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An Aquatic Gap Analysis of Iowa, 2005 Final Report

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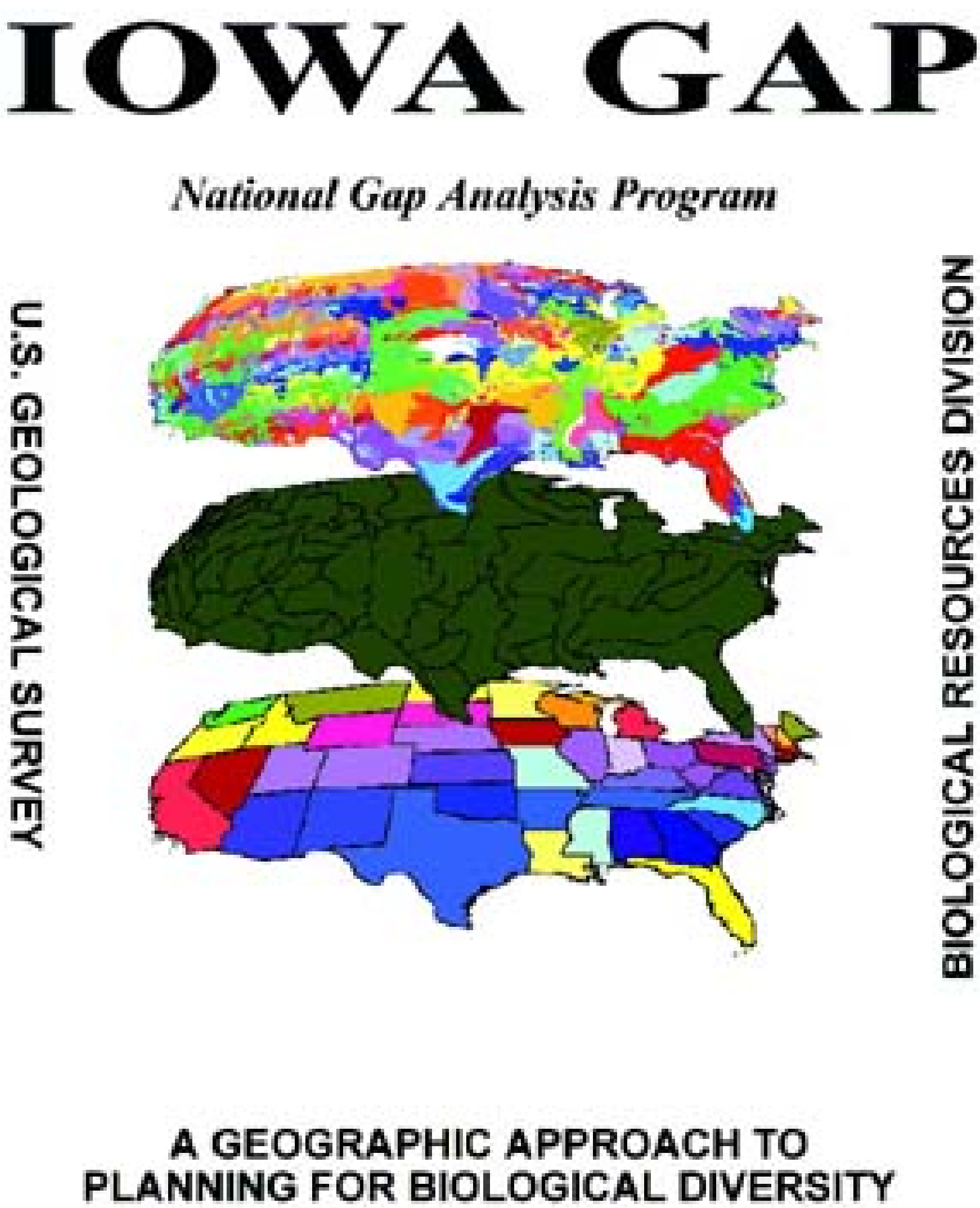

THE IOWA AQUATIC GAP ANALYSIS PROJECT

FINAL REPORT

30 June 2005

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EXECUTIVE SUMMARY

Introduction

The Iowa Aquatic Gap Analysis Project (IAGAP) began in 2001 to identify areas in the state where fish species richness lacked adequate protection under existing land ownership and management regimes. Another main goal of the project was to create fish prediction data for Iowa streams and rivers.

To accomplish these goals, the Iowa GAP team prepared an assortment of datasets that led to the creation of three main datasets:

- Iowa streams and rivers
- Iowa fish habitat models for 157 species
- Iowa land stewardship (ownership and management)

When the project began, there were few statewide datasets available that provided the type of data needed for this project. Consequently, much effort was devoted to building the previously mentioned key data layers at a sufficiently fine scale and resolution for subsequent analysis. The exception to this statement was land stewardship; it had been created for the terrestrial GAP project. It needed minimal editing to serve as a dataset for IAGAP. At the completion of the project, these data became freely available, with the intent that they will be used by those responsible for managing the state's valuable natural resources, and by the public, so that everyone can be better informed. With this in mind, we emphasize that these data are dynamic, and in some places, already out of date. Nonetheless, the data and analyses which constitute IAGAP represent an important first step toward understanding the status of fish biodiversity and conservation in Iowa.

Data Development

Stream Reach Dataset

The framework chosen as the base for fish prediction modeling for IAGAP was the National Hydrography Dataset (NHD) produced by the USGS, a nationwide comprehensive collection of information about surface water features. The Iowa Stream Reach (ISR) dataset creation process had three main phases. Pre-processing was conducted at ISU. All 57 HUC 8 watersheds extracted from the NHD were combined and projected to UTM zone 15, NAD83. Geological Survey Bureau (GSB) of the Iowa Department of Natural Resources (IDNR) digitized stream reaches in an area of lower stream network density discovered in northwest Iowa. These densified arcs were merged into the NHD arcs and topology was recreated. Several attributes were assigned to all stream reaches including segment ID. The dataset was also checked for disconnected polygons and stream segments and braided or looped reaches. The stream reach data for Iowa was sent to MoRAP GIS technicians for the bulk of attribute generation. ArcInfo AML scripts were run on the datasets at MoRAP to populate new attributes with data from existing datasets. Other new attributes were populated by calculations based on the topology of the dataset. Post-processing at ISU consisted of merging the two datasets received from MoRAP into one coverage, eliminating secondary channels from the modeling dataset, fixing missing or incorrect attribute values and creating the pool attribute used in the Great River models.

The Iowa Stream Reach dataset creation process resulted in a dataset with almost 84,000 segments and 76,000 individual reach codes. Out of the 54 variables in the ISR dataset, 25 are internal IDs or duplicate variables of some kind leaving 29 useful potential modeling variables. Some variables that MoRAP created for their dataset were not used in IAGAP and we added some variables we thought might prove useful to our particular situation. The most notable of the variables we chose not to create was the valley segment type (VST). Although the draft protocol for Aquatic GAP developed by MoRAP included the creation of a VST variable and was used by South Dakota for their Aquatic GAP modeling, we chose to forego using the concatenated VST, as did MoRAP eventually, and develop models using each of the input variables separately.

Biological Data Compilation

Although we had no sense of the breadth of biological sampling data available for fish species in Iowa, it was considered important to have the most comprehensive biological data set possible. Through a comprehensive data acquisition and organization program, we were able to compile a fish species occurrence database that we believe satisfies this objective.

Before compiling any data, it was essential to determine what types of information would be captured. Therefore the design of the database and creating a species list of fishes of Iowa were the first steps implemented. We compiled a species list using historic as well as current published and unpublished sources at the state and national level. The design of the Microsoft Access relational database included separate but related tables containing three primary elements: 1) information about the collector and collection, 2) information about the location of each collection, and 3) information about the species collected.

We used several methods to locate riverine fish records. These strategies included: 1) visiting all IDNR regional fisheries offices to acquire field notes and reports, 2) conducting literature searches to acquire published literature, 3) acquiring museum collection records and 4) contacting individual fisheries investigators to acquire unpublished field notes.

Predicted Vertebrate Distributions

Distributions of 144 fish species were predicted. The modeling process involved several steps. First, 8-digit HUC based geographic range limits for each species were determined based on the location of species records and professional review. We generated input data sets based on the known stream segment locations when these ranges and their associated ISR coverage habitat variables. Statistical models were then generated using AnswerTree® 3.1. When applicable, non-statistical "Great River" models were generated for species found in the Mississippi and/or Missouri Rivers. For several species for which an "AnswerTree" model could be built, a habitat generated model was generated based on the habitat literature. Final overall fish species' models were then used to select reaches in the Iowa Stream Reach coverage, based on the species' geographic range, the selected reaches constituting the predicted distribution. An accuracy assessment was done for fish species.

Geographic patterns of species richness generally suggest higher diversity in the eastern portion of the state, with the lowest diversity found in southwest Iowa. Greater species diversity occurred in most major streams and rivers associated with the Mississippi River system. With the exception of those in the Little Sioux River watershed in northwest Iowa, streams and rivers associated with the Missouri River Drainage Basin generally had lower species richness.

Considering the issue of scale and the depth of our biological collection data, we feel confident that our models performed reasonably well for Iowa aquatic systems. With this coarse-scale model approach, errors of commission will be more common than errors of omission. In other words, over estimation of a species distribution is more likely. Failure to predict a species' presence in an area where it actually occurs may cause inadvertent harm if land use decisions are made without that species in mind. If, however, a species is predicted to occur where it has never been recorded, it is more likely that the species will be targeted in future surveys and also considered in subsequent land use decisions.

Land Stewardship & Management

The term "stewardship" is used in place of "ownership" because legal ownership, especially in the case of public lands, does not necessarily identify the entity responsible for management of the land resource. At the same time, it is necessary to distinguish between stewardship and management status because a single land steward may manage portions of its lands differently.

The digital land stewardship layer was created by incorporating various administrative boundaries into a base layer of land ownership obtained from various sources. State lands were obtained from the Iowa Department of Natural Resources as an ArcInfo coverage. County lands were done by conducting an extensive mail survey through the Iowa Association of County Conservation Boards (IACCB). Individual counties submitted data on paper maps or as ArcView shapefiles if they possessed GIS capabilities. Each map feature in the stewardship layer was assigned a management status code and other required National GAP attributes. Status codes were determined by consulting management plans if they existed, talking with agency personnel or looking at legislation that pertained to a particular land designation such as the State Preserves System.

Lands were assigned to one of four management classes based on the relative degree to which land stewards were responsible for maintaining biodiversity values. Status 1 lands reflected the highest, most permanent level of restrictive management; such lands included National Monuments, lands designated as a State Preserve, Nature Conservancy Preserves, and some National Wildlife Refuges where multiple uses were not permitted. Management could be changed more easily on Status 2 lands, such as wildlife management areas, and National Wildlife Refuges where multiple uses were permitted, but it was still more restrictive than the remaining multiple use public lands or private lands, which were assigned to Status 3. Status 4 included lands with no irrevocable easement or mandate to preserve biodiversity values but contributed to the overall conservation system.

Steps were performed to ensure that all reaches within the State of Iowa boundary received Iowa GAP stewardship information. A comparison of the extents of the NHD reach layer and Iowa GAP stewardship layer was made to capture the correct stewardship attribute for the border rivers. The stewardship polygon layer described above was modified so that the border rivers as represented in the NHD data would be included within the state boundary where appropriate. An identity function, in ArcInfo, with the NHD and modified stewardship layer was performed to split the reaches with the stewardship boundary polygons in order to retain the original NHD attributes for each reach, while providing stewardship values from the Iowa GAP stewardship layer.

Private land makes up approximately 98% of land in Iowa. Public lands administered by federal, state and county agencies consist of less than 2% of the state. Other than a few exceptions most of Iowa's public land consists of relatively small disjunct areas within a vast amount of private land. Exceptions are areas along the Mississippi and Missouri Rivers, reservoirs along the Des Moines, Cedar and Iowa rivers and a scattering of larger complexes managed by many agencies and private individuals. Reaches contained within areas designated as public land accounted for approximately 3.6 % of the total length of reaches within the state of Iowa. Less than 0.1 % of the reaches were designated as status 1 or 2. Status 3 reaches made up 1.0 %. The majority of reaches were designated as status 4.

Analyses

Once the requisite statewide data were assembled, the actual gap analysis involved intersecting the GIS layers of NHD stream reaches and predicted fish distributions with land stewardship. These results form the basis of GAP's mission to provide land owners and managers with the information necessary to conduct informed policy development, planning, and management for the long-term maintenance of aquatic biodiversity. A practical solution to the problem of defining adequate representation for fish species is to report both percentages and absolute stream length in management areas and allow the user to determine which fish species are adequately represented in areas under active management.

Stream Reaches

Most streams in Iowa flow through privately owned property and the protected stream length numbers reflect this situation. Reaches contained within areas designated as public land accounted for approximately 3.6 % of the total length of reaches within the state of Iowa. There were few (total length = 64.7 km, < 0.1 %) reaches designated as status 1 or 2. Status 3 reaches made up 1.0 % (1,184.5 km) and the majority of reaches were designated as status 4 (115,338.6 km, 98.9%).

Predicted Fish Distributions

The 157 fish species modeled for Aquatic Gap were predicted to be found in 172,632 km of streams, which is all of the total 178,757 km in the Iowa Stream Reach dataset used for IAGAP minus the streams in two Minnesota watersheds that were excluded from fish ranges. Concerning predicted fish richness at the HUC 8 watershed level, hydrologic units contained from 14 to 111 fish species with a median of 57 species. Stream reaches were predicted to contain from 1 to 95 fish species but reaches with more than 50 species per reach were rare and predominately found in the Mississippi and Missouri Rivers.

Conclusions

Intensive agriculture, urban development, artificial tile drainage, soil erosion, deforestation, channelization of streams and rivers, and an extensive grid of transportation corridors have reshaped Iowa’s landscapes since the beginning of European settlement more than a century ago. The tallgrass prairies that helped develop the state’s highly productive soils have been reduced by more than 99 percent and about 95 percent of the once abundant prairie potholes have been drained. Over half of the original forest has been lost and the remainder has been severely fragmented and disturbed. Most of the natural areas that remain have experienced some kind of disturbance by grazing, fire suppression, or drainage. Streams have been subjected to straightening, which can increase water velocity and affects in-stream fish habitat.

Public lands in Iowa are limited to approximately 2.10% of the total land area of the state and reaches with a designation of public amount to approximately 3.6% of the total length of streams within the state boundary. This includes areas managed by the Federal Government, Iowa Department of Natural Resources, Iowa Department of

Transportation, and the 99 counties that comprise the County Conservation Board system. The remaining public land is managed primarily by federal and county agencies scattered throughout the state. Most public lands are managed for multiple uses and few areas are managed for biodiversity conservation.

With such a small amount of streams managed within public land, the role and relationships between private and public land managing entities is important for the long-term management of aquatic biodiversity in the state. In all cases, private lands are the primary stewardship class within watersheds. There were no watersheds that consisted of less than 87% private lands. Factors influencing stream and river biodiversity are probably closely related to actions implemented on private lands. Programs, whether at the state or federal level, encouraging private landowners to implement conservation practices directly influences the amount of land that supports biodiversity, encourages natural ecosystem functions, and soil conservation practices.

Because of Iowa's fertile soils and favorable climate, it is likely that the land will remain in agriculture and private ownership for the foreseeable future. Gap analysis can assist natural resource planners with identifying existing centers of aquatic biodiversity so that conservation efforts can be directed where they will do the most good. Large tracts of land for biodiversity management are seldom available; therefore, ways must be found to protect biodiversity on private lands and in the streams that flow through them, such as through long-term conservation easements and other voluntary initiatives.

Data Uses and Availability

How To Obtain the Products

It is the goal of the Gap Analysis Program and the USGS Biological Resources Division (BRD) to make the 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 homepage (URL below). Although the most convenient way to obtain and store the data may be on CD-ROM, they also can be downloaded via the Internet either from the national GAP home page (http://www.gap.uidaho.edu/gap) or the IDNR's Natural Resource Geographic Information System (http://www.igsb.uiowa.edu/nrgislibx/). The Iowa Gap Analysis homepage (http://www.ag.iastate.edu/centers/cfwru/iowagap) serves as a resource for data, final reports and the "Iowa Stream Fish Atlas" when it becomes available.

Minimum GIS System Required for Data Use

All GIS data are either ArcView shapefiles or ArcGIS geodatabases or ArcInfo vector coverages. ArcView 3.3, ERDAS Imagine, ArcGIS and GeoMedia will all be able to display and analyze the vector data available from IAGAP. Only ArcGIS is able to display the geodatabase format.

The GIS Facility at Iowa State University, Room 218 Durham Hall, Ames, Iowa provides access to computers and software available to students, faculty and staff of Iowa State for GIS analysis. Other interested persons can contact the facility personnel to arrange a contract for GIS services. ArcExplorer, a free GIS viewing and query package from ESRI, can be downloaded from http://www.esri.com/software/arcexplorer/index.html. There are also free or inexpensive complete GIS packages available on the Web capable of viewing, analyzing and printing aquatic GAP GIS data. Private GIS companies exist around the state and can be found through the phone book.

Disclaimer

Although these data have been processed successfully on a computer system at the BRD, 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 are directly acquired from a BRD server (see above for approved data providers) and not indirectly through other sources which 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 Biological Resources Division 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 fish and river segments over large geographic regions. The data may or may not have been assessed for statistical accuracy. Data evaluation and improvement may be ongoing. The Biological Resources Division makes no claim as to the data's suitability for other purposes. This is writable data which may have been altered from the original product if not obtained from a designated data distributor identified above.

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At the national level, we would like to thank Amos Eno and the staff of the National Fish and Wildlife Foundation, who funded the early development of the GAP concept and to the originators including J. Michael Scott, Blair Csuti, and Jack Estes and the pioneering scientists who forged the way. Thanks to John Mosesso and Doyle Frederick of the US Geological Survey Biological Resource Division (BRD) Office of Inventory and Monitoring, for their support of the national Gap Analysis Program, especially during its transition from the U.S. Fish and Wildlife Service to the National Biological Service and then to the U.S. Geological Survey BRD. Thanks to Reid Goforth and the staff at the USGS BRD Cooperative Research Units for administering Gap's research and development phase from headquarters. Without those mentioned above, there could not have been a Gap Analysis Program. Thanks also to the staffs of the National Gap Analysis Program, Center for Biological Informatics, and Biological Resources Division headquarters.

We acknowledge contributions to this report by Chris Cogan, Patrick Crist, Blair Csuti, Tom Edwards, Michael Jennings, and J. Michael Scott; as well as the previous GAP projects. Kevin Gergely, Doug Beard, Ree Brannon, Becky Sorbel and Elisabeth Brackney were especially important sources of information, encouragement and levity.

Several people deserve special mention for their all-around support and commitment to Iowa Aquatic Gap. They are Brenda Van Beek, Iowa Cooperative Fish and Wildlife Research Unit, for her administrative and logistical skills and Don Bonneau, Iowa DNR, who championed the cause in his department.

We would like to acknowledge the following people and organizations without whose help this project would not have yielded the high quality, comprehensive and useful results that it has.

Stream Reach Dataset

The Iowa Aquatic Gap Analysis Project has benefited from collaboration with and previous work done by South Dakota and Missouri; we specifically thank Scott Sowa, Gust Annis, and the staff at MoRAP for their assistance with the NHD modifications. GIS staff at the Geological Survey Bureau, Iowa DNR, were responsible for many improvements to the Iowa Stream Reach dataset. Several students at the ISU GIS Facility put in many hours editing the reach dataset and we are thankful for their assistance. They were: Jacob Groth, Henna Chou and Jessie Holland.

Stewardship

Data for the land stewardship layer was supplied primarily by Todd Bishop, IDNR and individual county conservation board offices. Don Brazleton and Julie Moss, IACCB, were especially helpful with coordinating data submission and providing land management status information, in addition to boundary locations, for county owned or managed lands. Boundary and management status data for federal land was provided by the Army Corps of Engineers field offices in Omaha, NE, Rock Island, IL and St. Paul, MN. Federal land data was also received from the US Fish and Wildlife Service McGregor District and Rock Island field office. The NRCS provided a large conservation easement data set detailing stewardship on private lands. Other information providing information and parcel boundaries for stewardship on private lands was provided by Kyle Swanson and Joe McGovern of the Iowa Natural Heritage Foundation, and Mike Polly from The Nature Conservancy.

Fish Prediction Modeling

As previously mentioned, the Iowa Aquatic Gap Analysis Project has benefited from work done by MoRAP; we specifically thank Mike Morey and Scott Sowa for their assistance with the modeling process. There were many generous individuals who provided us with species sampling data that was used in the modeling process. They are:

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Bruce Menzel, Professor, Department of Animal Ecology, ISU
Mel Bowler, IDNR, LTRMP

We are grateful that these people donated their time and expertise to fine tune species ranges. Heather Stricker and Tina Hayek assisted in the production of the species prediction and distribution maps.

Iowa Aquatic Gap Analysis Project could not have been completed without the generous help of all the people and organizations mentioned in this section. They only made the final products better; any errors or omissions are the sole responsibilities of the IAGAP team.

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Chapter 1

INTRODUCTION

Organization of This Report

This report is a summation of a scientific project. While we endeavor to make it understandable for as general an audience as practical, it reflects the complexity of the project it describes. A glossary of terms is provided to aid the reader, and for those seeking a detailed understanding of the subjects, the cited literature should be helpful. 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.

We begin with an overview of the Iowa Aquatic Gap Analysis Project (IAGAP) mission, concept, and limitations. We then present a synopsis of how the current biodiversity condition of the project area came to be, followed by stream reach mapping, biological data compilation, fish species distribution prediction, species richness, and land stewardship mapping and categorization. Data development leads to the Analysis section, which reports on the status of the elements of biodiversity (natural community alliances and fish species), for the state of Iowa. Finally, we describe the management implications of the analysis results and provide information on how to acquire and use the data.

The Iowa Aquatic Gap Analysis Project Mission

The mission of the Gap Analysis Program is to prevent conservation crises by providing conservation assessments of biotic elements and to facilitate the application of this information to land management activities. The aquatic component of GAP is intended to be integral with terrestrial gap analysis, which has, to date, been the focus of the national program. The Iowa Aquatic Gap Analysis Project is a statewide classification and mapping of aquatic habitats and fish species in Iowa. The goal of IAGAP is to identify and map these aquatic habitats and fish species as well as the conservation status of Iowa waterways to determine how well fish are protected and where "gaps" in their distributions and protection exist.

The Gap Analysis Concept

Like the national terrestrial GAP initiative and the Iowa Gap Analysis Project, IAGAP is primarily a tool to identify and analyze biodiversity in Iowa and the degree to which it is protected. Specifically IAGAP will:

- Provide a standardized base layer for fish sample locational accuracy
- Characterize aquatic biodiversity throughout Iowa at the regional, watershed, and stream reach scales

- Identify the extent to which current management efforts are conserving aquatic biodiversity in Iowa at the regional, watershed, and stream reach scales
- Help to direct management, protection, restoration, and educational efforts regarding Iowa's river resources
- Prioritize conservation efforts
- Provide easy accessibility to all information
- Integrate data with the Iowa terrestrial Gap project

To meet these objectives, it is necessary that GAP be operated at the state or regional level but maintain consistency with national standards.

For an in depth discussion of the complete "GAP concept" for which the IAGAP methodology was based upon, please refer to Scott et al (1993) or the Iowa GAP (terrestrial) final report (Kane et al. 2003).

General Limitations

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

1. IAGAP data are derived from small-scale datasets 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. IAGAP 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 and manage sites of high biodiversity value 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 assure their recovery.

3. IAGAP data products and assessments reflect the content of the underlying NHD stream dataset, in regard to both the attributes and spatial detail. A more spatially detailed NHD dataset is in development for Iowa but was not completed for use during this project's time frame. The stewardship data used for analysis was completed in 2002 for terrestrial Gap and was not updated for this more recent project. Therefore, the fish species and reach protection information is as current as the stewardship dataset.

4. IAGAP is not a substitute for a thorough national or state biological inventory. As a response to rapid fish species and habitat loss, gap analysis provides a quick assessment of the distribution of fish 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 must be continued and expedited, however, in

order to provide the detailed information needed for a comprehensive assessment of our nation's biodiversity. Stream reach and species distribution maps developed for GAP can be used to make such surveys more cost-effective by stratifying sampling areas according to expected variation in biological attributes.

The Study Area

Iowa ranks 30th in the United States in population with about 2.9 million people, and 26th in land area (National Atlas 2005). In agricultural production Iowa ranks first in corn, soybeans, eggs, and pork, and second in red meat production. According to the most recent data available, Iowa ranks third in the nation in the value of farm products exported with eighty-nine percent of the land area in the state in farms. Although Iowa is often referred to as the food capital of the world, manufacturing is the largest source of personal income; retail services, wholesale trade, and government follow (Iowa Department of Economic Development 2005).

Geology, climate and human history have shaped Iowa’s current landscape and biodiversity condition. The lowest land surface elevation in Iowa (480 feet) occurs in the southeastern corner where the Des Moines River empties into the Mississippi River. Elevations gradually increase to the north and west (see map p. 111 in Prior 1991). Iowa’s highest point (1,670 feet) is a knobby ridge of glacial drift in Osceola County.

Geology

The Iowa landscape can be described as a collection of seven landforms of characteristic shapes and features inherited from the geologic past (Prior 1991). These are the Des Moines Lobe, the Loess Hills, the Southern Iowa Drift Plain, the Iowan Surface, the Northwest Iowa Plains, the Paleozoic Plateau and the Alluvial Plains (See Figure 1.1). The transitions from the Missouri Alluvial Plain to the Loess Hills landform or from the Mississippi River Alluvial Plain to adjacent landforms are distinct and easily recognizable. However, the boundaries between other landforms are broad, subtle and often difficult to see unless one knows what to look for. The outlines of the Des Moines Lobe and other landforms can often be seen with satellite images because of differences in soils, vegetation, and drainage patterns.

Iowa’s oldest geological rock strata are igneous and metamorphic varieties that are up to 2.5 billion years old. Except for two locations in the northwest corner of the state, most of these strata are deeply buried under layers of sedimentary rock that range in age from the Cambrian era (530 million years ago) to the Cretaceous (66 million years). These deposits contain large numbers of fossils of marine organisms deposited during periods when the state was part of a vast inland sea.

Millions of years later during the Pleistocene era, continental glaciers covered the state with thousands of feet of ice. It is believed that as many as seven incursions of the ice sheet occurred during a time period referred to by geologists as the Pre-Illinoian (500,000 to 2.5 million years ago). Analysis of this glacial period is complex but there is evidence that the entire state was covered one or more times (Prior 1991). These glaciers deposited deep layers of glacial drift that eroded more severely in the northern than in the southern part of the state. The eroded Pre-Illinoian drift was then overlain in some regions with drift from later glacial advances or covered with a mantle of loess of varying depths.

The later Illinoisan glacier (130,000 to 300,000 years ago) covered only a small area in the southeastern part of the state. The Des Moines Lobe was a southern extension of the Wisconsin ice sheet that occupied north central Iowa relatively recent (10,500 to 30,000 years ago). The Wisconsin glacier advanced and retreated several times leaving deep deposits of glacial till containing large numbers of granite boulders transported from northern latitudes. In the thousands of years that have elapsed since the ice sheets disappeared, moderating climate, accumulation of prairie and woodland plant litter, root systems, and organisms have all contributed to the transformation of raw glacial deposits that are the basis of some of the richest agricultural soils in the world (Prior et al.1982).

The following brief descriptions of Iowa's landforms are adapted from Prior (1991).

The Loess Hills is a unique landform that formed at the end of the last Ice Age about 18,000 years ago. The formation is only one to fifteen miles wide but is about 200 miles long extending from near Sioux City, Iowa to St. Joseph, Missouri. Although deposits of windblown soils (loess) are found in many parts of the world, nowhere else but in China do they reach as high as in Iowa where some of the hills are more than 200 feet above the adjacent Missouri valley. The Loess Hills landform has other features that are easily noticed. Bedrock is exposed naturally in only a few places and the soil has unique physical properties. If the topsoil on the slope of a hill is removed, the exposed loess will erode quickly and deep gullies will form. Even when covered with topsoil, loess can slump, often in a unified way across a slope creating "cat-step" ledges along the sides of hills. However, when a loess hill is cut vertically the exposed wall will stand for decades.

The Des Moines Lobe has a landscape that is gently rolling with abundant moraines, shallow wetland basins or potholes, and a few relatively deep natural lakes. This landform still retains the imprints of recent glacial occupation. Loess is entirely absent. The most prominent landform patterns left by the Wisconsin glacier on the Des Moines Lobe are the end moraines. The Des Moines Lobe is part of the Prairie Pothole Region that extends north and west into western Minnesota, eastern North and South Dakota, and the Canadian Prairie Provinces. Most of the potholes have been drained with ditching and underground tile lines to make way for agriculture. Agriculture was also responsible for greatly increasing the rate at which streams and drainage patterns developed in this geologically young landform. Other interesting features of the Des Moines Lobe are kames, fens, eskers and kettles. Kames are conical shaped hills that were formed when large crevices and chambers within the melting glacier became filled with water-transported deposits of sand and gravel. Fens are unusual wetlands that occur where ground water seeps to the land surface along hillside slopes. Fens support a unique wetland biota including some of the state's rare plants. Fens on the Des Moines Lobe are

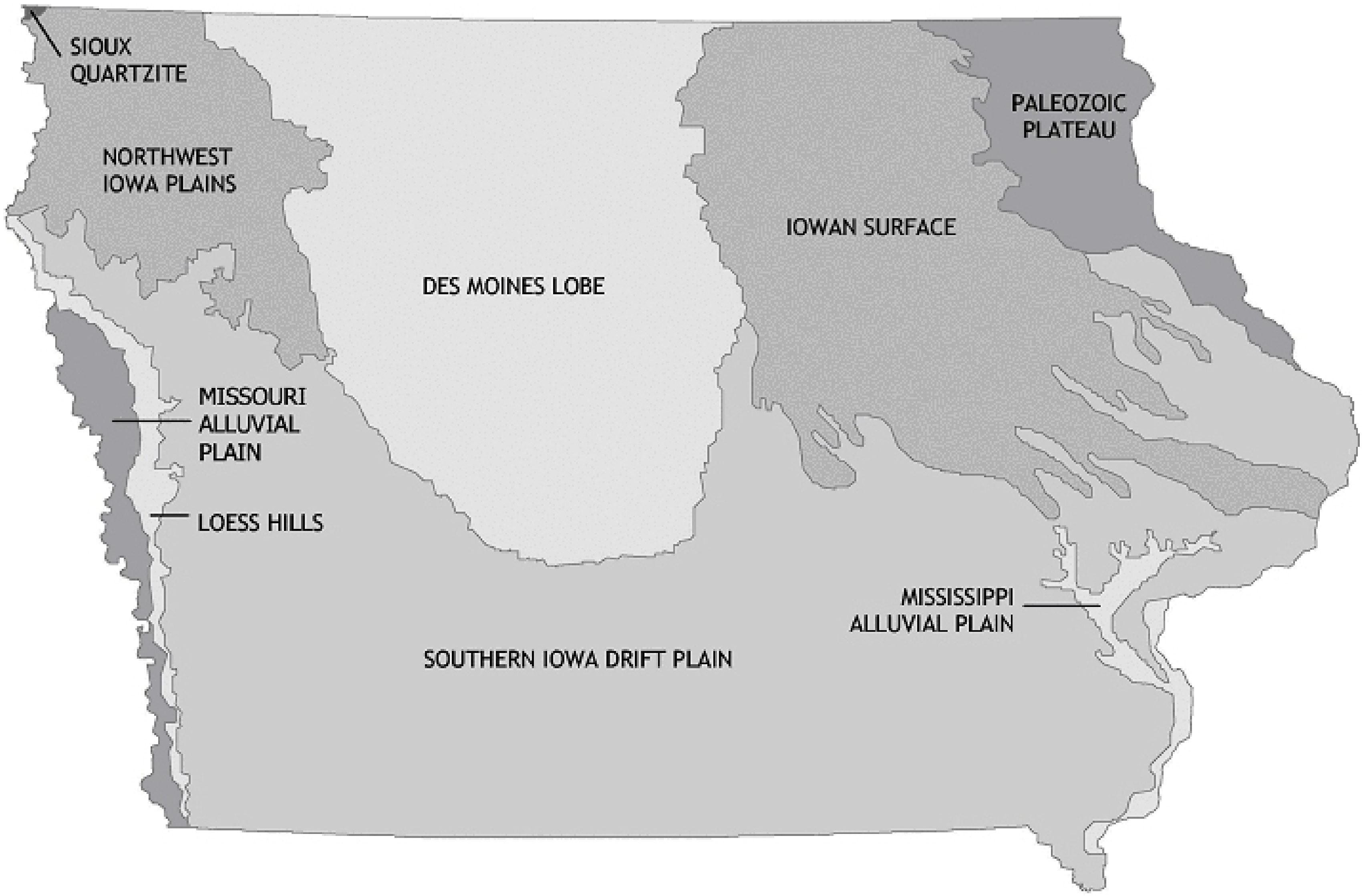

Figure 1.1. Landforms of Iowa, adapted from Prior (1991).

clustered in the northwestern portion of the region. Eskers are narrow winding ridges composed of sand and gravel that mark the location of stream channels that flowed beneath the ice. Kettles are bowl-shaped basins that mark the position of large relatively clean blocks of ice that melted slowly.

