



Gap Analysis

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A Geographic Approach to Planning for Biological Diversity

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The Gap Analysis Program ... in Brief

The mission of the Gap Analysis Program (GAP) <gapanalysis.nbii.gov> is to promote conservation by providing broad geographic information on biological diversity to resource managers, planners, and policy makers who can use the information to make informed decisions.

As part of the National Biological Information Infrastructure (NBII) <www.nbii.gov> – a collaborative program to provide increased access to data and information on the nation’s biological resources – GAP data and analytical tools have been used in hundreds of applications: from basic research to comprehensive state wildlife plans; from educational projects in schools to ecoregional assessments of biodiversity.

The challenge: keeping common species common means protecting them BEFORE they become threatened. To do this on a state or regional basis requires key information such as land cover descriptions, predicted distribution maps for native animals, and an assessment of the level of protection currently given to those plants and animals.

GAP works cooperatively with federal, state, and local natural resource professionals and academics to provide

this kind of information. GAP activities focus on the creation of state and regional databases and maps that depict patterns of land management, land cover, and biodiversity. These data can be used to identify “gaps” in conservation – instances where an animal or plant community is not adequately represented on the existing network of conservation lands.

GAP is administered through the U.S. Geological Survey. Through building partnerships among disparate groups, GAP hopes to foster the kind of collaboration that is needed to address conservation issues on a broad scale.

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FEATURES

A Brief Overview of the Southwest Regional GAP Land Cover Mapping Effort

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Introduction and Project Area

The Southwest Regional Gap Analysis Project (SWReGAP) was initiated in 1999 as a multi-institutional cooperative effort to map and assess biodiversity for a five-state region (Arizona, Colorado, New Mexico, Nevada, and Utah). This area comprises approximately 150 million hectares (560,000 square miles), representing approximately one-fifth of the coterminous United States. A key task in this effort was to develop a seamless land cover map for the region. The five-state region was divided into 20 ecologically and spectrally similar mapping zones. Each mapping zone provided a functional working area for project management, data collection, and modeling. Each state was responsible for the mapping zones roughly corresponding to their state jurisdiction (Figure 1).

Methods

Data Preparation

Landsat 7 enhanced thematic mapper plus (ETM+) images were selected from 1999–2001 for three seasons: spring, summer, and fall. Scenes were selected for optimal representation of seasonal phenology and minimal cloud cover. Landsat scenes

were standardized using a dark object subtraction method and mosaicked for each mapping area. Image transformations such as brightness, greenness, and wetness bands were created for each image mosaic. Digital elevation data, provided by the National Elevation Data Set (1999), were a subset for each mapping zone, as were subsequent digital elevation derivatives, such as aspect and landform. Each mapping zone had a 2 km overlap with the adjacent mapping area, providing an overall 4 km overlap region between modeling areas.

Training Sample Collection

Approximately 93,000 samples were available for the five-state region (Figure 2). The majority of samples were collected through field surveys conducted between 2001 and 2003. Field surveys involved recording ocular estimates of biotic characteristics (percent cover of dominant species for trees, shrubs, grasses, and forbs) and physical characteristics (elevation, slope, aspect, and landform). The location of each sample site was recorded with a global positioning system (GPS) reading and a polygon digitized using a laptop computer with thematic mapper (TM) imagery as a backdrop. In addition, two digital photographs were taken at each sample location. Sampling involved traversing all navigable roads in a mapping zone and opportunistically selecting samples based on appropriate size and composition (i.e., representative) of stands. Additional samples, obtained from other projects, imagery, or



Figure 1. Five-state region divided into mapping zones.

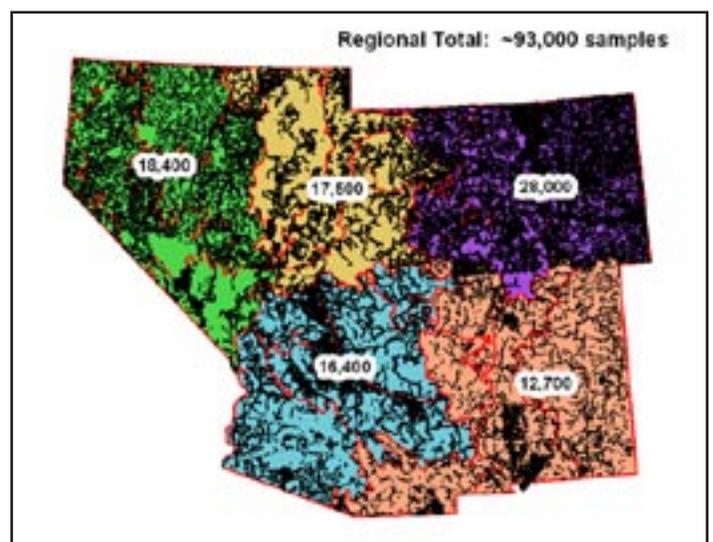


Figure 2. Approximately 93,000 training samples collected from various sources.

aerial photo interpretation, were also used, though these were in the minority.

Thematic Mapping Legend

The focus of the mapping effort was on natural and seminatural systems. The basic thematic mapping unit was the *ecological system* concept developed by NatureServe (Comer et al. 2003). Ecological systems represent recurring groups of biological communities that are found in similar physical environments and are influenced by similar dynamic ecological processes. They are intended to provide a thematic mapping unit mappable at a meso-scale level from remotely sensed imagery. Each sample site was assigned an appropriate land cover label in the database prior to the modeling process.

Land Cover Modeling

The majority of natural and seminatural land cover classes were modeled using a decision-tree (DT) classifier. DT classifiers are becoming a common approach used for land cover mapping (Lawrence and Wright 2001; Pal and Mather 2003; Brown de Colstoun et al. 2003). Advantages of DT include the ability to use both continuous and categorical predictor data sets with different measurement scales, good computational efficiency, and an intuitive hierarchical representation of discrimination rules. A major technical challenge in the past has been that of spatially

applying the decision-tree rules generated by the DT software within a geographic information system.

After experimenting with the development of several approaches, the project used See5/C5.0 (Rulequest Research 2004) for the DT classifier and ERDAS Imagine for spatially applying the DT-generated rules. The integration of these software systems was greatly facilitated by the use of a customized interface for ERDAS Imagine developed under contract by Earth Satellite Corporation for the U.S. Geological Survey Eros Data Center (Figure 3). Where the decision tree could not be used, other techniques, such as localized unsupervised clustering or screen digitizing, were used to map a minority of cover classes.

Results

Model Validation

DT models were validated by generating initial models using 80 percent of available samples, while withholding 20 percent of samples. Withheld samples were randomly selected and stratified by cover class. Withheld sample polygons were intersected through the land cover map to create an error matrix, presenting users, producers, and overall “accuracies.” The kappa statistic was also calculated for the error matrix. This validation process was performed on each of the 20 mapping

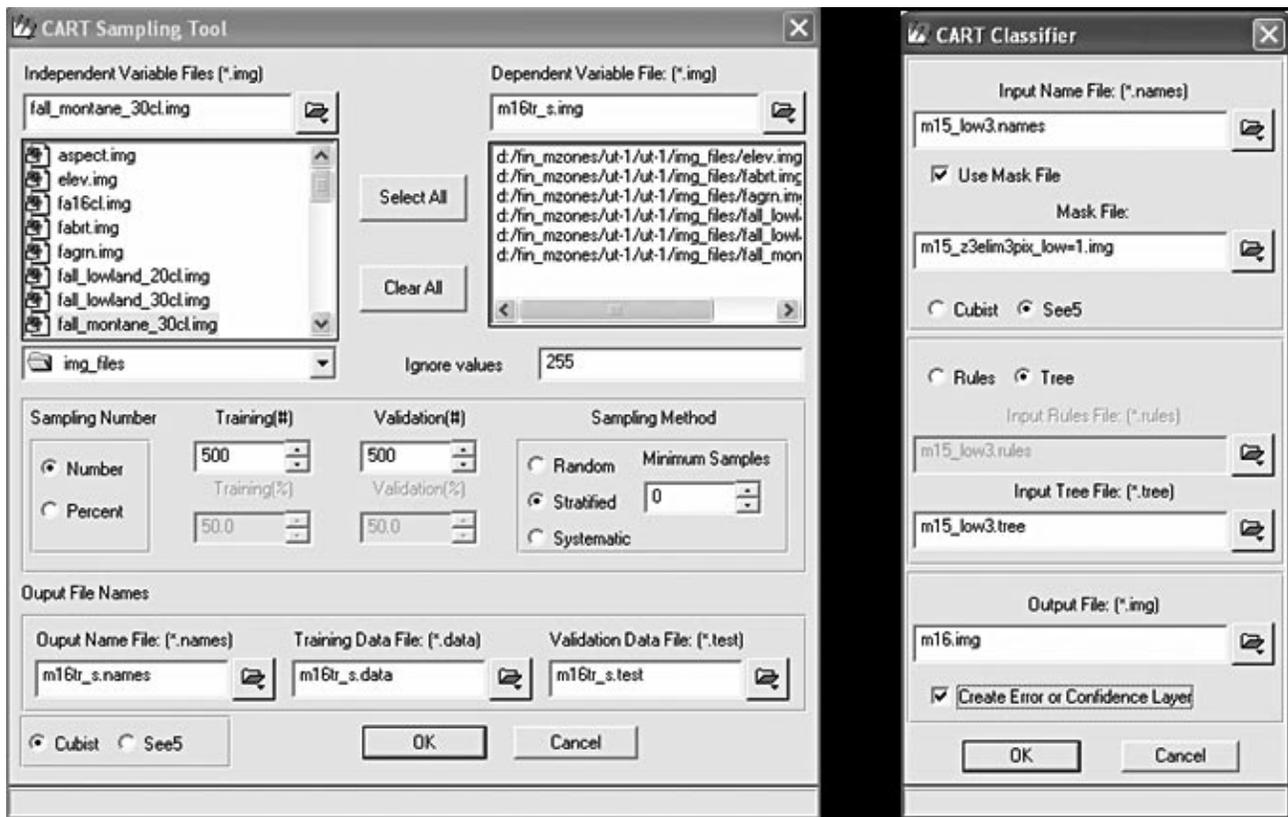


Figure 3. ERDAS Imagine custom interface for integrating Imagine with See5/C5.0.

areas for the five-state region. Overall accuracies (sum of diagonals) vary from mapping zone to mapping zone and will be presented in the final report.

Regional Mosaic and Data Set Delivery System

Using the 4 km overlap region between mapping zones, a “cutline” was used to edge-match adjacent mapping areas where land cover discontinuities resulted from the modeling process. The resulting five-state region mosaic was qualitatively reviewed by the five state teams and NatureServe. Following review, a limited number of errors were “flagged” for final editing. The “edits” that were determined to be relatively easy to correct with localized recoding, or a simple conditional model, were made to the regional map.

The SWReGAP land cover data set was completed in September 2004, and it is currently available to the public with “provisional” status from <http://earth.gis.usu.edu/swgap/landcover.html>. Because the data set encompasses such a large region, the web site allows users to download specific geographic segments of the region, such as individual states, counties, or ecoregions. Additionally, the web site offers an Internet map server from which users can interactively clip a specified rectangle in the region. The clipped data set is subsequently bundled with metadata and made available for download (Figure 4).

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Figure 4. Delivery system allows download by geographic subsets of the region.

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GAPServe Brings GAP Data Online

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Introduction

The Gap Analysis Program (GAP) is now in a very exciting period of development. With 36 state projects complete and more to be finished in the next year, GAP is tackling the challenge of effectively serving data products to customers. The sheer volume of data generated over many years makes it necessary to have better discovery and visualization tools, so that resource managers, scientists, and other interested parties can find and view the data from GAP.

After a year of design and development work, GAP is ready to introduce GAPServe. The full rollout of this new product occurred in June 2005. Usability testing will occur over the summer, and any modifications to the site will be made in the fall. GAPServe can be found at <http://gapanalysis.nbii.gov/>.

The primary goal of GAPServe is simple: to serve as a data warehouse where users can search for and visualize GAP data. It is important to note that this product is not intended for advanced mapping or analytical processing of GAP data over the Internet. Rather, it is designed to serve the data to any other Internet mapping service through the Open GIS Consortium's Web Map Service (WMS) 1.1 specification.

In the past, users trying to integrate data across state or regional boundaries had to download individual files for each state, then spend a considerable amount of time converting data into a single projection system so they could be used in a seamless manner within a mapping program. This process was tedious and time consuming.

With GAPServe, users can search for all applicable species distribution models by entering a common or scientific name, or by browsing through the taxonomy. This single user interface (Figure 1) allows users to explore available GAP data easily and efficiently.

Users can now view the data in any Internet browser using a map viewer. They can look for data on such things as land cover, stewardship, or single-species distributions, and the map viewer presents a seamless view across states based on the availability of online data. For example, the mountain beaver (*Aplodontia rufa*) species models, as delivered by California, Nevada, Oregon, and Washington, are shown in Figure 2.

GAP Data Issues

From the inception of the program, GAP projects have been conducted on a state-by-state basis and data have been delivered for single states. While each project used the processes and standards in the GAP Handbook, data from one state could be in a different format, projection, or classification scheme than data from neighboring states. When viewing multiple-state project data, therefore, users have encountered the following issues:

- differences in the species names and species models used by states;
- differences in the categorization of stewardship and management areas; and
- differences in the categories of land classification. For example, while one state might have four types of land cover (forest, agriculture, water, and urban), a neighboring state could have five (deciduous forest, coniferous forest, agriculture, water, and urban).

It is important to note that base data, as delivered from the state projects, remain in GAPServe. However, since the primary goal of GAPServe is to let users visualize the data on a map, some changes were made in the way the data are visualized. For example, in the case of land classification data, all of the classifications were cross-walked to a more generalized set of NLCD 2001 categories to present a meaningful seamless map. Species distribution models are shown as either Habitat (potential presence) or Not Habitat (potential absence), since different types of models could have been run in each state.



Figure 1. GAPServe's user interface.



Figure 2. Map viewer depiction of mountain beaver (*Aplodontia rufa*) species models.



Figure 3. Map viewer depiction of land cover types.

As shown in Figure 3, even though the land classification was cross-walked, there are still discrepancies associated with using the data in a seamless manner. These data discrepancies or differences will exist in GAP state data until the regional projects, which will address the data issues described above, are delivered. Once completed, these regional products will also be made available within GAPServe. The new five-state Southwestern U.S. data set will be available through the portal in late 2005.

Next Steps

As we release version 1.0 of GAPServe, we would like to gather comments from GAP researchers and data users. We are interested in your input so that the best product to showcase GAP data and results can be made available to the broader community. Comments on the current version of the portal should be sent to jmaxwell@uidaho.edu or droy@usgs.gov.

In addition to ensuring that the product meets the data searching and visualization needs of the user community, we have also redeployed the current GAP web site using tools and methodologies provided by the National Biological Information Infrastructure (NBII), a program managed within the U.S. Geological Survey Biological Resources Discipline. By using the

NBII tools, both GAP and NBII will meet the following objectives:

- allow for the creation of consistent content and gather input from distributed sources by applying NBII standards;
- allow the serving of GAP resources to and from NBII node web sites through the use of the input tool developed for resource cataloging;
- minimize the time spent in web page development and maximize content development and management efforts, thus allowing for richer content with less effort from the web developer;
- facilitate collaboration among GAP projects by providing discussion lists, document sharing, and project management capabilities; and
- make it easier for users to find resources and documents by using the power search engine used by NBII.

Summary

As GAPServe is rolled out, we look forward to your comments. We are confident that the new site and data warehouse, integrated more closely with the structure of the NBII, will enable us to more effectively deliver the results of over fifteen years of work by GAP professionals.

Refining Southeast Regional GAP Models for Use in Regional Bird Conservation Planning: A Pilot Project

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habitats. Selected species have been identified as priority species for monitoring and/or conservation efforts by Partners in Flight (Rich et al. 2004).

Introduction

The Southeast Regional Gap Analysis Project (SEReGAP) is partnering with the U.S. Fish and Wildlife Service (USFWS) in a pilot project to explore the potential for refining GAP vertebrate models for priority bird species to more closely meet the conservation needs of the avian conservation community. Traditional GAP models of presence/absence have not provided enough specific information about habitat suitability, which is critical for setting conservation goals and objectives. However, recent advances with inductive modeling techniques with small data sets have given GAP modelers new tools for developing more information-rich models (Phillips et al. 2004).

In September 2004, a meeting of regional biologists and modelers was hosted by the USFWS in Atlanta to review a variety of modeling approaches and the data sets available for modeling in the Southeast. The objectives of the meeting were as follows:

1. To inform partners about current regional modeling efforts by the USFWS, Joint Ventures, and SEReGAP
2. To get feedback on the draft aggregation of Ecological Systems (Comer et al. 2003) into Avian Habitat Types
3. To review the priority bird species selected for each habitat type
4. To review existing avian models for those species
5. To provide the background on ancillary data available for use in modeling and to work with partners to identify specific parameters based on their expertise (e.g., core area, distance to water)
6. To get feedback from partners on additional methods/data that could be used to improve modeling

Project Description

In this collaboration, SEReGAP brings to the table high-quality data sets and spatial modeling expertise, while the USFWS brings biological expertise on habitat quality, a network of experts, and the potential for monitoring and adaptive management (Figure 1).

