or obtain GIS services is provided below and on the GAP home page: (*http://gapanalysis.nbii.gov*). This report and associated data may be downloaded via the Internet from the USGS publications warehouse web site: (*http://infotrek.er.usgs.gov/pubs/).*

Minimum GIS Required for Data Use

Minimum requirements to view the Ohio Aquatic GAP GIS data vary with software used. The minimum requirements to view the data in the Environmental Systems Research Institute (ESRI) software in which most of the data were developed are the following:

- Computer: Industry-standard personal computer with at least a Pentium or higher Intel-based microprocessor and a hard disk
- Memory: 128MB RAM
- Operating System: One of the following: Windows 98/ME, Windows NT 4.0, and Windows 2000, Windows XP—Home Edition and Professional

Disclaimer

Although these data have been processed successfully on a computer system at the USGS, no warranty expressed or implied is made regarding the accuracy or utility of the data on any other system or for general or scientific purposes, nor shall the act of distribution constitute any such warranty. This disclaimer applies both to individual use of the data and aggregate use with other data. It is strongly recommended that these data be directly acquired from a USGS server and not indirectly through other sources that may have changed the data in some way. It is also strongly recommended that careful attention be paid to the content of the metadata file associated with these data. The U.S. Geological Survey shall not be held liable for improper or incorrect use of the data described and (or) contained herein.

These data were compiled with regard to the following standards. Please be aware of the limitations of the data. These data are meant to be used at a scale of 1:100,000 or smaller (such as 1:250,000 or 1:500,000) for the purpose of assessing the conservation status of aquatic animals and habitats over large geographic regions. The data may or may not have been assessed for statistical accuracy. Data evaluation and improvement may be ongoing. The USGS makes no claim as to the data's suitability for other purposes. These are writable data, which may have been altered from the original product if not obtained from a designated data distributor.

Metadata

Proper documentation of information sources and processes used to assemble GAP data layers is central to the successful application of GAP data. Metadata documents the legacy of the data for new users. The Federal Geographic Data Committee (FGDC) (1994, 1995) has published standards for metadata. Executive Order 12906 requires that any spatial data sets generated with Federal dollars have FGDC-compliant metadata.

Appropriate and Inappropriate Use of These Data

All information is created with a specific end use or uses in mind. This is especially true for GIS data, which are expensive to produce and must be directed to meet the immediate program needs. For Ohio Aquatic GAP, minimum standards were set to meet program objectives. These standards include: scale or resolution (1:100,000 minimum mapping unit), accuracy (90 percent accurate), and format (ESRI shapefiles and grids).

Recognizing, however, that GAP would be the first, and for many years likely the only, source of statewide biological GIS maps, the data were created with the expectation that they would be used for other applications. Therefore, both appropriate and inappropriate uses are listed. This list is in no way exhaustive but should serve as a guide to assess whether a proposed use can or cannot be supported by GAP data. For most uses, it is unlikely that GAP will provide the only data needed, and for uses with a regulatory outcome, field surveys should verify the result. In the end, it will be the responsibility of each data user to determine if GAP data can answer the question being asked and if GAP data are the best tool to answer that question.

Scale

The data were produced with an intended application at the ecoregion level; that is, geographic areas from several thousands to tens of thousands of square kilometers. The data provide a coarse-filter approach to analysis, meaning that not every occurrence of every animal species habitat is mapped—only larger, more generalized distributions. The data are also based on the USGS 1:100,000 scale of mapping in both detail and precision.

Appropriate Uses of GAP Data

- Statewide biodiversity planning
- Regional planning
- Regional habitat conservation planning
- County comprehensive planning
- Large-area resource management planning

- Coarse-filter evaluation of potential impacts or benefits of major projects or plan initiatives on biodiversity, such as utility or transportation corridors, wilderness proposals, and regional open space and recreation proposals.
- Determining relative amounts of management responsibility for specific biological resources among land stewards to facilitate cooperative management and planning.
- Basic research on regional distributions of aquatic animals and to help target specific species and geographic areas for needed research.
- Environmental impact assessment for large projects or military activities.
- Estimation of potential economic impacts from loss of biological resource-based activities.
- Education at all levels for students and citizens.