The Southern Iowa Drift Plain is the largest of Iowa's landforms. Like the Des Moines Lobe, it is composed almost entirely of glacial drift, but the Pre-Illinoisan glaciers that deposited material in this part of Iowa were much older. As a result, deep glacial drift, ranging from a few to several hundred meters, is the only evidence of their occupation. Instead of poorly drained and relatively level landscapes, streams have had time to erode the land surface and form well-defined drainage systems. Hilltops have similar elevations that reveal the approximate level of the land surface constructed by the last ice sheet. As erosion slowly dissected this landscape, a layer of loess ranging from 2 to 10 meters was deposited over the glacial till. Throughout the Southern Iowa Drift Plain the terrain varies considerably, but the pattern of relief resulting from its history of erosion is the dominant feature of the region. Many of the larger rivers had glaciers standing in their headwaters at the time the Des Moines Lobe was ice-covered. These valleys obtained much of their present width, depth, and alluvial fill from flooding as the Wisconsin ice sheet melted away from north-central Iowa. In many places the rivers have cut through the glacial drift into the underlying sedimentary bedrock. The rough wooded terrain adjoining these valleys supports many scenic and recreational areas and important wildlife habitat.

The Iowan Surface landform extends over a large region of northeastern Iowa and is characterized by long, gently rolling slopes, low relief, and open views of the horizon. Drainage networks are well developed, but stream gradients are low with some scattered areas of poor drainage and natural wetlands. The area was once part of the Pre-Illinoian Southern Iowa Drift Plain but experienced large-scale and more destructive erosion events, the latest occurring during the coldest part of the Wisconsin glaciation 16,500 to 21,000 years ago. Frost action, down slope movement of water-soaked soil materials, and strong winds were the dominant geologic processes in this region. Layers of loess are thin and scattered. Glacial boulders are numerous and many are very large. Elongated ridges and isolated oblong hills called pahas occur in the southern part of the Iowa Surface region. These features are covered with a mantle of silt and sand believed to have accumulated in response to strong northwesterly winds that occurred during the period of glacial cold. Soils mapped on the larger pahas indicate they developed under forest vegetation rather than prairie. Karst topography occurs in the northern part of the landform where cavities in the underlying limestone bedrock collapsed and formed sinkholes. Fens are also present but more scattered than in the Des Moines Lobe.

The Northwest Iowa Plain contains many of the terrain features and geologic materials present in other landforms and is similar in appearance to the Iowa Surface with a uniform low relief. Despite these similarities, the landscape differs from other regions because of a combination of factors. The western uplands of this region are underlain with highly eroded, Pre-Illinoian glacial tills. The eastern part these tills are covered with later glacial deposits from an early Wisconsin glacial advance known as the Sheldon Creek Formation that occurred 6,000 to 16,000 years earlier than the Des Moines Lobe advance. The entire region was then subjected to vigorous erosion activity that accompanied the later advance of the Wisconsin ice sheet. As a result, features of a freshly glaciated landscape were lost as a well-established branching network of streams formed over the entire region. The deeper thickness of the loess mantle, the overall elevation of the land surface, and the present precipitation and vegetation distinguish the Northwest Iowa Plains from the state's other landforms. Windblown loess is abundant and nearly continuous across the region ranging in thickness from 4 to 16 feet. Altitudes throughout the Northwest Iowa Plains are uniformly higher than any other portion of the state and topographically are continuous with the High Plains of the Dakotas. Average annual precipitation is lower than other parts of the state. Thus, the region is higher, drier and less timbered than any other in the state. Although bedrock exposures are rare in the Northwest Iowa Plains, the oldest bedrock in Iowa (Precambrian-age Sioux Quartzite) occurs here along the Big Sioux River.

The Paleozoic Plateau is the most distinctive of Iowa's landforms because of its abundant rock outcroppings, karst topography, a near absence of glacial deposits, many deep narrow valleys, cool-water streams, and heavily wooded uplands. The extent of the deeply dissected landscape is defined by erosion of the underlying sedimentary rock of Paleozoic age. The Paleozoic strata originated as sediments accumulating on the floors of tropical seas that occupied this area 300 to 550 million years ago. But, it wasn't until the time of the Wisconsin glacier, starting more than 30,000 years ago, that the deep entrenchment of the landscape occurred. This erosive process continues to the present day although at a slower pace. Vertical cracks extending through these rocks at various angles are responsible for blocky shapes and sheer faces along river bluffs and road cuts. The boundary between the gently rolling Iowan Surface landform and the deeply carved, high-relief Paleozoic landform can be seen along a line of bluffs that extends in a northwest-to-southeast direction. The eastern boundary of this landform is the high bluffs of the Mississippi River valley. Numerous gorges and ravines cause abrupt local changes in the direction of slopes and exposures. These sites provide abundant cool, moist and wooded habitats rich in diverse communities of plants and animals. Seeps and springs are common features along valley sides where strata of varying permeability are exposed and signify subterranean drainage systems. Ice caves and cold-air (algific) slopes are unique to this area. Unusual microclimates associated with these features support a particularly rare and sensitive biological habitat in Iowa. The steep rocky slopes are unsuited for agriculture and remain heavily forested. Remnant prairies occur on south and west facing slopes. Ecologists believe these prairies were more extensive before the suppression of naturally occurring fires following European settlement.

Alluvial Plains, often called floodplains, are constructed by water flowing off of the landscape and carrying with it boulders, cobbles, gravel, sand, silt, and clay. This process of erosion creates a dendritic-shaped landform of nearly level corridors with varying widths depending on the size and reach of the river. These corridors are largest along the Missouri and Mississippi Rivers but can be found along streams throughout the other landforms. The floodplain is a dynamic landform that is frequently disturbed, sometimes drastically, by flood and drought events. Stream channels may be cut off leaving backwater sloughs or oxbow lakes. Large-scale vertical changes may also occur within the floodplain due to the deposition of alluvium that forms terraces and benches. These structures are level but are elevated above existing floodplains by a distinct slope. Smaller tributaries that enter the floodplain of a larger river often form alluvial fans that may cover older floodplain materials. During low flow periods, wind becomes an important factor in the transport of materials. Exposed sand or soil having little or no vegetation to hold it place can be blown onto floodplain and terraces as well as onto higher elevations along valley margins. Sand dune topography occurs downwind of valley floors. The size, shape, and complexity of alluvial plains depend on the individual river's geological history, the age of its valley, the long-term variations in available water and sediment, the geologic material into which the valley is carved, and fluctuations in the level of the water body into which the river flows. These factors control valley characteristics and affect landforms along alluvial plains throughout the state.

Iowa's Waters

Like our land, the waters of Iowa are diverse. These include natural lakes, constructed lakes, ponds, streams, rivers, and wetlands. Iowa waters tend to be very productive–they are very rich in plant and animal life. This is due largely to the richness of Iowa soils; however, run-off from agricultural and urban areas also contains nutrients which can increase plant growth, sometimes to the extent that it is undesirable. In addition, heavy sedimentation, channelization and agricultural chemical pollution has altered the historic composition of the biological communities found in Iowa's waters.

The following brief descriptions of Iowa's water types are adapted from Project Wild Aquatic (2004) and Harlan et al. (1987).

Lakes

Natural lakes formed by glacial action are common in the north-central and northwest part of the state. Many of the more shallow lakes, marshes and prairie "potholes", present in the early part of the heritage of this state, have been drained and/or filled to become rich cropland, but 31 major natural lakes with a combined surface area of almost 29,000 acres and 17 marsh-like lakes with over 3,000 acres of combined surface area, are still present in Iowa.

Most of our natural lakes are "middle-aged" and have partially filled with windblown and water-carried sediments, vegetative remains from aquatic plants, and soils from eroding shorelines. Most of our marshes are older lakes that have filled with more sediment and plant remains. These waters generally have good water quality, but this can rapidly decline as a result of shoreline development or loss of soil and nutrients from unprotected land in the lake's watershed.

An oxbow lake, another type of natural lake found in Iowa, is formed when river channels change course and sediments block the ends of a meander in the old channel. Larger oxbows are found along the Missouri and Mississippi Rivers and smaller, pond-like oxbows are found along many interior rivers and streams. Man-made oxbows are also found in Iowa as a result of stream channelization.

Constructed lakes include recreational lakes, municipal water supplies, river impoundments, and surface-mine lakes. Over 100 lakes have been constructed in Iowa for recreation. These generally are small; less than one-fourth are over l00 acres.

Iowa streams and rivers have more than 200 dams on 25 major streams that provide water for a variety of purposes. Many are used for municipal water storage, some are used for flood control, others for recreation. These range in size from 15-acre Mitchell Lake to Lake Red Rock, which has a surface area of some 19,000 acres at normal pool level. This number does not include the numerous smaller mill damsites that were constructed on nearly all stream courses and served as centers of commerce during the state's settlement period in the latter half of the nineteenth century.

Ponds

There are more than 87,000 ponds in Iowa. Most are located in the southern half of the state because clay soils found there readily form a water-tight basin. (Soils in northern Iowa tend to be more porous.) Ponds are generally less than 10 acres in size and often man-made. Water quality and habitat in a pond are dependent on watershed management. Ponds with well-managed watersheds can support excellent fish populations and are very important fisheries. Ponds also provide reliable water sources for livestock and wildlife.

Wetlands

Wetlands are areas where soil is saturated for various lengths of time during the growing season. They are transitions between terrestrial and aquatic systems. All wetlands have three things in common: hydric soils, a hydrology where water is on or near the soil surface for most of the growing season, and the presence of hydrophytes.

Wetlands found in Iowa included marshes, wet meadows, bogs, fens, and wet prairies. Iowa marshes include prairie potholes formed during the last ice age, when the Des Moines Lobe of the Wisconsin glacier melted. As the glacier receded, it gouged thousands of shallow depressions to create the area of the northern Great Plains in the U.S. and southern Canada known as the Prairie Pothole region. Due to the rich soils under wetlands, these areas were drained or filled and converted to cropland. Of the estimated four million acres of wetlands in Iowa, only approximately 27,000 acres remain.

Rivers and Streams

Rivers and streams are Iowa's most widely distributed natural aquatic resources. Volume and size of a river or stream depend on the size of its watershed and amount of rainfall. Iowa rivers range in size from intermittent headwater streams, to the Mississippi, which drains nearly one-third of the continental United States. The diversity of plants and animals living in these waters is as varied as their sizes.

Interior Rivers and Streams

Iowa has over 19,000 miles of interior rivers and streams including 87 cold water trout streams located in northeast Iowa with a combined length of 266 miles. The 25 largest interior rivers in the state extend over 3,500 miles and each is fed by numerous smaller tributaries. All interior rivers in Iowa are part of either the Mississippi or the Missouri river drainages. Most of Iowa's interior rivers and streams have channelized stretches–some 3,000 miles of Iowa rivers have been lost to channelization.

Due to the nature of Iowa’s soil, intensive farming practices and drainage, Iowa’s rivers and streams are subject to violent and sudden fluctuations. Complete valley flooding at certain times of the year as well as dried up river beds at other times are not uncommon. Headwater streams tend to be more clear and less subject to water fluctuations. Lower stream reaches are usually more turbid and subject to greater agricultural and industrial pollution.

Rivers form the boundaries of Iowa with the Mississippi and Missouri Rivers making up most of the east and west borders, respectively. These are considered the “Great Border” rivers. The Big Sioux and Des Moines Rivers, which are more characteristic of interior rivers, make up small portions of the northwest and southeast borders.

Mississippi River

The Mississippi River borders Iowa for more than 300 miles and drains two-thirds of the state. It originates in Lake Itasca, Minnesota, and flows some 2,350 miles to the Gulf of Mexico. Through the ages it has formed chutes, side channels, and sloughs while flowing through four to six hundred foot bluffs and carving a valley two to six miles wide. It first served as a corridor for settlement by native Americans from the South and later as a major means of transportation for Euro-American settlers.

The Upper Mississippi River, from the mouth of the Missouri River to Minneapolis, was a mosaic of braided channels with rapids and shallow areas. Water levels were unpredictable and the river was vulnerable to drought and floods. Initial engineering occurred in 1824, when Congress authorized the removal of snags and other obstructions for navigation improvement. In 1905, the Keokuk power dam was constructed and by 1907, work began to form a six foot navigation channel in the Upper Mississippi. The Mississippi River became a major transportation route and the U.S. Army Corps of Engineers constructed locks and dams for navigation on the Upper Mississippi between 1930 and 1940. A nine-foot channel now is maintained by the Corps for barge navigation.

The level of the entire stretch of the river bordering Iowa is controlled by 11 locks and dams. Damming the Mississippi raised water levels so many chutes between islands, and even islands themselves, were inundated. The habitat structure of the river was changed from a continuous, flowing body of water to a series of "lake-like" pools. Each pool or stretch of river between two navigation dams is numbered in reference to the dam at its downstream end. Example: Lock & Dam 12 in Bellevue, Iowa creates Pool 12 above it.

Missouri River

The Missouri River was called the "Big Muddy" because its shifting sands were swirled by relatively fast-moving currents through a broad series of braided channels. The Missouri River Valley bordering Iowa contained lush hunting grounds used by the Dakota, Iowa, Oto, Winnebago, Sac, Fox, and Pottawattami peoples. Fur trading posts were established along the Missouri as bison, elk, deer as well as a diversity of small game, wild fowl and fish were abundant in the river valley.

Engineering work for flood control and navigation has had a profound effect on the Missouri. Early work began from 1876 and 1882, but accelerated channel stabilization occurred in the late 1920s and early 1930s. From 1923 and 1976 the Missouri river channel was altered drastically from its former broad, semi-braided appearance to a narrow, single channel with a series of gentle bends and well armored shoreline. This reduced the length of the river by 18 miles and the channel area by nearly 35,000 acres along the Iowa border alone. Currently, the Army Corps of Engineers maintains a nine foot channel for commercial river traffic, regulating flows using dikes and other structures instead of locks and dams.

Islands, sand bars, brush piles, and other habitat structures disappeared after channelization. Habitat diversity in the channel is nearly non-existent. With the loss of habitat and subsequent fish populations, sport and commercial fishing have suffered greatly in the Missouri. Commercial fishing yielded 50,000 to 80,000 pounds of fish each year between 1940 and 1955. In 1982, only 34 commercial fishing licenses were issued in Iowa.

Climate

Iowa's climate is characterized by strong seasonal variation that is the result of its north temperate latitude and location in the interior of the continent. About 70 percent of the annual precipitation occurs during the warm half of the year (April-September) when the prevailing southern flow of air comes from the Gulf of Mexico. In the cold half of the year (October-March), prevailing winds from the northwest bring masses of cold dry Arctic air to the region. More than half of the annual rainfall comes from thunderstorms that occur during a four-month period (May-August). Hail, wind, floods, lightning and tornadoes often accompany these thunderstorms. The highest mean annual precipitation occurs in southeast Iowa with 34 inches per year, and the rate of precipitation progressively decreases toward the northeast corner where the mean annual precipitation drops below 25 inches per year (Prior 1991). Snow and other frozen forms account for only about 10 percent of the total precipitation. Besides the typical seasonal variation that takes place within each year, there are large variations in annual precipitation. Wet and dry years follow a cyclic pattern with major droughts and years with peak flooding occurring 10 to 12 years apart.

Statewide, annual air temperatures average about 48 degrees Fahrenheit; averages vary from 45-46 degrees in the north to 51-52 degrees in the south. For a more detailed account of Iowa's weather and climate see Waite and Shaw (1982).

Human History

Stone tools, spear points, pottery and burials indicate that humans have inhabited Iowa for about 9,500 years. The following brief account is adapted from Schermer et al. (1995). These authors describe five periods of early human culture: Paleo-Indian (9,500-7,500 B.C.), Archaic (7,500-500 B.C.), Woodland (500 B.C.- A.D.1000), Late Prehistoric (A. D.1000-1650), and Historic (A.D. 1650-1700).

During the time that Paleo-Indians occupied Iowa the climate was cooler and wetter and much of Iowa was covered by boreal and conifer-hardwood forests. Prairie is believed to have been very limited. Paleo-Indians used Clovis and other fluted projectile points to hunt now-extinct large mammals such as mammoth, mastodon, and giant bison.

The Archaic period is viewed as a transitional period between cultures. Climate became warmer and more arid during this period and the boreal forests were replaced with deciduous woodlands mixed with prairies in western regions of the state. Human populations probably depended on bison for food in western Iowa and on deer and elk in eastern Iowa. Human numbers increased substantially towards the end of this period and the use of communal cemeteries indicated that populations were becoming more sedentary.

Woodland peoples continued to hunt deer and bison but also made heavy use of fish and clams in the major river valleys. These peoples became more dependent on cultivated plants and developed domesticated varieties of local native grain crops such as marshelder and goosefoot. Climatic conditions were similar to modern conditions and vegetation patterns were a mixture of forest, woodlands and prairie similar to those found in the early land surveys in the mid-19th century. Population levels continued to increase and in some parts of Iowa there is evidence of large, planned villages. Advanced spear point technology, pottery, artwork, complex mortuary programs, and extensive continent-wide trade networks developed during the Woodland period. Late Woodland peoples introduced the bow and arrow into the Midwest and corn was introduced after A.D. 800. The Effigy Mound Culture (A.D. 650-1000) is characterized by groups of linear, effigy, and conical mounds in northeastern Iowa.

The Late Prehistoric period marked the beginning of a distinctive adaptation to the tall grass and mid grass prairies of the northern Great Plains. Native peoples developed improved corn varieties, new storage methods for garden crops, earthlodge houses and a complex social organization. They also used the meat and hide of the bison for food, clothing, robes, and coverings for tipis and lodges. Bones were modified into a variety of tools. The Oneota culture dominated much of eastern Iowa as well as parts of central and northwestern Iowa during the Late Prehistoric period. The Oneota lived in widely scattered but densely populated settlements surrounded by huge uninhabited territories that were probably used for hunting, fishing, plant collecting and agriculture. The Oneota complexes are ancestral to several historic tribes such as the Iowa, Oto, Missouri and Winnebago.

The first Native Americans encountered by the French fur traders in Iowa were the Oneota. Early French trade goods such as glass beads, finger rings, and gunflints have been found at Oneota sites in northeastern and northwestern Iowa. After 1650, increasing European influences, including disease, disrupted the structure of and relationships among Indian groups such as the Iowa, Oto, Omaha, Missouri and Dakotas. These tribes gave way to Great Lakes groups including the Sauk, Mesquakie (Fox), Winnebago, and Potawatomi.

Early inhabitants were most likely mobile depending largely on bison in the western part of Iowa and on deer and elk in the eastern part of the state. In addition to the hunter-gather lifestyle, the Woodland tradition (500 B.C. – 1000 A.D.) saw an increased dependence on cultivated plants. Cultivation continued to increase and improve through the late pre-historic period (1000 A.D – 1650 A.D.) along with increased levels of social and political complexity. Mound building peoples occupied areas along the Mississippi River.

By the time of early exploration by Europeans, Native American tribes included the Sioux, Omaha, Pottawattamie, and Oto in the west and the Sauk and Mesquakie (Fox) in the east. In the late 1600s pressure from Euro-American competition for tribal alliances, trade competition, land dispossession and disease changed the cultural landscape.

Iowa was part of the Louisiana Purchase in 1803, and following the Lewis and Clark Expedition, the federal government built a series of forts along the Mississippi River. In the first half of the 19th century, the federal government negotiated land treaties with Native American tribes prior to relocating them further west. Much of eastern Iowa was opened for non-Indian settlement by 1833. In the 1850s the Mesquakie tribe purchased land in Tama County and this settlement continues to the present day.

Early European settlements and communities were common along major river ways and later along the railroad as railways spread throughout the state in the latter half of the 1800s. Iowa was admitted to the Union in 1846 and most of Iowa's cities and towns were established and farms covered the state by the mid-1800s (Schermer et al. 1995).

Iowa’s early settlers came primarily from other parts of the United States, especially from eastern and southern states. In the mid- to late 1800’s, Iowa attracted increasing numbers of people from northern and western Europe (Horton and Schwieder 1982).

Current Condition of Biodiversity

Intensive agriculture, urban development, drainage, soil erosion, deforestation, channelization of streams and rivers, and an extensive grid of transportation corridors have reshaped Iowa’s landscapes since the beginning of European settlement more than a century ago. The tallgrass prairies that helped develop the state’s highly productive soils have been reduced by more than 99 percent (Smith 1998) and about 95 percent of the once abundant prairie potholes have been drained (Bishop et al 1998). Over half of the original forest has been lost and the remainder has been severely fragmented and disturbed (Jungst et al 1998). Prairie streams throughout Iowa have been adversely affected by intensive row crop activity, accelerated rates of soil erosion, and in-channel sedimentation (Menzel et al. 1984). Most of the natural areas that remain have experienced some kind of disturbance by grazing, fire suppression, or drainage.

Perspectives on the declining flora and fauna of Iowa were presented in a special symposium at the 109th session of the Iowa Academy of Science held at Clarke College in Dubuque, April 25-26, 1997. Proceedings of the symposium were published in two issues of Vol. 105 of the Journal of the Iowa Academy of Science

Much of Iowa’s biodiversity occurs along stream corridors where the land is less suitable for agriculture. Bluffs and bottomlands along the Mississippi River on the eastern border of the state, and the Loess Hills and Missouri River on the western border represent some of the best of the remaining natural habitats. These major rivers together with smaller rivers and stream corridors throughout the state are important for species to move from place to place. Because most of these corridors generally follow a north-south orientation they are especially important for migratory birds. Of the state's inland river corridors, the Des Moines River traverses the entire middle of the state and may have the greatest potential for protecting and restoring biodiversity. The Loess Hills, grassland areas in the northwest and south central, the Iowa Great Lakes, and the northeast paleozoic plateau are also important centers of biodiversity and have potential for restoration and management.

Large free-ranging herbivores such as bison and elk and large predators such as mountain lion, wolverine, grizzly and black bears, and timber wolf were extirpated from the state in the early 1900's (Bowles, et al). Large birds such as trumpeter swan, whooping crane, and prairie chicken also disappeared then. Many fish species that inhabit prairie streams, including the blackchin shiner, ironcolor shiner, gilt darter, and redside dace also have not been sampled since this time. Currently, the Iowa Department of Natural Resources lists about 153 species of plants and 84 species of animals as threatened or endangered. Of these, nine species are on the federal list. These include three birds (bald eagle, piping plover, least tern), two mammals (Indiana bat, Gray wolf), two fish (pallid sturgeon, Topeka shiner), one mussel (Higgenseye), and one land snail (Pleistocene). A total of 17 fish species are on the state threatened and endangered list (571 IAC 77.2 (2004)). Many more are declining in numbers and their range distributions are shrinking because of habitat loss, pollution and perhaps other causes.

Games species, such as deer, pheasants, turkey, trout, bass and walleye, have been intensively managed since the 1930's for hunting recreation and their populations are healthy. State-owned wildlife management areas, although not managed primarily for biodiversity, provide habitat for both game and nongame species. Furbearers, such as muskrat, fox, and beaver, as well as commercially harvested fish species such as the shovelnose sturgeon are relatively abundant but have lost much of their economic value in recent years. The Iowa Department of Natural Resources (IDNR) has actively restored sustainable populations of Canada geese, white-tailed deer, eastern wild turkey, river otter, peregrine falcon, trumpeter swan, and prairie chicken. A few species that were once extirpated have returned with the help of strict protection (bald eagle, sandhill crane, bobcat). Still other species such as the cattle egret have moved into the state because of natural range expansion (Dinsmore 1998). Occasional recent sightings of mountain lion and timber wolf may indicate these large predators are moving back into the state, perhaps attracted by the large and thriving white-tailed deer herd. However, exotics like bighead and silver carp are also expanding their ranges into Iowa.

The Nature Conservancy and the Iowa Natural Heritage Foundation have been active in the protection, restoration and management of important natural areas. Organizations such as Ducks Unlimited, Pheasants Forever, and Whitetails Unlimited have contributed funds and volunteer labor towards habitat restoration. Education programs such as Fish Iowa!, Corridors of Exploration: Iowa's Rivers, and Iowater, focus specifically on aquatic recreation, appreciation and conservation. These programs will provide the societal foundation necessary for successful conservation of aquatic biodiversity.

Chapter 2

STREAM REACH DATASET CREATION FOR IOWA

Introduction

Iowa Aquatic Gap Analysis Project (IAGAP) has evolved from terrestrial GAP as a way to assess the biodiversity and protection status of aquatic ecosystems. As with terrestrial GAP, a framework was established within which certain attributes were mapped. The focus of IAGAP was to generate prediction data for fish species and show the current protection for those fish using stream reach length within protected property boundaries as a unit of measure. The mapping, modeling and evaluation process was multi-stepped; this chapter will describe the creation of the Iowa Stream Reach (ISR) dataset. The fish prediction modeling and biodiversity analysis information are found in later chapters.

General Background

IAGAP is comprised of 56 HUC 8 watersheds that overlap Iowa plus the watershed that contains the Des Moines River headwaters for a total of 57 watersheds (see Figure 2.1).

The framework chosen as the base for fish prediction modeling for IAGAP was the National Hydrography Dataset (NHD) produced by the USGS. The NHD was produced by integrating the USGS DLG data with the USEPA RF3 reach information and updating the result. The dataset is a nationwide comprehensive collection of information about surface water features. For more information about the creation, content and usage tools for the NHD, visit http://nhd.usgs.gov/. At the time the project began, datasets were offered by hydrologic unit code (HUC) 8 at a medium resolution of 1:100,000 in the ArcInfo coverage format. It was decided that modifications would be made to the standard NHD for Iowa to better reflect the IAGAP modeling needs.

The ISR dataset creation process had three main phases. Pre-processing work on the NHD was done at the GIS Facility at Iowa State University; that result was sent to the Missouri Resource Assessment Partnership (MoRAP) in Columbia, Missouri for further attribute generation; that result was returned to the GIS Facility for final processing and checking. The processing steps to achieve this modified dataset are explained below.

Methods

Pre-Processing

The original NHD datasets for 57 HUC 8 watersheds giving spatial coverage for Iowa were downloaded from the USGS NHD ftp site. An AML called Append_NHD was

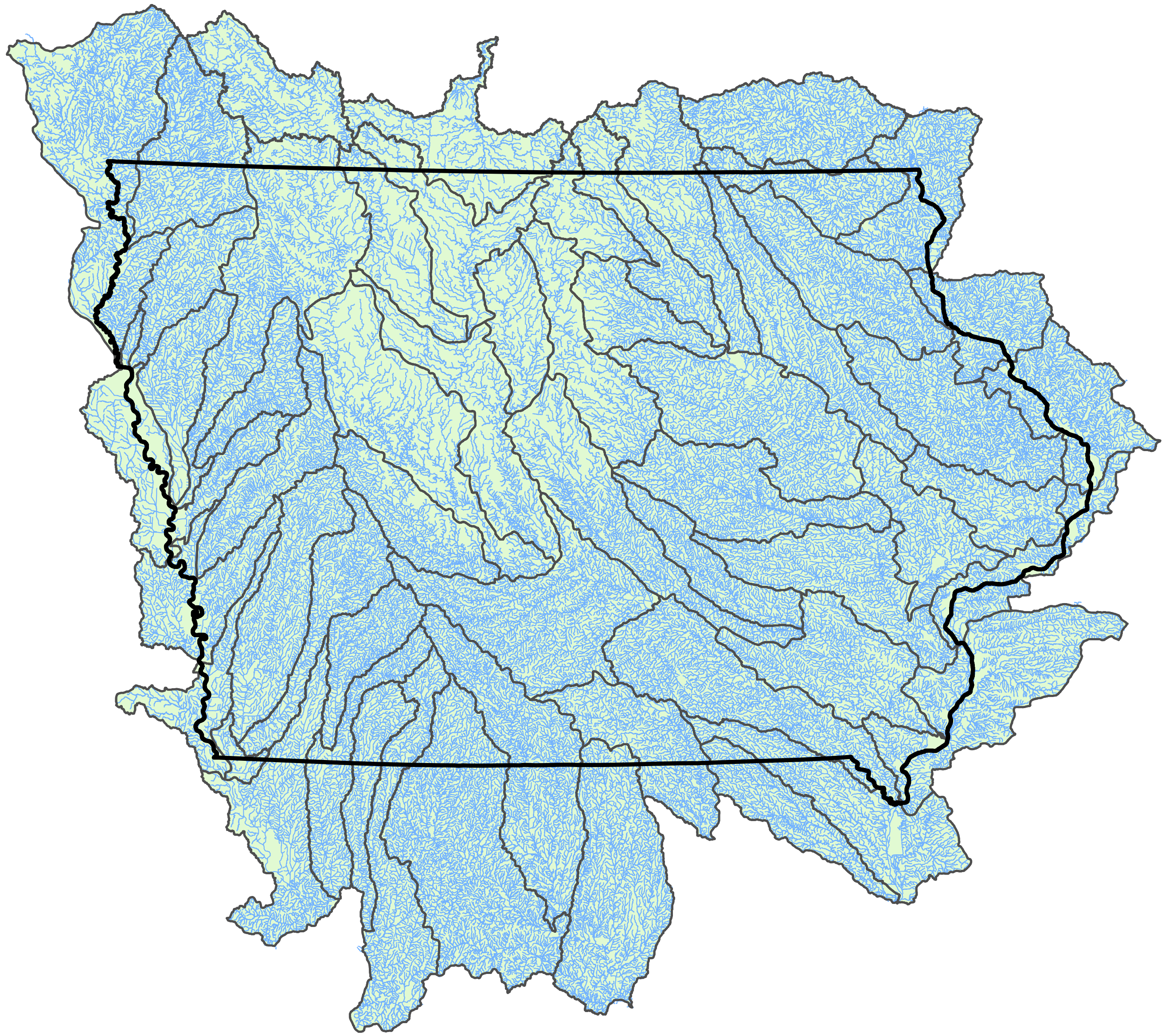

Figure 2.1. Iowa Aquatic Gap Analysis Project study site showing 57 HUC 8 watersheds and the Iowa Stream Reach dataset.

downloaded from the NHD website; it was run in ArcInfo 8 to properly combine the 57 workspaces into a single workspace. The datasets were in geographic coordinate space and after appending, were projected to UTM zone 15, NAD83. An AML from MoRAP was run on the reach dataset that pulled certain attributes from the drain and reach route and section tables and attached them to the reach attribute table. The result was an ArcInfo coverage with attributes necessary for further processing. As a part of this process, the included HUC 8 boundary polygons were extracted from each watershed dataset and merged. The result was one coverage with all 57 HUC 8 boundary polygons; a subset of this dataset was used as the base for fish ranges, fish richness and some analysis summaries (see Chapter 3: Mapping Geographic Ranges for an explanation why subset was used).

Upon examination of the statewide reach coverage, an area of lower stream network density was discovered in northwest Iowa. It appeared to align with USGS 100K quadrangle boundaries and did not reflect natural causes. The Geological Survey Bureau (GSB) of the Iowa Department of Natural Resources (IDNR) digitized stream reaches in the affected area using the 24K USGS topographical imagery as a backdrop. They filled in “missing” reaches to achieve a density that matched the surrounding area. The GSB also created new reach codes for each segment. This data was received as a shapefile and converted to an ArcInfo coverage. It was slightly modified spatially to align with the base NHD reach coverage. The densified arcs were merged into the NHD arcs and topology was recreated. An attribute was added to the table to reflect if the arc was densified or not. A unique segment ID was created for each arc by concatenating the NHD reach code and the ArcInfo internal ID of the coverage. The reach code was created by the developers of the NHD to be a unique identifier and for the most part it was unique. However there were situations where 2 distinct segments had the same reach code. This was consistent with NHD policy but problematic for our modeling techniques, so we created our own segment-based unique ID.