Three key habitat types—cove hardwoods, nonalluvial forested wetlands, and upland grassland-dominated habitats—have been identified as the focus habitats for this pilot project. Twenty-nine species of birds have been identified for modeling within those

Prior to the meeting, SEReGAP developed a series of models for seven of the priority species. These models were based on a habitat-affinity database derived from the literature and linked

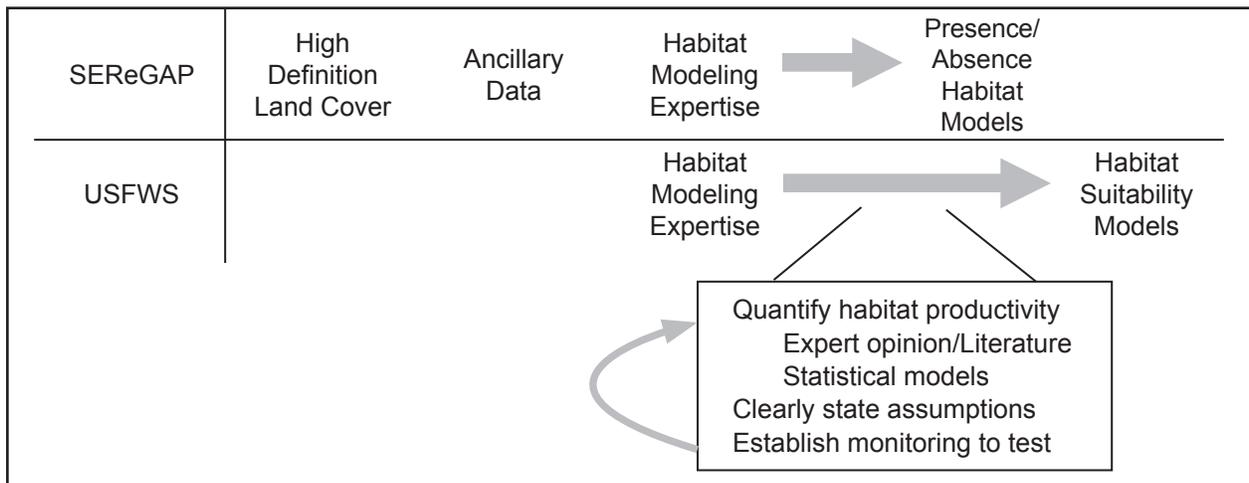


Figure 1. Contributions by SEReGAP and the USFWS to regional habitat-suitability models used in setting regional conservation goals.

to the state-based GAP land cover maps through a habitat list commonly used in the Southeast for describing bird habitats. At the meeting, presentations by the Mississippi Alluvial Valley Joint Venture office (MAV-JV) and the Upper Midwest Environmental Sciences Center (UMESC), as well as SEReGAP, set the stage for the range of modeling approaches that could be taken. Some of the feedback obtained at the meeting was immediately incorporated into changes in the ancillary data set development and the parameters used in the models, while other feedback is helping to shape the process to derive regional conservation goals from the final models.

Currently, SEReGAP and the USFWS are working on compiling the feedback from all participants and updating the cross-walk of the final habitat types to Ecological Systems. Once those changes have been made, habitat-suitability models will be developed incorporating both inductive and noninductive modeling approaches. In addition, sensitivity analyses of the data input layers will be run to identify those data sources that are critical to the model's performance. After models have been created, another round of meetings will be held to review those models and to work on incorporating the results into conservation planning efforts.

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APPLICATIONS

The Integration of GAP Data into State Comprehensive Wildlife Conservation Strategies

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Introduction

One of the primary goals of the Gap Analysis Program (GAP) has always been to facilitate conservation planning by providing objective information that local, state, and national decision makers can access for managing biological resources. GAP products, including land cover, predicted species distributions, species richness indices, land stewardship maps, species habitat models, and even the GAP approach itself, could be key tools in making decisions about conservation. GAP products are freely available to anyone who wants them, yet few conservation agencies have taken advantage of the available data and protocols (McClafferty and Waldon 2002).

Now, with the advent of a federal mandate requiring each state to develop a Comprehensive Wildlife Conservation Strategy (CWCS), a perfect opportunity for GAP implementation has presented itself. In turn, many state wildlife professionals, faced with the task of inventorying and planning for the conservation of fish and wildlife species in their states, have turned to GAP as one of the tools that can help them. This paper provides a brief legislative background of the State Wildlife Grants (SWG) program and summarizes how states have used GAP data to develop their CWCSs.

History of Wildlife Conservation Strategies

The SWG program is the direct result of a coordinated lobbying effort in the late 1990s by a coalition of state wildlife management agencies (Teaming with Wildlife), the public, and other interested organizations. The proposed Conservation and Reinvestment Act (CARA), which the coalition lobbied for, would have created a new long-term Wildlife Conservation and Restoration Fund focused on conservation, recreation, and education. Despite strong bipartisan support and a broad conservation coalition, Congress did not fund CARA. Instead, in October 2000, a compromise package of conservation spending was cobbled together. One component of this new package was the State Wildlife Grants program, which was designed to provide competitively awarded, cost-shared grants to states for conservation.

In 2001, Congress empowered the SWG program to award money on a formula basis. In contrast to earlier programs, which

focused primarily on game species or on threatened and/or endangered species, SWG projects are directed to focus on the conservation of fish and wildlife species of greatest conservation need (SGCN), while promoting proactive conservation to keep common species from becoming endangered. Since 2002, Congress has distributed \$270 million in SWG funds to the states, U.S. territories, the District of Columbia, and the Commonwealth of Puerto Rico according to a formula based on land area and population. Approximately \$75 million will be distributed in FY2005.

In exchange for the funding they receive, each state must complete a CWCS. The deadline for completion of the initial plans was October 1, 2005. Upon completion, each state must review and reevaluate its plan on a regular schedule of at least every 10 years. If a state did not produce a CWCS by the deadline, it may be required to repay all the SWG funds it has received.

The responsibility for developing the CWCS rests with each state. State fish and wildlife agencies are involving a broad spectrum of partners, including other government agencies, conservation groups, private landowners, and the public (IAFWA 2004b).

Guidelines to state planners regarding the development of their conservation strategies encourage state coordinators to use relevant existing information; in particular, to integrate appropriate elements of other plans, databases, GIS layers, reports, and information that overlap or complement the strategies they are developing (IAFWA 2002). Most states seem to be heeding this advice. As of January 1, 2005, 37 states had completed their GAP projects. Of these, 25 had incorporated GAP data into the development of their CWCSs. Another eight states that did not yet have complete GAP data sets and final reports were using the GAP data available to them for CWCS development.

Essential Elements of Comprehensive Wildlife Conservation Strategies

Congress directed that the state wildlife strategies must identify and be focused on SGCN species, yet also address the “full array of wildlife” and wildlife-related issues facing the state. To help establish a framework for the conservation plans,

Congress identified eight required elements to be addressed in each state's CWCS:

1. **Information on the distribution and abundance of species of wildlife**, including low and declining populations, as the state fish and wildlife agency deems appropriate, that are indicative of the diversity and health of the state's wildlife
2. **Descriptions of locations and the relative condition of key habitats and community types** essential to conserving the species identified in (1)
3. **Descriptions of problems** that may adversely affect species identified in (1) or their habitats, **and priority research and survey efforts** needed to identify factors that may assist in the restoration and improved conservation of these species and habitats
4. **Descriptions of conservation actions** proposed to conserve the identified species and habitats, and priorities for implementing such actions
5. **Proposed plans for monitoring** species identified in (1) and their habitats, for monitoring the effectiveness of the conservation actions proposed in (4), and for adapting these conservation actions to respond appropriately to new information or changing conditions
6. **Descriptions of procedures to review the strategy** at intervals not to exceed 10 years
7. **Plans for coordinating the development, implementation, review, and revision of the plan with federal, state, and local agencies and Indian tribes** that manage significant land and water areas within the state or administer programs that significantly affect the conservation of identified species and habitats
8. **Broad public participation**, which was affirmed by Congress through this legislation as an essential element of developing and implementing these strategies, as well as of the projects that are carried out as part of the strategies (IAFWA 2004a)

GAP Data Use in Comprehensive Wildlife Conservation Strategies

Four of these required elements could benefit from geospatial information in general, and from GAP data in particular. For the first element, there is a clear fit with GAP's predicted species distribution maps for fulfilling the requirement for information on the distribution of species. For the second element, GAP provides location information that can facilitate making site visits to assess the locations and relative condition of key habitats and community types. For the third element, GAP land stewardship and predicted species distribution data could be used, in conjunction with other data about land use, to identify areas threatened by impacts such as urbanization, invasive species, or mining. This would address the requirement to describe problems that may adversely affect species. And for the fourth element, GAP land stewardship and species richness data could be key in determining conservation opportunity areas that, if protected, could secure SGCN species and their habitat. These data would help address the requirement for descriptions of conservation actions proposed to conserve the identified species and habitats (NBII 2004).

The fifth element, which requires plans for monitoring species and their habitats, could be addressed by coordinating with GAP's NatureMapping program, which is currently operating in six states. One of the primary objectives of the NatureMapping program is the collection of data on wildlife and habitat by trained observers. Through carefully designed workshops, even people with little experience in field data collection are taught to observe wildlife and transmit their observations to a central database using online forms. All NatureMapping data are reviewed by experts before being accepted for entry into a database of observations. This database could later be used to validate habitat models or record species' expansions. By using NatureMappers to monitor wildlife and habitat in high-value conservation areas, states could get a dynamic picture of how their conservation efforts are progressing.

Since GAP data are potentially useful in completing CWCSs, the focus of this project was to investigate the extent to which GAP data were being used in their development. State wildlife strategy coordinators and GAP principal investigators were surveyed. Because this was a preliminary assessment, subjects were simply asked whether GAP data were being used for CWCS development in their state; if yes, how; and if no, why not. Responses were received from at least one person in 39 states, and of the 11 states that did not respond, three had not yet completed their GAP project.

Survey results (Figure 1) showed that GAP data have most often been used to address CWCS elements one and two. Sixteen states have used GAP data to develop or refine predicted species distribution maps for SGCN species. Sixteen states have used the

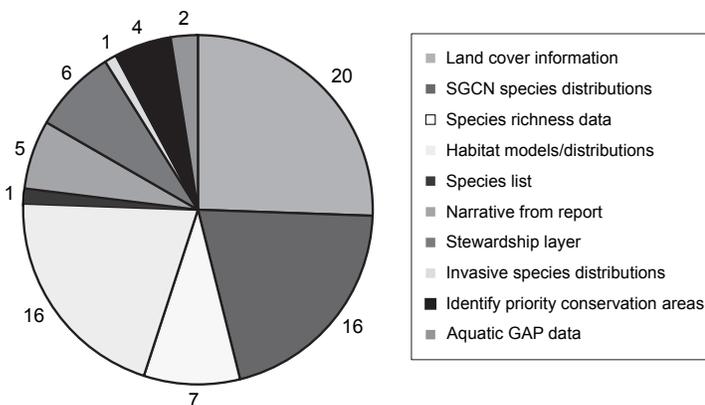


Figure 1. Use of GAP data in the development of state comprehensive wildlife conservation strategies.

data to develop maps of habitat for SGCN species, while seven states are using GAP data to update or refine species richness maps—often weighting the maps in favor of SGCN species to help identify priority conservation areas. For example, Kentucky used GAP predicted species distribution maps for high-priority species as a key layer in identifying the most important habitat parcels to protect. A species-weighting matrix was developed from NatureServe G and S ranks that allowed each species to be assigned a score reflective of rarity in Kentucky. GAP species distribution models were recoded so that each high-priority species was assigned a relative rarity score and each 30 X 30 meter pixel of the land cover map was given a score based on whether it provided no data (0), marginal (1), or optimal (2) habitat for that species. The “weighted” scores were summed using ESRI’s Spatial Analyst extension for all high-priority species across the landscape (Figure 2). The resulting predicted-species rarity layer was used in conjunction with other data sets to identify optimal conservation areas (Wethington 2003). New Mexico has used a similar process of rating target species, in combination with the use of intelligent assemblages to capture taxonomic diversity within identified land cover types, to identify priority habitat types (Schrupp and Boykin 2004).

GAP’s land cover data have been an important piece in plan development in 20 states. In five states, GAP land cover was the basis for the habitat classification system used (TWW 2003). Some states, such as North Carolina, reclassified land cover to a habitat map to show the distribution of broad habitat types. Other states made a subset of land cover that corresponded to natural vegetation to help identify potential conservation opportunity areas. Georgia incorporated GAP data for land cover, conservation lands, and predicted species distribution maps, along with ancillary data sets, to identify high-quality habitat patches—particularly patches adjacent to existing conservation lands (Ambrose 2004; Kramer and Ellittott 2005).

Other ways that states have used GAP data for their CWCSs include using the habitat narratives from GAP reports (four states), using the GAP stewardship layer to identify priority conservation areas (six states), using GAP aquatic data to develop models and predicted distribution maps for SGCN aquatic species (two states), and using the data to identify threats posed by invasive species (one state).

The six respondents who did not incorporate GAP into their strategies cited several reasons: one said the data in their state were too old to be useful, one said the data were too coarse to be useful for a small New England state, and four expressed frustration that data were not yet available for them.

Conclusion

GAP data have played an important role in the development of state CWCSs. This is an encouraging sign that some early challenges to GAP implementation are being met. Other challenges, such as the lack of awareness and access to GAP data, the difficulty of applying coarse-scale maps to small areas, and the age of the data, will be resolved as GAP moves into regional efforts.

It is possible that as planners and other land-use decision makers see GAP data being used, they will begin to incorporate them more into their own efforts. Because GAP projects were designed as collaborative projects, they have helped to develop and foster the cross-agency partnerships that will be essential to integrated conservation efforts, such as CWCSs, in the future. More important, as regional GAP projects, land cover maps, and data sets are completed, state conservation professionals will continue to find GAP data an important tool in conservation planning.

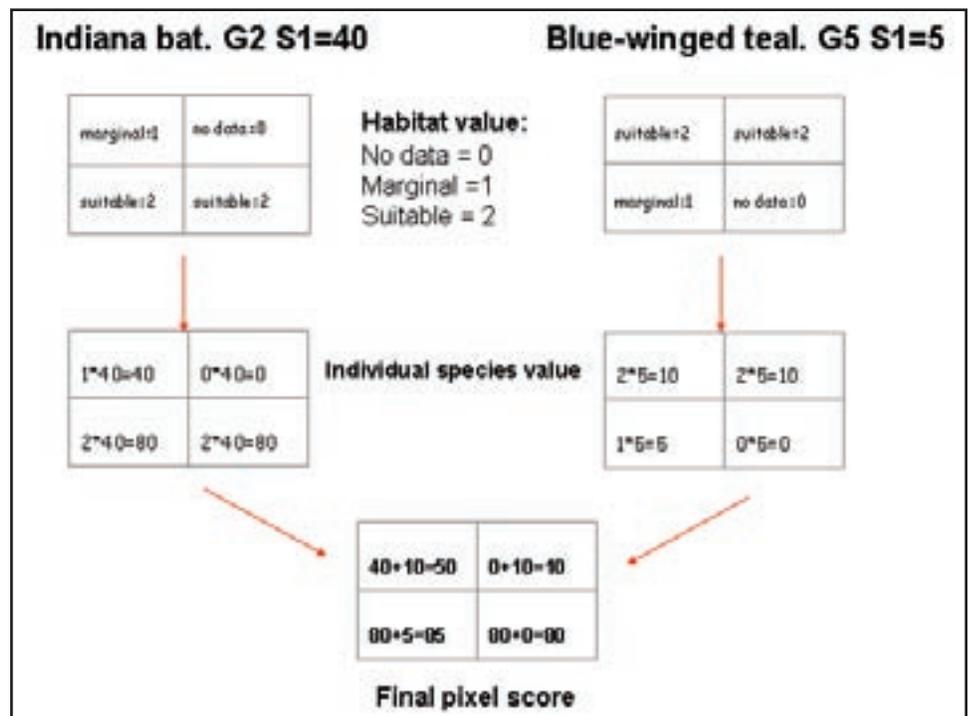


Figure 2. Matrix showing habitat and individual species values for Indiana bat and blue-winged teal and resultant final pixel scores.

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Identification of Conservation Priority Areas in Georgia

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Introduction

Congress is requiring all state agencies that receive funding through the State Wildlife Grants program to develop a statewide Comprehensive Wildlife Conservation Strategy (CWCS). The goal of this program is to create partnerships and provide a forum for coordinating conservation activities throughout each state. The CWCS process requires a landscape and ecosystem approach to planning for the protection of biodiversity. The Gap Analysis Program (GAP) provides landscape-scale information that can act as a coarse filter for identifying large areas of intact natural vegetation and habitats. It also provides information on the extent of existing conservation protection. GAP data include a land cover and vegetation map of the state, maps of the potential distribution of the terrestrial vertebrates found in the state, and a map of the distribution of conservation lands in the state.

In Georgia, GAP data allow us to identify coarse-scale habitat patterns, which play a key role in the long-term maintenance of wildlife populations. Habitat fragmentation is a key contributor to the decline in many wildlife species (Farhig 2003). By using spatial pattern analysis tools, large intact areas of vegetation can be identified and prioritized for the CWCS process.

The purpose of our project is to use GAP and other data to evaluate areas across Georgia for potential conservation opportunities. Products include new data that identify areas of natural vegetation that have been minimally fragmented. Additionally, these areas are evaluated to determine if they contain or are likely to contain rare species, how well these species are protected by the current conservation network, and whether they may be threatened by human encroachment. The different data sets may be used individually or in combination to determine which natural areas may need conservation protection.

Methods

Natural Vegetation

The primary data set for much of this project is the Georgia Gap Analysis Project (GA-GAP) 1998 vegetation map. This vegetation map was recoded to produce a map of natural vegetation. Table 1 lists the classes that were categorized as either natural vegetation or nonnatural. Although several classes not classified as “natural” for this project could certainly be considered so under a variety of circumstances (open water, clear-cut/sparse vegetation,

open-loblolly-shortleaf pine, loblolly-shortleaf pine, loblolly-slash pine), in most cases in Georgia they are in very active management (reservoirs, clear-cuts, pine plantations, etc.). We believe that excluding them results in a more accurate depiction of lands in a natural state.

For more detailed descriptions of GA-GAP vegetation classes and the methods used to map them, refer to Kramer et al. (2003).

Spatial Pattern Analysis

The primary analysis of Georgia’s natural vegetation was conducted in Fragstats 3.3. “Fragstats is a spatial pattern analysis program for categorical maps” (McGarigal et al. 2003). It allows for the computation of metrics that describe the distribution and character of patches of habitat across the landscape, thus it was ideally suited for analyzing natural vegetation in Georgia.

Several factors were deemed to be most important in describing the distribution, context, and character of Georgia’s patches of natural vegetation: these are size, shape, internal cohesiveness, distance from nonnatural habitats, and distance from other patches of natural vegetation. When combined, these factors may allow for an overall evaluation of patches of natural vegetation for biodiversity protection and conservation potential.

A significant limitation of Fragstats is the size of digital file that can be processed. A 30-meter grid of the natural vegetation of the entire state of Georgia, even when recoded to values of 1 and “No Data,” proved far too large and complex for calculation of the pattern metrics we desired. There were two potential solutions to this problem: resample the grid to a larger grain size (or more coarse resolution), or divide it into smaller areas. We decided to do both.