Inappropriate Uses

It is far easier to identify appropriate uses than inappropriate ones; however, care must be taken to ensure that the differences in resolution of the data, size of geographic area being analyzed, and precision of the answer required for the question are no longer compatible for use with GAP data. Examples include the following:

- Using the data to map small areas (less than a few square kilometers), typically requiring mapping resolution at 1:24,000 scale and using aerial photographs or ground surveys.
- Combining GAP data with other data finer than 1:100,000 scale to produce new hybrid maps or answer queries.
- Generating specific areal measurements from the data finer than the minimum mapping unit.
- Establishing exact boundaries for regulation or acquisition.
- Establishing definite occurrence or non-occurrence of any feature for an exact geographic area.
- Determining abundance, health, or condition of any feature.
- Establishing a measure of accuracy of any other data by comparison with GAP data.
- Altering the data in any way and redistributing them as a GAP data product.
- Using the data without acquiring and reviewing the metadata and this report.

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Glossary

algorithm - a procedure to solve a problem or model a solution (in GAP, typically refers to a GIS procedure used to model animal distributions.)

anthropogenic - caused by humans

assemblages - a group of ecologically interrelated plant and animal species

biodiversity - generally, the variety of life and its interrelated processes; the biological diversity

biogeographic - relating to the geographical distribution of plants and animals

biological diversity - *see* biodiversity

cartographic - pertaining to the art or technique of making maps or charts

classify (remote sensing) - to assign objects, features, or areas on an image to spectral classes on the basis of their appearance, as opposed to "classification" referring to a scheme for describing the hierarchies of vegetation or animal species for an area

coarse filter - the general conservation activities that conserve the common elements of the landscape matrix, or analysis on a landscape scale, as opposed to the "fine filter" conservation activities that are aimed at smaller areas and special cases, such as rare elements (Jenkins, 1985)

community - a group of interacting plants and animals

cross-walking - matching equivalent categories between two or more classification systems

delineate – to identify the boundaries between more or less homogenous areas

ecoregion - a large region, usually spanning tens of thousands of square kilometers, characterized by having similar biota, climate, and physiography (topography, hydrology, etc.)

ecosystem - a biological community (ranging in scale from a single cave to tens of thousands of square kilometers), its physical environment, and the processes through which matter and energy are transferred among the components

element - a habitat or animal species mapped by GAP

error of commission - the occurrence of a species (or other map category) is erroneously predicted in an area where it is in fact absent

error of omission - failure of a model to predict the occurrence of a species that is actually present in an area

extinction - disappearance of a species throughout its entire range

extrinsic omission – omission error associated with points used to test the model, as opposed to "intrinsic omission"

fine filter - the conservation activities that are aimed at fine scales or special cases, such as rare elements, as opposed to the "coarse filter" conservation activities, which are general and conserve the common elements of the landscape matrix (Jenkins, 1985)

gap analysis - a comparison of the distribution of elements of biodiversity with that of areas managed for their long-term viability to identify elements with inadequate representation

geographic information systems (GIS) - computer hardware and software for storing, retrieving, manipulating, and analyzing spatial data

habitat - the physical structure, vegetational composition, and physiognomy of an area, the characteristics of which determine its suitability for particular animal or plant species

hydrologic unit (HU) - hierarchical divisions and subdivisions of a watershed. Several 14-digit HUs are completely contained within an 11-digit HU. Hydrologic units may or may not be true watersheds, meaning that the full upstream portion of the stream network is encompassed within each of the areas defined as a watershed.

intrinsic omission – omission error associated with points used to create the model, as opposed to "extrinsic omission"

lotic – flowing; for example, water in a stream or river

metadata - information about data, such as their source, lineage, content, structure, and availability

minimum mapping unit - the smallest area that is depicted on a map

pixel - the smallest spatial unit in a raster data structure

polygon - an area enclosed by lines in a vector-based geographic information system data layer

proactive - acting in anticipation of an event as opposed to reacting after the fact

range - the geographic limit of the species

reach - a stream or river segment between inflowing tributaries

resolution - the ability of a system to record and display fine detail in a distinguishable manner; or; the smallest feature that can be distinguished or resolved on a map or image

scale, map - the ratio of distance on a map to distance in the real world, expressed as a fraction; the smaller the denominator, the larger the scale (for example, 1:24,000 is larger than 1:100,000)

species richness - the number of species of a particular interest group found in a given area

Universal Transverse Mercator – (UTM) one of several map projections or systems of transformations that enables locations on the spherical Earth to be represented systematically on a flat map

vector format - a data structure that uses polygons, arcs (lines), and points as fundamental units for analysis and manipulation in a geographic information system

watershed – the land area that drains to a particular lake, river, or location along a river

Maps of Predicted Species Distributions

Maps are alphabetized by common name within each taxon.
Fish
Crayfish
Bivalves

Lists of species depicted on the maps are available here, also alphabetized by common name within each taxon.
Fish
Crayfish
Bivalves