Before the Iowa Stream Reach coverage could be sent to MoRAP for further processing, several preliminary processing steps were completed. Processing for the state was done at the HUC 8 level; reaches for each watershed were extracted by HUC number. This was done for several reasons. Smaller datasets drew more quickly on the screen and speeded processing time; second, several students worked on this dataset and they were assigned data by watershed; lastly, as a watershed was completed, it was sent to MoRAP. The preliminary processing steps were as follows. First, the coverage was built to create polygon topology and polygons disconnected from the flow network (ponds) were deleted. Second, disconnected stream segments were evaluated for accuracy using 24K USGS topographical imagery and aerial photography. If it was apparent that the segment could be added to the flow network based on the presence of an obvious channel in the aerial photography or a blue river line in the topography map, then a segment was digitized and given a new reach code and segment ID. It was also flagged in a new attribute named Extended or Add_Rch, depending on the circumstance. Disconnected reaches that could not reasonably be attached to the network were flagged in the attribute Discon. Both the disconnected polygons and the disconnected segments were identified for processing by using a script, aselectconnect2.ave, from the ESRI ArcView ArcScripts library, http://arcscripts.esri.com/details.asp?dbid=11604.

Because of processing requirements of MoRAP AMLs, loops or braids in the stream network had to be flagged so they could be temporarily removed during attribute processing. An attribute named Ctype was created to indicate whether the stream segment was a primary or secondary channel. Once a loop was discovered, the 1:24K topography map was displayed in the background along with an aerial photo from 1994 to determine the channel type. Certain NHD attributes were also used to determine the primary channel (Flow, Level) however the aerial photo usually gave a better representation of reality.

The GSB also created an updated reach name dataset for 55 of the 57 watersheds. The GSB used their statewide rivers coverage as a standard for names. The name attribute changes were transferred to the NHD by joining on the reach code.

MoRAP Processing

The stream reach data for Iowa was sent to MoRAP GIS technicians for the bulk of attribute generation. Even though several watersheds were sent to them as they were completed, we later learned that processing was done once all watersheds were received to allow for correct stream order, downstream link and other watershed-position sensitive variables to be calculated. We also learned later that 15 of the watersheds that overlap the Missouri border were not processed based on the datasets we sent MoRAP (see Figure 2.2). Since MoRAP originally processed those watersheds for Missouri's Aquatic GAP project, we received those watershed datasets. This had an impact on the segment ID for reaches in those 15 watersheds since MoRAP generated a segment ID that was formatted differently than ours.

ArcInfo AML scripts were run on the datasets at MoRAP to populate new attributes with data from existing datasets. For example, the attribute Soil Texture was generated from the NRCS STATSGO Soil Database and the attribute Rockies was generated from the Geology of the Conterminous United States. Other new attributes were populated by calculations based on the topology of the dataset; examples of these are Strahler, Link and Dlink. In total, MoRAP added about 50 attributes to the dataset, however some attributes duplicated the same or similar information. For example, Subregion was designated as a code and as a text field. Also, some attributes were intermediate values needed to calculate a final value but were left in the dataset. For more information about the Aquatic GAP processing done at MoRAP, visit their website at http://www.cerc.cr.usgs.gov/morap/projects.asp?project_id=1.

ISU GIS Facility Post-Processing

The ISU GIS Facility received the enhanced NHD data for Iowa from MoRAP as two datasets split between the 15 watersheds that overlap the Missouri border and the rest of the 42 watersheds that cover the IAGAP study site (see Figure 2.2).

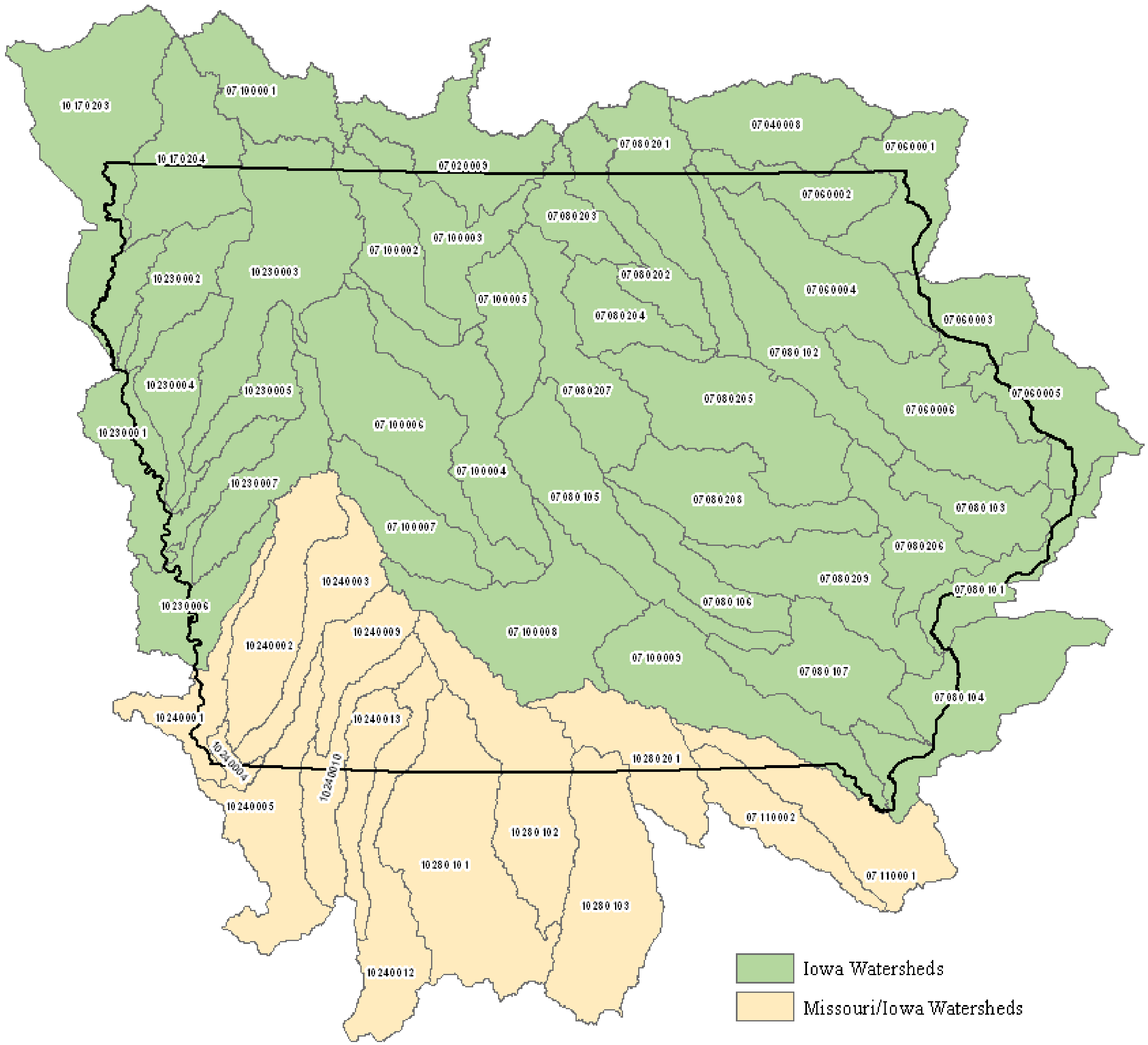

Figure 2.2. Missouri and Iowa watersheds separated by processing procedure.

The attributes for the two datasets did not match exactly so fields found in one dataset but not the other were added to the necessary one before merging. The ArcInfo Append command requires the fields to be the same for input datasets. The missing fields were all core NHD attributes, meaning they came as default with the coverages we originally downloaded. Also, those same NHD attributes were in the watershed tables we sent to MoRAP so in order to repopulate the dataset that was returned to us, we joined the table from both datasets on the Segment ID field and copied the data into the empty fields.

The purpose for the creation of the ISR dataset was to enable fish prediction modeling and the modeling was based on knowing values of certain key attributes. MoRAP only created attribute values for the reaches designated as primary channels; the secondary channels (the lower flow side of a loop or braid) were kept in the dataset but were missing values for many necessary attributes. Therefore, in order to create the dataset necessary for modeling, we selected only primary channel reaches and created a new ISR dataset. To enable easier attribute editing, the new modeling ISR was converted from a coverage to a geodatabase feature class. From this point on, unless otherwise noted, all the processing done was only on the modeling ISR dataset.

Upon examination of the attribute table, it was discovered that some attribute values were either incorrect or blank. We also noticed that some necessary attributes were not in the table. For a complete list of attributes in the modeling dataset, see Table 2.1. We fixed the missing or incorrect values using ancillary datasets or by manual examination of the NHD dataset. The attribute GeoOrder was found to have incorrect values in NW Iowa but the values were not fixed. The ancillary dataset that the values were based upon, 250K Geology of Iowa, showed a value inconsistency in adjoining polygons that displayed as a vertical line. This was probably an artifact from the creation of that geology dataset and was too time consuming for staff to correct.

Table 2.1. List of attributes from Iowa Stream Reach Dataset

Attribute	Description	Attribute	Description
OBJECTID	Internal ID	MIN_ELEV	Elevation of To Node
Shape	Geometry	GRADRCHMKM	Reach Gradient
FNODE_	From Node ID	GRADSEGMKM	Segment Gradient Excluding Headwaters
TNODE_	To Node ID	RGRAD_SUBR	Reach Gradient Category by Subregion
LPOLY_	Left Poly ID	SDISCR_11C	Size Discrepancy 11 Classes
RPOLY_	Right Poly ID	SDISCR_2C	Size Discrepancy 2 Classes
LENGTH	Arc Length	SOIL_TEXT	Soil Texture
NHD_MODEL_	Internal ID	SOILTXTENG	Soil Texture
NHD_MODEL_ID	Internal ID	GEOORDER	Geologic Order
FTYPE	Feature Type	UNIT	Geologic Unit
FCODE	Feature Code	ROCKDESC	Description of Rock Unit
FLOW	Flow	LINKR	Stream Link Category
RCH_CODE	Reach Code	DLINKR	Downstream Link Category
RCH_DATE	Reach Date	GRADSEGR	Categorical GradSegMKM
GNIS_ID	Geographic Name ID	COM_ID	Internal ID
NAME	Reach Name	RCH_COM_ID	Internal ID
CTYPE	Channel Type	WB_COM_ID	Internal ID
HUC	HUC Code	LEVEL_path	Main Channel Value
SEG_ID	Segment ID	TEMP_CODE	Temperature Code
EDU	Ecological Drainage Unit	MAXELEVR	Categorical Maximum Elevation
STRAHLER	Stream Order	SDISCR_5C	Size Discrepancy 5 Classes
LINK	Reach Link	SUBREGION	Subregion Name
DOWNORDER	Downstream Order	SUBREGION_CODE	Subregion Code
DLINK	Downstream Link	Shape_Length	Reach Length
SSIZE_CODE	Reach Size	GradrchR	Catergorical GradRchMKM
DSIZE_CODE	Downstream Reach Size	MinElevR	Categorical Minimum Elevation
MAX_ELEV	Elevation of From Node	Pool	Great River Pool Code

Many attributes had continuous values; the wide range of possible values would make modeling quite difficult. Those attributes were recalculated into categories that better suited the Aquatic GAP modeling process. The categorical attributes are designated with an “R” at the end of the attribute name. The categories for each of these variables were decided by staff at MoRAP. For a list of which variables were actually used in the modeling process, see Chapter 4, Table 4.1.

Much of the fish sample data collected to provide input to the modeling process was for the Mississippi River and to a lesser extent, the Missouri River. Some of these sample points could only be mapped to a pool number or general river confluence; no spatial coordinates were available. Not wanting to lose these datasets from the modeling process, a pool attribute was created for the two great rivers and reaches falling into the pools were given that pool number designation. For more information on the justification for this process, see Chapter 4: Great River Models. The Missouri River doesn’t have officially designated pools, so virtual pools were created based on river segments from the Missouri River Benthic Consortium (Berry and Young 2001).

Results

The creation of the Iowa Stream Reach dataset was a long, multi-step process. It resulted in a dataset with almost 84,000 segments and 76,000 individual reach codes (see Figure 2.1). Out of the 54 variables in the ISR dataset, 25 are internal IDs or duplicate variables of some kind leaving 29 useful potential modeling variables. Even though the MoRAP Aquatic GAP modeling process was used as a guide, our actual modeling process differed significantly from theirs. Relevant to this chapter are the differences in the underlying NHD dataset used for modeling. Some variables that MoRAP created for their dataset were not used in IAGAP and we added some variables we thought might prove useful to our particular situation. The most notable of the variables we chose not to create was the valley segment type (VST). The draft protocol for Aquatic GAP developed by MoRAP included the creation of a VST variable and this was used by South Dakota for their Aquatic GAP modeling. The VST is a coded concatenation of a series of variables that result from a unique combination of values. Every reach with the same VST would have the same values for each of the attributes that make up the VST. For example, if the VST comprised the three variables temperature, flow and link and one reach has a temperature code of 0, a flow code of 1 and a link code of 4, then the VST for that reach would be 014. Every other reach with a VST of 014 would have the same values for those three variables. After discussion with a spatial statistician at Iowa State University, IAGAP staff decided to forego using the concatenated VST and develop models using each of the input variables separately. As it turns out, MoRAP decided not to use the VST variable in its final modeling procedure either.

Limitations and Discussion

This dataset is the most comprehensive, spatially detailed and attribute-rich dataset for rivers that covers the extent of Iowa. Given that, there are limitations to this dataset that need to be discussed. These limitations go beyond its use as a framework for fish species modeling; they affect all uses of this dataset and should be taken into consideration. These limitations fall into two general categories: spatial and content. Each category will be discussed below.

Spatial

The most obvious of the spatial limitations of the Iowa Stream Reach dataset is that it is based on the 1:100,000 scale USGS Digital Line Graph hydrography. Streams depicted at that scale are larger and generally have well-defined channels. For statewide, and some county-wide uses, this scale contains sufficient detail. However, for larger scale areas (towns, parks, small watersheds) the smaller headwaters and tributaries will not be present. With the abundance of aerial photography and digital 1:24,000 topographic maps, it becomes easy to find streams that are not in the ISR dataset. The effect of this coarser scale stream dataset on IAGAP modeling was that some fish sample locations could not be used to generate models since their locations appeared on stream reaches not present at the 1:100,000 scale. These streams are most likely headwaters and possibly second order streams, which may not be present in the NHD version used for IAGAP species predictions. With this coarse-scale model approach, errors of commission will be more common than errors of omission. In other words, over estimation of a species distribution is more likely. A medium resolution NHD dataset based on the 1:24,000 topographic maps is being created as this project nears completion.

Ancillary datasets included with the original NHD data were HUC 8 watersheds. These 57 watersheds are contained in the data package for IAGAP and were not edited spatially. The 57 individual watersheds were merged into one comprehensive dataset for ease of use. Upon close inspection, users will notice stream reaches overlapping watershed boundaries. This is because the watershed boundaries were not generated from or in conjunction with, the NHD dataset; they were imported from a 1:250,000 scale dataset (USGS 2000). Reaches are associated with their HUC by a code contained in the reach code attribute. In this way reaches can be subset to a particular HUC without doing a spatial clip that may lose reaches that overlap the HUC boundary.

The last of the major spatial concerns involves inconsistent or odd reach representations that are an artifact of the original NHD dataset. Since the NHD was based on the 1:100,000 DLG lines, when those quadrangles were joined to make a nationwide dataset, mismatches at the quadrangle boundaries occurred. Sometimes a reach began or ended abruptly at a quadrangle boundary or, if the line continues, the attributes were different. No attempt was made by IAGAP staff to correct these; they were accepted as part of the errors inherent in any dataset. A few odd reaches were noticed in working with the data.

The most notable one is the whirlpool shown in Figure 2.3; the area is the Mississippi River main channel to the east of Allamakee County.

Figure 2.3. Example of odd reach arcs.

Content

In the attribute table, major rivers and streams have a name value. The NHD User's Guide acknowledges that although the names came from the Geographic Names Information System (GNIS), they may have been attached to the wrong reach in some cases. As was mentioned earlier in the chapter, IDNR made many updates to the names field of the Iowa Stream Reach dataset. Therefore, we believe the ISR dataset is more accurate regarding stream names than the original NHD. However, we expect there are still errors in this field.

The stream reach attribute table contains many variables, most of which came from ancillary datasets. For various reasons, some of the variables have blank values for some records. For example, the EDU variable (ecological drainage unit) has zeros for Iowa processed reaches because EDU codes have not been developed for Iowa yet. Missouri processed reaches have a code since they have EDUs completed for the state. We chose to leave this variable in the final dataset so that once IA EDUs are completed, the values can easily be added. The variables based on US geology (GeoOrder, Unit, RockDesc) were kept in the dataset even though we did not use them in the modeling process due to value errors. The majority of the study site has valid values in those geology variables and the values in question are similar enough to warrant inclusion in the final dataset.

Chapter 3

BIOLOGICAL DATA COMPILATION APPROACH

Introduction

Before the implementation of the Iowa Aquatic Gap Analysis Project (IAGAP), project coordinators had no sense of the breadth of biological sampling data available for fish species. However, as it is an essential part of any Aquatic GAP project, it was considered important to have the most comprehensive biological data set possible. Through a comprehensive data acquisition and organization program, we were able to compile a fish species occurrence database that we believe satisfies this objective.

Selecting Species

Before compiling any data, it was essential to determine what types of information would be captured. Therefore, the design of the database and creating a species list of fishes found in the rivers and streams in the State of Iowa were the first steps implemented. In formulating a riverine fish species list, it was important to us to include both historic, as well, as recent sources. This would ensure that we included species that may have been in Iowa historically but for which no data currently exists. We derived the species list by using several published and unpublished sources from both the state and national level. Such sources included websites (IDNR 2002, NatureServe 2004), species check lists (Aitken 1936, 1940; Bailey 1940, 1951, 1956) and fisheries guides and atlases (Harlan and Speaker 1951, 1969; Harlen et. al 1987; Lee et al. 1980). During the data entry process, the species list was altered to include additional species (mostly exotics) newly uncovered in the data or reported by fisheries biologists of the Iowa Department of Natural Resources. The list was further altered during the professional review process when reviewers rejected two species, *Esox niger* (chain pickerel) and *Erimyzon oblongus* (creek chubsucker), originally included in the species list. This finalized version of the list, which includes 157 fish species (143 native and 14 exotic), was used for the remaining duration of the project (Table 3.1).

Table 3.1. Iowa species list of fishes.

Scientific Name	**Common Name**
Acipenser fulvescens	lake sturgeon
Alosa alabamae	alabama shad
Alosa chrysochloris	skipjack herring
Ambloplites rupestris	northern rock bass
Ameiurus catus	white catfish
Ameiurus melas	black bullhead
Ameiurus natalis	yellow bullhead
Ameiurus nebulosus	brown bullhead

Amia calva	bowfin
Ammocrypta clara	western sand darter
Anguilla rostrata	american eel
Aphredoderus sayanus	pirate perch
Aplodinotus grunniens	freshwater drum
Campostoma anomalum	central stoneroller
Campostoma oligolepis	largescale stoneroller
Carassius auratus	goldfish
Carpiodes carpio	river carpsucker
Carpiodes cyprinus	quillback carpsucker
Carpiodes velifer	highfin carpsucker
Catostomus commersoni	white sucker
Chaenobryttus gulosus	warmouth
Clinostomus elongatus	redside dace
Cottus bairdii	mottled sculpin
Cottus cognatus	slimy sculpin
Couesius plumbeus	lake chub
Crystallaria asprella	crystal darter
Ctenopharyngodon idella	white amur
Culaea inconstans	brook stickleback
Cycleptus elongatus	blue sucker
Cyprinella lutrensis	red shiner
Cyprinella spiloptera	spotfin shiner
Cyprinus carpio	common carp
Dorosoma cepedianum	gizzard shad
Dorosoma petenense	threadfin shad
Erimystax x-punctatus	gravel chub
Erimyzon succetta	lake chubsucker
Esox americanus	grass pickerel
Esox lucius	northern pike
Esox masquinongy	muskellunge
Etheostoma asprigene	mud darter
Etheostoma caeruleum	rainbow darter
Etheostoma chlorosomum	bluntnose darter
Etheostoma exile	Iowa darter
Etheostoma flabellare	fantail darter
Etheostoma microperca	least darter
Etheostoma nigrum	johnny darter
Etheostoma spectabile	orangethroat darter
Etheostoma zonale	banded darter
Fundulus diaphanus	banded killifish
Fundulus dispar	starhead topminnow
Fundulus notatus	blackstripe topminnow
Fundulus sciadicus	plains topminnow
Gambusia affinis	mosquitofish
Hiodon alosoides	goldeye
Hiodon tergisus	mooneye
Hybognathus argyritis	western silvery minnow

Hybognathus hankinsoni	brassy minnow
Hybognathus nuchalis	mississippi silvery minnow
Hybognathus placitus	plains minnow
Hybopsis amnis	pallid shiner
Hypentelium nigricans	northern hog sucker
Hypophthalmichthys molitrix	silver carp
Hypophthalmichthys nobilis	bighead carp
Ichthyomyzon castaneus	chestnut lamprey
Ichthyomyzon fossor	northern brook lamprey
Ichthyomyzon unicuspis	silver lamprey
Ictalurus furcatus	blue catfish
Ictalurus punctatus	channel catfish
Ictiobus bubalus	smallmouth buffalo
Ictiobus cyprinellus	bigmouth buffalo
Ictiobus niger	black buffalo
Labidesthes sicculus	brook silverside
Lampetra appendix	american brook lamprey
Lepisosteu oculatus	spotted gar
Lepisosteus osseus	longnose gar
Lepisosteus platostomus	shortnose gar
Lepomis cyanellus	green sunfish
Lepomis gibbosus	pumpkinseed
Lepomis humilis	orangespotted sunfish
Lepomis macrochirus	bluegill
Lepomis megalotis	longear sunfish
Lepomis microlophus	redear sunfish
Lota lota	burbot
Luxilus cornutus	common shiner
Lythrurus umbratilis	redfin shiner
Macrhybopsis gelida	sturgeon chub
Macrhybopsis hyostoma	shoal chub
Macrhybopsis meeki	sicklefin chub
Macrhybopsis storeriana	silver chub
Margariscus margarita	pearl dace
Micropterus dolomieu	smallmouth bass
Micropterus punctulatus	spotted bass
Micropterus salmoides	largemouth bass
Minytrema melanops	spotted sucker
Morone americana	white perch
Morone chrysops	white bass
Morone mississippiensis	yellow bass
Moxostoma anisurum	silver redhorse
Moxostoma carinatum	river redhorse
Moxostoma duquesnei	black redhorse
Moxostoma erythrurum	golden redhorse
Moxostoma macrolepidotum	shorthead redhorse
Moxostoma valenciennesi	greater redhorse
Nocomis biguttatus	hornyhead chub

Notemigonus crysoleucas	golden shiner
Notropis anogenus	pugnose shiner
Notropis atherinoides	emerald shiner
Notropis blennius	river shiner
Notropis boops	bigeye shiner
Notropis buchanani	ghost shiner
Notropis chalybaeus	ironcolor shiner
Notropis dorsalis	bigmouth shiner
Notropis heterodon	blackchin shiner
Notropis heterolepis	blacknose shiner
Notropis hudsonius	spottail shiner
Notropis nubilus	ozark minnow
Notropis rubellus	rosyface shiner
Notropis shumardi	silverband shiner
Notropis stramineus	sand shiner
Notropis texanus	weed shiner
Notropis topeka	topeka shiner
Notropis volucellus	mimic shiner
Notropis wickliffi	channel shiner
Noturus exilis	slender madtom
Noturus flavus	stonecat
Noturus gyrinus	tadpole madtom
Noturus nocturnus	freckled madtom
Oncorhynchus mykiss	rainbow trout
Opsopoeodus emiliae	pugnose minnow
Osmerus mordax	rainbow smelt
Perca flavescens	yellow perch
Percina caprodes	northern logperch
Percina evides	gilt darter
Percina maculata	blackside darter
Percina phoxocephala	slenderhead darter
Percina shumardi	river darter
Percopsis omiscomaycus	trout-perch
Phenacobius mirabilis	suckermouth minnow
Phoxinus erythrogaster	southern redbelly dace
Pimephales notatus	bluntnose minnow
Pimephales promelas	fathead minnow
Pimephales vigilax	bullhead minnow
Platygobio gracilis	flathead chub
Polyodon spathula	paddlefish
Pomoxis annularis	white crappie
Pomoxis nigromaculatus	black crappie
Pylodictis olivaris	flathead catfish
Rhinichthys atratulus	blacknose dace
Rhinichthys cataractae	longnose dace
Salmo trutta	brown trout
Salvelinus fontinalis	brook trout
Scaphirhynchus albus	pallid sturgeon

Scaphirhynchus platorynchus	shovelnose sturgeon
Semotilus atromaculatus	creek chub
Stizostedion canadense	sauger
Stizostedion vitreum	walleye
Umbra limi	central mudminnow

Species Occurrence Database Design

Before compiling any data set, it is essential to determine what types of information are to be included. We started out following the methods developed by the Missouri Resource Assessment Partnership (MoRAP) Aquatic Gap Protocol Team (Sowa 1999). In order to this, we modified the Microsoft Access relational database, originally designed for the Missouri Aquatic Gap Project, by expanding it to reflect the additional information we wished to capture for Iowa. This information included additional tables for source, collector, collector samples, gear type, negative data and sample location.

From the onset of the project, we were unsure as to the quantity or quality of the sources of data. Therefore we captured as much information about each sample as possible, including source and collector of the data, as this information is essential for the future retrieval of the original data as well as for verification purposes. Elaborating on the original source field found in the samples table, the new collector tables includes fields for collectors' names and associated samples whereas the new source table includes the name of the associated institution, and the bibliographic citation or description of the source. The new gear type table provides additional sampling method information. Unlike the sampled species table, which indicates the presence of a species in a sample, the new table for negative data indicates the absence of a species in a sample when that species was specifically targeted. Iowa has many sites that have been sampled multiple times; negative data could help pinpoint the timing of extirpations. We also added a table for sample location as it relates to the National Hydrography Dataset (NHD) coverage including information about the stream reach and hydrologic units in which the sample was taken.

In addition to adding tables, we expanded the number of fields in pre-existing tables. Additional fields included information about abundance, sample type (community versus target), descriptive location details, descriptive method details, individual specimen details, a flag field for records of species of special concern which are not to be used in any public dissemination copy of the database and a field for the Index of Biological Integrity (IBI) (Wilton 2004), a widely used index of stream health.

After completing the modifications, the IAGAP species occurrence database consisted of 15 separate but related tables that contain two primary elements: information about the collection, including its location and source, and information about the species collected (see Appendix B1 for more detailed overview of database structure and contents).

Data Acquisition

Once the database was designed, the next step was to acquire the raw data. We first compiled a detailed list of all possible and known sources of data including historic and recent, print and electronic, and published and unpublished sources. We then compiled a detailed list of possible data acquisition strategies. We proceeded to matched appropriate strategies with possible sources and pursued those sources. For example, museum collections were a possible source for historic data. Possible strategies for retrieving museum collection records could be to search their online database and/or contact individual museum curators. We identified possible museums, both public and private institutions, at the local, state or national level. After performing a comprehensive Internet search to identify all museums that might have fish collections, we either searched their on-line database for Iowa-only records or contacted the curator.

Through this process we identified seven categories of source data:

- Published literature: monographs, theses, dissertations, and journal articles
- Federal reports: EPA, USFWS, ACE
- Museum collections
- Iowa Department of Natural Resources research and management reports
- Iowa Department of Natural Resources field notes
- Statewide biological inventory databases
- Individual researchers' unpublished field notes

We grouped all data acquisition strategies into four categories: literature searches, Iowa Department of Natural Resources field office visits, museum collection inquiries and individual contacts. Although searching Internet accessible databases, such as Fishbase (Froese and Pauly 2003) as a strategy was initially pursued, we discovered little Iowa community data that was not already available in primary sources. We limited our data acquisitions to riverine fish community sampling data only. A fish community sample was defined as a representative sample of the fish community collected from a particular stream reach, using one or more sampling methods. Such a sample contained most, if not all, fish species in the stream reach at the time of sampling.

Literature Searches

To compile fish data from published literature, we conducted literature searches using several different methods. We used bibliographies of known published sources of data or from appropriate secondary sources in order to trace back to historically published data in the same way one would use a citation index. This was useful for including journal articles and published reports that are not indexed elsewhere. For both historic and more current journal articles, we searched both print and electronic forms of subject indexes and abstracts. To ensure that the searches were comprehensive, Boolean keyword searching, field limited searches as well as controlled vocabulary were used. To find published reports, monographs, theses and dissertations, we searched library catalogs at the state and national level as well as the WorldCat database, an online union catalog of 23,000 libraries in 63 countries. Although most relevant sources of Iowa data where available through libraries located in Iowa, the WorldCat database uncovered some obscure reports that we were able to acquire through Interlibrary Loan. Thirty-six sources used in the IAGAP database were found through this strategy.

<u>Iowa Department of Natural Resources Field Office Visits</u>

Despite decades of data collection by management and research fisheries biologists across the state, no centralized depository for stream fish community data existed in Iowa before this project. We gathered fish sampling data during visits to all 15 Iowa Department of Natural Resources (IDNR) regional fisheries offices as well as the headquarters (see Figure 3.1). During these office visits, we met with IDNR fisheries biologists and technicians to which we explained and promoted the Iowa Aquatic Gap Analysis Project. We also acquired all of the riverine fish data located at each office. Almost half of all the sources used for the IAGAP database were obtained during these visits, including management and research reports not available elsewhere. As an example, over 1700 fish community samples ranging in date from 1941 to 2003 were obtained just from field notes stored in filing cabinets.

<u>Museum Collections</u>

During early explorations of Internet sources, we discovered the most useful source of such data came from museum collection on-line databases. After eliminating museum databases that did not include fish collections, we conducted searches on each database for Iowa-specific records. We were often able to download the result or otherwise create an electronic copy of the information. However, we also came across museum fish collections that were not available electronically. For those museums, we acquired Iowa-specific records by contacting the curator directly through email. We identified over 40 museums with Iowa fish collection records. For the purposes of the IAGAP, we were able to use the records of 9 museum collections totaling 261 historic fish community samples ranging in date from 1884 to 2000.

<u>Individual Contacts</u>

Through an extensive network of cooperators, both at Iowa State University and the Iowa Department of Natural Resources, we were directed to individuals who had collected fish community samples in Iowa. We contacted most of these individuals by email. Individuals contacted ranged from retired faculty of liberal arts colleges in Iowa to out-of-state fisheries biologists who visited the state only once. The majority of the resulting data were in the form of unpublished, hand-written field notes ranging from 1932-2000. The data uncovered in this fashion was extensive, resulting in over 2400 fish community samples covering all geographic regions of the state.