The initial 30-meter grid of Georgia’s natural vegetation was resampled, using a nearest neighbor function, to a 180-meter resolution. Although there were several problems with the results of doing this, most notably the coalescing of a number of larger patches that should probably be analyzed separately, they still proved useful. We calculated the Fragstats metrics of area, contiguity, core area, and proximity at a grain of 180-meters. Area simply measured the surface extent of clumps using a 4-pixel adjacency rule. Core area was similar, but restricted the surface measurement to areas of natural vegetation more than (in this case) 180 meters or 1 pixel from an edge. Contiguity is an indicator of shape, and describes the spatial connectedness or cohesiveness of cells within a patch; it is expressed as an index from 0 to 1, with higher values representing more cohesive patches. These areas are often represented by long continuous riparian forests.

The four indices calculated at a 180-meter resolution were recoded to nine ranked classes. The recoded indices were then added to create a summed index, which may serve as an overall

Table 1. Distribution of GAP vegetation and land cover classes into the natural vegetation and nonnatural classes for the natural vegetation map.

Natural Vegetation	Nonnatural
Beaches, dunes, mud (coastal areas)	Beaches, dunes, mud (noncoastal areas)
Coastal dune	Open water
Rock outcrop	Transportation
Mesic hardwood	Utility swath
Submesic hardwood	Low-intensity urban—nonforested
Hardwood forest	High-intensity urban
Xeric forest	Clear-cut/sparse vegetation
Deciduous cove hardwood	Quarries, strip mines
Northern hardwood	Parks, recreation
Live oak	Golf courses
Xeric pine	Pasture, hay
Hemlock-white pine	Row crop
White pine	Forested urban—deciduous
Montane mixed pine-hardwood	Forested urban—evergreen
Xeric mixed pine-oak	Forested urban—mixed
Mixed cove forest	Open loblolly-shortleaf pine
Mixed pine-hardwood	Loblolly-shortleaf pine
Shrub bald	Loblolly-slash pine
Sandhill	
Coastal scrub	
Longleaf pine	
Cypress-gum swamp	
Bottomland hardwood	
Salt marsh	
Shrub wetland	
Evergreen forest wetland	

patch quality evaluation. Using this summed index, we drew a series of 12 ecologically similar zones across the state, taking care to minimize splitting significant contiguous areas of natural vegetation (Figure 1). The goal of this exercise was to include large patches that crossed ecozones, which are normally divided along ecoregional boundaries. These zones became the basis for a new pattern analysis calculated at a 30-meter resolution.

For the 30-meter evaluation, we used slightly different indices. Core area and proximity were calculated again, but perimeter-to-area ratio and core area index replaced area and contiguity. Like contiguity, perimeter-to-area ratio is an indicator of shape. It is a simple index, perimeter/area, and describes the compactness of a clump or patch. Lower values indicate more compact shapes, and because area is in the denominator, it is inherently biased toward larger clumps when other factors are equal. For this reason, and the fact that we were already using core area, we did not feel that it was necessary to retain the area calculation. For the fourth index, we chose core area index. This simply calculates the



Figure 1. Ecologically similar zones delineated from an analysis of natural vegetation using 180-meter pixel size. The zones were identified by combining the results of spatial pattern analysis measures of area, contiguity, core area, and proximity run on a map of natural vegetation developed from the GAP vegetation map. These areas were defined to remove biases along ecoregion boundaries.

percent of a clump that is defined as “core area” (> 60 meters, at the 30-meter grain). It produces an evaluation of internal cohesiveness that is similar to contiguity.

As with the 180-meter analysis, these four indices were recoded to nine classes and ranked. The recoded indices were then added together to create a summed index, which serves as an overall patch quality evaluation.

Element Occurrence Data

The Georgia Natural Heritage Program (GNHP) tracks occurrences of a list of “Special Concern” plants and animals. This database is known as the element occurrence database. A complete list of tracked species is available at <<http://georgiawildlife.dnr.state.ga.us/content/specialconcernanimals.asp>>.

Besides quantifying the distribution, context, and character of Georgia’s patches of natural vegetation, we also sought to illustrate their relationship to known occurrences and potential habitat for GNHP-tracked species. To do this, we generated several indices across clumps of natural vegetation.

Based on a scheme devised by GNHP that we modified slightly for this project, element occurrences were weighted based on global and state status rankings by NatureServe. (Note: an explanation of NatureServe G-ranks and S-ranks may be obtained at the web link cited above.) Table 2 shows the original GNHP scheme. Our modification of this weighting scheme multiplies each “A” element occurrence by 3, each “B” by 2, and each “C” by 1. The most basic calculation we performed was a simple calculation of the total number of element occurrences per patch of natural vegetation. We also calculated a weighted density of individual points for each clump of natural vegetation by dividing the weighted total by the area. In addition, we generated a weighted density of element occurrences across the state (per 10,000 square meters or 1 hectare), and calculated the average weighted density per clump of natural vegetation.

A final use of the GNHP weighting scheme for Species of Concern involved incorporating them into the GA-GAP vertebrate models. These models are binary predictions of habitat/nonhabitat for all of Georgia’s 405 amphibians, breeding birds, nonmarine mammals, and reptiles. GAP vertebrate models included all species/subspecies from these taxa that are on the GNHP Species of Concern list (see <<http://georgiawildlife.dnr.state.ga.us/content/specialconcernanimals.asp>>) except the following: limpkin (*Aramus guarauna*), ivory-billed woodpecker (*Campephilus principalis*), green sea turtle (*Chelonia mydas*), leatherback (*Dermochelys coriacea*), black-billed cuckoo (*Coccyzus erythrophthalmus*), Chamberlain’s dwarf salamander (*Eurycea chamberlaini*), Florida panther (*Felis concolor coryi*), Eastern cougar (*Felis concolor cougar*), Sherman’s pocket gopher (*Geomys pinetis fontanelus*), black rail (*Laterallus jamaicensis*), Kemp’s ridley (*Lepidochelys kempii*), Blackbeard’s whitetailed deer (*Odocoileus virginianus nigribarbis*), Suwannee River cooter (*Pseudemys concinna suwanniensis*), Sherman’s fox squirrel (*Sciurus niger shermani*), Florida brown snake (*Storeria dekayi victa*), Bewick’s wren (*Thryomanes bewickii*), and Bachman’s warbler (*Vermivora bachmanii*). This was a total of 109 species. For a complete list of GA-GAP vertebrate models and their methods, see Kramer et al. (2003).

The GA-GAP vertebrate models for the 109 Species of Concern were multiplied by their GNHP weighting scores and added together, creating a weighted species richness grid. The mean and the maximum richness score were calculated for each clump of natural vegetation.

Conservation Lands

A third GA-GAP data set, the conservation lands database, was used in an analysis of how well the current conservation network protects patches of natural vegetation in Georgia. For each clump of natural vegetation, we calculated the percent of its total area that is currently under some sort of conservation protection. All lands in the conservation network were treated equally; we did not adjust for GAP codes in this study.

Table 2. Weighting scheme for the element occurrence data obtained from the Georgia Natural Heritage Program.

*Note: All state-protected species are automatically “bumped up” one rank.

Category	Designation	Weight
All federally protected species, all G1 or G2 species, G3/S1	A	3
G3/S2, G3/S3, G3/SH, G4/S1, G4/S2, G5/S1	B	2
G4/SH, G5/SH, G4/S3, G5/S2, G5/S3	C	1

Human Influence

Human influence may be considered a threat to natural vegetation through land-use conversion, the degradation of resources due to overuse, the introduction of exotic species, and other factors. We attempted to quantify this negative influence using two data sets: human population density, calculated from U.S. Census data, and road density. Roads may serve as an indicator of human influence because they facilitate development and provide access to areas.

Our calculation involved creating a population density grid by census block group (U.S. Bureau of the Census 2001) and reclassifying this grid by quantiles into nine classes. Using a statewide roads coverage (University of Georgia–Information Technology Outreach Services 1997), we created a grid of road density, calculated as linear meters per hectare, and reclassified this into nine classes using Jenks’s natural breaks (Brewer and Pickle 2002). We multiplied the reclassified road density by two and added this to the reclassified population density. We then calculated the average value of this surface per clump of natural vegetation. Especially when combined with the conservation lands assessment, this value may be considered a threats assessment for significant areas of natural vegetation in Georgia.

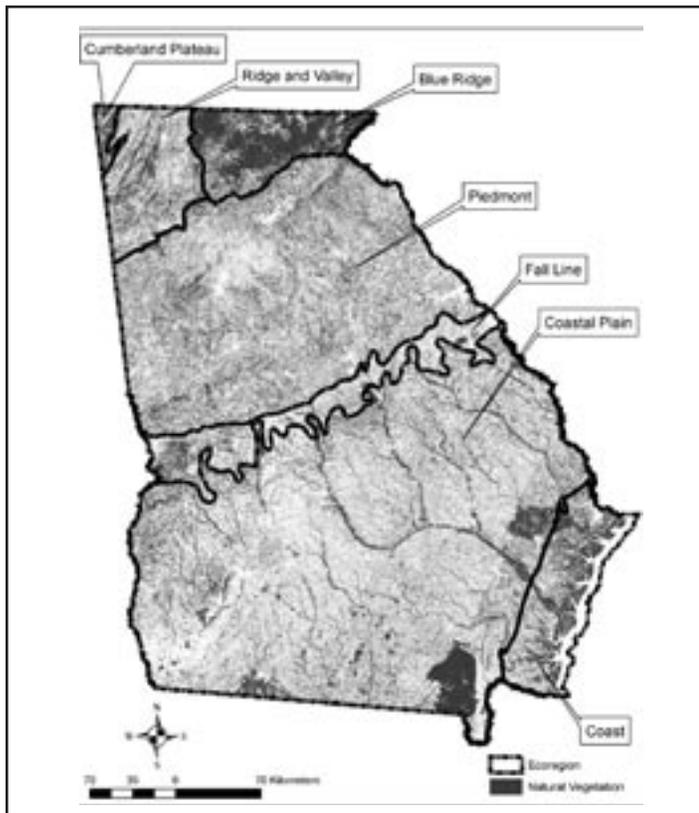


Figure 2. Natural vegetation classification of Georgia resampled to 180-meter pixel size. Derived from the GA-GAP vegetation map. The six major ecoregions of Georgia are shown in this figure.

Results and Discussion

Natural Vegetation

Based on our classification, approximately 36 percent of the state is covered by vegetation in a natural state (Figure 2). The Blue Ridge ecoregion has 78 percent of its land area in natural communities, whereas the Piedmont and Coastal Plain are 35 and 33 percent, respectively.

Pattern Analysis

The 180-meter resolution analysis resulted in the coalescing of many clumps of natural vegetation (Figure 3). For this reason, it is probably more valuable for broad-scale viewing than actual analysis and ranking of individual patches. The total index for the 30-meter scale analysis is found in Figure 4.

The results of the core area analysis highlight intact patches where “edge effect” is minimized (McGarigal et al. 2003). Many species of concern respond negatively to increased edges, especially those in urban areas (Collinge 1996). Patches with a large core area can provide havens for these species where they are less likely to suffer predation, brood parasitism, human

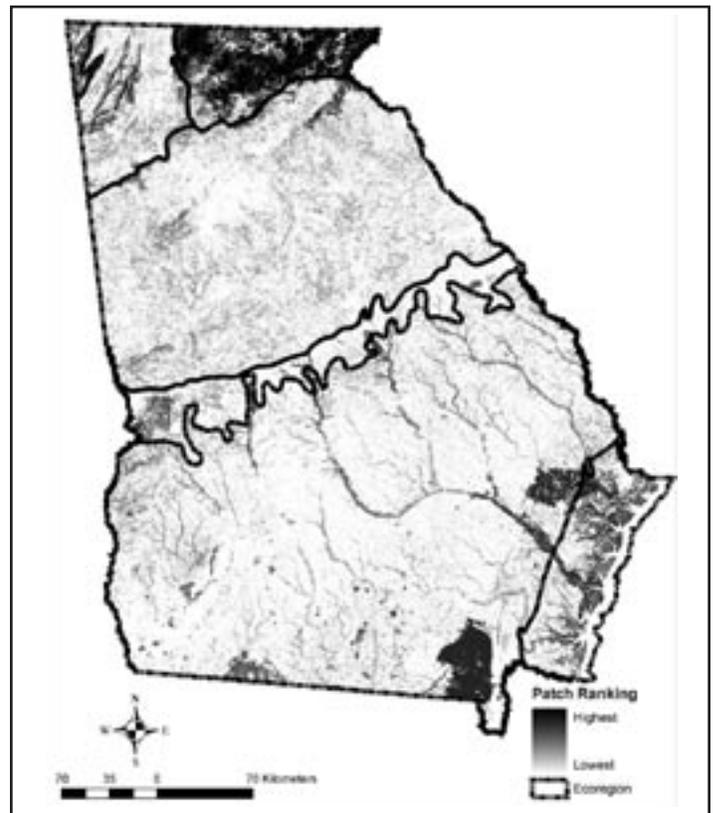


Figure 3. Index of patches of natural vegetation at 180-meter resolution. The index is derived by adding outputs of patch core area, contiguity, perimeter-to-area ratio, and proximity spatial pattern metrics into a single layer. Pattern metrics were derived using Fragstats software.



Figure 4. Sum of metric pattern metric rankings developed at 30-meter resolution. The metrics include core area, proximity, core area index, and contiguity. These metrics were derived from the natural vegetation map using Fragstats software.

encroachment, or other negative factors (McKinney 2002). Core area index is similar, but as a percentage is not biased toward larger parcels and provides a means for evaluating the internal integrity of parcels of any size (McGarigal et al. 2003). Contiguity and perimeter-to-area ratio both measure shape; perimeter-to-area ratio is useful for finding large, compact patches, while contiguity focuses on internal cohesiveness and may highlight intact corridors (McGarigal et al. 2003). Proximity is best used as part of an overall index (such as the summed index calculated here); it provides a measure of a patch's place within the landscape (McGarigal et al. 2003). Because it considers so many different factors, the sum of the individual measures may be the most useful data set for determining the quality of patches of natural vegetation.

It should be noted that these rankings are not necessarily a prioritization scheme for land protection in Georgia. For example, the dearth of high-ranking patches in the Piedmont, especially when compared to a region such as the Blue Ridge, does not mean that there are no lands worth conserving in the Piedmont. Priorities within the Piedmont may be different from those in the Blue Ridge, and parcels within the region may be evaluated relative to one another, rather than across regions.

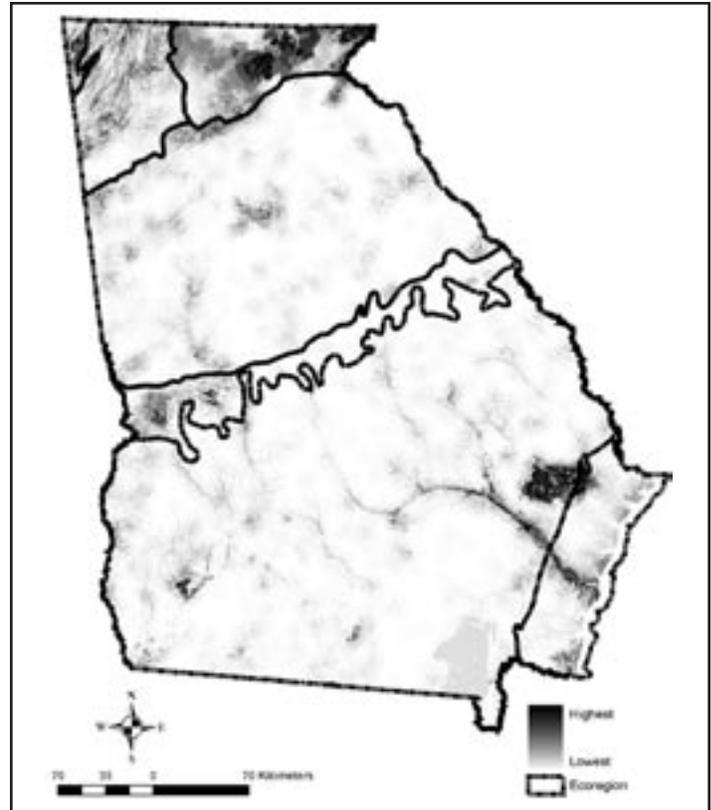


Figure 5. Average weighted density of element occurrences per patch of natural vegetation, calculated per 10,000 square meters. This map was derived using the Georgia Natural Heritage Program's element occurrences database. This database includes aquatic as well as plant and animal point data.

Many of the high-ranking patches are already part of the existing conservation network. Although a separate analysis looks at the conservation status of individual parcels, it is also informative to view the pattern analysis as it visually relates to the conservation lands of Georgia.

Element Occurrence Data

The different uses of GNHP element occurrences for this project illustrate slightly different values for individual patches, none necessarily better than another. The total number of GNHP element occurrences per patch appears to be somewhat biased toward large patches. However, this is not necessarily an unfair bias, as large patches may indeed be more likely to harbor a greater number of rare species than small patches. The weighted density of points per patch (total weighted value/area) highlights many small patches and a few larger ones that may be important for rare species. The average weighted density per patch illustrates a more even prediction across the landscape, emphasizing more broad-scale processes (Figure 5). Since the results of each analysis are so different, they should be seen as alternative views, each capturing a different conservation need.

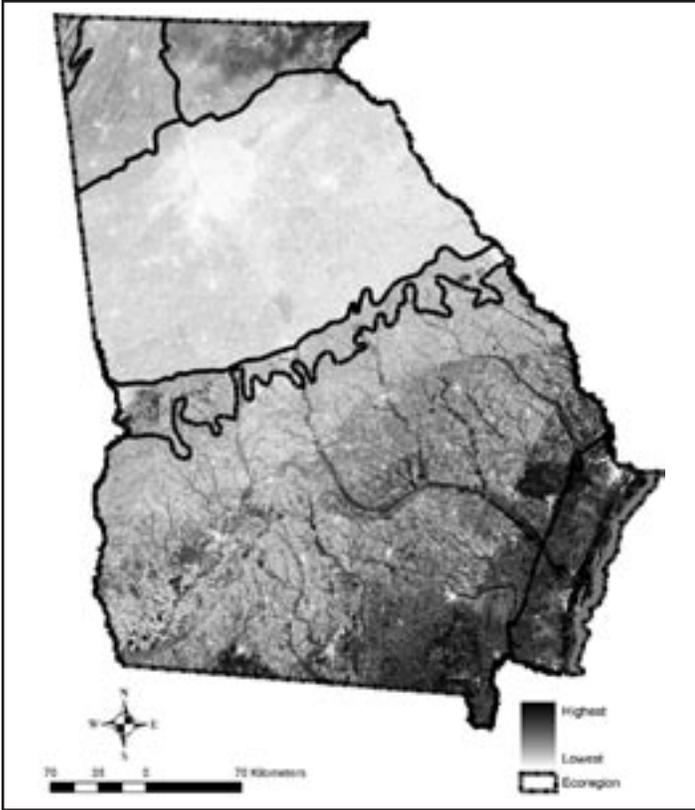


Figure 6. Weighted species richness of GNHP Species of Concern—amphibians, breeding birds, terrestrial mammals, and reptiles—at 30-meter resolution. These data were derived from the vertebrate model maps produced for GA-GAP.

The weighted species richness grid, calculated from amphibians, breeding birds, terrestrial mammals, and reptiles on the GNHP Species of Concern list, presents a completely different way of looking at biodiversity (Figure 6). Species richness was also evaluated at the patch level, both as an average and as a maximum across each patch of natural vegetation. The average tends to capture landscape-level trends, while the maximum focuses on specific areas of important habitat.

Conservation Lands

The conservation lands analysis provides an indication of how well the current conservation network is protecting natural vegetation (Figure 7). Significant patches that are lighter may be seen as being more threatened than darker colored patches. Under this scenario, significant lighter colored patches might be seen as conservation targets.

Human Influence

We calculated human influence at the natural vegetation patch scale to illustrate threats to individual patches, or perhaps targets for restoration (Figure 8). It is important to note that in areas of high human influence, patches of natural vegetation will be small, whereas in areas with low human influence, we find



Figure 7. Percent of patches of natural vegetation in current conservation network. These data represent the percentage of natural vegetation that makes up each property in the Georgia GAP Stewardship database.

larger patches. This is just one way of looking at this factor. As part of future analyses, another way that might prove valuable would be to examine human influence within the neighborhood surrounding each patch. This would perhaps gauge future threats more accurately.

Limitations

The process outlined above provides a coarse-filter approach to land conservation. Because the GAP mapping process makes a number of assumptions, these assumptions must be carried through when evaluating the results of these analyses. For example, GAP data does not take into account any measure of habitat quality and in fact uses vegetation communities as a surrogate for habitat. This method does not take into account the distribution of invasive species or other changes in a vegetative patch that might be modified by human management. The process only looks at natural or seminatural vegetation, thus removing some potential habitat that can be derived from agricultural areas, as well as managed pine plantations.

In addition to the limitations of GAP data, the distribution of element occurrence data used in this study has a number of limitations. The collection of these data is often biased to public



Figure 8. The average relative human influence per patch of natural vegetation. The map intersects areas of high human influence with natural vegetation. Metropolitan areas ranked high in human influence but low in natural areas and therefore do not appear on this map. These rankings represent areas where there is a combination of human influence and natural areas in close proximity.

lands and often to areas of high research interests, such as coastal and mountain areas. The element occurrence data does have an aquatic component; however, this exercise did not attempt a systematic approach to evaluating aquatic systems. This is particularly critical to the southeastern United States, which has a high distribution of aquatic biodiversity.

Conclusions

Approximately 36 percent of Georgia is covered by “natural vegetation.” Although there has been no long-term analysis of natural vegetation, the acreage of nonevergreen forest types has declined throughout most of the state since 1974, while acreages

for urban uses have increased sharply (Natural Resources Spatial Analysis Laboratory 2001). It is critical that Georgia complete an analysis of its remaining biological resources. GA-GAP was a first step toward this goal. Using our analysis as a guideline, biologists may begin to evaluate high-quality patches at a finer scale, such as the field data collection inventories. In addition, further analysis of the land-use trends data or historic vegetation distributions may provide additional information on sites for potential habitat restoration. Together these methods should lead to the development of sound conservation plans for Georgia.

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Development of a Community Stewardship Program for the Pierce County Biodiversity Network

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Introduction

The University of Washington's Department of Urban Design and Planning (UW-UDP) has been implementing a series of pilot projects that explore the feasibility of conducting a gap analysis at the local level. The lessons learned from these pilot projects, conducted in collaboration with the Washington Gap Analysis Project (WA-GAP) and the Washington Department of Fish and Wildlife (WDFW), will assist county governments in Washington State that are drafting plans for wildlife and habitat as required by the state Growth Management Act (Dvornich et al. 2003). These pilot projects are also providing information for other state initiatives (e.g., the Washington Comprehensive Wildlife Conservation Strategy, ecoregional assessments, and a state biodiversity council).

Over the past five years, the Washington Cooperative Fish and Wildlife Research Unit, Washington Department of Fish and Wildlife, and Pierce County Planning and Land Services conducted a GAP Pilot Project (Pflugh et al. 2000) that developed a Biodiversity Management Area (BMA) network identifying 16 biologically rich areas in Pierce County. WA-GAP data sets were used to develop the BMAs with additional input from the National Wetland Inventory, the County Wetland Inventory, Heritage data, and salmonid data from WDFW and other cooperating agencies.

Although the BMA Network was adopted into the Open Space section of Pierce County's Comprehensive Plan, finer-resolution mapping and habitat-quality assessment were needed before the development and implementation of biodiversity management plans could proceed. The Pierce County Biodiversity Alliance was formed to address these issues.

Goals

The Alliance's primary goals are as follows: (1) to educate local jurisdictions and the public and involve them in the biodiversity planning process; (2) to establish new surveys and monitoring programs where necessary; (3) to empower citizen-scientists to collect monitoring data; (4) to provide a level of quality assurance

through the use of experts; and (5) to develop biodiversity management plans that will provide detailed information on habitat quality and species presence/viability, restoration opportunities, and priorities for conservation and land acquisition for each defined BMA. The Alliance has chosen one BMA as a pilot, the Gig Harbor BMA. The process will be applicable throughout the network, regardless of habitat or community. The outreach and stewardship process is purposefully independent of the scientific process of developing a network. This allows the outreach and stewardship process developed in this pilot effort to be more widely applied to other communities or jurisdictions beyond Pierce County.

Methods

Network Assessment

WA-GAP land cover maps were updated with 1998 satellite imagery. The BMA network was ground-truthed in 2004 through a series of steps. First an analysis was done using recent satellite imagery and color digital orthophotos, and this was followed up by driving routes through BMAs that did not fall within Mount Rainier National Park and state and private timberlands. Fifty percent of the original habitat had to remain within the BMA after ground-truthing for the BMA to be accepted into the final network; one BMA was removed and only 1 percent of the original core area was removed from the network. Many corridors were originally riparian areas, but during the assessment all were realigned along major rivers and streams because the county had existing regulations that would be used for corridor protection. The original network and corridors included a quarter-mile buffer; these buffers were removed because they included too many fragmented lands.

The final Pierce County Assessment (Brooks et al. 2004) included all predicted and verified species lists for each BMA, an assessment of the habitat, and recommendations based on the ground-truthing efforts. Butterfly and recent Heritage data were obtained from WDFW and added to the report. The biodiverse lands identified by the Puget Sound ecoregional assessment (EA) were compared with the Puget Sound portion of Pierce County. BMAs that overlapped with the EA polygons were highlighted for their local and regional importance. Four BMAs did not overlap, however, indicating local biological significance. This report can be accessed through Pierce County's web site: <www.co.pierce.wa.us/pc/services/home/property/pals/other/biodiversity.htm>.

Pilot BMA Project

The Gig Harbor BMA was selected as a pilot implementation

project. The Alliance received small grants and conducted an intensive 24-hour species verification survey (bioblitz) in June 2005 and organized community outreach efforts on private lands with media coverage. Preparation for the bioblitz began with a NatureMapping workshop to train citizens and experts on data-collection protocols. Thirty-four landowners allowed access to their property. A total of 35 experts, 13 citizen-scientists, and 4 landowners observed 72 percent of the predicted bird species, 57 percent of the predicted amphibians, 32 percent of the predicted mammals, 40 percent of the predicted reptiles, 3 fish species, 148 invertebrate samples that are undergoing identification, and 169 plant species. A community meeting is planned to present the results of the bioblitz.

The Alliance was recently awarded another grant to continue its work in Gig Harbor and it plans to conduct another bioblitz within the BMA using trained community members under professional guidance who will go to properties missed during the first bioblitz. This training will enable citizens to help establish a benchmark of current species located within the BMA and will also contribute to long-term monitoring activity. Species observations recorded during this monitoring will be used to evaluate whether biodiversity conservation strategies are having positive and successful results.

The Alliance will convene a citizen-based advisory committee to help develop long-term biodiversity conservation strategies. The goal of these public workshops and committee processes will be to develop implementation measures to conserve biodiversity. These measures may include such actions as enrolling in county incentive-based land-protection programs (Public Benefits Rating System) or permanently dedicating or purchasing properties as open space (Conservation Futures Program), restoring native vegetation in areas of degraded habitat (Landowner Incentive Programs, Backyard Wildlife Sanctuary Program), and educating people on acceptable riparian/wetland land management. The Alliance will continue to invite new partners and organize community-planning sessions to craft a local vision plan for stewardship of their BMA. The plan may also be used to solicit funding for various implementation measures, such as native vegetation restoration.

The last step, and possibly the most important, is to provide continued feedback to the community and the Pierce County

Biodiversity Alliance in the form of maps, data, and reports illustrating the progress of the Gig Harbor Pilot BMA Project.

Conclusions

Problems with landscape-scale planning documents result from the failure to implement the products in a meaningful way and the short life span of the products (Christensen 2004). Instead of land-use guidance implemented through short-term, often unfavorable, land-use regulations, the Pierce County Biodiversity Alliance aims for a community-based approach for the long-term maintenance of biologically rich lands within Pierce County. The vision for protection or stewardship will be locally driven and tied to tangible factors, such as habitat loss, the introduction of exotic species, environmental degradation, and increased runoff and pollutants within the network. A locally based process is more likely to garner community support. Using media coverage, we anticipate more landowners will engage in the process beyond those owning property within the network. Therefore, it is the Alliance's long-term goal that local governments and communities will work together to educate private landowners about conservation and collaborate to help them maintain biodiversity through better planning, both within and outside the network.

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LAND COVER

Identifying Longleaf Ecosystems Using Polytomous Logistic Regression

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Southeast, PLR would be well suited to differentiate forested ecosystem types.

Introduction

Longleaf ecosystems, one of the most species-rich plant ecosystems outside of the tropics, are estimated to occupy 1.2×10^6 ha across the Southeastern United States, a mere 5 percent of the 24.3×10^6 ha pre-European settlement estimate (Outcalt and Sheffield 1996). This dramatic loss of habitat has had a substantial impact on numerous plants and animals, and is the primary reason that many Southeastern species have been listed as threatened or endangered (Tuldge 1999). These findings indicate a strong need for the conservation and restoration of these critically endangered ecosystems (Noss et al. 1995).

While conservation and restoration efforts have begun, they have been limited, in part, by the lack of information depicting the current location of these ecosystems. Long-term studies, such as the Forest Inventory Analysis, have been useful in identifying trends in longleaf ecosystem decline (Kelly and Bechtold 1990; Outcalt and Sheffield 1996), but are ill-suited to provide meaningful information at fine spatial scales. Due to the coarse nature of these data sets (e.g., 20 km grain), organizations have had to take a broad-based approach toward longleaf ecosystem management, monitoring, and restoration, often limiting the efficacy of their efforts. To become more effective, these organizations need accurate, fine-scale data sets that identify forested ecosystem types and depict the current location and distribution of longleaf ecosystems.

Remotely sensed data provide a unique opportunity to generate such a data set by linking fine-grain (30 m) spectral information with spatially explicit examples of forested ecosystem types. Few analysts, however, have successfully differentiated longleaf ecosystems from other coniferous ecosystems using common classification techniques (e.g., maximum likelihood classifiers, clustering, classification trees, and artificial neural networks) due to the amount of spectral overlap among coniferous ecosystems in the Southeast. Using polytomous logistic regression (PLR), which allows for > 2 response variables, we demonstrated the flexibility and utility of probabilistic classifiers when substantial spectral overlap among land cover types exists (Hogland et al. *in progress*). Given the similarities between longleaf and other coniferous ecosystems in the

Methodology

To identify the current distribution of longleaf ecosystems, we employed an iterative hierarchical classification scheme (IHCS) that utilized PLR (Agresti 2002), digital elevation models (DEMs), and multitemporal Landsat enhanced thematic mapper plus (ETM+) imagery. Each Landsat ETM+ scene was preprocessed by the Multi-Resolution Land Cover Consortium to Level 1T standards (NASA 2005) and grouped into one of three seasons based on the acquisition date: leaf on spring, leaf on fall, and leaf off winter. Due to the inherent variability among multitemporal Landsat ETM+ scenes, all scenes were normalized and merged, by season, to a common radiometric scale using a newly developed normalization procedure (Hogland and MacKenzie *in progress*). PLR, statistical analyses, and accuracy assessments were performed using SAS version 8.2 (SAS® 2005). Model implementation was performed using ARCGIS version 8.3 and ESRI's Spatial Analyst extension (ESRI® 2005).

Our IHCS is a multistage classification that constrains the conditional probabilities of one PLR classification by the specific classes of a more general PLR classification. The benefits of IHCS include fewer field samples, the preservation of modeling and classification errors, a hierarchically organized classification, and the ability to account for confounding temporal features (TF).

Stage 1, iteration 1 of our IHCS identified generalized land cover types (after Homer et al. 2004), and seasonal TF (Table 1) using training data, normalized multitemporal ETM+ imagery, and a maximum likelihood allocation rule (MLAR). To account for the effects of TF, pixels categorized as clouds, smoke, or burn areas in the first iteration of stage 1 were allocated to land cover types by restricting the explanatory variables of the second iteration PLR models to seasonal ETM+ imagery that did not have a given season's TF (Table 1). Land cover types identified in each iteration of stage 1 were then merged to produce our final land cover map. Land cover training data, used to develop our stage 1 classification model, were collected through image and photo interpretation. To assess the accuracy of our stage 1 land cover map, we used a cross-validation technique that estimated the level of agreement (kappa), on a scale of -1 to 1, between observed and predicted land cover types (SAS® 2005).

Table 1. Land cover types, cross-validated MLAR accuracies, and the number of training points for stage 1 land cover classification.

Land Cover Types	Training Points	Cross-Validated User Accuracy (%)	Cross-Validated Producer Accuracy (%)
Winter Burn *	355	95	95
Winter Smoke *	63	98	100
Fall Burn *	244	85	82
Fall Clouds *	98	92	98
Fall Smoke *	82	89	89
Spring Burn *	637	92	90
Spring Clouds *	176	88	88
Spring Smoke *	132	80	83
Fields	547	99	98
Bare Ground / Urban	144	99	99
Deciduous	341	91	92
Evergreen	341	82	85
Water	438	99	99
Wet Vegetated Areas	265	86	87

* Confounding seasonal TF. Once identified, these TF were reanalyzed using a subset of ETM+ bands representing seasons not affected by the season of the TF and classified as one of the six remaining land cover types.

Stage 2 of our IHCS generated a series of forested ecosystems probability distributions using field-interpreted samples, ETM+ spectral values, and DEMs. Similar to stage 1, TF had confounding effects on forested ecosystem probabilities. To account for these effects, an iterative scheme, as described in stage 1, was used to generate a series of ecosystem PLR models. The probability distribution of each ecosystem iteration was constrained to Deciduous and Evergreen land cover types using corresponding stage 1 iterations. Forested ecosystem probabilities were then merged, using each iteration of stage 2, to produce a final probability distribution for each forested ecosystem.

Forested ecosystem types were defined for our project as systems composed of primarily one overstory species (i.e., one species makes up at least 75 percent of the overstory, Table 2). Longleaf ecosystem types were split into two basic subgroups, Coastal Plain Longleaf ecosystems and Mountain Longleaf ecosystems, based on density, topography, species composition, and moisture availability (after Peet and Allard 1993).

Field data were collected for each of the ecosystem types and related to ETM+ imagery and DEMs using ground coordinates collected with a global positioning system (GPS). Due to access availability and the presence of large, contiguous, coniferous, and deciduous stands on public lands (Outcalt and Sheffield 1996), field data were primarily collected in national forests,

national wildlife refuge areas, and military installations. Map accuracy, kappa estimates, and model validation were assessed using independent field samples and an MLAR (Hogland et al. *in progress*).

To simplify our PLR models, redundant and insignificant explanatory variables were removed from each stage/iteration of our IHCS using a stepwise procedure (SAS 2005). Thresholds for variables entering and staying in each PLR model were set at a significance level of 0.15 and ≤ 0.05 , respectively.

Results

We developed a statistically significant PLR model for the first iteration of stage 1 in our IHCS ($X^2_{df=234} = 17,011.4$, p-value < 0.0001; $\tilde{R}^2 = 0.9953$). Overall accuracy for this model, using an MLAR, was 92 percent with a mean kappa score of 0.91 (95% CI; 0.90, 0.92). In this model, all Landsat ETM+ bands contributed significantly to our ability to distinguish land cover and TF types ($\alpha \leq 0.05$). For pixels categorized as one of the TF types, we developed statistically significant PLR models with high overall accuracies and kappa scores (Table 3). In these models, some ETM+ bands did not significantly contribute to our ability to distinguish land cover types (at $\alpha \leq 0.05$) and subsequently were removed (Table 4). Using an MLAR, land cover types were assigned to each pixel across our study area (Figure 1).

Table 2. Ecosystem types, validated MLAR accuracies, predicted accuracies, and the number of samples for the first iteration ecosystem classification.

Ecosystem Types		User* Validated Accuracy (%)	Lower (95% CI) Predicted User Accuracy (%)	Upper (95% CI) Predicted User Accuracy (%)	Producer* Validated Accuracy (%)	Training Sample Size	Validation Sample Size
Slash		58	39	78	60	127	36
Hardwoods		75	72	98	83	94	186
Mixed		35	32	84	41	89	147
Longleaf	Mountain Longleaf	100	56	98 ⁺	79	86	15
	Coastal Plain Longleaf	66	41	78	62	130	187
Loblolly		64	31	82	69	96	25

* User and producer accuracies were adjusted for unequal sample size and refer to the probability of accurately classifying an observed ecosystem type versus the probability of accurately classifying a predicted ecosystem type, respectively.