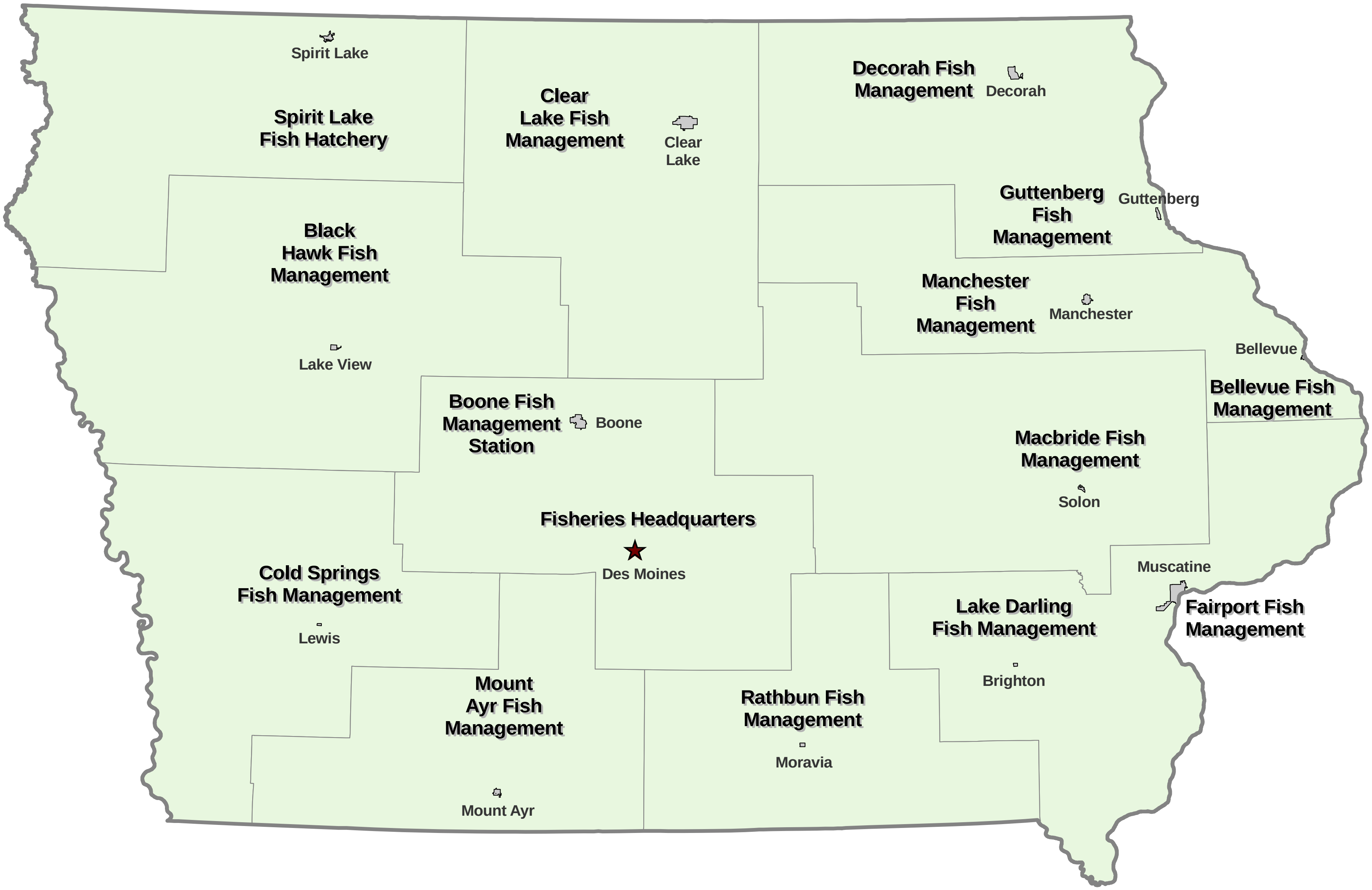

Figure 3.1. Iowa Department of Natural Resources regional fisheries offices.

Data Organization

Once obtained, data were either directly transferred or manually entered into the IAGAP species occurrence database. To ensure a direct relationship back to the source, we gave each sample a unique numeric identifier. We inserted these unique codes into each respective source table, in the case of electronic data, or as we had a tremendous amount of print material, labeled each print sample with its unique sample identifier. This allows information not captured in our database to be retrieved by future investigators. For a complete list of data sources, see Appendix B5.

Database Summary

The IAGAP species occurrence database contains 10,993 fish community samples taken from 1884 through 2002. It contains 97,790 sampled species records including 143 native and 14 exotic species. The database is geographically comprehensive with samples from every county and almost every 8-digit and 10-digit hydrological unit in Iowa (see Table 3.2).

Table 3.2. Iowa Aquatic Gap Analysis Project species occurrence database summary.

Number of fish community samples	10,993
Number of species occurrences	97,790
Number of fish species sampled	143 native, 14 exotic
Sampling date range	1884-2002
Number of individual sources of data	205
Number of Iowa counties sampled (99 total)	99
Number of unique stream reaches sampled	2954
Percent of all 8-digit HUCs sampled	98.2
Percent of all 10-digit HUCs sampled	92.4
Percent of all 12-digit HUCs sampled	73.5

Mapping Geographic Ranges

After completing the species occurrence database, each collection in the database was then geographically linked, reach-by-reach (i.e., between tributary confluences), to the Iowa Stream Reach dataset (ISR). The Iowa Stream Reach dataset is a modified version of the original USGS National Hydrography Dataset (NHD) (USGS 1999). Each collection was also geographically associated to the appropriate 8, 10 and 12-digit HUC provided in the original Iowa NHD dataset. All spatial data manipulation was done using ArcGIS 8.3 (ESRI 2003). All stream reaches in the Iowa Stream Reach dataset and in the 8-digit HUCs have a unique numeric identifier which can be used to link tabular data to these spatial datasets within a GIS. For detailed information about the NHD, the ISR, and the HUC 8 datasets, see Chapter 2.

After the NHD reach codes and HUC IDs had been obtained for every sample, we made both digital and hardcopy versions of range maps for each species for professional review. Figure 3.2 is an example of range map used during this process. Several individuals participated in the professional review process including John Olson and Tom Wilton, Iowa Department of Natural Resources, TMDL/WQ Assessment Section, Dr. Neil Bernstein, Department of Biology, Mount Mercy College, Mel Bowler, Iowa Department of Natural Resources, Bellevue LTRMP Station and Dr. Bruce Menzel, Department of Animal Ecology, Iowa State University.

At this point we had to determine which HUC coverage would be used to generate and define the geographic ranges within which our predictive models would be applied. Determining the size of the spatial unit used to generate that range is not a simple task. Issues of data suitability (number and spatial coverage of samples), time, money, as well as the expertise of the professional reviewers must all be considered. When considering all of these factors we decided to deviate from the Missouri Aquatic Gap Project, which used the 10-digit HUC coverage, and determined that Iowa geographic ranges would be generated and professionally reviewed at the 8-digit HUC level. We concluded that we would prefer to err on the side of commission rather than omission (For error rates, see Chapter 4: Results). To reduce the possibility of extending the geographic range of the species outside of the true range, we also used additional sampling data that was not included in the species occurrence database to determine species range. These data could not be geographically linked to a particular reach in the NHD. However, they are viable in indicating the presence of a species in a particular watershed.

We did encounter the possibility of underestimating the true range of a species. Two watersheds in the study site, HUC 07100001 and HUC 07040008, which fall either completely or almost entirely outside of the state boundary, were excluded from any species' range. Unfortunately the scope of IAGAP did not include acquiring data from outside of the state, thus we did not have any known locations for fish species within these two watersheds. Since known fish sampling locations serve as the basis for inclusion of a watershed in a species range, these two watersheds were not included in any of the range maps on which our predictive models were based. This is also why these two watersheds were not included in the species richness dataset.

Professional reviews of the distribution maps were conducted using hard-copy maps. Reviewers emailed comments at their convenience. Reviewer's edits were entered into a separate, but related, Microsoft Access database which allowed us to easily incorporate changes into the final distribution maps, but also keep the two information sources separate for future reviews and possible revisions. Professional reviewers were able to review most but not all species. For those few species not professionally reviewed, their range was evaluated by contacting the collectors of the samples directly, when possible, as well as by using several authoritative written sources (Harlan and Speaker 1951, 1956, 1969; Harlan et al. 1987; Pitlo et al. 1995; Rasmussen 1979).

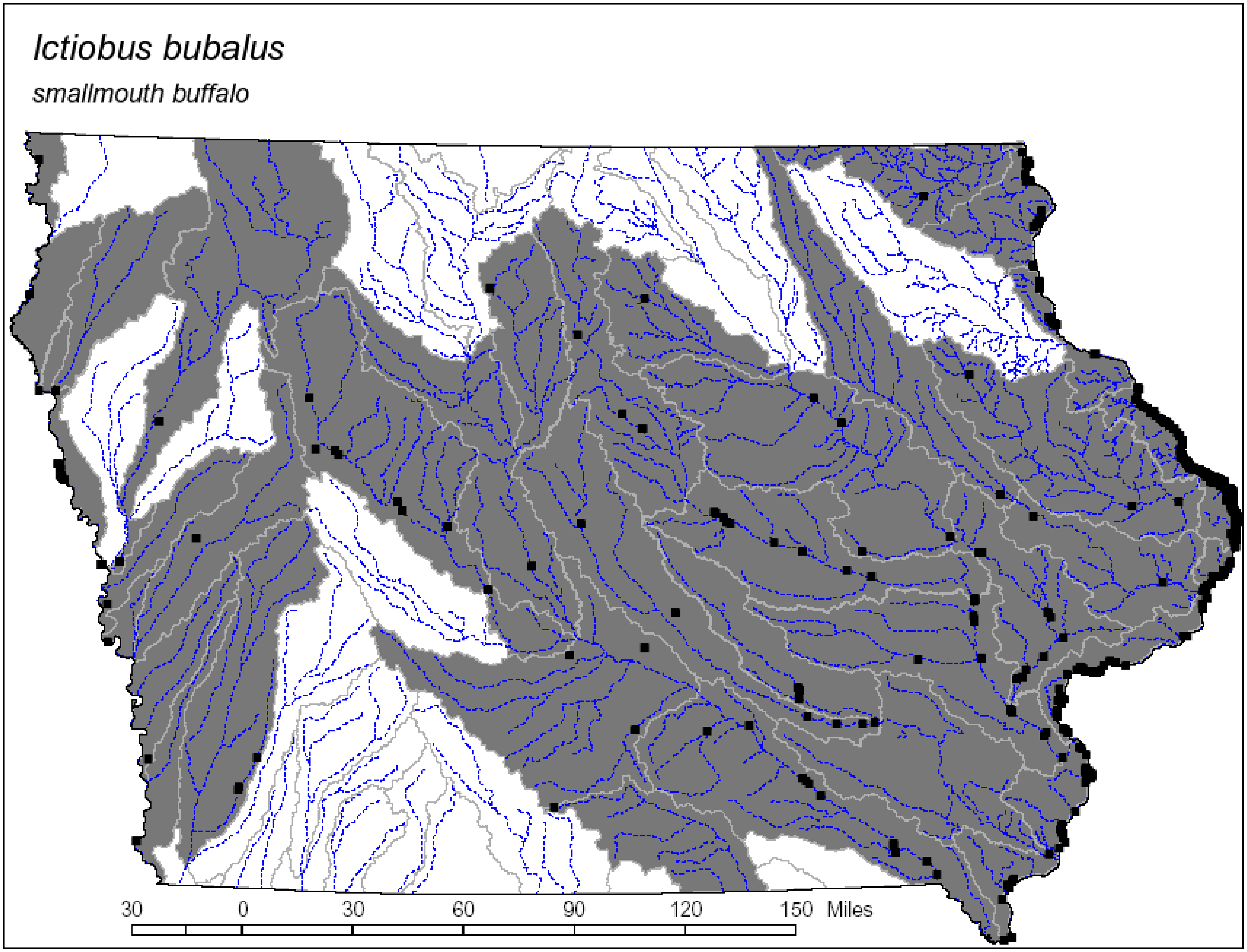

Figure 3.2. Example range map used for professional review process.

Chapter 4

PREDICTIVE FISH MODELING

Introduction

To accomplish the goals of the Iowa Aquatic Gap Analysis Project (IAGAP), detailed statewide distribution maps needed to be created for each individual species. Of the three types of distribution expressions: actual distribution based on long-term, exhaustive surveys, known distribution based on current knowledge and predictive distribution, which combines known distribution and knowledge of habitat affinities of the species to extrapolate to locations where the species is expected to occur (Csuti and Crist 1998), the pilot project developed by Missouri Aquatic GAP (MoRAP) found that predictive distributions best fit the project's objectives (Sowa et al. 2004). By following the Missouri Aquatic GAP methodologies as much as possible, we have created statewide predictive species distribution maps for Iowa fish species that can be used for gap analysis of watersheds in Iowa and the Lower Missouri River and Upper Mississippi River Basins.

Gap analysis uses the predicted distributions of animal species to evaluate their conservation status relative to existing land management (Scott et al. 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, great 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, they should be viewed as testable hypotheses to be confirmed or refuted in the field. We encourage biologists and naturalists to conduct such tests and report their findings in the appropriate literature or to the Iowa Aquatic Gap Analysis Program so that new data may improve future iterations.

Previous to IAGAP there were no maps available, digital or otherwise, showing the likely present-day distribution of species by aquatic habitat type across their ranges. Because of this, ordinary species (i.e., 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. Their decline, because of incremental habitat loss can, and does, result in one threatened or endangered species "surprise" after another. Frequently, the records that do exist for an ordinary species are truncated by state boundaries. 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 one of the most necessary and basic elements for preventing further erosion of biological resources.

In Iowa, habitat fragmentation and loss of both terrestrial and aquatic systems has been an on-going landscape transformation for more than 150 years. With a dynamic landscape associated with intense agriculture and development, an assessment of how

Iowa's aquatic species are faring can be a daunting project. Relating habitat needs and distributions of aquatic species to the stream characteristics delineated from the NHD is considered a coarse-scale approach, limited by the resolution of the stream data layer. Despite the constraints that are involved with the coarse resolution of the stream dataset, predicting species distributions according to environmental features that have been mapped from remotely sensed data is a rapid and efficient approach to estimating the biodiversity status of aquatic taxa within and across a landscape. IAGAP is the first attempt to assess the overall biodiversity status of aquatic taxa in Iowa. In the past, the state has relied on various sources and types of data to document species presence or absence.

Constructing Decision Tree Models

Statistical Methods

For the majority of the fish species found in Iowa, decision tree analyses were used to construct prediction distribution models. Decision tree analyses are nonlinear/nonparametric classification techniques that usually employ a recursive-partitioning algorithm which repeatedly partitions the data set into a nested series of mutually exclusive groups, each of which is as homogeneous as possible with respect to the response variable (Olden and Jackson 2002). The resulting output is a tree-shaped structure that represents sets of decisions or rules for the classification of a particular dataset. These rules can then be applied to a new unclassified dataset to predict which records or, in our case, location will have a given outcome (Sowa et al. 2004). We used AnswerTree® 3.1, an extension of the SPSS® statistical software package, to generate our decision tree models. It has the four most current and widely used analytic methods for performing decision tree analyses; a) Chi-squared Automatic Interaction Detector (CHAID), b) Exhaustive CHAID, a modification of CHAID that is more effective in examining all possible splits per predictor but takes longer (Biggs et al. 1991), c) Classification and Regression Trees (C&RT or CART), and d) Quick, Unbiased, Efficient Statistical Tree (QUEST). All four methods perform similar analyses of the predictor variables in a data set to find the one that initially provides the best classification or prediction of the target variable by splitting the data into subgroups (AnswerTree 3.0 User's Guide 2001). This process is then applied recursively to these subgroups to define sub-subgroups, and so on, until the decision tree is completed, as determined by user-defined stopping criteria. As no difference in performance was found among the four algorithms (Sowa et al. 2004) and for standardization among Aquatic GAP projects, we used Exhaustive CHAID to build our models.

AnswerTree® 3.1 is a software program that imports a user defined input dataset and generates rules to classify the data into useful categories or subsets. These classification rules are illustrated by charts called decision trees. They start with one root node (each node is illustrated as a box) that contains all of the observations in the dataset. As you continue down the tree, the data branch into mutually exclusive subsets (AnswerTree 3.0 User's Guide 2001). User defined criteria determine when to split the nodes to create more branches (growing criteria), when to stop generating more branches (stopping criteria) and which potential predictor variables to use (variable selection criteria). See Figure 4.1 for an example of an AnswerTree® decision tree. An example branch would consist of Nodes 5, 8 and 9. Node 5, the parent node of this branch, with a predictor variable value of GradSegR >5, was split further with predictor variable SDiscr_2C to create child nodes, Nodes 8 and 9.

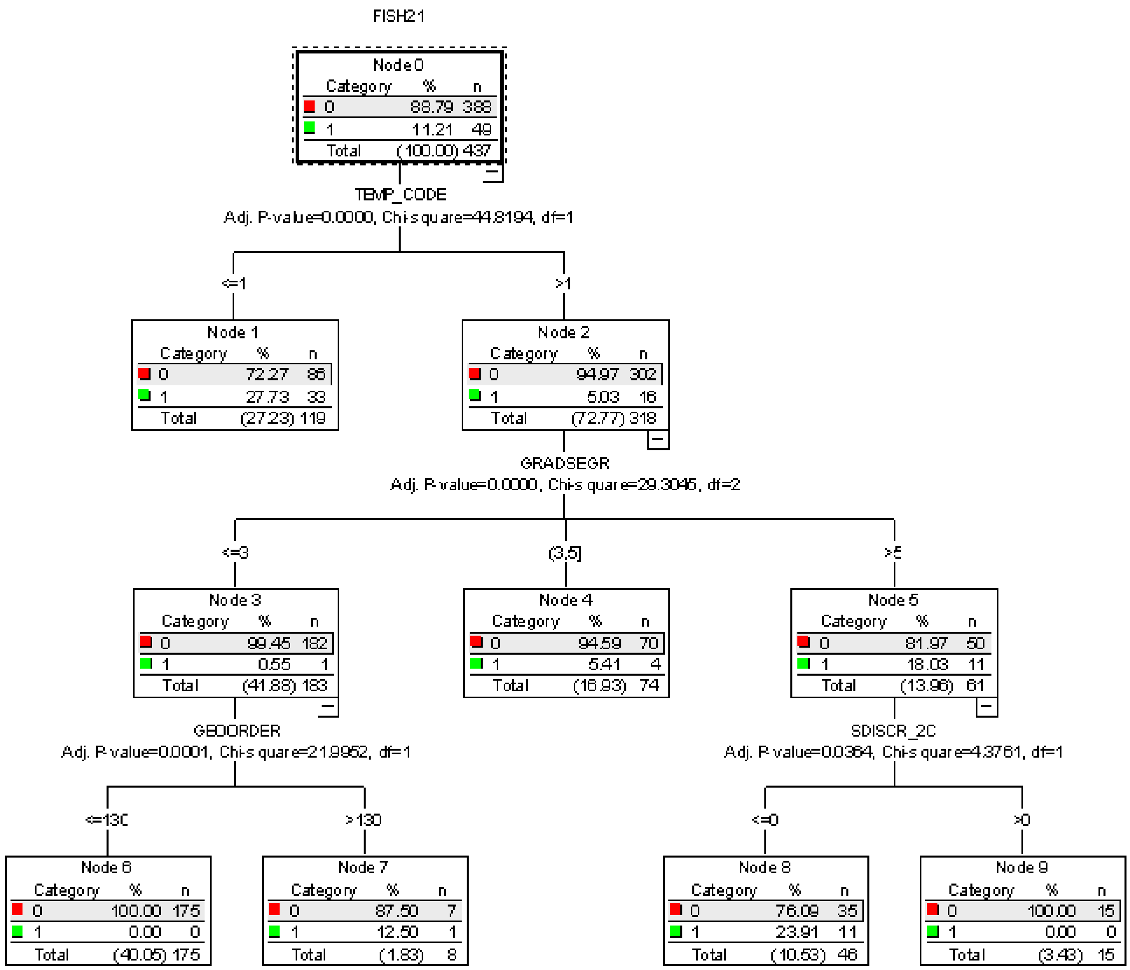

Figure 4.1. Decision tree for Brook trout, *Salvelinus fontinalis*

GIS Base Layer For Predictive Modeling

The base layer for our predictive distributional models was our Iowa Stream Reach (ISR) dataset, which is a substantially edited and enhanced version of the 1:100,000 National Hydrography Dataset (NHD) (see Chapter 2). The finest resolution of our predictions was the stream reach, which in most instances is a section of stream between tributary confluences. Within the project watershed boundaries, there are approximately 84,000 individual stream reaches in our 1:100,000 ISR dataset with an average length of 2.1 Km. For predictive modeling, only those reaches within the state boundary of Iowa were used.

Predictor Variables

The ISR dataset contained a wide variety of data attributes that could be used in the modeling process (see Chapter 2, Table 2.1 for a complete list of attributes in the ISR dataset). However, since we were attempting to construct models that would predict the presence of a fish species, only those attributes relating to the animal's surroundings would be appropriate to include. Moyle and Cech (1982) found that there were four factors which were most effective for predicting patterns of distribution and abundance: measures of stream size, gradient, temperature regime and flow regime. We therefore selected all the variables as potential predictors, which specifically or generally cover these four factors.

Flow

The variable Flow measures the constancy of stream water flow (i.e. perennial vs. intermittent) during normal annual low-flow conditions or periods of no rainfall (Allan, 1995). As this can have a dramatic influence on the composition of community structure and abundance of riverine assemblages (Matthews and Heins 1987; Matthews 1998), it is an essential variable for modeling distribution in aquatic systems.

Stream size measures

It has long been recognized that the physical processes outside a river affect the biological processes along a river which in turn affect the biological and physical processes within a river, and that as water travels from headwaters to large rivers, the nature of biological communities change, in a downstream direction just as the river itself does (Vannote et al. 1980). In order to measure the associated continuum of change in the biotic and abiotic character of streams, most investigators utilize a hierarchical classification system of discrete stream size classes developed by Horton (1945) and modified by Strahler (1952). Due to the Strahler ordering system's wide recognition and the fact that it is the one most often used by stream ecologists (Hansen 2001), we chose to include the variable Strahler as a measure of stream size. However, Shreve (1966) developed another measure of stream size, called link magnitude, which is thought to adjust for problems in the Strahler order system. The variables LinkR, DinkR, Ssize_code and Dsize_code are based on the Shreve link magnitude ordering system. To provide a general measure of the position of a stream reach within the larger drainage network (Sowa, et al. 2004), we also included measurements of stream size discrepancy. As several studies have indicated that the size of the confluent stream often influences fish species assemblages found in the lower reaches of streams (Fowler and Harp 1974; Gorman 1986; Osborne and Wiley 1992, Osborne et al. 1992), variables Sdiscr_2, Sdiscr_5 and Sdiscr_11 were included as possible indicators of this influence.

Gradient measures

Many studies have shown that gradient is related to many key environmental variables. It has been found to be associated with the presence, nature and diversity of riverine habitat types (Moyle and Cech 1982), as well as mean annual discharge, drainage area, and median size of bed material (Hack 1957; Nino 2002). There is evidence that gradient can influence mean values and spatial patterns of stream temperatures and dissolved oxygen concentrations at local scales (Knighton 1998; Moyle and Cech 1982). For this reason, gradient is a potentially useful predictor of fish species distributions. We included the variables GradSegR, which represents actual stream segment gradients divided into equal categories for modeling and GradRchR, which represents stream reach gradients divided into equal categories for modeling.

Temperature

Temperature is a critical factor in the aquatic ecosystem. It has a diverse and marked effect on the reproduction, growth, behavior, physiology, condition, and survival of aquatic organisms (Fry 1947; Magnuson et al. 1979; Allan 1995) as well as on aquatic community composition (Matthews and Heins 1987; Jacobsen et al. 1997; Rabeni et al. 1997). Studies have also found a relationship between thermal regimes and species distribution (Vannote and Sweeney 1980; Keleher and Rahel 1996; Wehrly et al. 2003). For these reasons, we included Temp_Code, a measurement of temperature, as a potential predictor.

Additional Potential Predictors

In addition to flow, temperature, gradient and stream size measures, we also included addition potential predictor variables. We included two variables that measured elevation: Max_ElevR and Min_ElevR. Max_ElevR represents the elevation of the upstream end of a stream segment divided into equal categories for modeling; Min_ElevR represents the elevation of the downstream end of a stream segment divided into equal categories. We also included a variable to measure soil texture. Due to inaccuracies in the geology source dataset, the geology variables included in the ISR could not be used in the modeling process (see Chapter 2). To account for regional variation, we also included subregion as a possible predictor since we chose not to construct regionally-specific input datasets.

In addition to those we selected as potential predictor variables, there are many other habitat characteristics that would be useful in predicting the presence of a fish species, such as vegetation, bottom substrate, and turbidity. However, all of the variables selected for our prediction models (see Table 4.1) could be mapped within a GIS at a scale of 1:100,000 (Sowa, et al. 2004) See Appendix B2 for modeling attribute values and definitions. Details as to how these variables were mapped and attributed to each individual stream reach within the ISR dataset can be found in Chapter 2.

Table 4.1. Potential predictor variables used for modeling.

Attribute	Habitat measurement
Flow	Flow
Strahler	Stream size
Ssize_Code	Stream size
Dsize_Code	Stream size
LinkR	Stream size
DlinkR	Stream size
Sdiscr_2	Stream size (discrepancy)
Sdiscr_5	Stream size (discrepancy)
Sdiscr_11	Stream size (discrepancy)
GradSegR	Gradient
GradRchR	Gradient
Max_ElevR	Elevation
Min_ElevR	Elevation
Soil_Text	Surface soil texture
Subregion_Code	Aquatic subregion
Temp_Code	Temperature

Generating Input Datasets

Accuracy Assessment Test Dataset

Once the prediction distributions were generated, we needed to conduct an accuracy assessment of all fish species. In order to accomplish this, we created a test dataset from our existing data, which was excluded from the modeling process, and used exclusively to determine error of commission, error of omission and overall success rates for species predictions (see Results for error rates). Prior to generating the modeling input datasets, we randomly selected 5% (295) of the total number of sampled reaches and created a test dataset to which the prediction models, once generated, were compared for accuracy. MoRAP, in conducting their accuracy assessment, used a total of 80 sampled reaches of independent data. The decision not to use independent data for IAGAP was based on the following; 1) we did not have the resources to collect sufficient independent data, 2) other sources of 'independent' data were already included in the biological database, and 3) due to landscape and habitat changes over time, current sampling data would not be representative of the data used for modeling. By randomly selecting sampled reaches from our compiled dataset, we were assured inclusion of samples across time and space. Professional judgment was also used in determining the percentage of sampled reaches for the accuracy assessment dataset. By including a sampled reach to increase the sample size used for accuracy, we were also excluding the reach from being used in the modeling process. By selecting only 5%, we maintained a high sample size for our modeling input dataset while at the same time, the number of sampled reaches included in the accuracy assessment dataset was more than three times greater than the pilot Aquatic Gap Project.

Modeling Datasets

Once we excluded the accuracy assessment dataset, we generated the modeling input datasets, an important step in the overall modeling process. Because distributional constraints would hinder model development (Wiens 1989), we used only those sample records within the 8-digit HUCs from which a species had actually been collected to define the input dataset to be used for decision tree analysis for each species. Due to time constraints, we chose to construct only statewide input datasets. We used a modified version of a SAS® program provided us by Missouri Aquatic GAP to generate the input datasets. This program also generated contingency tables that determined the inclusion of binary predictor variables in a species' model. Binary predictor variables, which contained a value of 0 or 1 as defined in the input dataset contingency tables, were automatically added to the species' final model (see Coding the Model). See Figure 4.2 for an example of contingency tables. In this example, Subregion would be added to the species' final model as a predictor. Temp_Code would be included as a potential predictor in the decision tree algorithm (see Appendix B2 for variable values and definitions).

```
    Table of FISH21 by TEMP_CODE

FISH21(FISH21)     TEMP_CODE(TEMP_CODE)

Frequency,
Percent  ,
Row Pct  ,
Col Pct  ,       1,       2,
ƒƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒˆ
       0 ,     86 ,    302 ,    388
         ,  19.68 ,  69.11 ,  88.79
         ,  22.16 ,  77.84 ,
         ,  72.27 ,  94.97 ,
ƒƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒˆ
       1 ,     33 ,     16 ,     49
         ,   7.55 ,   3.66 ,  11.21
         ,  67.35 ,  32.65 ,
         ,  27.73 ,   5.03 ,
ƒƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒˆ
Total         119      318      437
            27.23    72.77   100.00
```

Variable Value

Species Presence/ Absence

```
   Table of FISH21 by SUBREGION

FISH21(FISH21)     SUBREGION(SUBREGION)

Frequency,
Percent  ,
Row Pct  ,
Col Pct  ,       1,       2,  Total
ƒƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒˆ
       0 ,     19 ,    369 ,    388
         ,   4.35 ,  84.44 ,  88.79
         ,   4.90 ,  95.10 ,
         ,  95.00 ,  88.49 ,
ƒƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒˆ
       1 ,      1 ,     48 ,     49
         ,   0.23 ,  10.98 ,  11.21
         ,   2.04 ,  97.96 ,
         ,   5.00 ,  11.51 ,
ƒƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒˆ
Total          20      417      437
             4.58    95.42   100.00
```

Figure 4.2. Contingency tables for Brook trout, *Salvelinus fontinalis.*

Variable Selection Criteria

AnswerTree® 3.1 allows the user to define which variables in the input dataset are to be used as predictors and which is to be the target. The fish species presence variable, labeled Fish#, was always chosen as the target. We included all of the potential predictors for every model for every species. This allowed the algorithm used in the decision tree analysis to determine the "best" predictors, with the caveat that the variables chosen are predicting the presence of species based on the available data and not that those variables not included in the model are unimportant to the species actual habitat conditions. This resulted in more complex models, but each was completely objective.

Model Selection Criteria

Stopping Criteria

AnswerTree® 3.1 allows the user to define apriori stopping criteria related to the number of branches in the tree and the minimum number of collection records that can occur in any given child node. These stopping rules reduce the probability of gross overfitting of the model, a problem with extremely large datasets containing a large number of predictor variables (AnswerTree User's Guide 2000). We set the maximum number of levels allowable in the final tree equal to 7, which was higher than the number of levels ever achieved. The minimum number of collections allowable in a parent node (the node that is split) we set to 10% of the total number of sampled stream segments for that particular species. The total number of sampled stream segments was equal to the number of collection records in the input dataset. The minimum number of collections allowable in a child node (the result of splitting a parent node) we set equal to 1.

Growing Criteria

A decision tree is grown by splitting the nodes using the automatic tree-growing algorithms (AnswerTree 3.0 User's Guide 2001), in our case, Exhaustive CHAID. We set the alpha level for splitting and merging equal to 0.05, used the Pearson chi-square type for nominal target and used the Bonferoni alpha adjustment to allow for the correction of alpha levels for multiple comparisons. We opted for the more conservative alpha value to ensure a higher level of confidence in our statistically generated models. If no model could be generated using these growing criteria, we created a more subjective, non-statistical habitat model (see Habitat Generated Models). If no habitat model could be built using either of these techniques, the final distribution map for that species simply represents the stream reaches where the species has been documented (see No Model). See Figure 4.1 for an example of an AnswerTree® decision tree schematic.

Pruning Criteria

Algorithms used in decision tree analyses tend to overfit the data and produce trees with too many branches and terminal nodes (Breiman et al. 1984). When overfitting occurs, the user can “prune” the decision tree, removing nodes or branches from the tree that increase misclassification rates. We followed an efficient and standardized “relative 50%-approach” used in other Aquatic GAP projects to select which nodes would be “pruned” and which would be included in each final model (Sowa, et al. 2004). For each species model we initially identified the node with the highest occurrence percentage that also contained at least 4% of all the collection records from the input dataset. For example, if the input dataset contained 1000 total collection records, we would only identify the highest occurrence percentage among those nodes having 40 or more total collection records. We then divided the highest occurrence percentage by 2 and selected all nodes having occurrence percentages equal to or greater than this percentage. Those nodes having occurrence percentages less than 50% of the highest occurrence percentage were eliminated. We then identified any parent nodes where all the child nodes were in the list of nodes to include. Since all nodes on that branch were selected, we were able to simplify the model by using the one parent node in the final model instead of coding out all of the individual child nodes.

Coding the Model

Once the nodes of the decision tree have been selected, the model must be constructed in a GIS-compatible syntax or code. This is a Boolean selection statement using the predictor variable names and values as determined by the selected nodes. We chose the syntax recognized by ArcGIS 8.3 for a shapefile (ESRI 2003). We first considered the binary predictor variables that contained a value of 0 or 1 as defined in the input dataset contingency tables (see Classification/Prediction Variables). These variables were added first to the model code. For example, if a particular species was always found only in the Eastern Broadleaf Forest subregion (see Figure 4.2), the model code would be Subregion = 2. We then coded each branch individually until all selected nodes were included. For example, if the primary predictor variable was Temp_Code and it had two nodes selected, with nodes below them, this would constitute two branches. The first Temp_Code node had a value of less than or equal to 1. This branch would be coded: (Temp_Code <=1). The second Temp_Code node selected had a value of greater than 1. It had a selected node below it, GradSegR with a value of greater than 5. This selected node also had a selected node below it, SDISCR_2 with a value of less than or equal to zero. This branch would be coded: ("TEMP_CODE" > 1 AND "GRADSEGR" > 5 AND "SDISCR_2C" <= 0). All branches were joined using the operator OR and were then combined with the selected binary variable using the operator AND to construct the model. See Figure 4.3 for this example of the syntax of a prediction model. For explanation of a complex model, see Appendix B3. Although the syntax has to be the same for all models, the derivation of the selection statements for the non-statistical models varied slightly (see Constructing Non-Statistical Models).

```
("SUBREGION_" = 2 AND
        ("TEMP_CODE" <= 1 OR
        ("TEMP_CODE" > 1 AND "GRADSEGR" > 5 AND "SDISCR_2C" <= 0)))
```

Figure 4.3. Prediction model for the Brook trout, *Salvelinus fontinalis.*

Constructing Non-Statistical Models

Although we were able to use decision tree analyses for the majority of the fish species, there were 124 species for which we constructed non-statistical prediction models. The “Great River” models, predictions of presence/absence of species in the Mississippi and/or Missouri Rivers, were created in addition to the decision tree generated models. There were also fish found in interior rivers for which statistical models could not be reliably created and therefore habitat-based models had to be produced. These habitat-generated models, predictions of presence/absence of species based on qualitative descriptions of habitat affinities, were built only when a statistical model could not be generated.