⁺Observed value not within 95 percent confidence interval.

Table 3. Stage 1 land cover model statistics. Model naming convention identifies ETM+ imagery used in each PLR model (i.e., minus winter indicates that all the winter imagery was removed from that PLR model, thereby removing the confounding winter TF).

Model Iteration	Model Name	Chi-Square	Degrees of Freedom	p-value	\tilde{R}^2	Overall Accuracy (%)	Mean Kappa
1	All ETM+ Imagery	17011.4	234	< 0.0001	0.9953	92	0.91
2	Minus Winter	6487.23	55	< 0.0001	0.9879	95	0.94
	Minus Fall	6559.06	45	< 0.0001	0.9894	95	0.94
	Minus Spring	6606.11	55	< 0.0001	0.9903	95	0.95

For stage 2, iteration 1 of our IHCS, we generated a statistically significant PLR model that accurately predicted forested ecosystem probability distributions ($\chi^2_{df=60} = 1241.57$, p-value < 0.0001; $\tilde{R}^2 = 0.89$). In this model, not all Landsat ETM+ bands significantly contributed to our ability to distinguish among ecosystem types (Table 4). Overall independent classification accuracy for this model, using an MLAR, was 66 percent, with a mean kappa score of 0.60 (95% CI, 0.56, 0.63). Based on an independent measure of model fit, this model accurately predicted pixel probabilities for all but the Mountain Longleaf ecosystem type (Table 2), indicating a good model fit. Subsequent ecosystem PLR models, for field samples occurring in TF types, indicated similar trends. Applying these ecosystem models back to the imagery produced an accurate depiction (i.e.,

good model fit) of the probability distribution of each ecosystem type across our study area (Figure 2). Using an MLAR, the most probable ecosystem type was assigned to each pixel across our study area (Figure 3).

Discussion

We accurately mapped longleaf and other coniferous and deciduous ecosystem probability distributions across portions of the Southeast using PLR and an IHCS. These data sets can be used to identify the most probable locations of longleaf ecosystems, to identify potential longleaf ecosystem restoration sites, and to incorporate ancillary data sets to prioritized restoration locations. By weighting the area of each pixel

Table 4. Landsat ETM+ bands that were removed from each PLR model in our IHCS. ETM+ bands (rows) that have an “x” in one of the stage 1 or 2 PLR models (columns) were removed from that analysis.

Season / Band	PLR Land Cover Models				PLR Ecosystem Models			
	Initial	Minus Winter	Minus Fall	Minus Spring	Initial	Minus Winter	Minus Fall	Minus Spring
Winter Band 1		x				x		
Winter Band 2		x			x	x	x	x
Winter Band 3		x	x			x		
Winter Band 4		x				x		
Winter Band 5		x				x		x
Winter Band 7		x		x	x	x		
Fall Band 1			x				x	
Fall Band 2			x				x	
Fall Band 3			x				x	
Fall Band 4			x				x	
Fall Band 5			x		x		x	
Fall Band 7			x		x	x	x	x
Spring Band 1			x	x				x
Spring Band 2				x				x
Spring Band 3		x		x				x
Spring Band 4				x				x
Spring Band 5			x	x	x		x	x
Spring Band 7				x	x		x	x

by the probability of each ecosystem, managers can obtain a spatially explicit estimate of the amount of ecosystem area for a predefined location. If managers want a certain level of assurance of area estimates, they can incorporate model error into their area calculation, producing area confidence intervals.

PLR was chosen as our classification technique based on its flexibility and modeling assumptions (Hosmer and Lemeshow 1989; Agresti 2002; Johnson and Wichern 2002; Hogland et al. *in progress*). The flexibility in the PLR methodology comes from its focus on directly modeling class probabilities, the way in which it estimates means and variances (i.e., multinomial distribution), and the way it estimates slope parameters (i.e., maximum likelihood estimation). This allows for categorical and continuous explanatory variables, and maintains useful model building tools that help assess issues of parsimony, overparameterization, and model fit. In addition, PLR estimates model error, thus providing a way to determine a level of confidence in modeled probabilities.

While PLR is a very flexible and robust classification technique, there are potentially a few drawbacks. The first deals with

the efficiency of PLR (Efron 1975). With today’s computers, though, this is no longer an issue. Second, PLR cannot solve a maximum likelihood estimate (MLE) for beta values when there is no overlap in class explanatory values. While an unsolvable MLE may be troubling in terms of mathematic complexity and model fit estimates (Agresti 2002), viewed from a classification perspective this situation means that some of the class types can, with 100 percent accuracy, be separated from the rest of the class types given a set of rules. In this situation, a probabilistic classification is not required. Instead, class types can be assigned using Boolean operators.

Summary

Using multitemporal Landsat ETM+ imagery, DEMs, PLR, and an IHCS, we accurately depicted the current distribution of longleaf ecosystems. By presenting these data sets in terms of probabilities, we provide users with a more accurate representation of our classification and the flexibility needed to answer fine-scale longleaf ecosystem questions. Finally, in light of our success with PLR and our IHCS, we are incorporating these data sets and methods into the Alabama Gap Analysis Project.

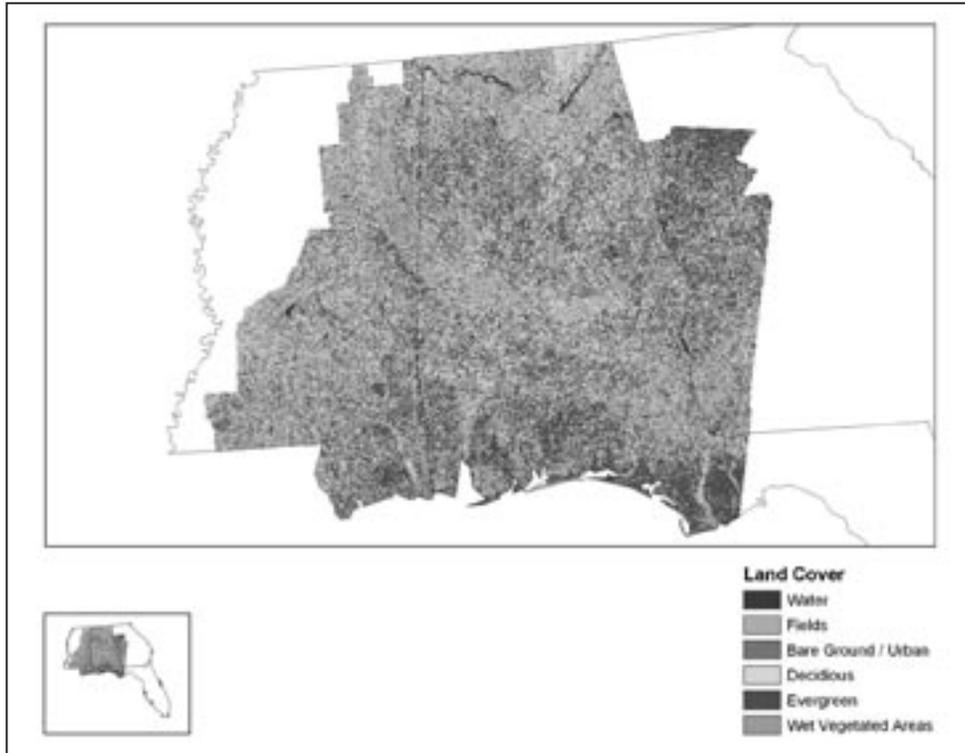


Figure 1. Final land cover map after adjusting for confounding seasonal variables.

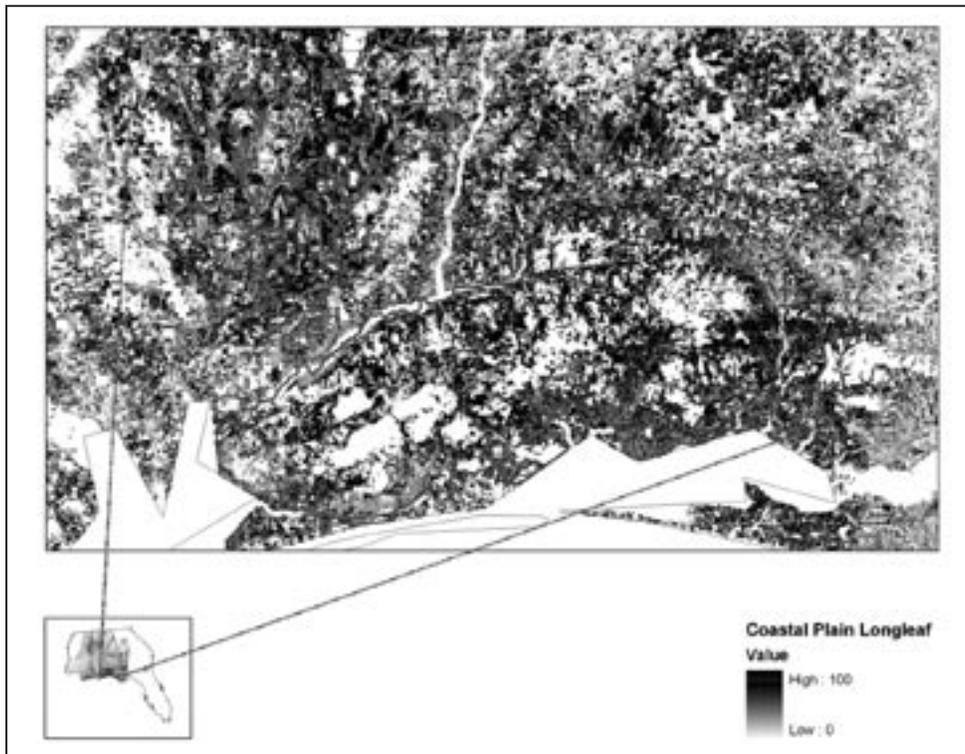


Figure 2. Example of one forested ecosystem probability distribution for Blackwater State Forest and Eglin Air Force Base, located in the panhandle of Florida. As color transitions from white to black, the probability of finding the Coastal Plain Longleaf ecosystem increases from 0 percent to 100 percent.

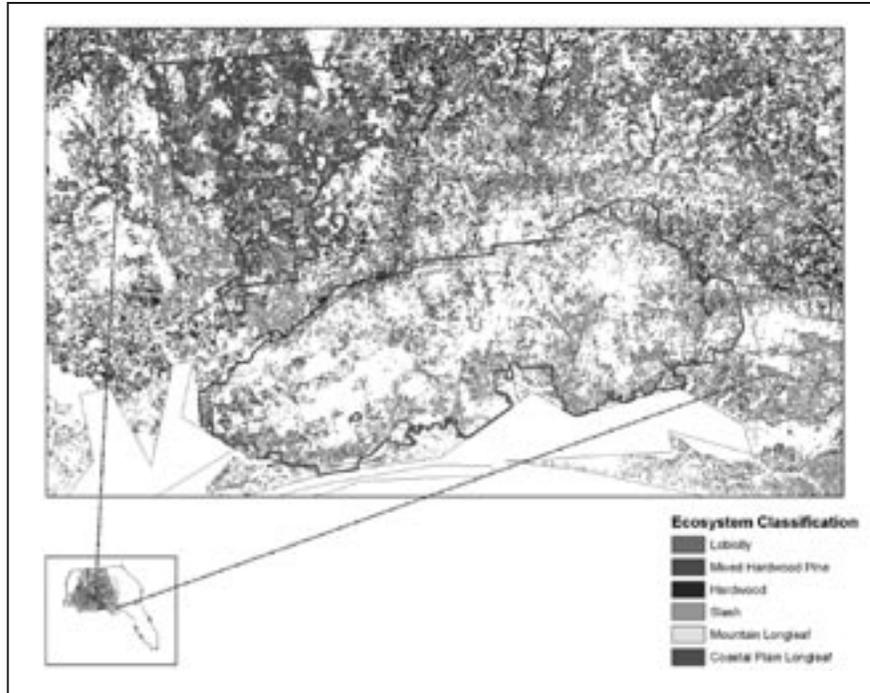


Figure 3. The most probable forested ecosystem type for Blackwater State Forest and Eglin Air Force Base, located in the panhandle of Florida, based on an MLAR. Unclassified areas (areas in white) represent a land cover type other than Evergreen or Deciduous.

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Ecological Systems as GAP Map Units in the Southeastern United States

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Through partnerships, the Gap Analysis Program (GAP) has played a major role in the evolution of vegetation classification systems for the United States (Jennings 1997; Grossman et al. 1998). The Ecological Systems Classification (Comer et al. 2003), developed by NatureServe for the Nature Conservancy, is a set of units that are reasonable mapping targets and also reasonable conservation targets at a variety of scales.

The Ecological Systems Classification is available for the lower 48 United States, and regional GAP efforts have generally adopted them as target map units. The developers of the Ecological Systems Classification were influenced by the recognition on the part of state GAP programs that in many cases, a consistent recombination of alliance and association units represented a more appropriate or practical set of map legend units than did individual alliances. The development of “Ecological Complexes” and “Compositional Groups” was an intermediate step in this process (Pearlstone et al. 1998; Menard and Lauver 2000). While GAP has moved away from mapping at the alliance level of the National Vegetation Classification System (NVCS), it is safe to say that without the association- and alliance-level descriptive work done for the NVCS, our understanding of the ecological systems would be far less complete.

Southwestern Regional GAP has recently completed a regional map for a five-state area with 109 of their 125 map units representing ecological systems (USGS-National Gap Analysis Program 2004). In the Southeast, we are targeting the systems and have added modifiers to accommodate variability within key systems. The Southeastern Regional GAP map legend will contain approximately 135 map units representing ecological systems and their modifiers. We are committed to mapping matrix, large-patch, and linear systems. Small-patch types will be mapped where possible on a case-by-case basis.

We have identified modifiers to the ecological systems in response to three different circumstances. First, there is structural variability within the system that may be important for improving the vertebrate models. Second, there is a successional expression of a community that dominates large areas. Third, there is variability in the underlying ecological processes that is expressed in the vegetation. In each case, the modifiers have only

been developed for systems where we expect spectral differences to correlate to the variability we need to recognize.

For example, the Southwest Florida Perched Barriers Salt Swamp and Lagoon, as described by NatureServe, can include patches of both mangrove forest and salt marsh. These structural variants should be spectrally distinct in the imagery, as well as important with respect to animal modeling. It would be desirable to recognize this within-system variation in the map legend.

In the Southeast, some plant communities have been reduced to mere remnants of their former distributions (Frost 1993; Noss et al. 1995). In these cases, identifying ecological systems in the field can be difficult because the reduced area or remnants occur within converted or managed landscapes. NatureServe in the Southeast has been developing spatial ranges for each of our target systems (Figure 1). These ranges are initially based on the Level III and IV Ecoregions of EPA Region 4 (EPA 2004) and refined with other environmental data and range data for dominant or characteristic plant species. The development of these spatially explicit range maps has been helpful in refining the concepts for some of these highly fragmented, but historically important, systems and in putting the existing vegetation in the context of the historic land-use patterns.

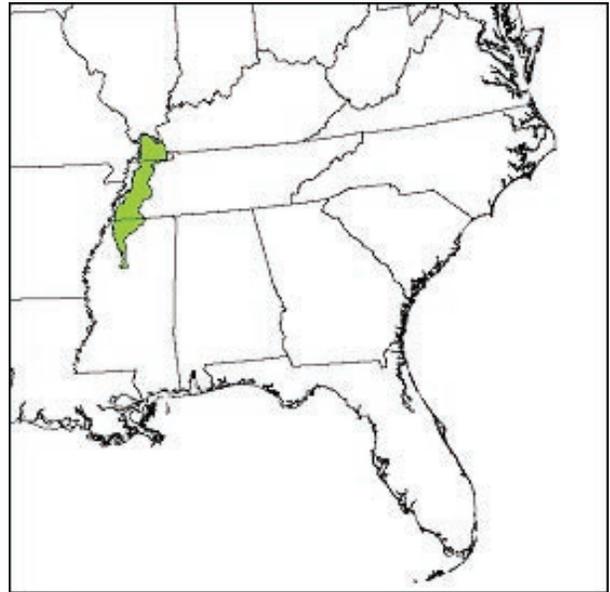


Figure 1. Preliminary range map for the East Gulf Coastal Plain Northern Loess Plain Oak-Hickory Upland (CES203.482). This system is restricted to the Coastal Plain of Western Kentucky and Tennessee and northern Mississippi.

For disturbed systems, the development and application of the Ecological Systems Classification in the Southeast requires that we interpret the existing patterns that we currently see through the “lens” of historic patterns of land use and plant community succession. For the most highly disturbed conditions, such as pine plantations, we are not attempting to recognize the ecological system, but for the more moderately altered cases, we feel that recognizing the systems in their modified condition helps to place those sites in a clear context for conservation planning and restoration.

Natural low-elevation, dry-mesic forests in the Piedmont may be locally referred to as “oak-hickory” forests (e.g., Schafale and Weakley 1990; Wharton 1978), but most broader, regional treatments call these southeastern forests “oak-pine” forests (Braun 1950) or “oak-hickory-pine” forests (Küchler 1964; Skeen et al. 1993). In NatureServe’s classification, this is called “Southern Piedmont Dry Oak-(Pine) Forest.” This nomenclature attempts to recognize both that there is an increase in the amount of naturally occurring pine in this system as one moves from north to south, and that patterns of land clearing, regeneration, and succession have obscured much of the original patterns of natural vegetation (Braun 1950; Skeen et al. 1993). Today, much of the Piedmont supports loblolly pine-dominated stands that represent a long-term successional type that resulted from large-scale land clearing and subsequent abandonment of farmland (Schafale and Weakley 1990). Therefore we have recognized two expressions of the Southern Piedmont Dry Oak-(Pine) Forest: the loblolly pine modifier, representing the successional type, and the mixed/hardwood modifier, representing the mature expression of the type.