Great River Models

A majority of Iowa’s fish species is found in either the Mississippi River, the Missouri River or both. However, the reaches of the Mississippi and Missouri Rivers were not included in the statistical predictive distribution modeling due to processing differences for these reaches by MoRAP. Values for certain attributes that IAGAP chose to include for the statewide modeling input were not calculated or calculated differently for the Mississippi and Missouri Rivers. Where values were calculated for necessary attributes, they were usually placeholder values and not something that could be reliably used in a predictive model. For this reason, the great rivers were included in the predictive modeling process using a pool-based approach. Using ArcGIS 8.3 (ESRI 2003), the two rivers were divided into “pools”. For the Mississippi River, we used the pool designations established by the U.S. Army Corps of Engineers and adapted for GIS for the U.S. Geological Survey’s Long Term Resource Monitoring Program (LTRMP 2001) . For the Missouri River, we used the segment designations established for the Missouri River Benthic Consortium (Berry and Young 2001). We created separate “Great River models” for fish species found in one or both of the great rivers. These models were constructed to show general predictive ranges throughout these two important rivers bordering Iowa. To create the model, we initially included all pools within the species 8-digit HUC range. We then included additional pools where the species was documented based on existing collection data. We consulted the literature and rejected from the model any pools lacking literature support from two or more sources. For example, there are documented collection data records for the Iowa darter in the Mississippi River in pools 9 and 10 only. The species’ range would suggest adding pool 8 to the prediction model. Sources from the literature support adding pool 8 (LTRMP 2004; Pitlo et al. 1995; Rasmussen 1979), therefore the resulting model is: "pool" >= 'S08' AND "pool" <=

'S10'. However, if two of the above three sources did not support adding pool 8, the model would only have included pools 9 and 10: "pool" >= 'S09' AND "pool" <= 'S10'.

<u>Habitat Generated Models</u>

There were some fish species that were documented in Iowa's interior rivers for which we could not generate a statistical predictive distribution model. For 7 of these species, we created a habitat-generated model. Information was gathered from the literature about each species' habitat affinities (see Appendix B7 for individual species atlas pages and Appendix B6 for additional reading). We then included in the model the variables available in the ISR dataset which most closely corresponded to the species' habitat affinities. For example, according to the habitat affinity literature, the blue catfish is found predominately in large, permanent-flowing rivers and streams. Therefore, it has a habitat generated model of: "FLOW" = 1 AND "SSIZE_CODE" = 4 (see Appendix B2 for variable values and definitions).

<u>No Model</u>

We were unable to construct any type of model, statistical or non-statistical, for 13 fish species documented in Iowa (see Table 4.2). These species had small sample sizes, were not found in either the Mississippi or Missouri Rivers, and did not have habitat affinities that could be measured by the available habitat data in the ISR dataset. For these species, we generated 8-digit HUC range maps based on documented sample locations only. The final distribution map for a particular species simply represents the stream reaches where the species has actually been collected.

Mapping GIS Predictions

<u>Overall Prediction Models</u>

To create the prediction distribution maps, we combined all appropriate models for a particular species into one overall model. For many species, the overall model consisted of a statistical model generated through the decision tree analysis process added to one or both great river models. An example of this type of overall model would be the following:

("FLOW" = 1 AND "TEMP_CODE" = 2 AND "LINKR" > 5) OR
("pool" >= 'S08' AND "pool" <= 'S20') OR ("pool" >= 'O17' AND "pool" <= 'O19')

This allowed us to generate maps that predicted fish species distributions using all reaches in the Iowa Stream Reach dataset. Having the Missouri River as one Iowa border and the Mississippi River as another Iowa border, any predicted distributions of Iowa fish species would be incomplete without these important rivers.

Selection

Once the overall models were built, we used each fish species' model to select reaches in the Iowa Stream Reach dataset using ArcGIS 8.3 (ESRI 2003), based on the species' geographic range (see Chapter 3: Mapping Geographic Ranges). The selected reaches constituted the species' predicted distribution. See Figure 4.4 for an example of a final prediction map.

Calculating Richness

Richness sums by watershed were calculated by overlaying each species' predicted distribution with the 8-digit hydrologic unit layer; if any stream reach was predicted within an 8-digit HUC, the species was coded as present (1) for that HUC. Richness sums by stream reach were calculated by concatenating each species' predicted stream reaches into a spreadsheet and summarizing by stream reach. We calculated species richness at the end of the modeling process rather than at the beginning.

Results

A total of 308 predictive models were ultimately generated. Of the 157 fish species in Iowa, we were able to generate models using decision tree analysis for 106 species. Using habitat affinity alone, we generated seven additional statewide models for a total of 113 statewide predictive distribution models. We also generated 195 "great river" models, 120 for the Mississippi River and 75 for the Missouri River. There were 31 species for which we could only generate a "great river" model. Overall we were able to predict the distributions of 144 fish species. We were unable to create any type of predictive distribution model for 13 of Iowa's fish species (see Table 4.2).

Geographic patterns of species richness generally suggest higher diversity in the eastern portion of the state, with the lowest diversity found in southwest Iowa (Figure 4.5). Greater species diversity occurred in most major streams and rivers associated with the Mississippi River system. With the exception of those in the Little Sioux River watershed in northwest Iowa, streams and rivers associated with the Missouri River Drainage Basin generally had lower predicted species richness.

After generating the predictive distribution models, we determined predicted fish species richness by HUC as well as by stream reach. Hydrologic units contained from 14 to 111 fish species with a median of 57 species (see Agap CD:\Fish\Spdsheet\PredictedHuc8_ SpeciesRichness.dbf for individual HUC data). See Figure 4.5 for total predicted species richness by 8-digit HUC.

Iowa's stream reaches were predicted to contain from 1 to 95 fish species with the most common number of predicted species per reach peaking at 13 (see Figure 4.6).

(see Agap CD:\Fish\Spdsheet\PredictedSeg_SpeciesRichness.dbf for individual reach data). Stream reaches with more than 50 species per reach are rare and predominately located in the Mississippi and Missouri Rivers. See Figure 4.7 for total predicted species richness by stream reach.

After compiling the biological database, we determined that 0.035% of the stream reaches in Iowa have been sampled. However, using the prediction distribution models, we were able to predict species presence in 97.0% of Iowa's stream reaches with an average overall accuracy of 45.5%, ranging from 2.9 to 100% accuracy.

An accuracy assessment was conducted for fish species using the subset of sample data set aside for this purpose (see Accuracy Assessment Test Dataset*)*. The overall average error of commission was 54.5% and the overall average error of omission was 16.8%. (see Appendix B4 for accuracy rates by reach).

Table 4.2. Fish species without a prediction model.

Scientific Name	**Common Name**
Clinostomus elongatus	redside dace
Couesius plumbeus	lake chub
Erimyzon succetta	lake chubsucker
Etheostoma microperca	least darter
Fundulus diaphanus	banded killifish
Fundulus dispar	starhead topminnow
Fundulus sciadicus	plains topminnow
Lepomis megalotis	longear sunfish
Micropterus punctulatus	spotted bass
Notropis anogenus	pugnose shiner
Notropis chalybaeus	ironcolor shiner
Notropis heterolepis	blacknose shiner
Percina evides	gilt darter

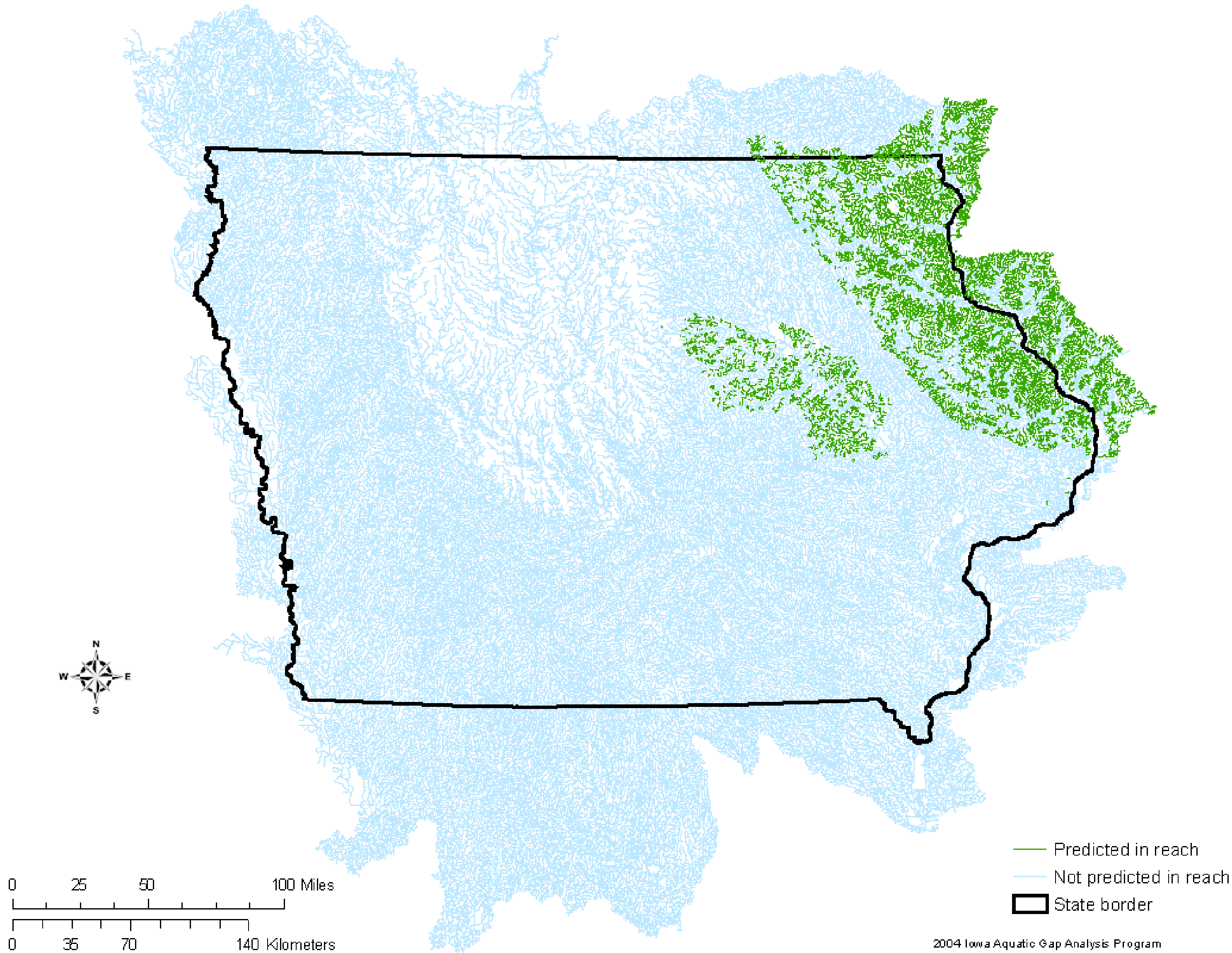

Figure 4.4. Predicted distribution of the Brook trout, *Salvelinus fontinalis.*

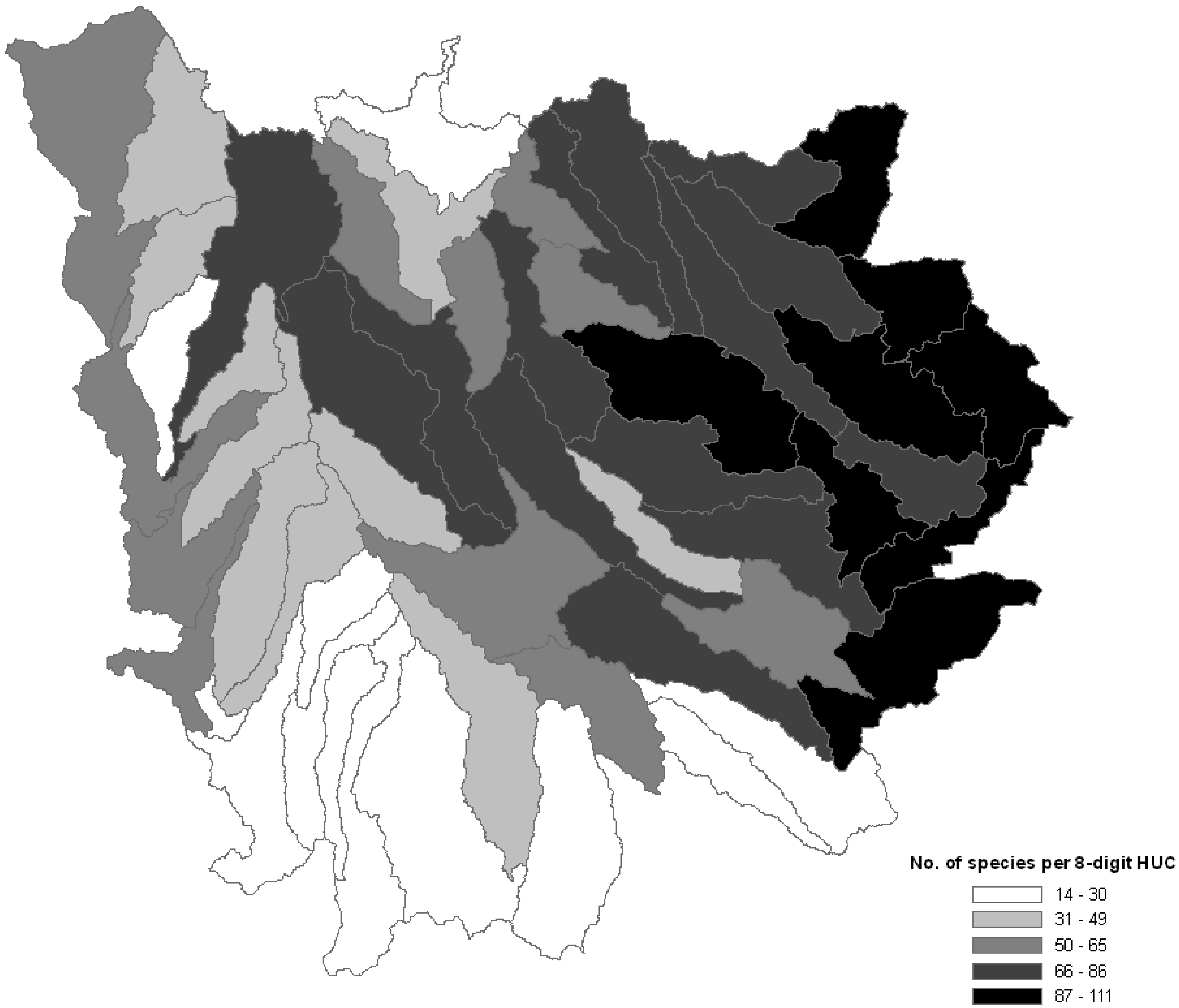

Figure 4.5. Predicted distribution of total fish species richness by 8-digit hydrologic unit for Iowa.

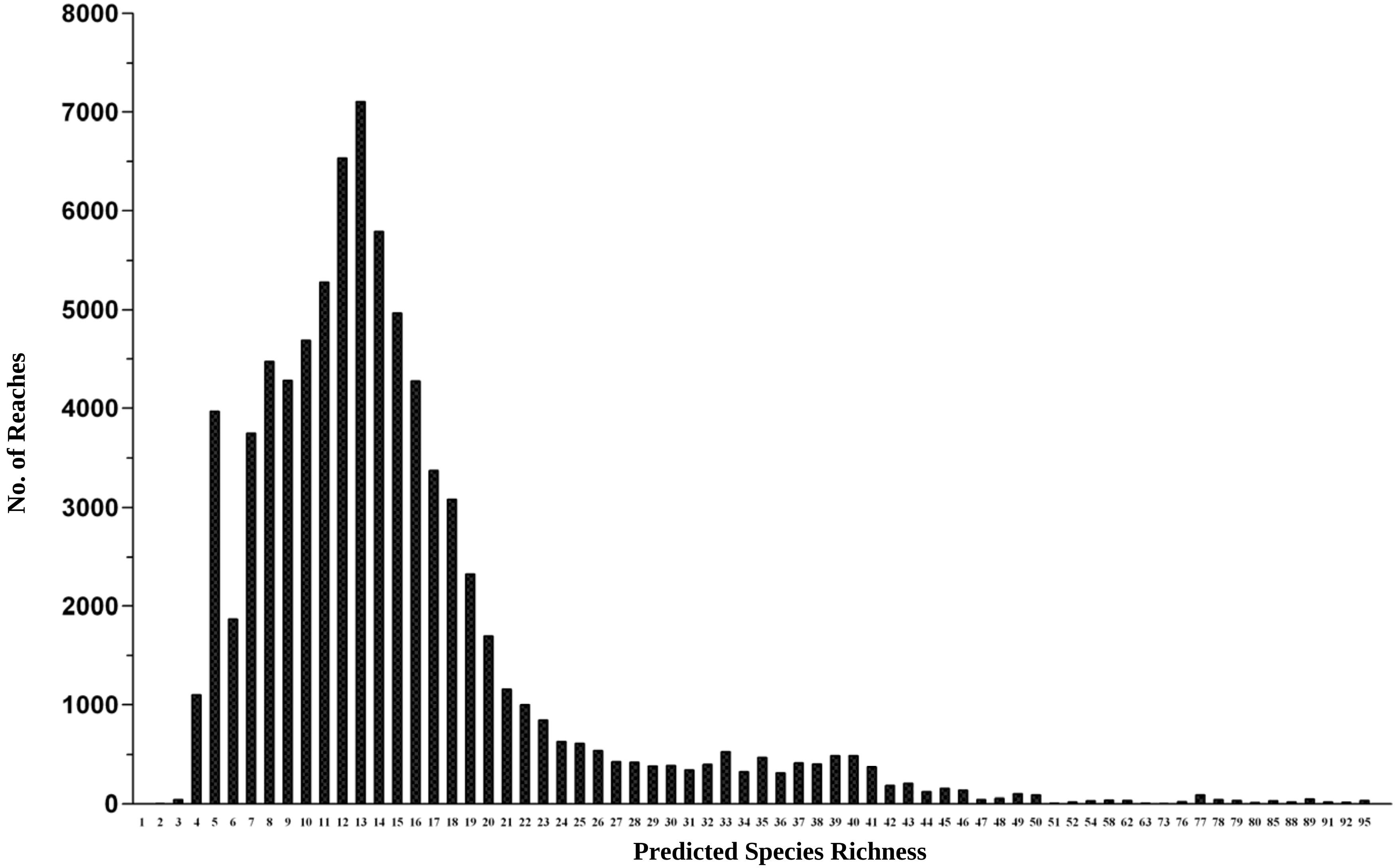

Figure 4.6. Frequency distribution of predicted species richness for 157 fish species within the 83,719 stream reaches across Iowa.

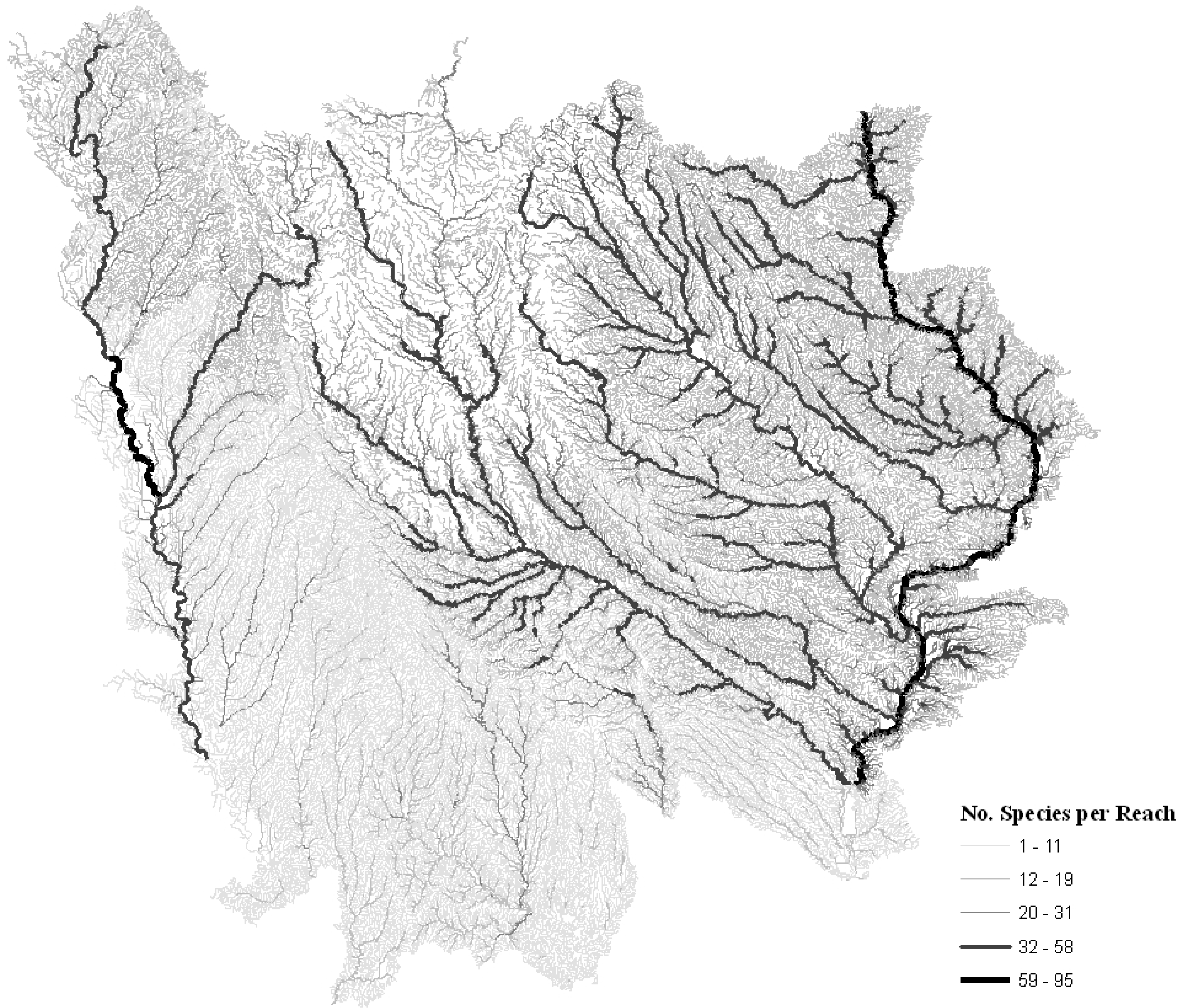

Figure 4.7. Predicted distribution of total fish species richness by stream reach for Iowa.

Species Richness Application

Aquatic GAP has often been associated with the mapping of species-rich areas or "hotspots." Richness maps identify the co-occurrence of species in the same geographic location. In the case of our data, where multiple fish species are mapped for the same HUC polygon or stream reach line, the polygons or lines are shaded in intensity from the highest levels of co-occurrence (richness), to the lowest (see Figure 4.5 and Figure 4.7 respectively). This is only one of many possible analyses that may be conducted using the data. Richest areas may or may not indicate best conservation opportunities; they may occur in already protected areas or may represent already protected species or those not at risk. Still, it is often a useful starting point to examine conservation opportunities in combination with other analyses described in other chapters of this report. Richness maps may also be useful for other applications such as identifying places of interest for fisheries observation and study. Certainly, finding "gaps" in species diversity can be important for conservation biology.

Accuracy Assessment

Assessing the accuracy of the predicted species distributions is subject to many of the same problems as assessing any GIS dataset, as well as a host of more 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 home page (http://www.gap.uidaho.edu/). It is, however, necessary to provide some measure of confidence in the results of the aquatic gap analysis for species collectively, if not individually, to allow users to judge the suitability of the distribution maps for their own uses. We, therefore, feel it is important to provide users with a statement about the accuracy of IAGAP-predicted fish distributions within the limitations of available resources and practicalities of such an endeavor. We acknowledge that distribution maps are never finished products but are continually updated as new information is gathered. This reflects not only an improvement over the modeling process, but also the opportunity to map true changes in species distributions over time.

The IAGAP conducted an accuracy assessment for the fish species habitat modeling using the test dataset described earlier. Acknowledging that sample size issues could affect the accuracy of the individual models, we also provided the users of individual maps, the exact numbers of reaches and/or pools used to determine the model.

We suggest future research using the predicted fish species distributions be directed toward conducting additional accuracy assessments of these maps. Since the completion of the biological inventory database in 2002, additional fisheries data have been collected by the Iowa Department of Natural Resources. These data could be used to test the predictions of species distributions on a statewide scale. But, the only way to truly assess the performance of the models is by thorough and systematic field surveys.

Implications and Limitations

Our predicted distributions are based on a synthesis of information pertaining to 157 fish species in Iowa. The breadth of the data on which the models were based, as well as the scale at which these models were processed (1:100000 scale), represents the first time any such aquatic vertebrate mapping has been conducted for the entire state. Our models reflect the current and complete state of knowledge of fish species in Iowa. We did have higher commission errors versus omission type errors, which means that the models are more likely to over-predict species distributions than to under-predict them. In the context of management decisions, this is desirable for the same reason that Type I statistical errors are more serious than Type II errors. Failure to predict a species' presence in an area where it actually occurs may create potential for inadvertent harm if land-use decisions are then made without that species in mind. If, however, a species is predicted to occur where it has never been reported, it is more likely that the species will be targeted in future surveys and also considered in subsequent land-use decisions. This can lead to a more comprehensive and effective conservation effort.

The most general limitations of the Aquatic GAP modeling approach relate to species-habitat relationships. For some species, habitat associations are not well defined because of lack of study; others have been well studied, but perhaps not in Iowa. Still others have been well studied within the state or region, but habitat associations could not always be well represented within our GIS model. Some habitat features could not be included in the modeling process, either because they were not available as GIS layers, or because their scale was too fine or too coarse. For example, several important aquatic habitat variables such as turbidity, presence and type of aquatic vegetation and stream substrate (such as rubble, mud, or sandy bottoms in stream beds) could not be measured. Human disturbance factors were not assessed; their absence may have led to over-predicted distributions in some cases, especially in Iowa. Although consideration of human disturbance is not a part of the Aquatic GAP approach, which focuses on potential habitat, a number of species are undoubtedly limited by such factors. Additional data layers can be used for a more holistic conservation analyses.

All of the preceding limitations must be recognized so users of IAGAP products know the extent of the accuracy and precision of the species' distribution maps. Aquatic GAP is a coarse-scale baseline approach to biodiversity assessment and conservation. Predicted distributions of fish species represent a snapshot in time based on the data of the underlying stream reach dataset. Therefore, IAGAP products will need to be updated to reflect changes in distributions and to refine the status of the prediction maps.

Aquatic GAP strives to recognize sites of high biodiversity (hotspots) for long-term maintenance of populations of native fish species before they become critically rare. This is a proactive approach, helping to reduce the rate at which threatened and endangered species are listed. IAGAP is not a substitute for threatened and endangered species listing and recovery projects. Species that are presently threatened and endangered still need individual efforts to assure their recovery success. IAGAP is one of the tools to make conservation efforts successful.

IAGAP can provide a rapid assessment of habitat associations and the fish species that live there. It is not meant to be a tool for national or state biological inventories. Rather, IAGAP products can provide the data to aid local, regional, and national efforts to maintain biodiversity before it's gone. The process of improving our knowledge base in systematics, taxonomy, and species distributions is time consuming and expensive. That process should be encouraged and continued so as to provide the needed information about species biodiversity nationwide. IAGAP species distribution maps provide a starting point for such endeavors and a comprehensive synthesis of existing information.

Chapter 5

LAND STEWARDSHIP

Introduction

The Iowa Gap Analysis Program made an effort to map land stewardship and terrestrial species distribution in an attempt to provide useful information for future conservation decisions. Using similar techniques and data, Iowa Aquatic Gap Analysis Project (IAGAP) used land stewardship information to map stream and river stewardship from the land management perspective. Understanding some of the relationships between land stewardship and the river and stream network is important for the long-term management of aquatic biodiversity in the state.

Land ownership and stewardship are estimated on a reach basis from terrestrial Iowa GAP stewardship data. Reaches are based on the National Hydrography Dataset (NHD). Explained further in the Analysis section, these comparisons do not measure viability, but are a start to assessing one mode of future threat to aquatic species through habitat conversion or land-use practices. We use 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 not suitably mapped by Iowa GAP.

The purpose of comparing biotic distribution with stewardship is to provide a method by which aquatic resource managers or land stewards can assess their relative amount of responsibility for the management of aquatic vertebrates, invertebrates and habitat diversity. Classifying distributions in this way may also facilitate the identification of other stewards sharing a responsibility for an aquatic resource. This information can reveal opportunities for cooperative land management practices that may influence the aquatic resource and directly supports the primary mission of GAP. The GAP mission is to provide objective, scientific information to decision makers and managers to make informed decisions regarding biodiversity. It also is not unlikely that a steward that has previously provided the major responsibility for managing a species may, through such analyses, identify a more equitable distribution of that responsibility. We emphasize, however, that IAGAP only identifies private land as a homogeneous category and does not differentiate between individual tracts or owners, unless the information was provided voluntarily to recognize a long-term commitment to biodiversity maintenance, watershed functions, or conservation practices.

After comparing 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, in the case of IAGAP, reaches containing high degrees of diversity. Such changes are accomplished in many ways that do not affect the stewardship status.

While it will eventually be desirable to identify specific management practices for each reach, and whether they are beneficial or harmful to each element, GAP currently uses a scale of 1 to 4 to denote relative degree of maintenance of biodiversity for each parcel of land. This method was also used to classify reaches. A status of "1" denotes the highest, most permanent level of maintenance, and "4" represents the lowest level of biodiversity management, or unknown status. This is a highly subjective area, and we recognize the subjective nature of this approach and the variety of limitations. The assigning of status codes to reaches is based on the principles outlined within the original Iowa Gap Analysis Program. The underlying assumption is that a reach will take on the attributes of the stewardship tract through which it passes. Explanation of the status code is from the perspective of the stewardship parcel. Further details regarding the attribution of reaches with stewardship information is in following sections. Our first principle is that land ownership is not the primary determinant in assigning status. The second principle is that while data are imperfect, and all land is subject to changes in ownership and management, we can use the intent of a land steward or legal and institutional factors 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, we use that 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).
- Relative amount of the tract managed for natural cover.
- Inclusiveness of the management, single element or species versus all biota.
- Type and degree of management that is mandated through legal and institutional arrangements.

The four status categories can generally be defined as follows (after Scott et al. 1993, Edwards et al. 1995, Crist et al. 1995):

Status 1: An area having permanent protection from conversion of natural land cover and a mandated management plan in operation that maintains a natural state and allows disturbance events (of natural type, frequency, and intensity) to proceed without interference or 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 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 subject to extractive uses of either a broad, low-intensity type or localized intense type. It also implies 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. Allows for intensive use throughout the tract. Also includes tracts for which the existence of such restrictions, or sufficient information to establish a higher status, is unknown.

Mapping Standards

The Iowa GAP stewardship component involved obtaining land tract information from the major conservation entities throughout the state. This effort included the acquisition and delineation of boundaries, attributing the mapped units with the correct owner/manager information, and assigning each tract with a biodiversity management code. A concerted effort was given to obtaining information from all federal, state and local public lands, and publicly available private lands information.

While many of Iowa's individual properties may be less than the GAP minimum mapping unit of 100 hectares, we felt it was important to attempt to catalog all properties managed for a number of reasons. In many cases individually mapped parcels create larger complexes consisting of a mix of stewardship and management scope. Additionally, because of recent farm programs, parcels that were not previously contiguous have been connected. Opportunities like the NRCS wetland reserve program (WRP) and emergency wetlands reserve program (EWRP) have contributed to the overall increase in areas potentially managed for biodiversity and have also increased connectivity of previously non-contiguous parcels. Similarly, programs like the U.S Fish and Wildlife Service waterfowl production areas (WPA) have contributed to the ability to create larger complexes managed for biodiversity.