The Atlantic Coastal Plain Nonriverine Swamp and Wet Hardwood Forest is another example in which a key ecological variable is well-correlated with a difference in vegetation that can be recognized in the satellite imagery. In this example, water level throughout the season varies enough to develop two phases of this system: the oak-dominated areas in the shallower water and the bald-cypress/gum portions in the deeper water. This variability in the composition and structure can be recognized in the imagery because the bald-cypress/gum variant is generally more open and should be spectrally separable and is also important for some animal models.

The weaknesses of the Ecological Systems Classification are those common to most detailed classification systems. The classification is evolving as knowledge is gained, the descriptions of the systems vary in completeness depending on our current understanding, and the classification describes ideal conditions within a plant community that may be more the exception than the rule, especially in the Southeastern landscape. This requires that we recognize some existing vegetation patterns through the use of modifiers.

The advantages, especially in the Southeast, include that this classification has evolved in parallel with GAP mapping efforts and therefore is more practical for mapping. In addition, it builds on the detailed framework of association- and alliance-level data, it has involved Heritage ecologists in its development, and the units are generally more recognizable to a broader audience than those of the U.S. National Vegetation Classification System.

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AQUATIC GAP

Central Regional Database for Great Lakes Regional Aquatic GAP

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Introduction

Great Lakes Regional Aquatic GAP began as a regional project in 2001 with the objective of developing an aquatic gap analysis for riverine systems in all eight states in the Great Lakes region by 2009 (Myers et al. 2002). In addition, three pilot studies are under way in western Lake Erie, eastern Lake Ontario, and Lake St. Clair as part of the Great Lakes Coastal Pilot subproject. The goals of the Great Lakes Regional Aquatic GAP Project are (1) to evaluate the biological diversity of Great Lakes aquatic habitats and identify gaps in the distribution and protection of these species and their habitats; and (2) to use an integrated approach in which common methods and protocols are established and results are comparable across the Great Lakes landscape. An objective of the project is to produce a central database for Great Lakes Regional Aquatic GAP data. Development of this regionally consistent database and spatial data layers, with uniformity across state boundaries, is a major focus of the Great Lakes Regional Aquatic GAP Project (Stewart et al. 2004).

Data Sources and Types

Georeferenced biological data (catch, effort, and location) were contributed by state and federal agencies and academic institutions, which are collaborating in Great Lakes Regional Aquatic GAP (Table 1). Variability in the accuracy of latitude and longitude for fish sampling locations has presented a problem, and some collections could not be loaded into the central database. Some of these locations were manually corrected using other descriptive information, such as railroads, highway crossings, and other landmarks. Central database staff members have needed to achieve an understanding of the raw data and underlying structures to extract and load the data into the central database structure. Fish data (fish species and locations) have been reviewed by expert reviewers for each state to ensure quality assurance/quality control (QA/QC). QA/QC is conducted by the central database staff during the assessment and loading of the data into the database. The enduring features data have been obtained from federal (e.g., National Hydrography Data Set [NHD], National Elevation Data Set [NED], Hydrological Unit Code [HUC]), state (e.g., surficial geology, bedrock geology, and land cover), and academic institutions (PRISM climate data from Oregon State University). Collaborators at the Institute of Fisheries Research (Michigan) and the Wisconsin Department of Natural Resources are generating stream water-temperature data by modeling, using regression equations containing groundwater flow and other variables.

Table 1. Fish catch and effort data currently loaded into the central database for streams in four Great Lakes states. Provisional numbers are subject to further updates of the database.

State	Effort	Fish Catch Taxa			Sites	Streams
		Species	Family	Hybrids		
WI	18,389	162	14	64	14,570	1,844
MI	16,514	167	10	-	5,790	981
OH	15,652	163	7	53	5,686	1,046
NY	9,547	167	28	2	6,834	874

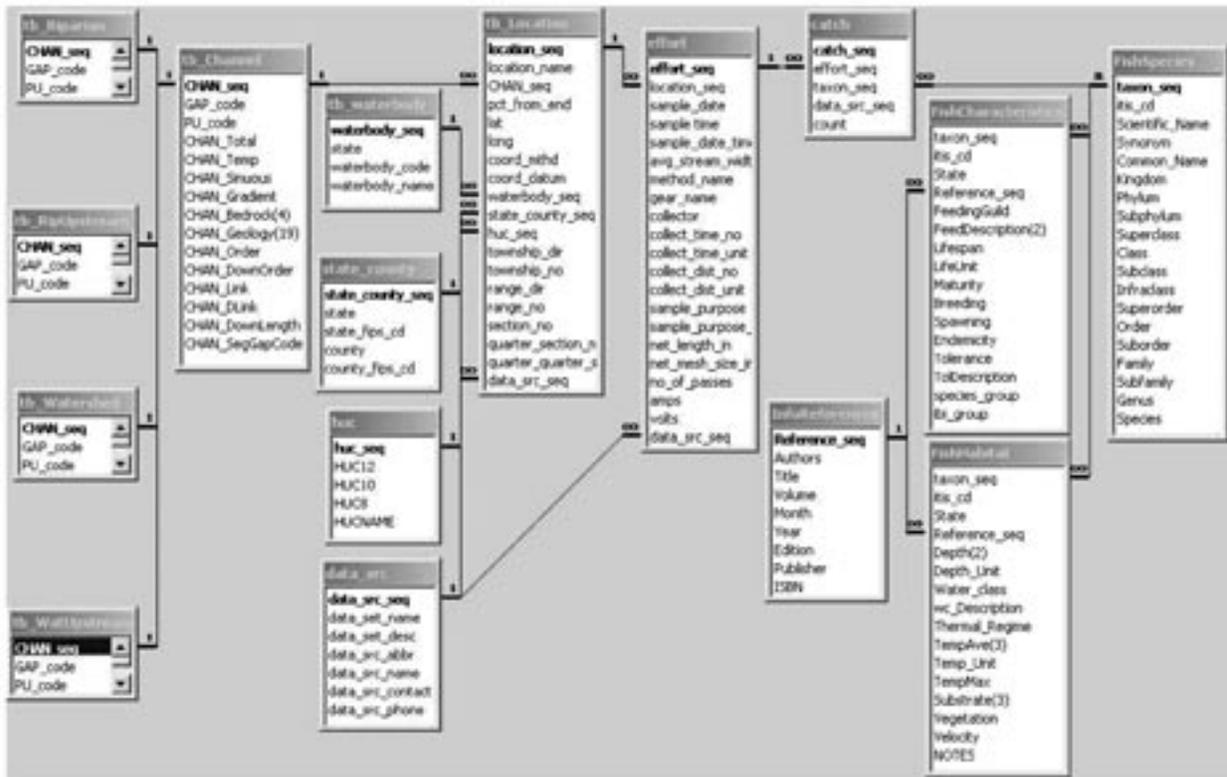


Figure 1. Database structure for the central regional database of the Great Lakes.

Fish life history and fish habitat affinity databases have been acquired from NatureServe and from Eakins (2005). These data are being integrated with data from the fisheries literature and entered into the habitat affinity component of the central database. The process of linking the fish sampling locations to the National Hydrography Data Set has been time-consuming, but habitat specialists in the Water Resources Discipline, U.S. Geological Survey, have used processing scripts (Arc Macro Language [AMLs]) to facilitate this step.

Data Structure and Standardization

The Central Regional Database for the Great Lakes Regional Aquatic GAP Project is centrally housed at the Great Lakes Science Center in Ann Arbor, Michigan. The database is built using Oracle® relational database software, with interfaces that utilize Oracle Discoverer and Oracle 9i web-enabled technology. The Great Lakes database was built with a common structure to ensure regional consistency for the three Great Lakes Aquatic GAP states. Data structure was based in part on the Missouri Aquatic GAP, the Ohio Aquatic GAP, and the Nature Conservancy database structures. The database has three major components: enduring features, biological catch and effort, and habitat affinity characteristics (Figures 1 and 2). The structure is flexible in that columns can be added to tables to describe further attributes, and tables can be added to model new entities.

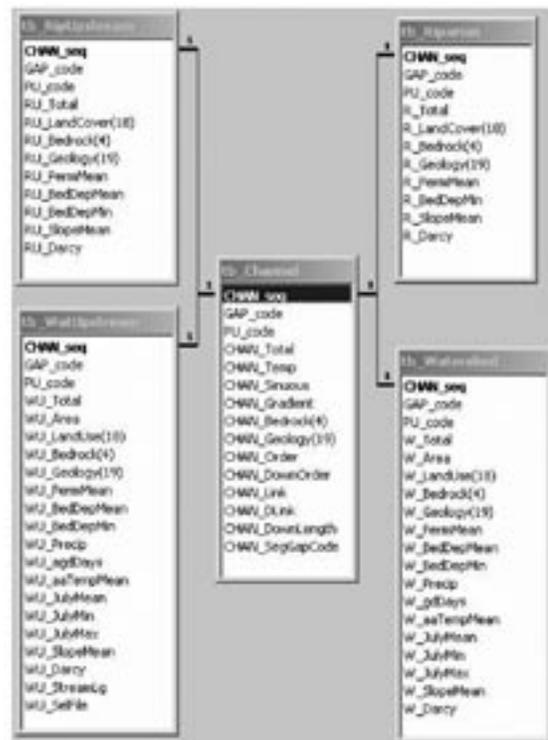


Figure 2. Structure of the enduring features component of the Central Regional Database.

Standardization within each component is a major task. For instance, the Integrated Taxonomic Information System (ITIS) codification and naming system for fish species is used for standardization across the basin.

Database Interface

Investigators in Great Lakes Regional Aquatic GAP access the data through Oracle Forms (Figure 3) and Oracle Discoverer (Figure 4), which are both accessed using a web browser. Data are flagged for data ownership, and ownership issues determine access to the data. Comprehensive query access to all tables and columns is provided through Oracle Forms and Discoverer interfaces. The Forms interface is an interactive data-entry system (Figure 3). Discoverer (Figure 4) permits point-and-click access to tables and columns. Subsets of data can be downloaded to a local system for further analysis through the Discoverer interface. Investigators in Great Lakes Regional Aquatic GAP are accessing the data to conduct modeling of fish-habitat interactions and produce fish distribution maps (Rosenfeld 2003; McKenna et al. *forthcoming*; and Steen et al. 2005). Collaborators in Great Lakes Regional Aquatic GAP access the data through a password-protected interface. In the future, we anticipate that data developed for this project will be used as the core information in a decision-support system for developing basin-wide freshwater biodiversity plans for the Great Lakes (Sowa et al. 2004).

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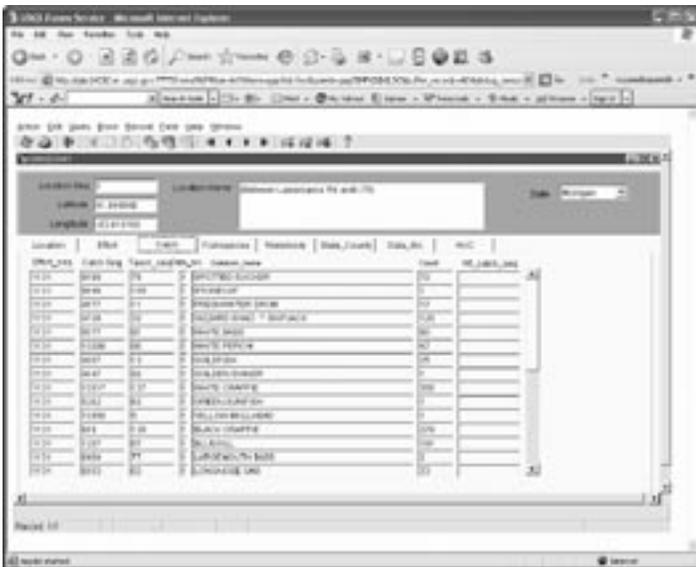


Figure 3. Screen shot of the Great Lakes Regional Aquatic GAP web form.



Figure 4. Oracle Discoverer interface into the Great Lakes Aquatic GAP database.

Great Lakes Regional Aquatic GAP: Development of a Physical Habitat Geographic Information System (GIS) Database for Riverine Systems in the Great Lakes Basin

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Introduction

Great Lakes Regional Aquatic GAP is an example of a regional, collaborative project with the goal of adapting the traditional terrestrial approaches of gap analysis to the conservation of aquatic species in the Great Lakes basin. One fundamental component of Great Lakes Regional Aquatic GAP is the development of a physical habitat GIS database. Great Lakes Regional Aquatic GAP has represented riverine habitat at multiple spatial scales using GIS-based habitat data. This approach necessitates the development of a comprehensive habitat database that can be used in modeling efforts to predict species distributions. Given the lack of availability of micro-scale (site-specific) aquatic habitat information for large areas such as the Great Lakes basin, the physical habitat database consists solely of macro-scale or landscape-scale habitat information commonly available in GIS data sets. While not ideal, macro-scale habitat data provide surrogates for finer-scale habitat characteristics that are impractical to measure for large areas. The database was structured so that it maintains the fidelity of numerical attributes by retaining continuous data types, rather than classification into arbitrary, discrete classes.

Spatial Data Sets

Spatial data sets that are national or regional in extent were used, wherever possible, to avoid edge-matching and attribute consistency problems across state lines. These data sets include the U.S. Geological Survey (USGS) 1:100,000 National Hydrography Data Set (NHD), the USGS 1:24,000 National Elevation Data Set (NED), and the Natural Resources Conservation Service (NRCS) 1:250,000 State Soil Geographic Database (STATSGO). In cases where data sets were not available for the entire Great Lakes basin, the best available statewide data were used and a standardized classification scheme was developed to provide consistency between states. Experts in their respective fields were consulted to ensure that the classification schemes employed were representative of the geographic areas under consideration.

The data sets included bedrock geology type and depth, surficial geology, land use/land cover, and climate. In cases where a habitat variable is not currently available in a GIS database, statistical

modeling techniques were used to compute estimates of the variable. A GIS data set was then derived from the statistical model. Modeled variables include groundwater potential, stream temperature, and stream flow. Existing and modeled data were then used to calculate a variety of potentially significant variables for each spatial unit.

Spatial Units

The term *spatial unit* refers to a feature representation of a geographic entity at a specific scale. The spatial units we delineated included the channel, watershed, riparian zone, upstream catchment, and upstream riparian zone. Multiple spatial units were employed because fish species respond to environmental factors at multiple spatial scales. Our spatial units are hierarchical and nest within each other to represent a continuum of habitat variables that directly and indirectly affect in-stream habitat.

A channel is composed of a single confluence-to-confluence stream segment except in the case of in-channel lakes, which are treated separately. To characterize the land area immediately adjacent to a specific stream segment, a 60-meter riparian buffer on either side of the stream channel was generated. The riparian zone represents a more indirect influence on riverine habitat than the character of the stream channel itself; it represents the immediate interface between the riverine system and the upland system and the geomorphologic processes that shape the stream channel. The surrounding landscape (in the form of the watershed and upstream catchment) influences aquatic habitat at a larger scale. Watersheds and catchments may affect in-stream habitat indirectly through surface runoff and groundwater input, and more directly through nutrient and sediment loading. A watershed is delineated based on a hydrologically correct drainage-enforced Digital Elevation Model (DEM) derived from the NED. Watersheds constitute the land area that drains to a channel segment. By tracing up the river network, upstream riparian zones and watersheds were identified. They were then aggregated to form the upstream riparian zone and upstream catchment spatial units.

Methodology

The attribution of spatial units was largely carried out using a series of overlays with the categorical and numerical GIS habitat data sets and the delineated spatial units. In some cases, such as stream order and sinuosity, habitat variables were calculated directly from a GIS data set. Connectivity metrics will be calculated based on network traces on the NHD and the spatial relationship between

stream segments and barriers to fish passage, such as dams and waterfalls. The GIS operations required to attribute the spatial units with habitat information are largely automated. Network tracing, computing connectivity metrics, and many other GIS tasks are relatively complicated and thus lend themselves to a programmatic approach. This is accomplished through a series of AML (Arc Macro Language) scripts. Automation of many of the GIS tasks facilitates standardization within Great Lakes Regional Aquatic GAP. The gains in efficiency are also large, especially considering the low overhead of a scripting language like AML running in command line ARC/INFO, compared to more current but much more resource-intensive languages such as Visual Basic for Applications (VBA) running in ArcMap.

Progress

Great Lakes Regional Aquatic GAP is well on its way to completing a comprehensive macro-scale GIS database of

riverine habitat within the Great Lakes basin. As of June 2005, the GIS habitat database is complete (except for connectivity metrics) in Michigan, Wisconsin, New York, and Illinois and Indiana for the land area within the Great Lakes basin. Ohio is in the process of completing its habitat database.

Conclusions

The physical habitat database contains a variety of GIS-derived attributes aggregated at multiple spatial scales. This multiscale approach provides fish modelers with the habitat variables needed to produce robust predictive models of riverine fish species distributions. The habitat database, as well as derivative GIS data sets, is potentially useful in a variety of other ecologic and hydrologic applications, such as fisheries management, designing stream sampling protocols, predicting stream flow distributions, and monitoring flood frequency, base flow, and water quality.

Habitat Vulnerability Assessment in the Hudson River Valley

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Introduction

The Hudson River Valley (HRV), extending from Albany to New York City, provides habitat for hundreds of migratory and resident species of wildlife while supporting approximately half of New York State's human population. Recent data developed by the New York Gap Analysis Project (NY-GAP, Smith et al. 2001) shows that over 80 percent of the terrestrial vertebrate species within New York State can be found in the Hudson River Valley. A subsequent, regional gap analysis project (Smith et al. 2002) focused on the Hudson River Valley (HRV-GAP).

To date, HRV-GAP has identified the extent to which the HRV contributes to statewide diversity of terrestrial vertebrates (fine-filter biodiversity elements). Currently in New York, 69 percent (25 species) of all amphibian species, 58 percent (28 species) of all reptile species, 87 percent (214 species) of all breeding bird species, and 90 percent (57 species) of all total mammal species can be found in the HRV. Among terrestrial vertebrates, 75 percent have all or a significant portion of their entire range within the HRV study area (Smith et al. 2002).

This concentration of biodiversity occurs in a region that is under constant development pressure, largely emanating from New York City. Additionally, the HRV may well be facing a period of reindustrialization and concomitant residential development, which will continue to threaten the overall ecological health of the ecosystem and the community (Smith et al. 2004). The ability to accurately predict the loci of human development and subsequently identify the ecologically and culturally sensitive areas susceptible to the resulting impacts could empower decision makers. Possessing knowledge about potential conflict areas could enable decision makers to take actions to minimize adverse effects and maintain wildlife and fish habitat, biological diversity, and regionally significant historical/cultural sites.

The adverse effect of sprawling urbanization on ecologically sensitive areas has prompted a growing effort to understand spatial patterns of residential development (Birch 1971). In the Habitat Vulnerability Assessment for the HRV project, our goal was to develop a census-based model that would show local

officials where residential development was likely to occur in the near future and to highlight locations where such development would affect vulnerable habitats and animal species. A census-based model allows one to consider explicitly both social and economic factors that can affect regional biodiversity. Such an approach can be used to integrate both biological and human demographic elements into the planning process. The Habitat Vulnerability Assessment Project area covers ten counties (Albany, Columbia, Dutchess, Greene, Orange, Putnam, Rensselaer, Rockland, Ulster, and Westchester) in the HRV of New York State.

Methods

Determination of Residential Development Hot Spots

To obtain the finest spatial resolution possible in our predictions of areas with high potential for residential development, we used census block groups as our geographical units of analysis. Block groups are used in the decennial censuses of U.S. population and housing for the collection and tabulation of responses to the census questionnaires. These areas contain approximately 1,000 persons and 400 housing units and may vary in size and location of boundaries from one census to another. For Census 2000, the ten counties of the HRV contained 2,212 block groups with a minimum, maximum, and mean area of 0.02, 544.16, and 7.37 square kilometers, respectively. As reported in Census 2000, the number of housing units in block groups in the HRV varies from a minimum of 0 to a maximum of 2,602, with a mean of 396 (Census 2002). Block groups are statistical units of census geography, rather than political units, such as counties, cities, towns, and villages. Data from the census long-form questionnaires administered to a sample of households are tabulated for block groups and summarized by the U.S. Census Bureau (U.S. Census Bureau 1994, 1999, 2002).

To determine the level of residential development within block groups, we used data from the Census 2000 on the year that housing units were built. We defined new housing units as those built over the interval 1990 to 2000. For small areas, such as the block groups used in this analysis, a ten-year interval as presented by the decennial census data is advantageous for a number of reasons. First, the data are measured in a consistent and uniform manner across all types of housing units and for all political and administrative jurisdictions. Second, the ten-year interval is longer than a typical business cycle and therefore the net change over the decade—net of new construction, conversion of existing units, and demolitions—is more representative of longer-term trends than a shorter time frame, which might overemphasize a boom or bust period.

We used other variables from the previous census, Census 1990, to explain variations in the amount of residential development among block groups. We found that the best model for explaining variations in residential development had five independent variables: (1) the neighborhood stage of development (cf. Birch 1971); (2) the number of housing units built in the prior decade; (3) the regional labor market area; (4) the density of the local road network; and (5) the proximity to centers of population. An explanation of these variables follows.

Independent Variable: Neighborhood Stage of Development
Using 1990 census data, we identified the growth stage for each block group. Neighborhood development and housing

characteristics were modeled as stages, from single-family subdivision, to buildup, to structure-type conversion, to downgrading, and finally renewal (Hoover and Vernon 1959, 190–207). We adapted Birch’s (1971) method of identifying neighborhood growth stages for our project. The six stages of neighborhood development are rural, suburbanization, infill, packing, thinning, and recapture. Table 1 provides a description for each of these six stages of neighborhood growth.

According to the theory, as a neighborhood moves from one growth stage to another, it experiences changes in its level of construction activities, housing prices, and population density. Figure 1 diagrams these trends. New housing construction is the

Table 1. Description of neighborhood growth stages (adapted from Birch 1971 and Bourne 1981).

Stage	Major Neighborhood Characteristics
Stage 1. Rural	Low population density, a predominance of single family units and absence of multi-unit structures, very little housing construction
Stage 2. Suburbanization	Increasing population density, high rates of new construction of mainly single family units, and absence of multi-unit structures
Stage 3. Infill	Increasing proportion of multi-unit structures, high property values and rents, moderate population density, low and decreasing rates of housing construction
Stage 4. Packing	Maximum population densities, aging housing stock, overcrowded living condition, low rates of housing construction
Stage 5. Thinning	Continuing deterioration of housing units, absolute population decline, little or no housing construction
Stage 6. Recapture	More profitable use of properties, high density, a predominance of renter-occupied housing units

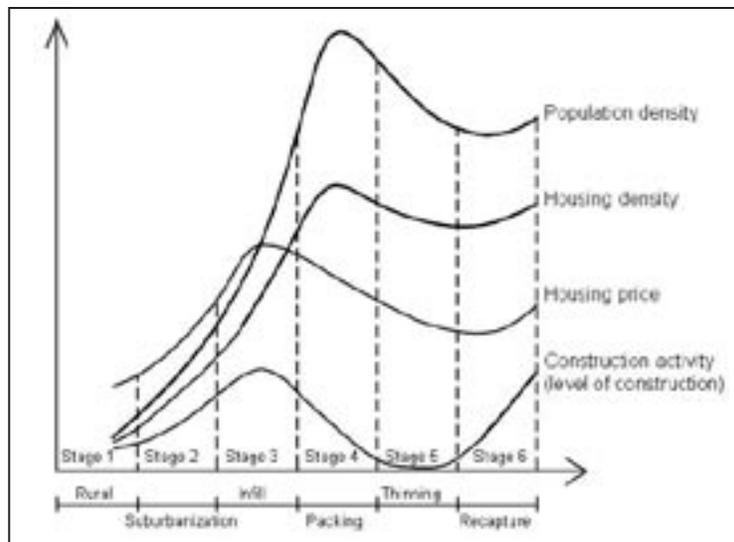


Figure 1. Neighborhood changes in one life cycle. Units of the Y-axis are modifiable according to the labeling on the graph (right side) and are not scaled to reflect the real units (Yang 2001; adapted from Birch 1971).

most active when a neighborhood is at stage 2 or 3. The level of new construction declines in stage 4, reaches the lowest by stage 5, and may resume in stage 6.

Characterizing neighborhood change by “stages” may falsely imply that this is an evolutionary process and that all neighborhoods have passed and will pass through each stage; that is not the case. However, these stages can help us classify block groups in terms of their present level of development and suggest possible transitions.

Independent Variable: New Housing Units in Prior Decade

A simpler approach than neighborhood life stage is one of development inertia. Simply stated, those block groups with little or no residential development are likely to continue to have little or no development. On the other hand, block groups that experienced high levels of residential development in the prior decade are likely to continue to be areas attractive to development. The prior level of new housing construction is already captured in the variable for neighborhood stage of development; however, it is combined with other characteristics to arrive at a stage score. By including these data as a simple variable, we are giving development momentum greater weight in suburbanizing areas.

Independent Variable: Regional Labor Market Area

The ten counties of the study area do not represent a single economic region, but rather they fall into four regions based on commuting patterns. We have used the economic grouping of counties developed for the U.S. Department of Agriculture (Tolbert and Killian 1987; Tolbert and Sizer 1996) and defined as labor market areas (LMAs). The counties of the United States were grouped into 394 LMAs, and the ten counties bordering the Hudson River were part of four such LMAs.

We used the LMAs to classify block groups by stage of neighborhood development. Indicators such as population density and housing value were evaluated relative to the other block groups within the LMA.

LMAs were also used as independent variables to see if there was a regional effect on residential development. Regional labor markets were used to calibrate the neighborhood housing characteristics to regional (multicounty) levels. How high is high? High housing values and high levels of housing density are different for the counties in the New York City labor market area than for the labor market area covering the mid-Hudson and upper-Hudson regions. The relationship was significant and LMA was kept in the model.

Independent Variable: Density of Local Road Network

The purpose of the road density layer was to identify block groups possessing a substantial transportation network, which might provide the necessary access for development. Land area

that can be accessed by an existing road is apt to have a lower development cost and thereby is more likely to be developed.

Independent Variable: Proximity to Centers of Population

To capture the proximity of each block group to the centers of population (Edmonston 1975) within the region, we used a measure of “population potential.” Population potential measures the proximity of a place or point to concentrations of population. Places with a population of greater than 25,000 were used as “centers of population.” The advantage of using population potential is that it summarizes the potential influence of all centers of population, relative to their distance from the block group.

Determination of Expected Species Biodiversity Hot Spots

In this approach, we are assuming that it is desirable to at least maintain the terrestrial vertebrate species richness associated with a given block group. If local planners want to incorporate the conservation of biodiversity into the planning process, it could be desirable to direct development activities away from clusters of block groups that have higher species richness.

We developed data sets of total expected vertebrate class distributions for amphibians, reptiles, mammals, breeding birds, and a total aggregation of all vertebrate classes using the HRV-GAP (Smith et al. 2002) predicted species distribution data, available as a raster (grid cell) data set with a 30 x 30 meter cell resolution. Expected or predicted species were those likely to occur in a block group on the basis of species habitat association models developed for NY-GAP (Smith et al. 2001) and applied to the HRV (Smith et al. 2002).

These expected species distribution data contained an identifier for each unique combination of species. All grid cells with that unique combination were assigned to a single class. For each of these unique combinations, a total species count for all species in each vertebrate group was calculated. This was also done for species that are threatened, endangered, or of special concern, as identified by the New York State Department of Environmental Conservation (NYDEC 1999), for each vertebrate group.

To assign a species count number to a specific block group, each unique species count is weighted by the area of the block group involved (species count area). A weighted species count is computed for each table cell entry using the following formula: (species count area/block group area) * number of species.

These weighted species counts were then tallied for all unique species counts in the block group to arrive at the final weighted species count for each block group. This weighted species count was ineffective for understanding the relative concentrations of mammals, amphibians, reptiles, or breeding birds. The weighted species counts were converted into percentages of total species expected for each vertebrate class. Using the percentage of total

species enabled comparisons of relative concentrations between vertebrate classes. This same process was used to develop data and maps for species that are threatened, endangered, and of special concern.

The methodology described above resulted in an underestimation of species expected within any block group. This underestimation arises from the fact that species counts from any one 30 x 30 meter grid cell to another did not adjust for species composition changes. In other words, the ten species contributing to the species count for “Cell A” may not be the same ten species contributing to the species count for “Cell B.”

This integrated error was deemed acceptable for three reasons. First, the 30 x 30 meter resolution of the species richness grid was determined by the satellite imagery used to map the plant community types, and does not reflect the resolution of the species data collected (most species data exists at a township or similar scale). Second, since relative species distributions were desired to rank the block groups and the identification of individual species was not required, the discrepancies introduced

by not accounting for different species across grid cells within a block group were not important. Third, a separate analysis for species already identified as endangered, threatened, or of special concern allows for explicit consideration of the potential effects of development on those sensitive species. Subsequent field studies or a substantially more complicated analysis could refine these estimates of species richness.

Results

We have identified 77 block groups out of a total of 2,212 in the ten counties of the HRV that are prime candidates for a major share of the new housing to be built between 2000 and 2010 (Figure 2). These are the predicted “hottest” spots for high levels of residential development. To associate these hot spots with counts of new housing units, we refer to the new housing experience of the previous decade, 1990–2000. The Census 2000 reported that over the previous decade, 89,648 new housing units were built in the HRV. If the same level of residential development occurs in this decade, it is probable that, on average, each of the “hottest” block groups will receive 135 or more new housing units.

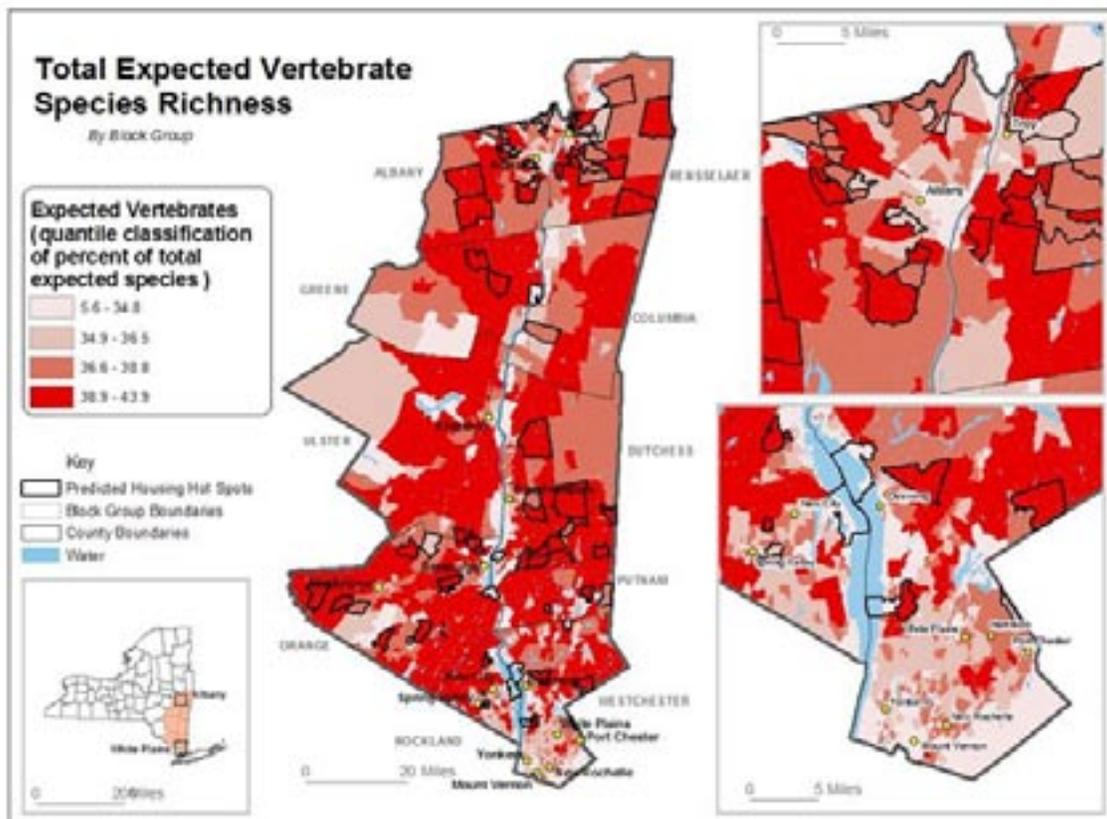


Figure 2. Total expected terrestrial vertebrate species richness, based on wildlife habitat association models for block groups in the Hudson River Valley study area. Because block groups are of different sizes and the total number of expected species varies by vertebrate group, a quartile classification is used. Species richness is expressed as a relative density of all species expected. Areas of greatest potential conflict are represented by those block groups with the greatest potential for new housing by 2010, outlined in black on the map. Areas of potential conflict merit more detailed study to verify species occurrences within their boundaries.

Species richness values for all block groups were calculated as a ratio of all species expected in the block group and all species expected within the study area. These ratios provide a relative concentration rating for each of the species groups, permitting comparison across groups.

For all terrestrial vertebrates (Figure 2), the regions of greatest potential future conflict lie at the north and south ends of the HRV, influenced by the spread of development outward from New York City and Albany. Effects are not limited to block groups in proximity to the Hudson River; in both regions, potential conflicts span the width of the HRV. Secondary centers of more local potential conflicts are associated with the cities of Kingston, Middletown, and Poughkeepsie.

Table 2 shows percentages of each species group found within the residential development hot spot block groups. A large number of the 77 block groups identified as residential development hot spots contain species concentrations that place them in the upper distribution quartile (Table 2). Total vertebrates, amphibians, reptiles, and mammals are heavily represented in the 77 block groups each having more than 48 percent of the block groups in their fourth quartile of species richness. Breeding bird species richness is more heavily concentrated in the second quartile, which comprises more than 57 percent of the hot spot block groups. When reviewing the threatened and endangered species (TES) species by species group, again, total vertebrates, reptiles, and mammals are heavily concentrated, with more than 41 percent of the hot spot block groups being in the fourth quartile of richness. What is surprising is that TES breeding bird species are similarly concentrated, with 44 percent of the hot spot block groups being in the fourth quartile of richness. Also surprising is that expected TES amphibian species richness does not follow the same distribution. More than 63 percent of the 77 block groups rank in the lowest quartile of TES amphibian species richness, and this percentage expands to 75 percent when the second quartile is included.

Discussion

This process should be seen as a coarse-filter approach for identifying block groups likely to receive residential growth within the next decade. This model integrates social and economic variables with the biological variables typically associated with the conventional coarse-filter approach. As stated earlier, the model was specifically designed not to rely on or incorporate local or site-specific data. For this reason, application of the results to site-specific areas without implementing further filtering processes is not recommended. The purpose of this analytical process is to identify block groups of potential concern. These block groups require further investigation of the zoning restrictions, the presence of public land holdings, or other site-specific limitations to determine to what extent these localized conditions will affect the likelihood of the prediction being fulfilled.

Specifically, this model is viewed as a method to assist town, county, and regional planners in the identification of block groups that may need additional development planning or control efforts. HRV-GAP (Smith et al. 2002) now provides a baseline of data against which future planners will be able to review the impacts of their land-use decisions on species distribution and biodiversity in general. This biodiversity data, coupled with the residential growth predictions, can provide planners with an opportunity to direct growth and control efforts to maximize species protection.

The identification of the 77 high-growth-probability block groups will enable conservation efforts to be focused on these more vulnerable areas, and thereby increase the effectiveness of those efforts. With such limited funds for conservation efforts, the ability to target vulnerable areas or vulnerable species would be highly beneficial. In situations where intense development pressures exist, conservation efforts targeted toward large-scale land preservation are likely to face legal challenges and may fail

Table 2. Distribution of vertebrate species predicted to occur within the 77 predicted residential development hot spots in the Hudson River Valley, New York.

Vertebrate Group	Species Richness Quartile Based on All Block Groups			
	1st Quartile	2nd Quartile	3rd Quartile	4th Quartile
Total Expected Vertebrates	7.8	13.0	26.0	53.2
Expected Amphibians	3.9	5.2	42.9	48.1
Expected Reptiles	9.1	2.6	39.0	49.4
Expected Mammals	3.9	10.4	24.7	61.0
Expected Breeding Birds	24.7	57.1	11.7	6.5
Total Expected TES Vertebrates	2.6	3.9	51.9	41.6
Expected TES Amphibians	63.6	14.3	1.3	20.8
Expected TES Reptiles	0.0	10.4	41.6	48.1
Expected TES Mammals	3.9	2.6	28.6	64.9
Expected TES Breeding Birds	2.6	2.6	50.6	44.2

unless sufficient scientific data can be amassed to support such actions. The acquisition of such empirical data can be very costly and time consuming. The identification of probable development areas will enable the focusing of monitoring efforts that will, over time, acquire the scientific data required to assess and demonstrate cause-and-effect relationships between habitat use or change and species viability

The growth allocation model can also be used to identify block groups where predicted development will have minimal effects on species and biodiversity. Identification of these block groups could help direct development toward less sensitive areas that are still desirable sites from the perspective of housing stages, road density, and population potential. Such proactive use of the model has the advantage of being less confrontational and thereby less controversial.