Methods

<u>Stewardship Mapping</u>

The Iowa GAP stewardship layer was created from a variety of source materials from more than 100 different agencies. Table 5.1 includes an overview of the agency and the source of data used to compile the stewardship database, Figure 5.1 provides an overview of lands mapped according to managing agency, Figure 5.2 maps reach managing agency or agency charge with stewardship, and Figure 5.3 maps the reaches according to GAP status code.

Table 5.1. Source and scale of data added to the Iowa stewardship database.

Data	Source	Format	Scale
Army Corps of Engineers-Wildlife Management Areas, Forest Reserves, Refuges, Reservoirs, Pools and Easements	Army Corps of Engineers Omaha District, Rock Island District, St. Paul District USGS County Auditors Iowa Department of Natural Resources	ArcInfo coverage 7.5’ DRG Orthophotos County Auditor Plats Shapefile	1:12000 1:24000 1:24000 1:12000 1:24000
County Conservation Board (99 separate agencies)	Individual CCBs Iowa Department of Natural Resources	FSA Aerial Photos Shapefile DOQQ 7.5’ DRG County Auditor Plats Shapefile	1:20000 1:24000 1:24000 1:24000 1:12000 1:24000
Iowa Department of Natural Resources-State Parks, Preserves, Wildlife Management Areas	Iowa Department of Natural Resources	Shapefile	1:24000
Iowa Department of Transportation	Iowa Department of Natural Resources	ArcInfo coverage	1:24000
Iowa Natural Heritage Foundation	Iowa Natural Heritage Foundation	Shapefile	1:24000
National Park Service	Iowa Department of Natural Resources	ArcInfo coverage	1:24000
Natural Resources Conservation Service-EWRP, WRP, CRP	Natural Resources Conservation Service / Iowa Department of Natural Resources Individual CCBs	Shapefile See Individual CCBs	1:24000 1:24000
State Preserves	Iowa Department of Natural Resources	Shapefile	1:24000
The Nature Conservancy	The Nature Conservancy	Shapefile	1:24000
U.S. Fish and Wildlife Service-Refuges, Easements and Waterfowl Production Areas	U.S. Fish and Wildlife Service Iowa Department of Natural Resources Army Corps of Engineers	ArcInfo coverage Shapefile FSA Aerial Photo Shapefile ArcInfo coverage	1:24000 1:24000 1:20000 1:24000 1:12000

Federal lands

The U.S. Army Corps of Engineers (ACE) owns, manages or leases a large amount of land along the Mississippi and Missouri Rivers, and a number of reservoirs dispersed throughout the state. Three different ACE offices serve Iowa. The ACE-Rock Island District supplied Iowa GAP with a number of ArcInfo coverages that covered Pools 9-19 along the Mississippi River. Additional ArcInfo coverages were obtained that included Red Rock, Coralville and Saylorville Reservoirs. Data for the Mississippi River Pools were tiled and edge-matched in ArcInfo and reprojected to UTM Zone 15 NAD83. The coverage was then clipped to a state boundary coverage supplied by the Iowa Department of Natural Resources. This clipped layer was used as a base layer to delineate ownership and management boundaries. Digital orthophotos and 7.5’ DRGs were used as background images to check the accuracy of the outer ACE/USFWS boundary in the coverage. In some cases the original data appeared to have been digitized inconsistently, registered incorrectly or had polygons that collapsed during processing. Boundaries were corrected to delineated federal boundaries on the 7.5’ DRGs where appropriate. Additional information was obtained from the county auditor’s office in a number of counties where discrepancies appeared between the 7.5’ DRGs and the ACE coverages. Attributes in the original coverage were used to attribute owner, manager and unit information. Reservoir boundaries were also checked against 7.5’ DRGs and orthophotos and corrected to section and fence boundaries where appropriate through an on-screen digitizing process. Additional attribution of the stewardship layer was done using attributes from the original ACE coverage, information from the Iowa Department of Natural Resources and information from the USFWS. The ACE-Omaha District supplied Iowa GAP with an ArcInfo coverage that included realty they have jurisdiction over along the Missouri River. The coverage was reprojected to UTM Zone 15, NAD83 then compared to 7.5’ DRGs, and orthophotos, and then attributed using the attributes contained within the ACE coverage and Iowa Department of Natural Resources wildlife management information. The Iowa Department of Natural Resources created an ArcView shapefile of Rathbun Reservoir and supplied it to Iowa GAP. This data was already attributed with stewardship information. The shapefile was converted to an ArcInfo coverage prior to merging it with other federal land layers.

Data identifying parcels under the jurisdiction of the US Fish and Wildlife Service (USFWS) were obtained from a variety of sources. Data supplied by the Army Corps of Engineers was the primary source of information for stewardship information along the Mississippi River corridor. The same procedure used to reconcile ACE lands along the Mississippi River was done with USFWS areas; parcels from the ACE coverage were compared to 7.5’ DRGs to ensure the spatial accuracy. Desoto NWR, Neil Smith NWR, and Union Slough NWR were obtained directly from the Region 3 USFWS Office in the form of ArcInfo coverages. Information for the Driftless Area NWR was obtained on FSA aerial photos, registered to orthophotos and digitized on-screen. The Iowa Department of Natural Resources also maintains a database of USFWS Waterfowl Production Areas (WPA) and USFWS No Drainage Easements that were included in the stewardship layer.

In cooperation with the Iowa Department of Natural Resources, the Natural Resources Conservation Service compiled a GIS dataset that included private lands that were under an NRCS Wetland Reserve Program (WRP), Emergency Wetlands Reserve Program (EWRP) easement or a designated USFWS Waterfowl Production Area (WPA). The WPA and EWRP coverage was obtained from the NRCS, and the WPA data was obtained through the IDNR, each was edge matched to the other datasets.

State lands

The Iowa Department of Natural Resources maintains and periodically updates an ArcInfo coverage of property they own and manage. The coverage was reprojected to UTM Zone 15 NAD83 then checked for accuracy against 7.5’ DRGs and orthophotos. If necessary the parcel boundaries were adjusted to fencerows and section lines. Stewardship attribution was done by reconciling lists of IDNR state parks, recreation areas and wildlife management areas with the mapped parcels.

County and local lands

The County Conservation Board system in Iowa is comprised of 99 separate boards that manage a variety of conservation and recreational lands and represent a major stakeholder in biodiversity management within the state. There was no single source to obtain ownership and management information. At the beginning of Iowa GAP, a request was sent to counties to submit parcel information outlined on 7.5' topographic maps or copies of Farm Service Agency (FSA) 9"x 9" photos. Boundaries that were submitted were registered to orthophotos and digitized on-screen. Owner and management attributes were done using additional data provided by individual counties. In some instances, information was not submitted by a county and was obtained from plat information available through the county auditor's office. Information pertaining to property managed by the county but owned by the Iowa Department of Natural Resources came from the Iowa Department of Natural Resources.

Private and local land trust lands

The Nature Conservancy supplied an ArcView shapefile containing boundaries for property they own or for which they have conservation easements. Areas contiguous with other previously mapped parcels were edge matched. Only one major land trust organization was identified for the Iowa GAP project. The Iowa Natural Heritage Foundation (INHF) provided an ArcView shapefile of property that is owned by them or has a permanent conservation easement. In a similar manner to TNC properties, areas were edge matched and added to the main stewardship database.

Management Status Categorization

One of the secondary goals of the Iowa GAP program was to compile a comprehensive stewardship database for the state. An additional status category of 5 was added so that areas that would have been omitted due to not having a management plan or not being managed primarily for biodiversity could be included in the dataset. Iowa's lack of federal public land, the size of the areas being managed and the mix of managing entities justified including all areas that could potentially be managed for biodiversity.

Prior to attributing each area with a status code each area was attributed with yes, no, intent or unknown for each of the following categories: managed for biodiversity, protected, management plan, allows disturbance events. Using these criteria the dichotomous key described in the GAP Handbook was used to categorize each parcel (Crist et al. 2000). Figure 5.3 provides an overview of reaches categorized by GAP status code.

Reach attribution

Several steps were performed to ensure that all reaches within the State of Iowa boundary received Iowa GAP stewardship information. A comparison of the extents of the NHD reach layer and Iowa GAP stewardship layer was made to determine whether all of the border rivers represented in the NHD would capture the correct stewardship attribute. The stewardship polygon layer described above was modified by extending the east and west boundaries of the state so that the Big Sioux, Mississippi and Missouri Rivers, as represented in the NHD data, would be included within the state boundary where appropriate. An identity function, in ArcInfo, with the NHD and modified stewardship layer was performed to split the reaches with the stewardship boundary polygons. This retained the original NHD attributes for each reach, as well as providing stewardship values from the Iowa GAP stewardship layer. All reaches outside the state boundary were deleted since they would be excluded from analysis. The attribute table resulting from this operation was exported to Microsoft Access for analysis and summary.

Results

Analysis from the Iowa GAP study determined that public lands make up approximately 2.10 % of Iowa, with 1.14 % under state, 0.54 % under federal and 0.42 % under county or local government jurisdiction. State lands jurisdiction is mainly under the Iowa Department of Natural Resources (IDNR). Federal lands are split primarily between the jurisdiction of the U.S. Fish and Wildlife Service and the U.S. Army Corp of Engineers. Private land makes up the majority of land (97.90 %) in Iowa. Private lands managed for biodiversity make up approximately 0.29 %, which are areas managed by The Nature Conservancy, Iowa Natural Heritage Foundation (local land trust) and private individuals with WRP, EWRP or WPA easements on their property. Also included in this designation are private lands with an Army Corps of Engineers perpetual flow easement.

River and stream length, when classified by steward and status, were expected to reflect similar proportions. Reaches contained within areas designated as public land accounted for approximately 3.6 % of the total length of reaches within the state of Iowa. Broken down into steward categories, reaches designated as being managed by federal agencies accounted for 1.0 %, state agencies 1.7%, and 0.9 % being managed by county or local government.

Using the analysis techniques outlined above, there were few (total length = 64.7 km, < 0.1 %) reaches designated as status 1 or 2. Status 3 reaches made up 1.0 % (1,184.5 km) and the majority of reaches were designated as status 4 (115,338.6 km, 98.9%). Table 5.2 represents summary statistics of reach lengths and proportions within stewardship and management categories in the state.

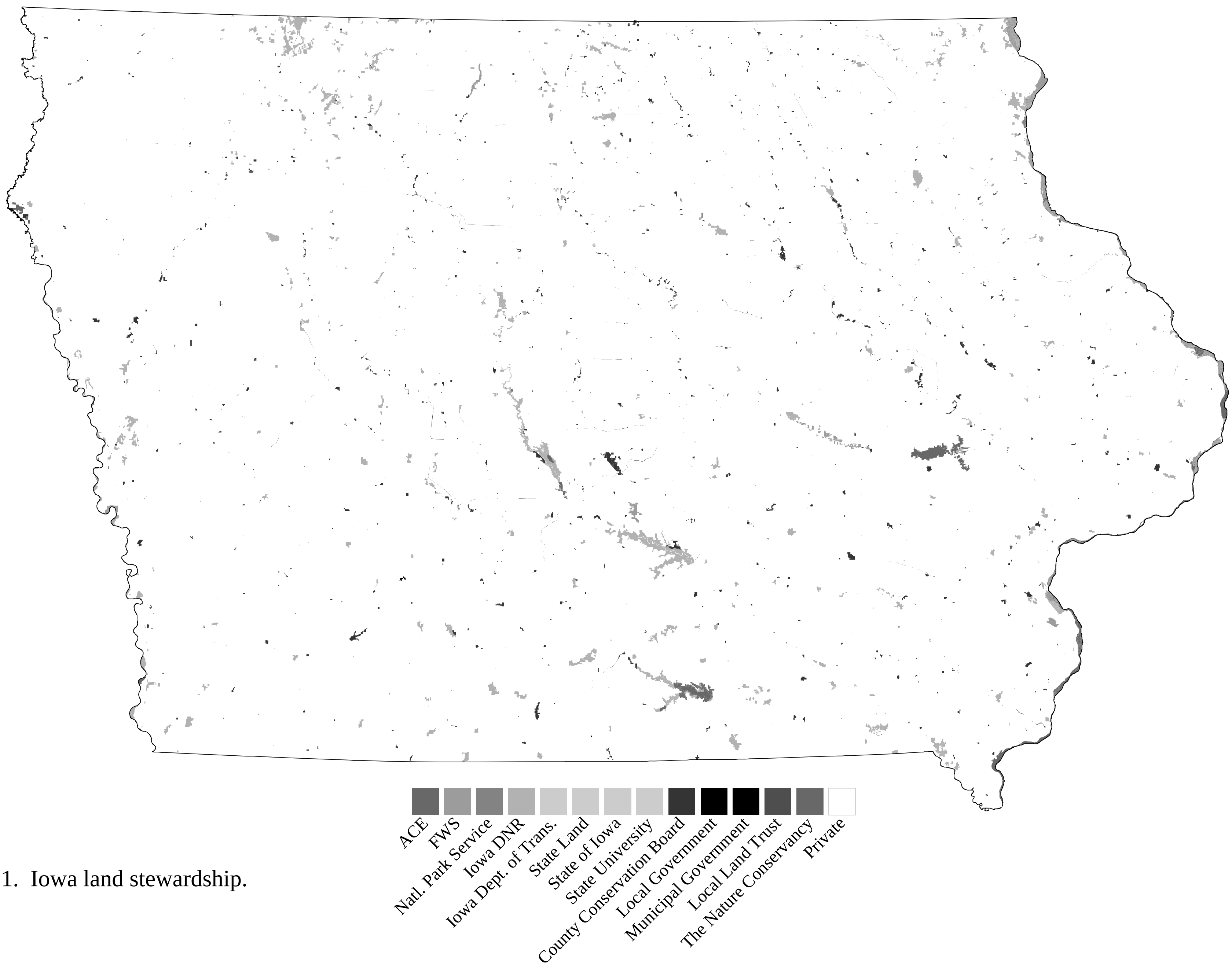

Figure 5.1. Iowa land stewardship.

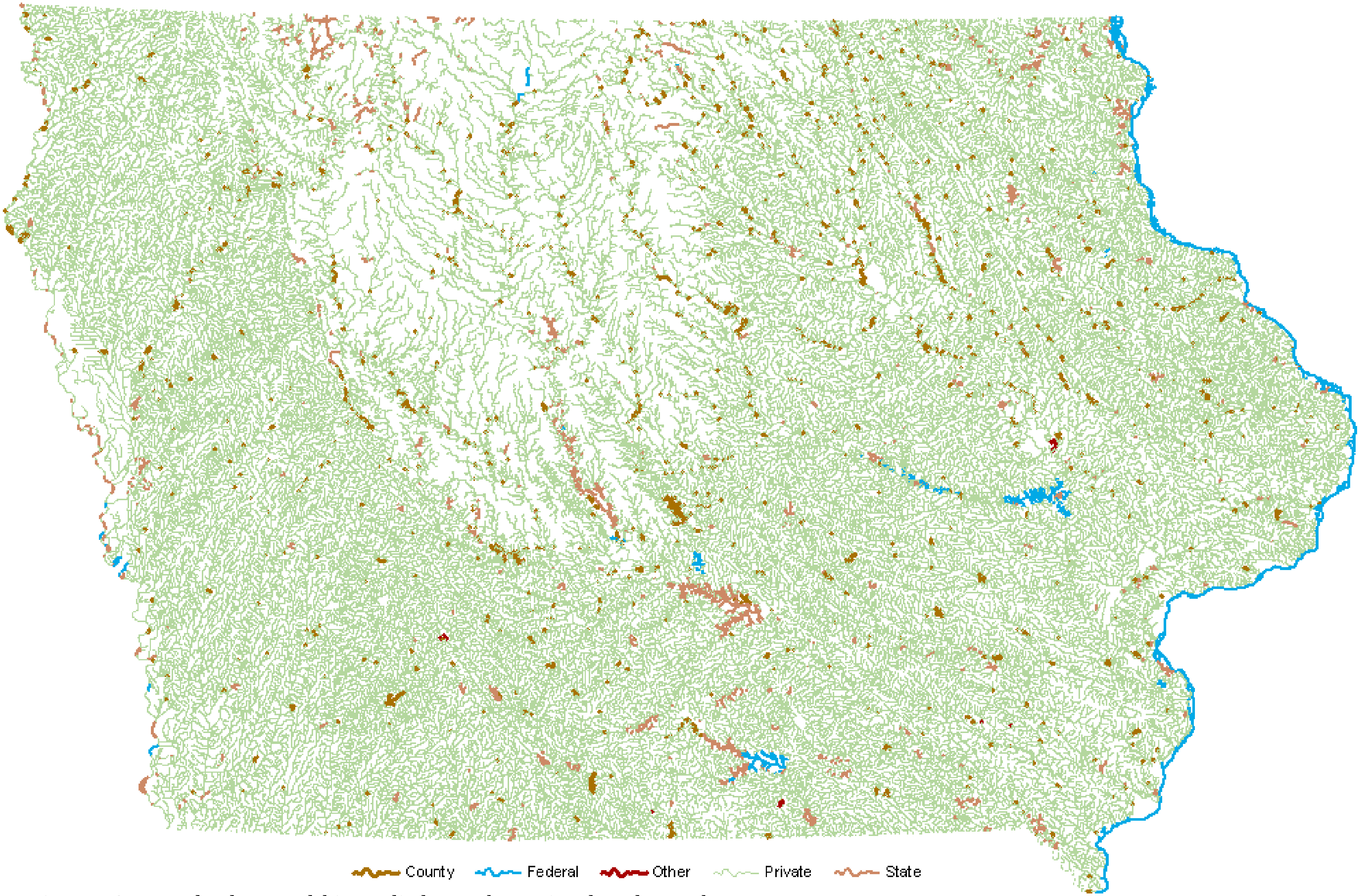

Figure 5.2. Iowa land stewardship applied to to the National Hydrography Dataset.

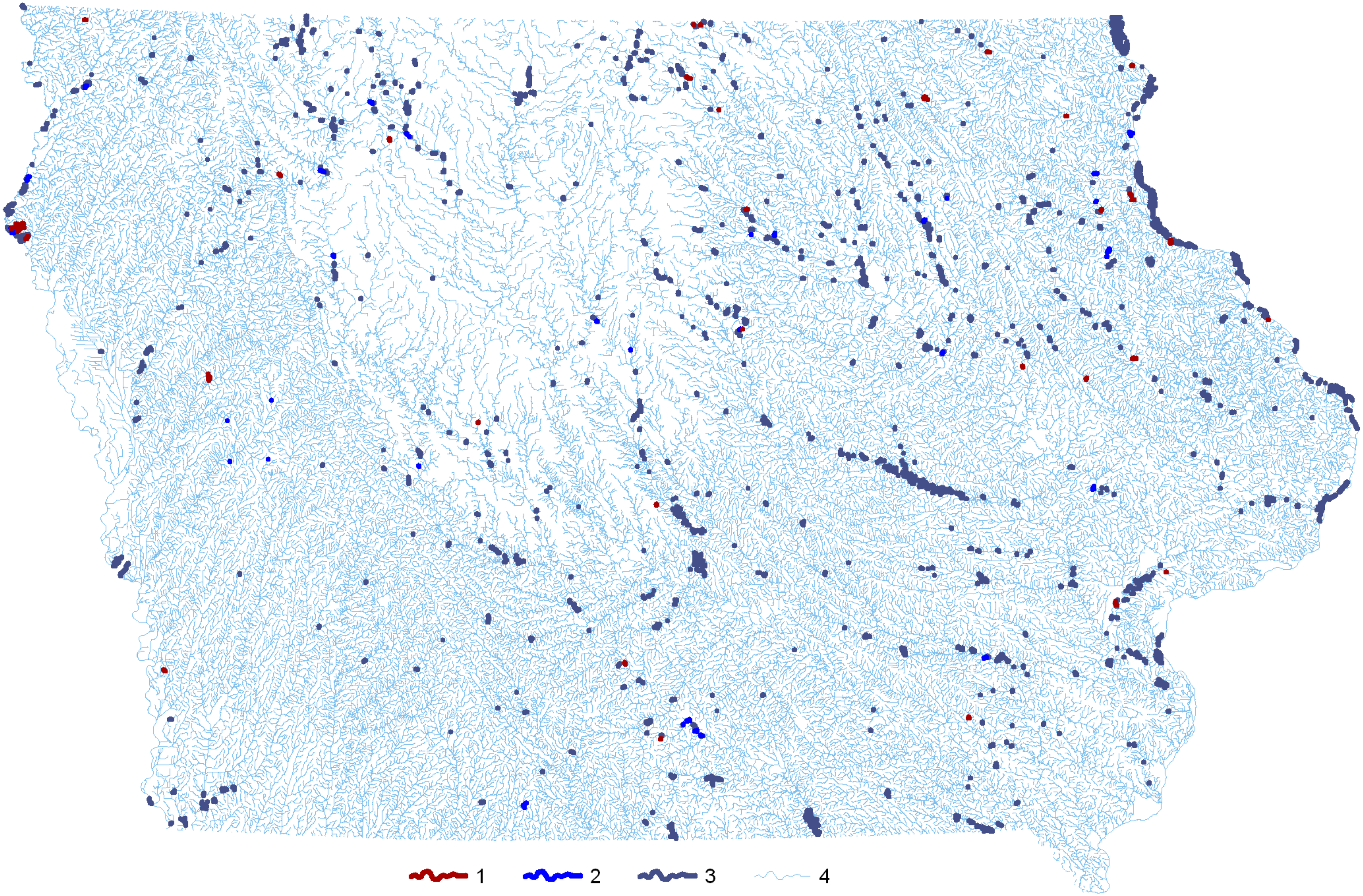

Figure 5.3. Reaches categorized with status codes.

Table 5.2. Length in kilometers and percent of reach stewardship categories by management status in Iowa.

	Status 1		Status 2		Status 3		Status 4		Total	
Land stewardship category	km	%	km	%	km	%	km	%	km	%
FEDERAL										
National Park Service (Total)	**0.0**	**0.0%**	**2.7**	**0.0%**	**0.0**	**0.0%**	**0.0**	**0.0%**	**2.7**	**0.0%**
National Monument	0.0	0.0%	2.7	0.0%	0.0	0.0%	0.0	0.0%	2.7	0.0%
U.S. Army Corps of Engineers (Total)	**0.0**	**0.0%**	**0.0**	**0.0%**	**0.0**	**0.0%**	**797.7**	**0.7%**	**797.7**	**0.7%**
Managed Area	0.0	0.0%	0.0	0.0%	0.0	0.0%	797.7	0.7%	797.7	0.7%
U.S. Fish and Wildlife Service (Total)	**0.0**	**0.0%**	**4.8**	**0.0%**	**410.6**	**0.4%**	**2.1**	**0.0%**	**417.5**	**0.4%**
National Wildlife Refuge	0.0	0.0%	4.8	0.0%	373.9	0.3%	0.2	0.0%	378.9	0.3%
Managed Area	0.0	0.0%	0.0	0.0%	0.0	0.0%	1.9	0.0%	1.9	0.0%
Managed Area w/ WRP easement	0.0	0.0%	0.0	0.0%	36.7	0.0%	0.0	0.0%	36.7	0.0%
Total Federal Reaches	**0.0**	**0.0%**	**7.5**	**0.0%**	**410.6**	**0.4%**	**799.8**	**0.7%**	**1,217.9**	**1.0%**
STATE										
Iowa Department of Natural Resources (Total)	**0.0**	**0.0%**	**3.0**	**0.0%**	**127.7**	**0.1%**	**1,818.0**	**1.6%**	**1,948.7**	**1.7%**
State Park or Recreation Area	0.0	0.0%	0.0	0.0%	0.0	0.0%	298.6	0.3%	298.6	0.3%
State Preserve	0.0	0.0%	0.0	0.0%	0.0	0.0%	9.7	0.0%	9.7	0.0%
Wildlife Area	0.0	0.0%	3.0	0.0%	127.7	0.1%	1,420.8	1.2%	1,551.5	1.3%
Water	0.0	0.0%	0.0	0.0%	0.0	0.0%	88.9	0.1%	88.9	0.1%
Iowa Department of Transportation (Total)	**0.0**	**0.0%**	**0.0**	**0.0%**	**0.0**	**0.0%**	**0.0**	**0.0%**	**0.0**	**0.0%**
Managed Area	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%
State University (Total)	**0.0**	**0.0%**	**0.0**	**0.0%**	**0.0**	**0.0%**	**0.7**	**0.0%**	**0.7**	**0.0%**
Managed Area	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%
State Preserve	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%
State Land (Total)	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.7	0.0%	0.7	0.0%
State Preserve	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%
Total State Reaches	**0.0**	**0.0%**	**3.0**	**0.0%**	**127.7**	**0.1%**	**1,818.7**	**1.6%**	**1,949.4**	**1.7%**
LOCAL										
County Conservation Board (Total)	**6.4**	**0.0%**	**20.3**	**0.0%**	**357.5**	**0.3%**	**612.3**	**0.5%**	**996.5**	**0.9%**
County Park or Wildlife Area	3.8	0.0%	1.8	0.0%	308.4	0.3%	605.7	0.5%	919.7	0.8%
Managed Area w/ WRP easement	2.6	0.0%	17.5	0.0%	40.1	0.0%	0.0	0.0%	60.2	0.1%
Managed Area w/ FWS no drainage easement	0.0	0.0%	0.0	0.0%	0.5	0.0%	0.0	0.0%	0.5	0.0%
Managed Area w/ CRP easement	0.0	0.0%	0.0	0.0%	1.2	0.0%	0.0	0.0%	1.2	0.0%
State Preserve	0.0	0.0%	1.0	0.0%	7.3	0.0%	6.6	0.0%	14.9	0.0%
Local Government(Total)	**0.0**	**0.0%**	**0.0**	**0.0%**	**0.5**	**0.0%**	**0.5**	**0.0%**	**1.0**	**0.0%**
Managed Area	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.5	0.0%	0.5	0.0%
Managed Area w/ WRP easement	0.0	0.0%	0.0	0.0%	0.5	0.0%	0.0	0.0%	0.5	0.0%
Municipal Government(Total)	**0.0**	**0.0%**	**0.0**	**0.0%**	**1.0**	**0.0%**	**14.0**	**0.0%**	**15.0**	**0.0%**
Managed Area	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%
Managed Area w/ WRP easement	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%
State Preserve	0.0	0.0%	0.0	0.0%	1.0	0.0%	14.0	0.0%	15.0	0.0%
Total Local Reaches	**6.4**	**0.0%**	**20.3**	**0.0%**	**359.0**	**0.3%**	**626.8**	**0.5%**	**1,012.5**	**0.9%**

Table 5.2 continued. Length in kilometers and percent of reach stewardship categories by management status in Iowa.

	Status 1		**Status 2**		**Status 3**		**Status 4**		**Total**	
Land stewardship category	**km**	**%**	**km**	**%**	**km**	**%**	**km**	**%**	**km**	**%**
PRIVATE										
Local Land Trust(Total)	**11.6**	**0.0%**	**0.0**	**0.0%**	**1.4**	**0.0%**	**0.0**	**0.0%**	**13.0**	**0.0%**
Preserve	11.6	0.0%	0.0	0.0%	1.4	0.0%	0.0	0.0%	13.0	0.0%
Private (Total)	**0.0**	**0.0%**	**0.0**	**0.0%**	**285.8**	**0.2%**	**112,093.3**	**96.1%**	**112,379.1**	**96.4%**
Managed Area	0.0	0.0%	0.0	0.0%	0.0	0.0%	1.9	0.0%	1.9	0.0%
Managed Area w/ WRP easement	0.0	0.0%	0.0	0.0%	276.5	0.2%	0.0	0.0%	276.5	0.2%
Managed Area w/ FWS no drainage easement	0.0	0.0%	0.0	0.0%	9.3	0.0%	0.0	0.0%	9.3	0.0%
Managed Area w/ ACE easement	0.0	0.0%	0.0	0.0%	0.0	0.0%	336.2	0.3%	336.2	0.3%
Private (Not known)	0.0	0.0%	0.0	0.0%	0.0	0.0%	111,750.0	95.9%	111,750.0	95.9%
State Preserve	0.0	0.0%	0.0	0.0%	0.0	0.0%	5.2	0.0%	5.2	0.0%
The Nature Conservancy (Total)	**15.9**	**0.0%**	**0.0**	**0.0%**	**0.0**	**0.0%**	**0.0**	**0.0%**	**15.9**	**0.0%**
State Preserve	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%
TNC Preserve	14.1	0.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%	14.1	0.0%
TNC Easement	1.8	0.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%	1.8	0.0%
TNC Management Agreement	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%
Total Private Reaches	**27.5**	**0.0%**	**0.0**	**0.0%**	**287.2**	**0.2%**	**112,093.3**	**96.1%**	**112,408.0**	**96.4%**
Total All Reaches	**33.9**	**0.0%**	**30.8**	**0.0%**	**1,184.5**	**1.0%**	**115,338.6**	**98.9%**	**116,587.8**	**100.0%**

Limitations and Discussion

The Iowa stewardship map is a compilation of ownership maps provided by a variety of sources that are individually responsible for their accuracy. It was created solely for the purpose of conducting the analyses described in this report and is not suitable for locating boundaries on the ground or determining precise area measurements of individual tracts or management of streams. In addition, the analogy of ‘stream stewardship’ derived from Iowa GAP parcel stewardship data should only be used as an indicator of how land is managed adjacent to a particular reach. There are a host of factors influencing stream biodiversity including localized and landscape level stewardship, management practices and conservation measures. Water rights and ownership is a complex subject not well documented and difficult to model. For example, navigable waters somewhat influenced by Iowa legislation, were not included within this analysis because of the difficulty in collecting this type of information.

Iowa GAP made a reasonable effort to obtain accurate boundary and attribute information for all areas represented in the Iowa GAP stewardship database. Several difficulties encountered while compiling information included cooperation of agencies identified as having information to contribute, the availability of existing data at a variety of scales, and changes due to time of acquisition.

Edge matching boundaries of different data sources, in most cases was not a problem. However, in some cases discrepancies existed between stated owner and manager. This was most evident along the Mississippi River corridor. The Fish and Wildlife Service (USFWS), Army Corps of Engineers (ACE) and the Iowa Department of Natural Resources (IDNR) are the primary stewards for lands in this area. The ACE data provided the most inclusive documentation of land along the Mississippi River and was supplemented by more recent data from USFWS and IDNR. Recent data available from the IDNR generated from internal real estate documents were used to document parcel inholdings that were not present within the ACE data. Discrepancies between county and state owned or managed areas were few and were resolved by contacting the appropriate agencies.

Assigning of GAP status codes can be highly subjective. An attempt was made to standardize the coding of this attribute by attributing parcels and reaches with information that followed the status codes. Despite this method, errors may still exist in the status coding due to a lack of information or incorrect information from ancillary data sources.

Data obtained from individual County Conservation Boards was digitized, and then sent back to the individual counties for review. Corrections, if any, were made to the data. The IDNR data was taken as is. The data obtained was assumed to be correct since it had been developed using IDNR realty documents during the same time period as the Iowa GAP stewardship database. ACE and USFWS data was also assumed correct except for some discrepancies discovered while edge matching IDNR and ACE data.

Data will be discovered that has been omitted from the Iowa GAP stewardship database. Omitted data may be the result of additional property being acquired after data was submitted to Iowa GAP, a managing entity not submitting data, or failure of Iowa GAP recognizing an area as being managed for biodiversity. It is not the intent of the Iowa GAP land stewardship map to be used as a legal document. It is intended for use at a landscape scale to identify general stewardship patterns and stream management patterns throughout the state.

Conclusions

Public lands in Iowa are limited to approximately 2.10% of the total land area of the state and reaches with a designation of public amount to approximately 3.6% of the total length of streams within the state boundary. This includes areas managed by the Federal Government, Iowa Department of Natural Resources, Iowa Department of Transportation, and the 99 counties that comprise the County Conservation Board system. The remaining public land is managed primarily by federal and county agencies scattered throughout the state.

With such a small amount of streams managed within public land, the role and relationships between private and public land managing entities is important for the long-term management of aquatic biodiversity in the state. Figure 5.4 represents the proportion of private land within watersheds within Iowa. In all cases, private lands are the primary stewardship class within watersheds. There were no watersheds that consisted of less than 87% private lands. Factors influencing stream and river biodiversity are probably closely related to actions implemented on private lands. Programs, whether at the state or federal level, encouraging private landowners to implement conservation practices directly influences the amount of land that supports biodiversity, encourages natural ecosystem functions, and soil conservation practices. One recent example of this is the NRCS WRP program that, during the short period of its funding, added over 20,000 hectares throughout the state providing the establishment and protection of wildlife habitat, streamside vegetation and potentially, improved water quality.

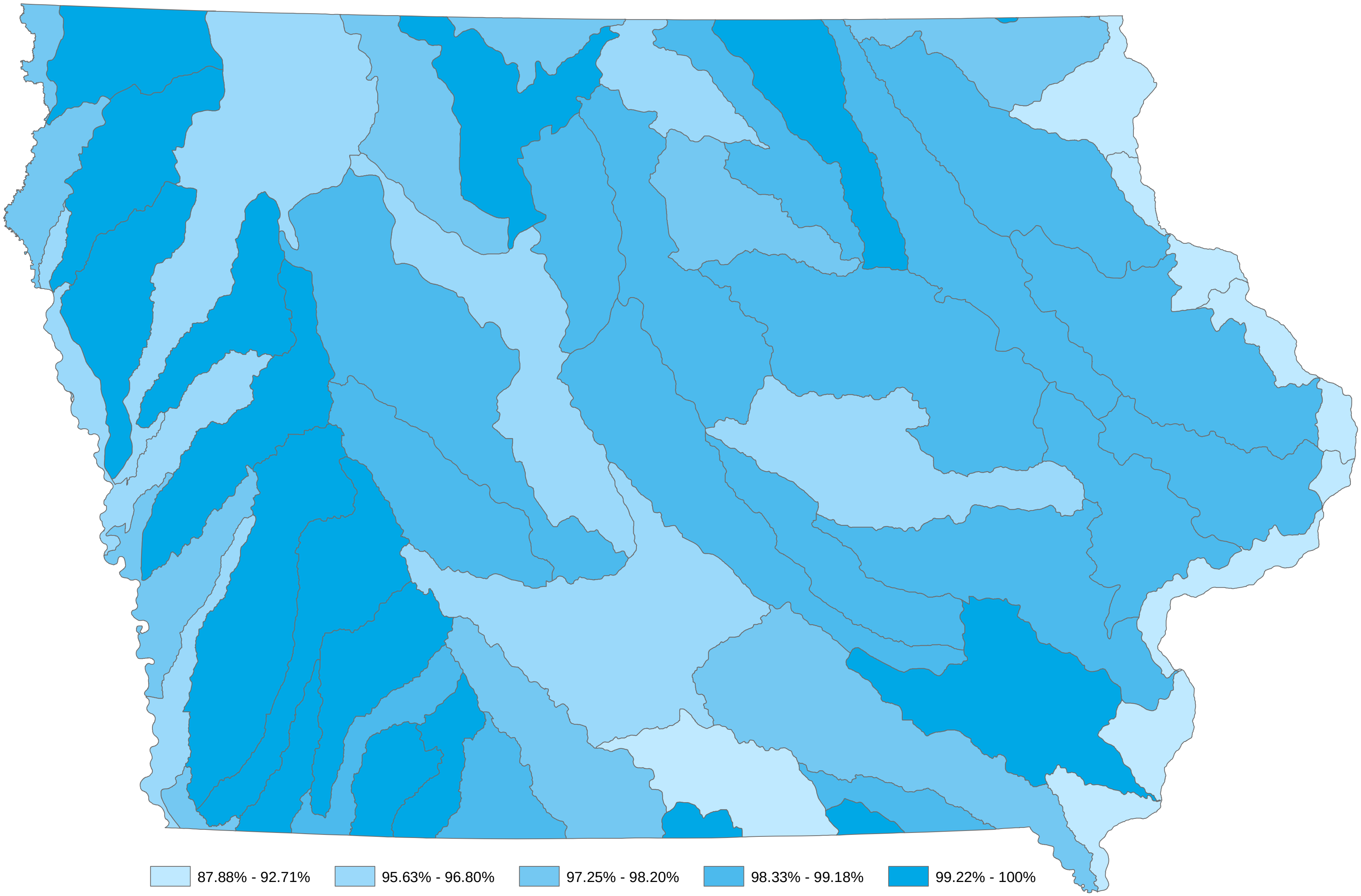

Figure 5.4. Percent of private land management in watersheds (HUC-8 boundaries).

Chapter 6

Stream and Watershed Analysis Based on Stewardship and Management Status

Introduction

This chapter describes the methods and results of the aquatic gap analysis as used by the Iowa Aquatic Gap Analysis Project (IAGAP). Anyone familiar with the terrestrial component of gap analysis should make note that many of the same concepts used in the terrestrial gap analysis were applied to the aquatic component with a couple of exceptions. As described in the general introduction of this report (see Chapter 1), the primary objective of GAP is to provide information about the distribution and status of fish diversity throughout the state. One of the main mapping components of terrestrial GAP was the land cover mapunit used for species predictive modeling; the analogous component to this in Aquatic GAP is the river reach as modeled by the National Hydrography Dataset (NHD). The smaller scale or regional perspective uses the hydrologic unit (HUC) as modeled by the USGS as the mapping unit. The goals of terrestrial GAP were to identify areas in need of protection. In Aquatic GAP these goals remain the same, however instead of using the land cover mapunit as the unit of analysis, we found it more appropriate to use the watershed and reach as a basic framework for management analysis. This chapter will take a descriptive approach to looking at watershed characteristics to explore the relationships between predicted species richness, stewardship and dominant land cover. Additionally, this chapter will explore the reach-based distribution of individual fish species from the perspective of stewardship and management status.

In Chapter 4, Predictive Fish Modeling, an approach to estimating the distribution of aquatic fish taxa was outlined. In addition, output from these models was visualized using watersheds and reaches. Many of the predictor variables used in the modeling process are difficult to visualize and make comparisons to other variables such as stewardship at a statewide or watershed scale. In this chapter we will revisit the watershed richness map and present with this analysis various other watershed descriptors that may act as surrogates for understanding the relationship between some of the model predictor variables and the predicted richness patterns. While this does not specifically address individual reach richness numbers, it may provide some insight to statewide richness patterns.

This chapter will start to examine the relationship between the predicted species distribution maps found in Appendix B7 and stewardship patterns. The data are provided below in tables or figures or in Appendix D3. Predicted species richness maps were developed from all records in the Iowa fish database described in Chapter 3. A more complete analysis of temporal fish distribution patterns may be possible using sub-samples from the database, but was not done for this analysis.

Background

Various studies have examined species richness and factors potentially affecting aquatic species richness and distribution patterns. Revenga et al. (1998) examined fish richness in watersheds throughout the world and found that larger watersheds tended to support more fish species and more endemic fish species than smaller ones. Fausch et al. (1984) also found that the number of fish species increased as watershed area increased. Increased stream order also positively influenced the number of fish species present. Fish distribution patterns may also be influenced by factors including temporal and geologic characteristics associated with watershed divides (Warren et al. 1991, Jackson and Harvey 1989).

Several watershed scale variables may influence water habitat and ultimately species richness and distribution patterns. Moyle and Leidy (1992) explain that the ultimate cause of loss of aquatic biodiversity is the result of human population growth. Direct causes include competition for water, habitat alteration, pollution, introduction of exotic species, and commercial exploitation (Moyle and Leidy 1992, Allan and Flecker 1993).

Land use patterns and their relationship to macroinvertebrate populations and habitat were studied by Richards and Host (1994). They examined the effects of these patterns on local instream characteristics and found that stream embeddedness increased with increasing agriculture and substrate size decreased with housing density. Algal abundance was positively correlated with housing density and negatively correlated with the mixed forest land use. Roth et al. (1996) studied a Midwestern watershed to examine the usefulness of using land use and land cover as indicators of stream integrity (IBI) and instream habitat through a habitat index. They found that stream integrity was negatively correlated with the proportion of agriculture in the watershed and positively correlated with the proportion of forest and wetland. They also determined that watershed land use variables were effective at predicting habitat index scores. Instream habitat scores were negatively correlated with the proportion of agriculture.

Using simulations to model the effects of land use/cover change and stream flow on the sustainability of smallmouth bass populations in a Midwestern river, Peterson and Kwak (1999) suggest that altered land use results in decreased fish populations. Shifts in watershed scale land use/cover, such as increased agricultural activity have also been shown to reduce aquatic diversity (Harding et al. 1998). Karr et al. (1985) examined changes to fish communities in watersheds in Illinois and Ohio and found that over time fish species have become less abundant or have disappeared. They attribute this historic trend to changes in headwater streams such as channelization and wetland drainage. Watersheds with higher proportions of urban land uses and areas with highly connected impervious surfaces had lower species richness than those watersheds with lower proportions of urbanization (Wang et al. 2001). Fish diversity, density and stream IBI scores were also lower under these landscape configurations.

Urban and pasture dominated watersheds were found to influence stream water quality in two studies in the Missouri Ozarks (Smart et al. 1981, Smart et al. 1985). In these studies increased proportions of pasture and urban land use classes in a watershed had a positive correlation with nutrient and chemical concentrations in streams, while forested watersheds had an inverse response. Hunsaker and Levine (1995), in a study of several watersheds in Illinois and Texas, also determined that as the proportions of agriculture, barren, and rangeland increased within a watershed so did nutrients within streams. In agricultural watersheds, forested riparian areas may help in buffering nutrient discharge from surrounding areas as well as provide streambank stabilization and shading (Lowrance et al. 1984). Osborne and Wiley (1988), in an Illinois watershed study looking at land use/cover and water quality relationships, determined that nutrient concentrations in streams are seasonally affected by both agricultural and urban land uses.

Methods

We performed a descriptive analysis of Iowa watersheds, looking at land use/cover proportions and stewardship patterns. Using this information, we analyzed species richness at the watershed scale and compared this to the watershed land use/cover proportions. Additionally, richness differences between the Mississippi River and Missouri River basins were examined. Finally, we looked at reach scale information detailing stewardship, richness and individual species relationships.

Watershed Scale

The descriptive analysis of Iowa watersheds was performed using two readily available geospatial datasets. Land use/cover was modeled using the 2001 National Land Cover Dataset (NLCD) available from the Multi-Resolution Land Characteristics (MRLC) Consortium. The NLCD is a 30-meter resolution raster dataset classified into 29 land use/cover classes and derived from Landsat 7 imagery. Watershed boundaries were obtained from the USGS through their National Hydrography Dataset (NHD) program. Boundaries were at the 8-digit hydrologic unit code (HUC) level. Typical watershed areas for the 8-digit HUC in, or partially in, Iowa range from 180 sq mi. to 3,320 sq. mi. IAGAP chose the 8-digit HUC to better conform to the historic sampling resolution of fish species. Land use/cover proportions were calculated for the watersheds by using the ArcGIS 9.0 Tabulate Area function which calculates the area of each raster class (land use/cover) in square map units for the zones (8-digit HUCs) in another spatially coregistered dataset. Percentages were calculated using Microsoft Excel. Maps of the dominant land use/cover classes by HUC were then generated by joining the calculated land use/cover proportions to the HUC dataset.

Watershed stewardship analysis was done by intersecting Iowa GAP stewardship data with the 8-digit HUC boundaries. This resulted in a hybrid 8-digit HUC stewardship map clipped to the Iowa boundary. Ideally we would have liked to include stewardship data for watersheds having some point of contact with the state but data did not exist for all surrounding states. Therefore, calculations for the stewardship proportions in each watershed were based on the clipped 8-digit HUC boundaries.

Variability of species richness among watersheds and between the two major drainage basins in the study site was examined using species richness maps described in Chapter 4. Watersheds that collectively drained to the Missouri River or to the Mississippi River were grouped to look at differences in species richness by major basin. Watersheds were grouped using the first three digits of the HUC code. Species richness for each watershed within a major basin was compared using the derived watershed characteristics described above. Specifically, species richness for each sub-watershed was compared to the proportions of dominant land use/cover types for the same sub-watershed using JMP (SAS Institute, Inc.).

Reach Scale

A stewardship analysis of species distributions at the reach level was done to look at patterns of protection or gaps within the current management system. This was done by using the Iowa Stream Reach (ISR) dataset, clipped to the Iowa border and attributed with stewardship information, which is described in Chapter 5. The IAGAP species occurrence database described in Chapter 3 contained a table with reach codes for all reaches in which a species was predicted and the stewardship status of that reach. Using that predicted reach code table, a matrix was created detailing stewardship information for each fish species in all Iowa reaches. Microsoft Access and the Python programming language were used to summarize this table by GAP status code and stewardship entity. Using the summary data, tables were then created for each individual species modeled (see Appendix D1).

The IAGAP species occurrence database described above also contained a table with reach codes for all reaches in which a species was predicted, regardless of stewardship status. An attribute of that table was the total number of fish species found in that reach. Using that predicted reach code table joined to the ISR dataset, a more specific dataset was created detailing fish species richness in all Iowa reaches.

Results

Watershed Scale

Watershed description

Land use/cover, stewardship and other human activities play a large role in determining water quality and ultimately aquatic biodiversity. Species richness information was modeled for 55 of the 57 watersheds completely within or passing through Iowa. Because not all watersheds had richness measures, land use/cover was also limited to these 55 watersheds.

Typical watershed areas for the 8-digit HUCs in, or partially in, Iowa range from 180 sq mi. to 3,320 sq. mi. We looked at land use/cover across the state. In almost all watersheds agriculture was the dominant land use ranging from 21.9% to 90.7% of the land area (see Figure 6.1). Other dominant land use/cover types were forest (deciduous, evergreen, mixed, and wooded wetland) 0.6% to 41.3%, pasture 3.0% to 45.6%, and urban/commercial classes 0.9% to 10.4%. The northwest portion of the state is primarily agriculture, the northeast dominated by forest and pasture, and the southern portion of the state consists of large percentages of pasture and forest.

Watershed Analysis of Stewardship

Because of the nature of aquatic systems, private land ownership and management at the watershed scale can have large influences on various aspects of aquatic systems. Aquatic GAP was not designed to explicitly measure these relationship but we feel it is important to outline the stewardship configuration of Iowa watersheds. The table in Appendix D3 outlines the specifics of watershed stewardship for watersheds within the bounds of the state of Iowa and Figure 5.4 provides visualization for private stewardship and Figure 6.2 includes other stewardship classes in this visualization. Watersheds throughout the state are mainly under the stewardship practices of private landowners. Private lands range from 87.9% to 100.0% of the total land area in individual watersheds. For individual watersheds federally managed lands range from 0.0% to 10.8%, state lands 0.0% to 4.1%, and county lands, primarily County Conservation Boards, 0.0% to 1.1%.

Species Richness Patterns

It should be noted that there are very few areas which have large expanses of protected areas relative to areas having high protected status according to GAP status codes. Species richness at the watershed scale is somewhat tied to land use/cover. There is a positive correlation between the proportion of forested land in a watershed and species richness (Figure 6.3). This figure also shows a negative correlation between the proportion of row crop and species richness. Watersheds with more urban land use patterns also showed a positive correlation to species richness. This goes against other studies that have found a strong negative correlation between species richness and urbanized watersheds (Wang et al. 2001). Stating this could be misleading since the distribution modeling was done at the 8-digit HUC level, land use/cover relationships with species distributions may not be adequately represented. A finer scale distribution analysis at a 10-digit or 12-digit HUC would be necessary to see if there was truly a relationship between land use/cover patterns and species richness.

Species Richness Between Major Drainage Basins

There were differences found between the watersheds draining directly to the Mississippi River and those draining to the Missouri River. The watershed within the Mississippi River Basin had an average of 66 species per watersheds (min. 16, max 111, s.d.22) with watersheds that are immediately draining into the Mississippi River showing the highest species richness (Figure 6.4). The Missouri River watersheds in contrast had a lower average richness with 37 species (min. 14, max 65, s.d. 15).

Reach Scale

Analysis of Stewardship and Fish Distributions

Iowa Aquatic GAP used the terrestrial Iowa GAP stewardship database for analysis and the results may be inadequate for determining localized stewardship practices and conservation at the reach scale. This is because the stewardship dataset attributes were not collected with a focus on stream conservation. The information in the stewardship database pertains specifically to the land contained within the property boundaries; any associated benefit to a stream reach flowing through the protected property is assumed to be conferred by spatial coincidence. This assumed benefit cannot be accurately confirmed, however, based on usual management procedures, it seemed a likely conclusion.

Aquatic GAP is a coarse-scale analysis and examining conservation of fish species at an individual stream reach does not show the larger picture and may even falsely imply greater conservation than is actually occurring. The very nature of streams as flowing bodies of water containing fish that move along those streams means that a protected stretch of stream is only benefiting fish in that segment. The stream is impacted by instream and surrounding land management practices both upstream and downstream. Though Iowa Aquatic Gap predicted and summed particular stream reaches for individual fish species (Appendix D1), those length amounts don't explain the fish's situation in the larger context of the watershed. Most of the streams in a fish's range occur on private property, with the exception of fish in the Mississippi River. Certain conservation practices are assumed to occur on public lands; conservation practices, or lack thereof, cannot be determined on private property even though those lands have the most influence on a fish and it's habitat. Therefore, the watershed level analyses give a broader assessment of fish biodiversity and should be used unless a specific stream reach is being researched.

Regarding just the predicted distributions for the 144 fish with model results, total stream predicted lengths ranged from 5.6 km (Alabama Shad) to 108,544 km (Creek Chub). For the Creek Chub, 97% of that length flows through private property; however, the Alabama Shad is predicted only in federally managed waters, one pool of the Mississippi River. The Alabama Shad is thought by some to not occur in Iowa currently; the next two fish with the lowest predicted stream lengths are the Bigeye shiner and the White catfish, both at 37 km and both with an uncertain presence in Iowa. These both are also predicted to occur in only one pool of the Mississippi River. The two fish with the lowest predicted reach length that can reliably be found in Iowa are the Freckled madtom and Spotted gar at 54.4 km., both in Pool 13 of the Mississippi River.

For a general picture of length of protected streams in relation to the management category, see Figures 6.5 and 6.6. The most obvious message is that the majority of almost every fish's predicted reaches are on private property. Of the publicly managed reaches, state agencies have the most at 1,949 km; federal and county agencies follow with 1,218 km and 997 km, respectively (See Figure 6.7).

Limitations and Discussion

Water rights, stewardship and control is a complex attribute to map and analyze. One of the major limitations in the analysis of aquatic biodiversity in relation to surface water stewardship is the accurate way to represent these relationships. We attempted to use the Iowa GAP stewardship layer as a starting point for understanding these relationships. A watershed perspective of land use/cover patterns probably works better for this type of analysis because of the relationship surface vegetation and land use has on water quality, stream temperature, riparian habitat and other factors important to supporting aquatic life. Our analysis at the 8-digit HUC level was adequate in getting a snapshot of the overall pattern of land influences that may be affecting species richness across the state. Looking at the same patterns using a finer division of watersheds, such as the 10-digit or 12-digit HUC, would probably reveal different relationships between land use/cover and species richness.

Future Work

There are many other factors describing fish richness and distribution that could potentially be explored using this data and may provide an alternative assessment of statewide diversity. These include:

- Historic loss or gain in range distribution
- Use of historic fish data and chronologically coincident land cover from aerial photos to examine interrelations and compare to current data
- Further detail the nature of historic or current spatial distributions
- Immediate versus long term risk
- Degree of local adaptation among populations of the biotic elements that are worthy of individual conservation consideration
- Examination of fish richness with land cover percentages at the HUC 10 or 12 level

Such analyses are beyond the scope of this project, but we encourage their application. Another endeavor using the provided data results would be field confirmation of the mapped distributions and reach predictions. The accompanying digital data distributed with this report should allow users to make additional queries to suit their own interest or objectives. This forms the basis of GAP's mission to provide land owners and managers with the information necessary to conduct informed policy development, planning, and management for the long-term maintenance of aquatic biodiversity.

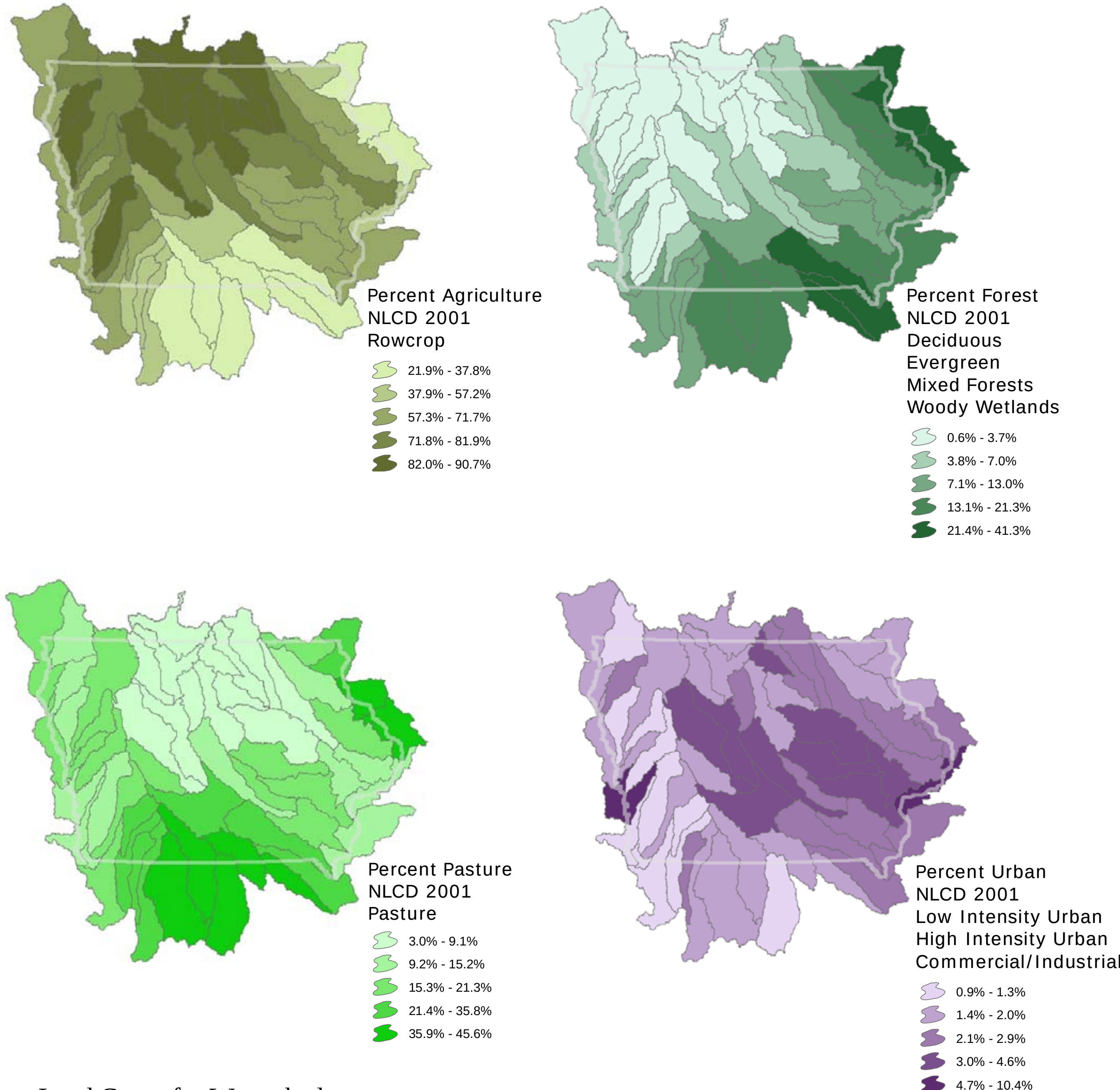

Figure 6.1. Percent Land Cover for Watersheds.

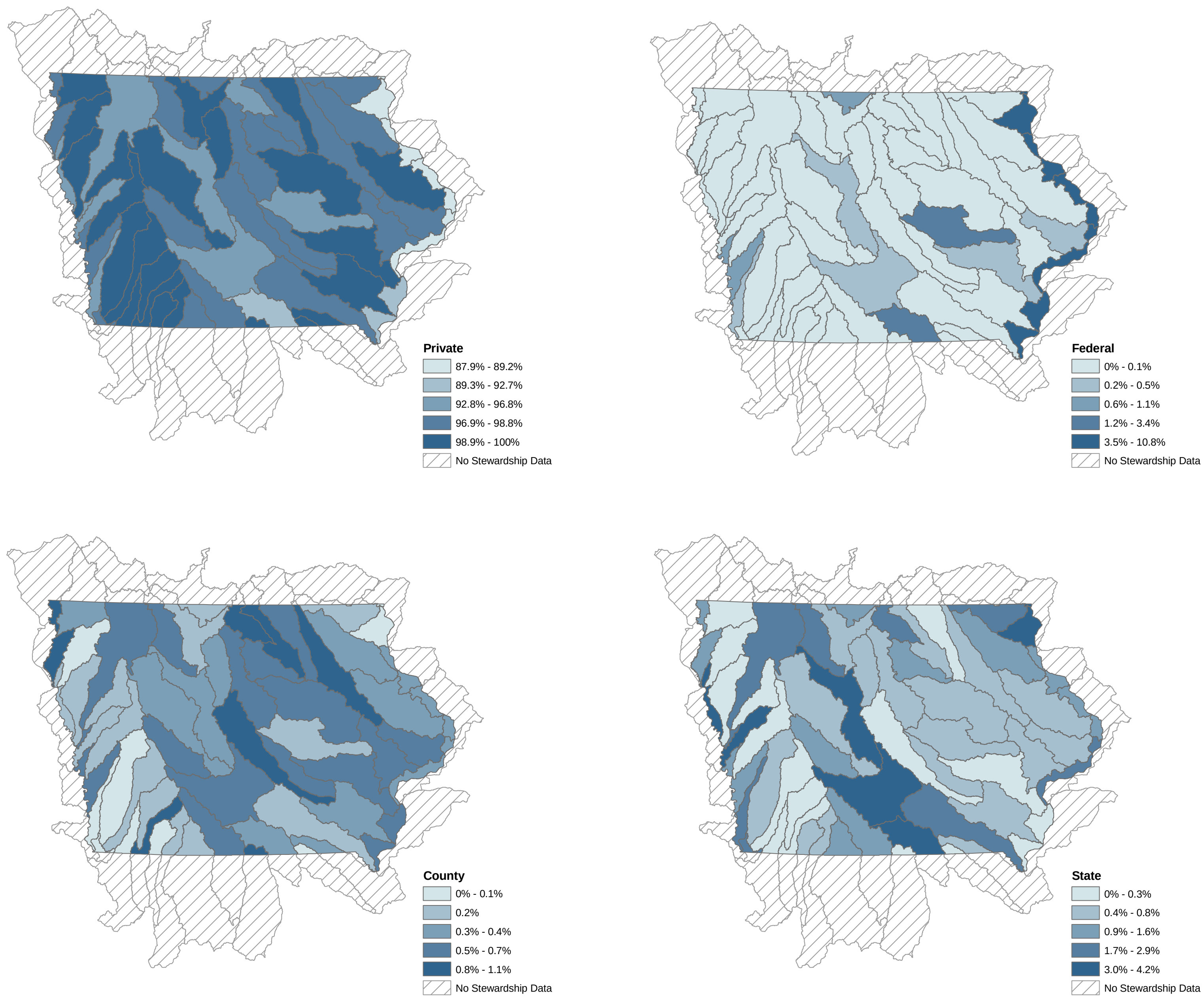

Figure 6.2. Percent steward by 8-digit hydrologic unit code (HUC-8).

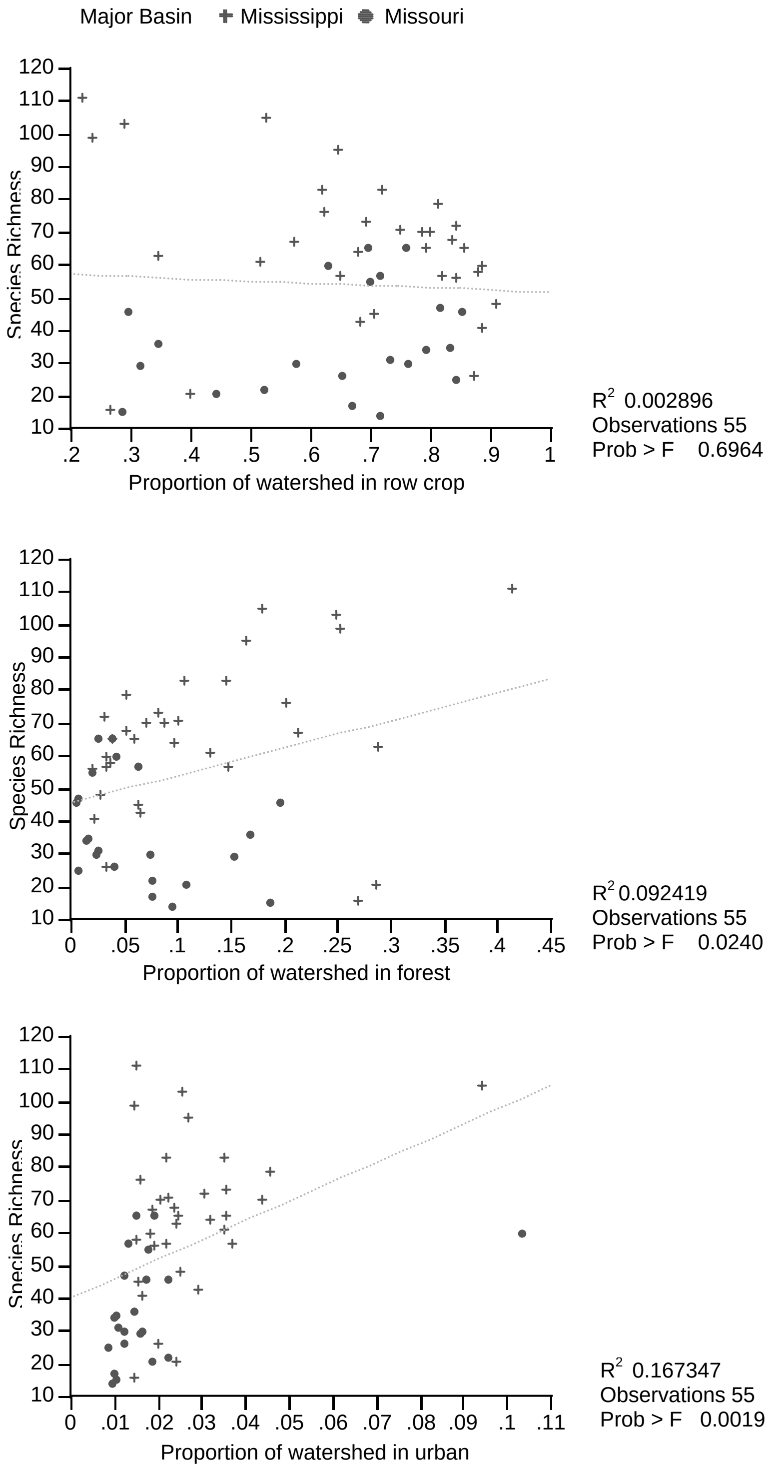

Figure 6.3 Species Richness and Watershed Land Use/Cover Proportions.

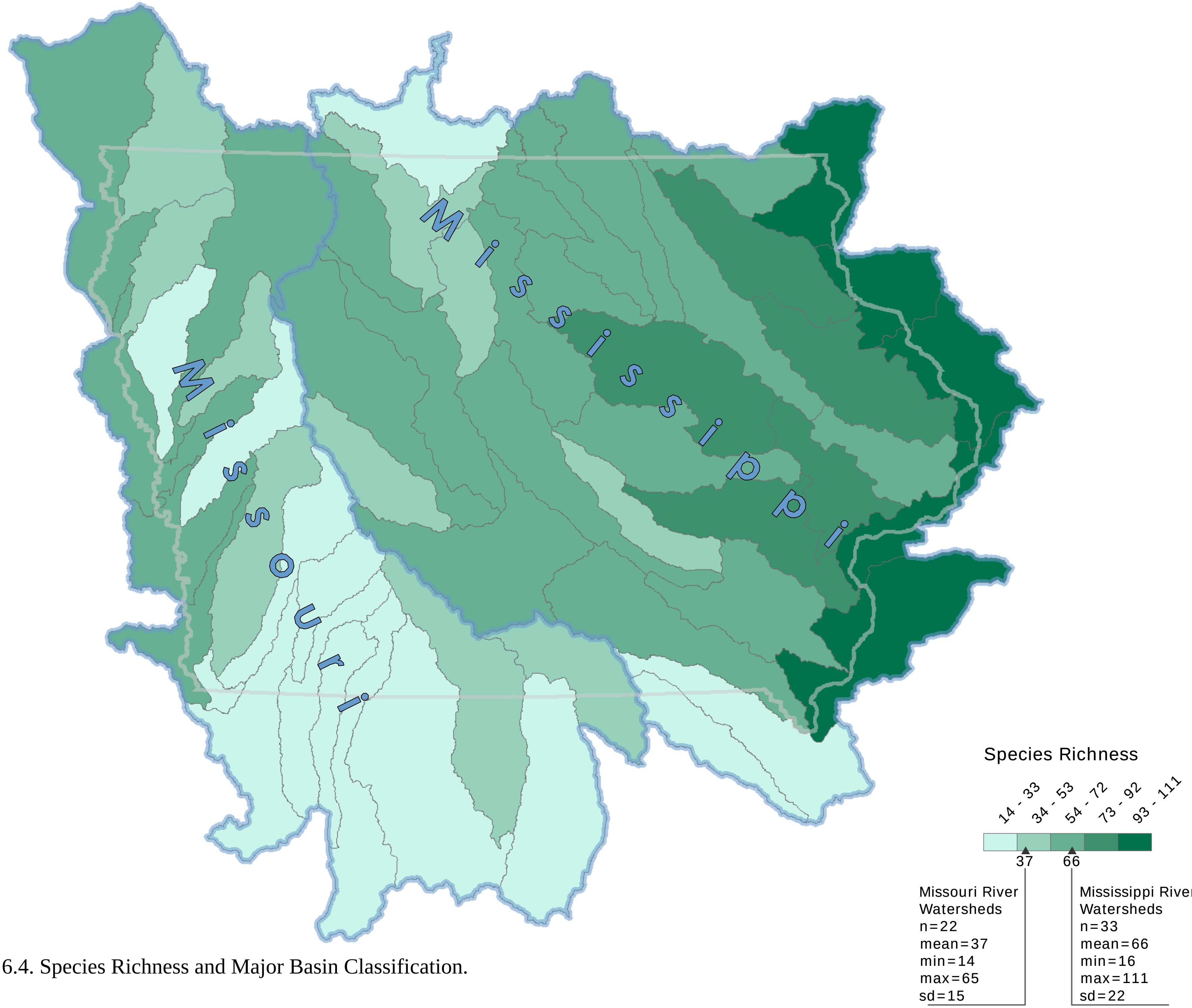

Figure 6.4. Species Richness and Major Basin Classification.

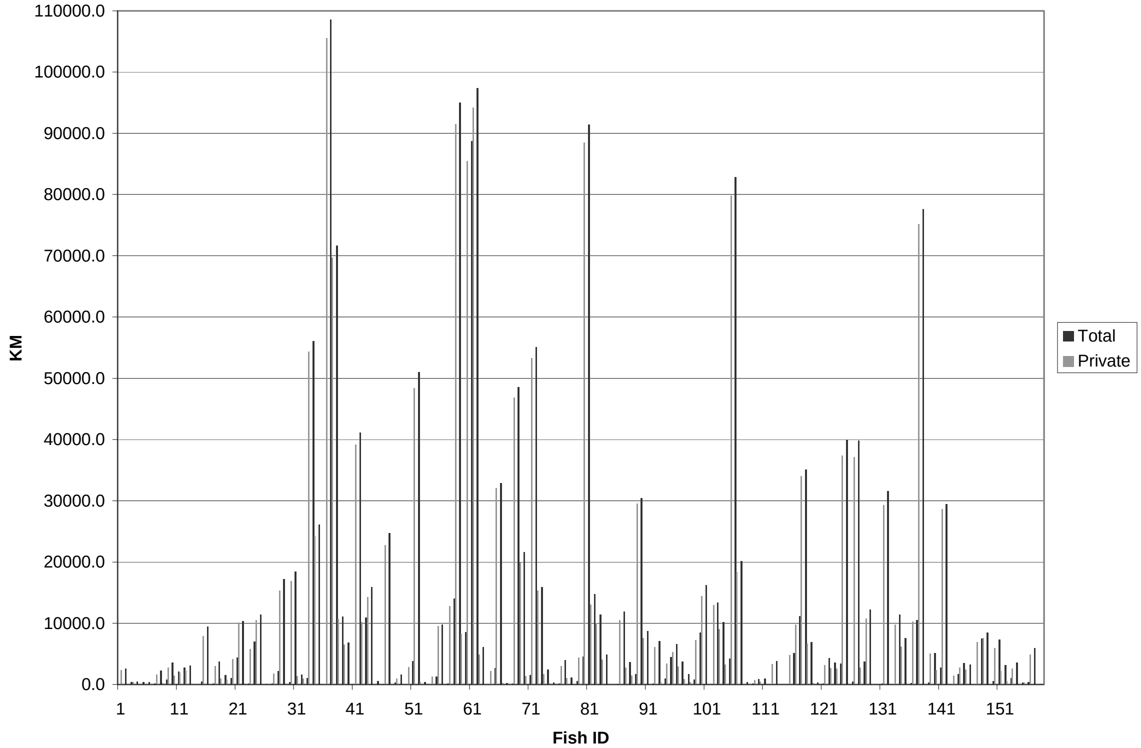

Figure 6.5. Length of Predicted Streams by Management Category

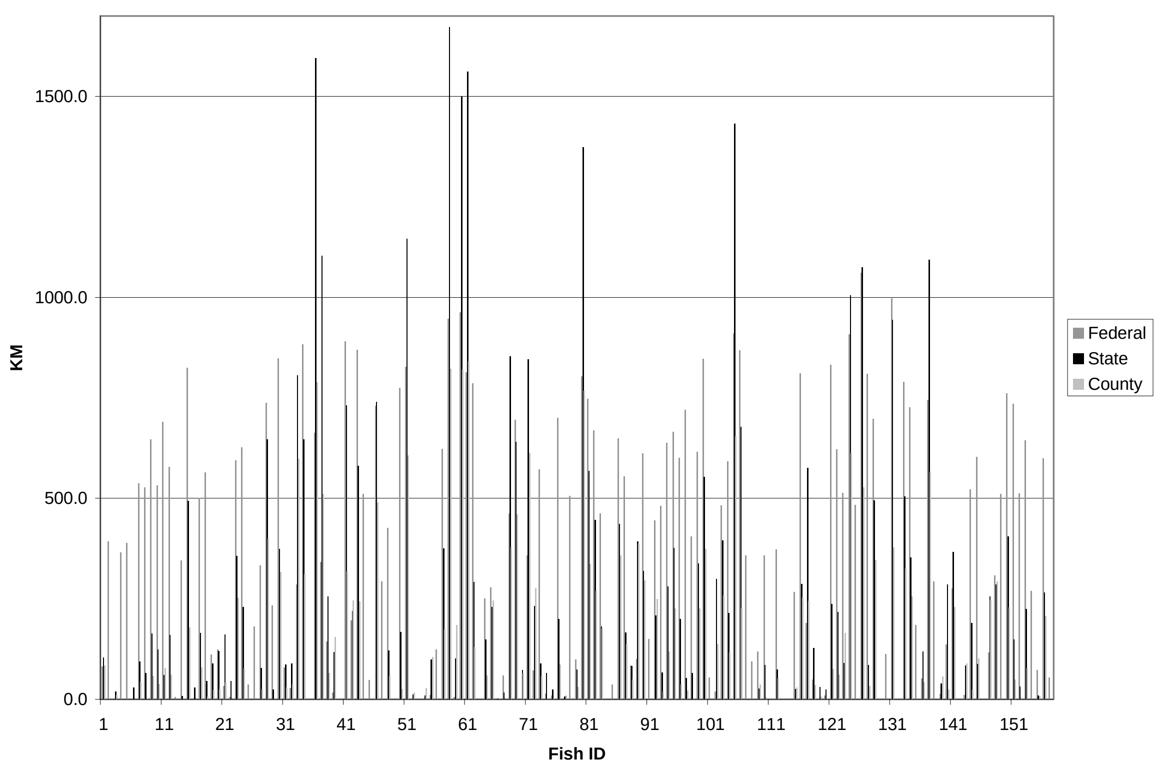

Figure 6.6. Length of Predicted Streams by Management Category

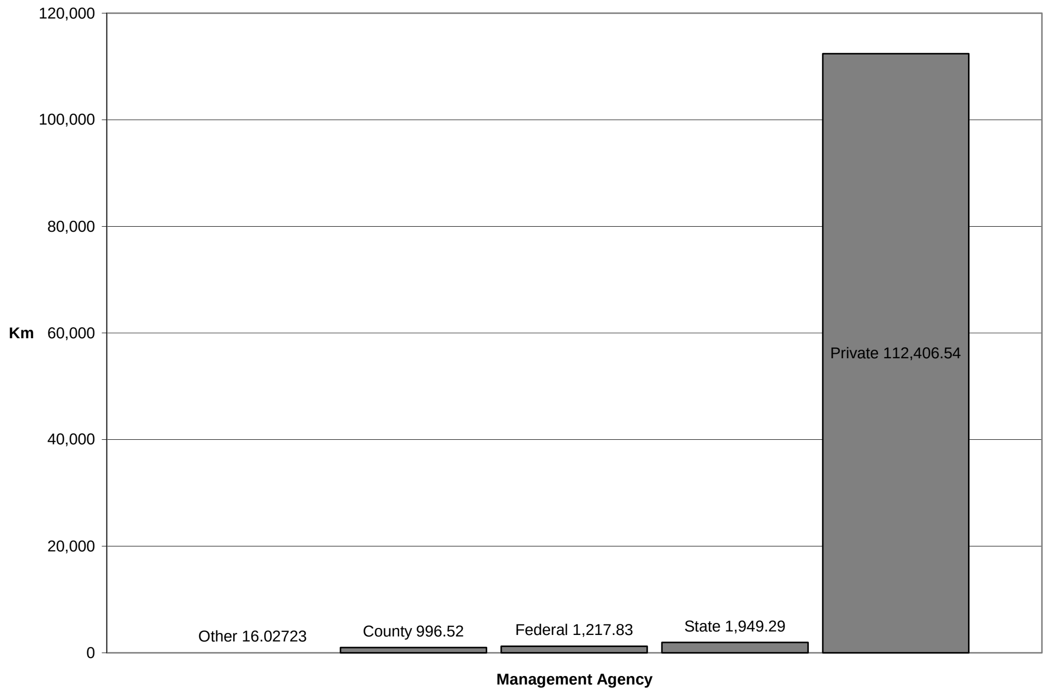

Figure 6.7. Total Reach Length by Management Agency

Chapter 7

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

Introduction

Iowa Aquatic Gap Analysis Project (IAGAP) was an ambitious effort with a broad mission. It constructed a statewide database and a GIS framework for analysis of stream channel and watershed characteristics down to the level of individual stream reaches, such that the potential for supporting fish species in individual reaches could be characterized. At the same time, the project assembled a comprehensive, historical, statewide database of fish community samples that documented the presence of species in stream reaches. These two efforts were then combined in species-presence modeling to establish the potential fish communities that every stream reach throughout the state could be expected to support. Land stewardship along stream reaches was then characterized to enable comparison of potential fish communities to the degree of stream protection. Finally, recommendations for conservation planning were made from comparisons of potential species distributions and streamside stewardship.

Chapter 1 outlined seven major objectives of IAGAP. Chapters 2-6 describe in detail how these objectives were addressed, and the extent to which they were met. The following paragraphs list each of these objectives in succession, summarizing key findings and conclusions.

Objectives

Provide a standardized base layer for sample locational accuracy.

Creation of the Iowa Stream Reach (ISR) data set was a major accomplishment of IAGAP (see Chapter 2). Starting with the nationally consistent NHD and built in cooperation with MoRAP, the ISR is a consistent, detailed, statewide data set covering all 57 HUC 8 watersheds and nearly 84,000 individual stream reaches, with many variables describing each reach. Many problems were confronted and solved during development of the ISR data set. The ISR data set serves as the foundation for IAGAP.

The ISR dataset was not only essential for IAGAP, but also formed the backbone of the Iowa Rivers Information System (IRIS) (http://maps.gis.iastate.edu/iris). IRIS is an internet-based tool for professionals and the public to obtain information about rivers and streams in Iowa and the diversity of natural resources they support. IAGAP and IRIS were developed by the same research team, which benefited both projects through efficiency and sharing of resources and ideas.

Characterize aquatic biodiversity throughout Iowa at the regional, watershed, and reach scales.

Creation of the Iowa Species Occurrence Database (see Chapter 3; Loan-Wilsey et al. 2004) and modeling potential fish communities in all stream reaches statewide (see Chapter 4) were major accomplishments of IAGAP that, together, allow an unprecedented characterization of the diversity of fish communities in Iowa streams and rivers. No centralized depository of stream fish community data existed in Iowa before this project. Not only were the data decentralized, many only existed in raw form on paper. The database contains 10,993 fish community samples recorded from 1884 through 2002. It contains 97,790 species records, including 143 native and 14 exotic species. Gathering all these data and combining them in a coordinated, flexible, electronic, internet-accessible format was itself a huge achievement of IAGAP. The Iowa Species Occurrence Database enabled completion of two major IAGAP products, (1) updated range maps for each species based on known occurrences, and (2) predictive species-presence modeling to establish the potential fish communities that every stream reach throughout the state could be expected to support.

Range maps (see Appendix B7) illustrated the known distribution of species in Iowa's major watersheds. If a species was recorded anywhere within one of Iowa's 57 major watersheds (HUC 8 level), then the entire watershed was assumed to be within the potential range. These maps are updated versions of the maps published in Harlan et al. (1987).

Predictive species-presence modeling combined stream attributes from the ISR data set with known species occurrences to predict the potential occurrence of species in unsampled reaches. These predicted species occurrences were a cornerstone of IAGAP because they allowed comparison of the potential species distributions with conservation status for every stream reach in the state.

Identify the extent to which current management efforts are conserving aquatic biodiversity in Iowa at the regional, watershed, and reach scales.

Our analysis of land stewardship along streams and rivers in Iowa identified an alarmingly low level of protection (see Chapter 5). Stewardship was classified on a scale of 1 to 4, with class 1 representing the highest level of protection and class 4 indicating essentially no protection. Roughly 99% of stream reaches in Iowa were class 4, which are defined as, "Lack of irrevocable easement or mandate to prevent conversion of natural habitat types to anthropogenic habitat types. Allows for intensive use throughout the tract. Also includes tracts for which the existence of such restrictions, or sufficient information to establish a higher status is unknown." Because only approximately 2% of the land in Iowa is publicly owned and managed, increasing the level of protection for aquatic biodiversity in the future will be heavily dependent on effective education and partnership with private landowners.

Help to direct management, protection, restoration, and educational efforts within Iowa's river resources.

Chapter 6 outlined the results of combining predicted species distributions with information about land stewardship characteristics at the watershed and reach scale. The focus was on species richness and management at the watershed scale rather than at a reach scale because of the complexity and lack of information on stewardship and species information at the reach scale. Private land stewardship and dominant land use/cover types probably play important roles in the species richness and diversity of Iowa's rivers and streams. Watersheds dominated by forest tended to have higher species richness and watershed having highly altered landscapes having lower species richness. Aquatic GAP was only a coarse scale analysis and can offer no support to the impacts of conservation practices at a smaller watershed scale. A historic perspective at a finer watershed scale is needed to assess the differences that altered and natural communities play in Iowa rivers and streams.

IAGAP will be an important tool to help understand and improve protection of Iowa's aquatic biodiversity (see Chapter 6). Education, restoration of stream reaches and riparian lands, increased protection of riparian lands, and on-going management of streams and watersheds will all be important components of a successful strategy to accomplish this goal. Education is the key to gaining acceptance of conservation programs. The Iowa Gap Analysis Program has encouraged the establishment of NatureMapping to raise public awareness and acquire needed data on animal distributions. This fledgling program should be continued. Fish Iowa!, Corridors of Exploration: Iowa's Rivers, Iowater, and other aquatic education programs are excellent programs focusing specifically on aquatic recreation, appreciation and conservation. These programs will provide the societal foundation necessary for successful conservation of aquatic biodiversity.

Because of Iowa's fertile soils and favorable climate, it is likely that the land will remain in agriculture and private ownership for the foreseeable future. IAGAP can assist natural resource planners with identifying existing centers of aquatic biodiversity so that conservation efforts can be directed where they will do the most good. Large tracts of land or long stretches of streams are seldom available for biodiversity management. Therefore, ways must be found to protect biodiversity on private lands such as through long-term conservation easements and other voluntary initiatives. Private landowners are demonstrating a growing interest in the restoration of natural function to ecosystems, and streams and riparian lands have been at the forefront of this interest. Education, technical assistance and funding incentives should continue to be directed toward helping foster this interest.

Prioritize conservation efforts.

The dire state of land stewardship along Iowa's streams and rivers (see Chapter 5) makes it abundantly clear that improving the conservation status of riparian land should be a top priority for conserving aquatic biodiversity in Iowa (see Chapter 6). As mentioned previously watershed management probably plays a key role in the stability of Iowa's aquatic resources. Conservation programs focusing on private land stewardship efforts that promote healthy watershed functioning are

Provide easy accessibility to all information.

This report is the most complete source of information and data products from IAGAP. The databases, maps, analyses, results and conclusions of IAGAP are available in a variety of locations and media. Appendices to the report are a rich source of supporting information and data too detailed to include in the chapters. Chapter 8 describes use and availability of IAGAP products in detail.

Integrate data with Iowa terrestrial Gap project.

Much of the focus of the Iowa Gap Analysis Projects, as other states, is the aggregation of many different data sources into a suite of complementary data sets. One of the most obvious uses of both the aquatic and terrestrial data is the use of these products in the long-term monitoring of species at regional scales. The accessibility of this information to the scientist and also to the general public can provide some basic information to understanding Iowa's natural history. The Iowa DNR has been actively using the Iowa terrestrial GAP data in their statewide wildlife plans and they anticipate using aquatic GAP data in a similar fashions. Watershed planning or bioregional assessments are another area where we anticipate users merging the information from these projects to focus on protection, conservation and restoration efforts of aquatic and terrestrial systems.

Chapter 8

PRODUCT USE AND AVAILABILITY

How to Obtain the Products

It is the goal of the Iowa Aquatic Gap Analysis Project (IAGAP) and the USGS Biological Resources Division (BRD) to make the 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 (URL below). While a CD-ROM of the data will be the most convenient way to obtain the data, it may also be downloaded via the Internet from the national GAP home page at:

http://www.gap.uidaho.edu/default.htm

The home page will also provide, over the long term, the status of our state's project, future updates, data availability, and contacts. Within a few months of this project's completion, CD-ROMs of the final report and data should be available at a nominal cost--the above home page will provide ordering information. To find information on this state's Aquatic GAP project's status and data, follow the links to "Ongoing projects-Aquatic" and then to the particular state of interest. Data can eventually be acquired from the Iowa Natural Resource Geographic Information System (NRGIS) available through the Iowa Department of Natural Resources (http://www.igsb.uiowa.edu/nrgislibx/).

The Iowa Gap Analysis homepage (http://www.ag.iastate.edu/centers/cfwru/iowagap) will also have links to download the available data, how to order a CD-ROM of the data and final report and how to request a printed copy of the final report. There will also be printed copies available for order of the *"Iowa Stream Fish Atlas"* when it becomes available.

The Iowa Aquatic Gap Analysis data will also be available in several formats including traditional file based GIS data and as web map services (WMS). This information can be found on the IRIS site at http://maps.gis.iastate.edu/iris. The final data products will be available for basic online GIS analysis via the online mapping application for those interested persons without access to GIS software or a local GIS company.

Minimum GIS System Required for Data Use

All GIS data are either ArcView shapefiles or ArcGIS geodatabases or vector coverages. ArcView 3.3, ERDAS Imagine, ArcGIS and GeoMedia are able to display and analyze the shapefiles and vector data available from IAGAP. Only ArcGIS is able to display the geodatabase format.

The GIS Facility at Iowa State University, Room 218 Durham Hall, Ames, Iowa provides access to machines and software available to students, faculty and staff of Iowa State for GIS analysis. Other interested persons can contact the facility personnel to arrange a contract for GIS services. ArcExplorer, a free GIS viewing and query package from ESRI, can be downloaded from http://www.esri.com/software/arcexplorer/index.html. There are also free or inexpensive complete

GIS packages available on the Web capable of viewing, analyzing and printing aquatic GAP GIS data. Private GIS companies exist around the state and can be found through the phone book.

Disclaimer

Although these data have been processed successfully on a computer system at the BRD, 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 BRD server (see above for approved data providers) 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 Biological Resources Division 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 fish and river segments over large geographic regions. The data may or may not have been assessed for statistical accuracy. Data evaluation and improvement may be ongoing. The Biological Resources Division makes no claim as to the data's suitability for other purposes. This is writable data that may have been altered from the original product if not obtained from a designated data distributor identified above.

Metadata

Proper documentation of information sources and processes used to assemble IAGAP data layers is central to the successful application of IAGAP data. Metadata documents the legacy of the data for new users. The Federal Geographic Data Committee (FGDC 1994, 1995) has published standards for metadata and NBII (http://www.nbii.gov) has updated those standards to include biological profiles. Executive Order 12906 requires that any spatial data sets generated with federal dollars will have FGDC-compliant metadata. Each spatial data layer provided is accompanied by its metadata (*.xml file) in the same directory and as a *.txt file in the \metamaster subdirectory.

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 is expensive to produce and must be directed to meet the immediate program needs. For IAGAP, some suggested project guidelines were set (see http://www.gap.uidaho.edu/projects/aquatic/default.htm) to meet program objectives. These standards include: using the USGS National Hydrography Dataset and following the procedures established by the Missouri Resource Assessment Partnership as much as is practical and applicable.

Recognizing, however, that IAGAP would be the first, and for many years likely the only, source of statewide fish species GIS maps, the data were created with the expectation that they would be used for other applications. Therefore, we list below both appropriate and inappropriate uses. 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 IAGAP data. For most uses, it is unlikely that IAGAP 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 IAGAP data can answer the question being asked, and if they are the best tools to answer that question.

Scale

First we must address the issue of appropriate scale to which these data may be applied. The data were produced with an intended application at the ecoregion level, that is, geographic areas from several hundred thousand to millions of hectares in size. The data provide a coarse-filter approach to analysis, meaning that not every occurrence of a water feature or fish location 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. When determining whether to apply IAGAP data to a particular use, there are two primary questions: do you want to use the data as a map for the particular geographic area, or do you wish to use the data to provide context for a particular area? The distinction can be made with the following example: IAGAP fish prediction data could be used to determine the approximate sum of stream length for a particular fish occurring in a watershed. To reach a more exact amount, you would otherwise need to sample every stream in the watershed. The IAGAP data could then be used to determine the approximate percentage of all possible reaches containing habitat for that particular species in the region, by comparing the region to the specific watershed. This would quantify the importance of the watershed's distribution to maintaining that fish species in the area of concern.

Appropriate Uses

The above example illustrates two appropriate uses of the data: as a coarse map for a large area such as a county, and to provide context for finer-level maps. The following is a general list of applications:

- Statewide biodiversity planning
- Regional (Councils of Government) 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, regional open space and recreation proposals, etc.
- 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 fish and to help target both 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 and for both students and citizens.

Inappropriate Uses

It is far easier to identify appropriate uses than inappropriate ones, however, there is a "fuzzy line" that is eventually crossed when 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. Examples include:

- Using the data to map small areas (less than thousands of hectares), typically requiring mapping resolution at 1:24,000 scale and using aerial photographs or ground surveys.
- Combining IAGAP data with other data finer than 1:100,000 scale to produce new hybrid maps or answer queries.
- Generating specific linear measurements from the data finer than the nearest thousand meters.
- 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 IAGAP data.
- Altering the data in any way and redistributing them as an IAGAP data product.
- Using the data without acquiring and reviewing the metadata and this report.

Chapter 9

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Chapter 10

GLOSSARY OF TERMS AND ACRONYMS

Terms

alpha – the criterion for significance in a statistical test. Used to determine when to split nodes in a decision tree, when to merge categories of the target variable in the split, and which variable to choose for defining the split

anthropogenic - caused by man

assemblages - a group of ecologically interrelated plant and animal species

attribute - A fact describing an entity in a relational data model, equivalent to the column in a relational table. OR A trait, quality or property describing a geographical feature

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

biological diversity - see biodiversity

branch – a portion of a decision tree consisting of a single node and all nodes below (descended from) it

channelization – the practice of straightening a waterway to remove natural meanders and make water flow faster

child node – a node that is the result of splitting another node (called the parent node)

coarse filter - the general conservation activities that conserve the common elements of the landscape matrix, as opposed to the "fine filter" conservation activities that are aimed at special cases such as rare elements

community - a group of interacting plants and/or animals

coverage – older ESRI vector data format used in ArcInfo. It is being phased out in favor of the geodatabase.

digital raster graphic (DRG) - a scanned image of a U.S. Geological Survey standard series topographic map, including all map collar information

digitization - entering spatial data digitally into a Geographic Information System

ecoregion - a large region, usually spanning several million hectares, characterized by having similar biota, climate, and physiography (topography, hydrology, etc) ecosystem - a biological community (ranging in scale from a single cave to millions of hectares), its physical environment, and the processes through which matter and energy are transferred among the components

element - a river segment or fish species mapped by GAP. May also be referred to as "element of biodiversity"

endemic – exclusively native to a place or biota.

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 - when a model fails to predict the occurrence of a species that is actually present in an area

exotic – a non-native species that is present in a region, watershed, or habitat due to direct or indirect human intervention

extinction - disappearance of a species throughout its entire range

extirpation - disappearance of a species from part of its range

fine filter - see "coarse filter"

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 - computer hardware and software for storing, retrieving, manipulating, and analyzing spatial data

grid format - An ESRI data format for storing raster data that defines geographic space as an array of equally sized square cells arranged in rows and columns. Each cell stores a numeric value that represents a geographic attribute (such as elevation) for that unit of space. When the grid is drawn as a map, cells are assigned colors according to their numeric values. Each grid cell is referenced by its x,y coordinate location.

ground truthing - verifying maps by checking the actual occurrence of plant and animal species in the field at representative sample locations

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

hydrography – The representation of the location, connectivity and direction of flow of water bodies. In Geographic Information Systems, it usually refers to datasets depicting various water features.
hydrologic unit codes (HUC) – Hydrologic unit codes are a way of identifying all of the drainage basins in the United States in a nested arrangement from largest (Regions) to smallest (Cataloging Units). A drainage basin is an area or region of land that catches precipitation that falls within that area, and funnels it to a particular creek, stream, river and so on, until the water drains into an ocean. The term watershed is often used in place of drainage basin.

metadata - information about data, e.g., their source, lineage, content, structure, and availability

negative data- information indicating the absence of a species in a stream reach even though the reach was sampled with the expectation of collecting that species

node – a part of the tree in AnswerTree® that represents a subset of cases defined by having certain values of predictor variables

orthophoto - an aerial photograph that has been rectified such that it is equivalent to a map of the same scale. The rectification process eliminates or minimizes the scale, tilt and relief distortions that are present in raw aerial photographs. Scale is consistent across the image even in areas where there may be large differences in elevation. It is a photographic map that can be used to measure true distances, an accurate representation of the earth's surface.

overfitting - using too many covariates for the number of outcome events in a multivariable predictive model; In statistics, overfitting is fitting a statistical model that has too many parameters. An absurd and false model may fit perfectly if the model has enough complexity by comparison to the amount of data available. Overfitting is generally recognized to be a violation of Occam's razor.

parent node – a node that has been split into smaller nodes (child nodes)

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 or a region of contiguous homogeneous pixels in a raster system

predictor(s) – in decision tree analysis, the variable(s) used to predict the value of the target variable

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

quadrangle – four-sided area, bounded by parallels of latitude and meridians of longitude, used as an area unit in mapping (dimensions are not necessarily the same in both directions). Typically refers to a map sheet published by the USGS, a 7.5 minute quadrangle series or the 15 minute quadrangle series. Also known as a topographic or topo map.

range - the geographic limit of the species

raster - A spatial data model that defines space as an array of equally sized cells arranged in rows and columns. Each cell contains an attribute value and location coordinates. Unlike a vector structure, which stores coordinates explicitly, raster coordinates are contained in the ordering of the matrix. Groups of cells that share the same value represent the same type of geographic feature.

reach - a stream or river segment between inflowing tributaries

resolution - the ability of a remote sensing 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, such as a TM pixel

riverine -- Relating to, formed by, or resembling a river including tributaries, streams, brooks, etc.

scale, map - the ratio of distance on a map to distance in the real word, expressed as a fraction; the smaller the denominator, the larger the scale, e.g. 1:24,000 is larger than 1:100,000

shapefile – a ESRI vector data format for storing the location, shape and attributes of geographic features. A shapefile is stored in a set of related files and contains one feature class.

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

stewardship – care or management of land or waters with an implied responsibility to future generations for the condition of these resources

target- relating to the sampling of a stream reach for the expressed purpose of collecting a specific species

target variable- in decision tree analysis, the variable whose values are to be predicted

taxa - Any organism or group of organisms of the same taxonomic rank; for example, members of an order, family, genus, or species

topology- The spatial relationships between connecting or adjacent coverage features (eg, arcs, nodes, polygons, and points). For example, the topology of an arc includes its from- and to-nodes, and its left and right polygons. Topological relationships are built from simple elements into complex elements: points (simplest elements), arcs (sets of connected points), areas (sets of connected arcs), and routes (sets of sections, which are arcs or portions of arcs). Redundant data (coordinates) are eliminated because an arc may represent a linear feature, part of the boundary of an area feature, or both.

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

variable – an attribute of a case that takes on different values for different cases. In GIS terminology, an attribute. In database terminology, a field.

vector format - a data structure that uses polygons, arcs (lines), and points as fundamental units for analysis and manipulation in a Geographic Information System

Acronyms

ACE U.S. Army Corps of Engineers
AML ArcInfo Macro Language
BRD Biological Resources Division (USGS)
CART Classification and Regression Trees
CCB County Conservation Board
CHAID Chi-squared Automatic Interaction Detector
CRP Conservation Reserve Program (USDA)
DLG Digital Line Graph
DOQQ Digital Orthophoto Quarter Quads
DRG Digital Raster Graphic
EDU Ecological Drainage Unit
EPA Environmental Protection Agency
ERDAS Leica Geosystems GIS & Mapping, LLC (a GIS software company)
ESRI Environmental Systems Research Institute (a GIS software company)
EWRP Emergency Wetlands Reserve Program (USDA)
FGDC Federal Geographic Data Committee
FSA Farm Service Agency
FTP file transfer protocol
GAP Gap Analysis Program
GIS Geographic Information System
GMNH Georgia Museum of Natural History
GNIS Geographic Names Information System
GSB Geological Survey Bureau (IDNR)
HUC Hydrologic Unit Code
IBI Index of Biological Integrity

ID Identifier
IDNR Iowa Department of Natural Resources
IACCB Iowa Association of County Conservation Board
IAGAP Iowa Aquatic Gap Analysis Project
IMS Internet Mapping Service
INHF Iowa Natural Heritage Foundation
IRIS Iowa Rivers Information System
ISR Iowa Stream Reach (coverage)
ISU Iowa State University
LTRMP Long Term Resource Monitoring Project
MoRAP Missouri Resource Assessment Partnership
MRLC Multi-Resolution Land Characteristics Consortium
NAD83 North American Datum of 1983
NAWQA National Water Quality Assessment (USGS)
NBII National Biological Information Infrastructure
NHD National Hydrography Dataset
NLCD National Land Cover Dataset
NRCS Natural Resources Conservation Service
NRGIS Iowa Natural Resource Geographic Information System
NWR National Wildlife Refuge
QUEST Quick, Unbiased, Efficient Statistical Tree
STATSGO State Soil Geographic Database (NRCS)
TMDL/WQ Total Maximum Daily Load/Water Quality
TNC The Nature Conservancy
URL Universal Resource Locator
USEPA RF3 US Environmental Protection Agency's River Reach Files
USFWS US Fish & Wildlife Service
USGS US Geological Survey
UTM Universal Transverse Mercator
VST Valley Segment Type
WPA Waterfowl Production Areas (USFWS)
WRP Wetland Reserve Program (NRCS)