As was our goal, all of these data were acquired or derived from readily available public sources. Restricting ourselves to these data perhaps reduces our predictive power relative to specific block groups, but it greatly increases the applicability of this model to other regions in the state or in other states. Additionally, a model not relying on detailed digital local data is likely more realistic for regional studies. At the present time, complete detailed digital local data do not exist for much of the state and country. Used as an enhanced coarse filter to identify areas of concern, the model is effective and potentially a useful tool for county and regional planning.

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- Institute for Resource Information Systems, College of Agriculture and Life Sciences, Cornell University, 302 Rice Hall, Ithaca, New York 14853.

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Development of a Coastal Habitat Framework for Near-Shore Coastal Systems

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The coastal zone of the Great Lakes basin is an important buffer and link between the open water and inland ecosystems. This zone has a variety of habitats and is home to over 120 native or established fish species, which use this area as spawning and nursing grounds. However, development and other human activities have greatly reduced the habitat available to support common aquatic species (Whillans 1987, 1990; National Research Council 1992). Only by conserving the coastal habitats of the Great Lakes can we preserve the diversity of aquatic species that rely on them. Coastal GAP is intended to identify these habitats and extend the analysis of Great Lakes Regional Aquatic GAP developed for riverine habitats to the nearshore zone of the Great Lakes coast. Two of the basic needs of Great Lakes Regional Aquatic GAP are the acquisition of data and the development of a classification framework for habitats based on enduring features.

The methodology for conducting a coastal gap analysis was developed and tested initially on selected pilot study sites in the Great Lakes basin. Pilot sites were chosen based on the availability, extent, and quality of databases containing the required abiotic and biotic data. Initial pilot studies began in Eastern Lake Ontario and Western Lake Erie. Other sites may include the Les Cheneaux Islands, Saginaw Bay, and Central Lake Erie as data become available. Many of the habitat characteristics we initially propose to use for classifying coastal habitats are derived from other data. These data, from which the derived values come, must be available at the scale and resolution necessary for the project. Preliminary investigation indicates that most of the necessary data are available for each of the pilot coastal areas. In some cases, a small amount of field effort was required to collect data that filled in some of the data gaps and was also used to ground-truth other aspects of the data.

Framework

The aquatic gap analysis modeling approach used in this coastal pilot project establishes a relationship between the location of species and the characteristics of the habitat at that location

before grouping similar habitat types. Unlike the traditional approach (Figure 1) of classifying habitats and relating species information to these classifications, the modified approach (Figure 2) allows the species information to define the natural breaks in the habitat.

This conceptual design will be tested as appropriate to determine its efficacy. The resulting framework will be described in such a way that appropriate data may be applied to it through a database management system compatible with that used by the larger Great Lakes Regional Aquatic GAP.

Although there are many influences on the habitat characteristics of the coastal zone, coastal GAP will be focusing on the enduring features of the Great Lakes basin. Influences such as anthropogenic modifications, invasive species, and water chemistry, though very important to species distributions, are not easily analyzed on a landscape level such as Great Lakes coastal GAP activities. With this in mind, the enduring habitat features will be used within this modified framework developed for this project.

Habitat Characterization

Coastal GAP has begun the process of identifying candidate variables that best characterize and distinguish the coastal habitat types. These variables represent conditions in a hierarchy of spatial scales and are presumed to have significant influence on the fish assemblages found in a particular habitat. At the top of the hierarchy are the individual basins of Lake Ontario, Lake Erie, Lake Huron, Lake Michigan, and Lake Superior. The division by basin allows for an ecologically significant distribution of the habitat characteristics and the standardization of processing units for subsequent data.

The coastal zone has been defined using thermal regime or depth of water as the boundary between nearshore and open water. With the limited amount of temperature data available and the varying characteristics of each basin, this project defined the coastal zone based on the effect of energy on the coastal sediment. Energy in these systems is generally provided by wind and waves, as opposed to the influence of gravity, and water movement is not confined to the limits of a streambed. While there is a longshore drift of water and sediment, exposure to (or protection from) wave and wind energy is what most strongly influences coastal habitats. Orientation to and fetch size of prevailing winds and the resulting waves determine whether a particular habitat type is in a high- or low-energy zone. For this

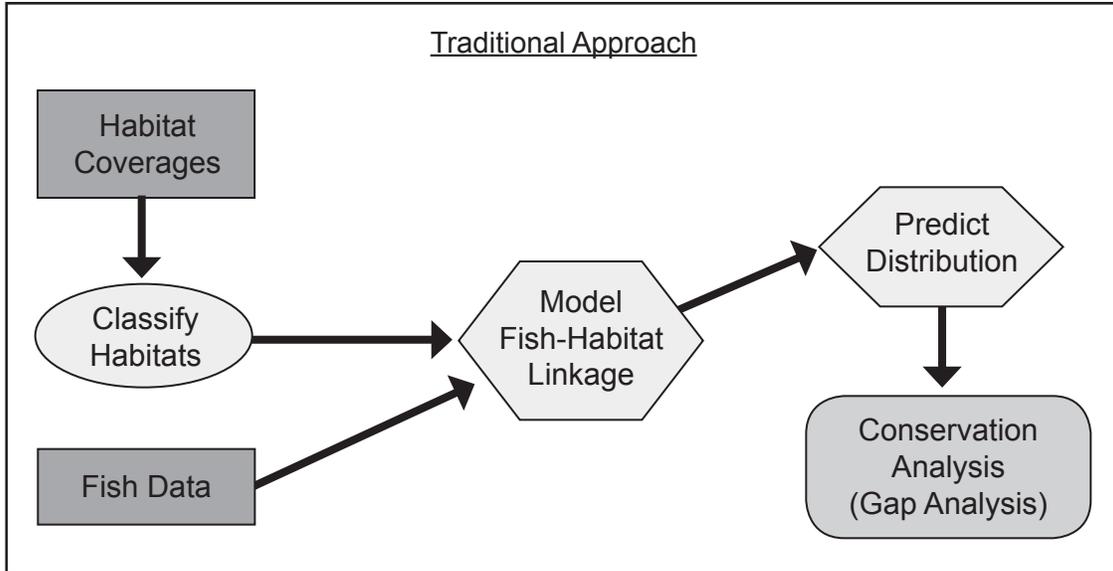


Figure 1. The traditional modeling approach classifies habitats based on environmental characteristics and relates species information to those classifications.

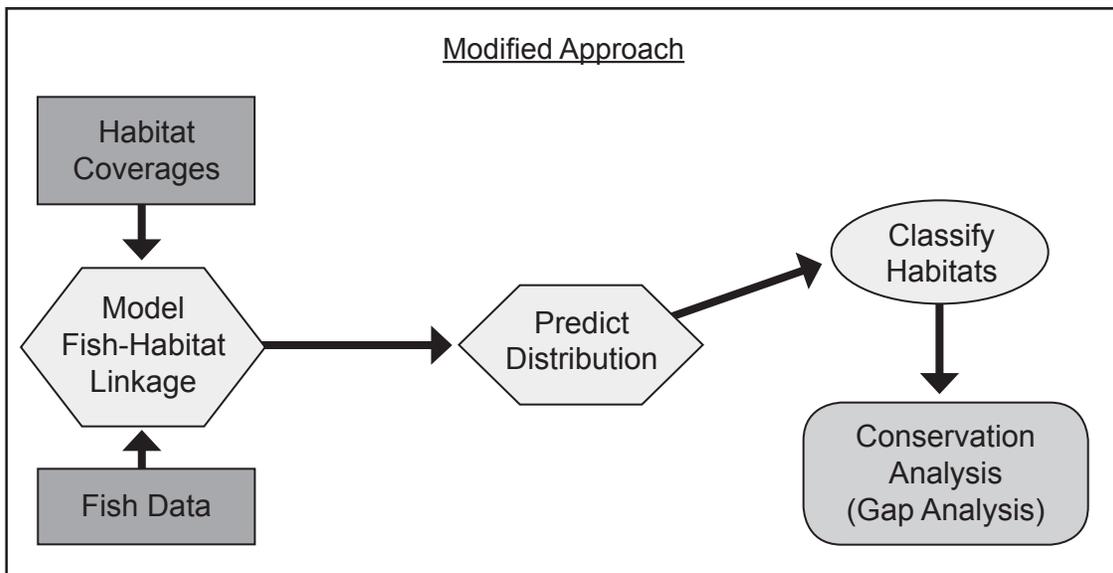


Figure 2. The modified approach used for the aquatic gap analysis allows the species information to define the natural breaks in the habitat.

project, the coastal zone is defined as the area from the mean lake water line to the depth of water at which prevailing wave conditions no longer rework sediment or 10 meters of water, whichever is larger:

Depth of Water at outer boundary = $((\sqrt{(g \cdot h) \cdot T}) / 2)$ or 10 meters depth

g = accelerations due to gravity (9.8 m/s)

h = wave height

T = time period

For example, waves 2 m high every 3 seconds will potentially rework sediment to a depth of 6.6 m.

Within this nearshore area, each lake has distinct differences in the distribution of its habitat and the range of values for the habitat. Many of these habitat characteristics were available from published or unpublished sources or derived through analysis of those data. The characteristics identified for this project include subaquatic vegetation (SAV), geomorphology, geologic formations, submerged substratum, submerged slope and aspect, and circulation and currents. We believe these characteristics have a significant influence on the location and distribution of aquatic species.

One of the more important habitat characteristics for our model is the prediction of subaquatic vegetation. In Figure 3, we have applied Minns's algorithm (Minns et al. 1995) to define this variable for our project in the following steps:

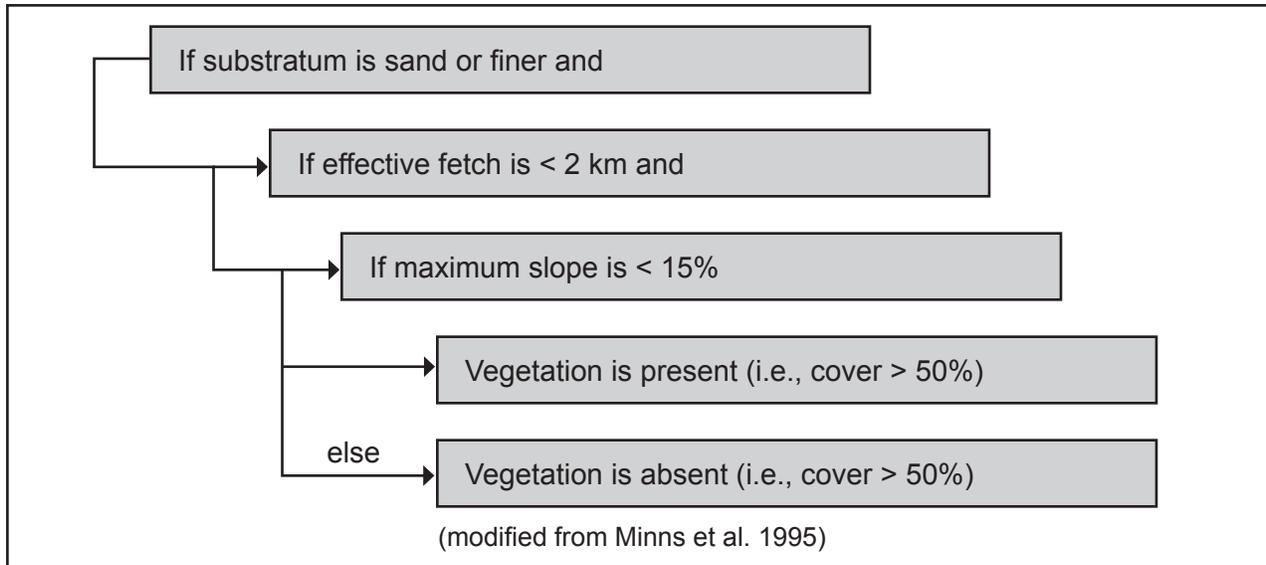


Figure 3. Steps used to predict subaquatic vegetation occurrence.

Geomorphology of the coast ranges from sandy beaches and mud flats to sheer cliffs and headlands. The coast is also marked by bays, inlets, coastal ponds, large and small river mouths, wetlands, and other features that disrupt the coastline and regulate much of the flow of water into the lakes. Orientation and relation of these nearshore features to other coastal features, water influences, and physical characteristics can also affect the character of coastal habitat. Circulation and currents influence the large-scale movement of water through the basin, within each lake, and within the connecting channels. The relationship to large tributaries and other sources of water movement and currents can provide a major resource of organic content, temperature, water chemistry, and food sources. Most of these enduring features are being used and tested as surrogates for the habitat characteristics that we believe are the most influential and readily available for modeling the aquatic species.

The final stages of gathering basic habitat data are being completed. Fish databases have been compiled and modeling fish-habitat linkages for each species will begin shortly. Predicted distributions and identification of distinct habitat types will follow. The resulting geographic information system will then be available for conservation analyses.

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FINAL REPORT SUMMARIES

Michigan Gap Analysis Project

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Introduction

The Michigan Gap Analysis Project (MI-GAP) began in 1994 as part of the Upper Midwest Gap Analysis Project (UMGAP). UMGAP includes Minnesota, Wisconsin, Illinois, and Michigan, and was coordinated through the U.S. Geological Survey's (USGS) Upper Midwest Environmental Sciences Center (UMESC). In Michigan, the project was coordinated by the Michigan Department of Natural Resources (DNR). Major cooperators are the Michigan State University Department of Fisheries and Wildlife and the Michigan Natural Features Inventory (MNFI), Michigan State University Extension.

Michigan contains some of the most biologically diverse and valuable habitat for many threatened, endangered, and candidate species in the Upper Midwest. Significant habitat diversity exists here, including oak savanna, jack pine and oak barren, boreal forest, northern hardwood forests, and dune ecosystems. Michigan has six federally threatened and endangered terrestrial vertebrate species and one candidate species for federal threatened and endangered status. There are 21 globally imperiled and rare animal species in Michigan (MNFI 1999).

Information produced by MI-GAP provides an overview of the distribution and management status of Michigan's terrestrial vertebrates and land cover biodiversity. Gap analysis seeks to identify vegetation types and wildlife species that are not adequately represented in the current network of conservation areas. These are the "gaps" in the present-day overall mix of conservation lands and activities. Decision makers can use this information for land management planning so that fewer species become endangered and fewer conflicts occur in natural resource management.

Land Cover

The MI-GAP land cover layer was derived from the classification of Landsat satellite imagery. It required 19 scenes to cover all of Michigan. Three dates of imagery (spring, summer, and fall) were acquired for each scene. Image dates ranged from 1999 through 2001. Both supervised and unsupervised classification techniques were used in conjunction with multiple ancillary data sources to produce 32 categories of land cover (Table 1). An accuracy assessment of the final land cover layer determined it to be 87 percent accurate at level 2 in the hierarchical classification

scheme. At the finest level of classification detail (level 3), class accuracies range from 36 percent to 87 percent.

Land Stewardship

The MI-GAP stewardship layer classified conservation lands in Michigan based on the existence of an identified management direction for the protection of biodiversity. This layer was derived through acquisition and analysis of federal, state, and some land conservancies' ownership and management records. This data layer classified land by ownership (federal, state, conservancy, and private) and by biodiversity protection status (Table 2). Approximately 1.5 percent of Michigan's land area is classified as a stewardship level 1 or 2 (highest biodiversity protection status). Michigan has 19.4 percent classified as stewardship level 3 (some biodiversity protection) and 79.1 percent classified as level 4 (no plan for the protection of biodiversity, or unknown).

Terrestrial Vertebrate Distributions

The MI-GAP vertebrate species modeling effort produced predicted range and predicted habitat maps for 22 amphibians, 30 reptiles, 61 mammals, and 214 birds. Range maps were produced by summarizing the existing literature on the range for each species to produce a draft range map. The draft range maps were reviewed by experts who had the opportunity to update the range map based on the most recent occurrence data and their expert knowledge. Habitat maps were produced by developing a wildlife habitat relationship model for each species. Each model relates the life requisites of the species to GAP land cover classes and other ancillary data sets. The predicted habitat map for each species was clipped by the predicted range to produce a spatially explicit model of the location of habitat for a species within its range.

Species richness, measured by the number of species present, varied geographically for each of the four major taxonomic groups. Amphibian species richness was highest in the southwest Lower Peninsula. Reptile species richness was highest in the entire southern Lower Peninsula and the lowest in the Upper Peninsula. Mammal species richness was highest in the western Upper Peninsula and portions of the northern Lower Peninsula. Bird species richness was highest in the eastern Upper Peninsula. For birds and mammals, the areas of highest species richness in the state also had relatively large amounts of public land in stewardship categories 1–3. The species-rich areas of the state for reptiles and amphibians contained very little land in stewardship categories 1, 2, or 3.

Table 1. Total area (km²) and percent of each land cover type mapped by MI-GAP. Water type does not include the Great Lakes.

Land Cover Type	Area (km ²)	Percent (%)
Urban Types (Total)	7,857	5.22
Low Intensity Urban	2,184	1.45
High Intensity Urban	1,405	0.93
Airports	37	0.02
Roads/Parking Lots	4,232	2.81
Agricultural Types (Total)	38,420	25.52
Non-Vegetated Farmland	237	0.16
Row Crops	16,125	10.71
Forage Crops	21,322	14.16
Orchards/Vineyards/Nursery	736	0.49
Open Land Types (Total)	15,277	10.15
Herbaceous Open Land	11,033	7.33
Upland Shrub and Low Density Trees	3,928	2.61
Parks and Golf Courses	315	0.21
Upland Forest (Total)	56,798	37.73
Northern Hardwood	17,287	11.48
Oaks Types	6,270	4.17
Aspen Types	10,274	6.83
Other Upland Deciduous	163	0.11
Mixed Upland Deciduous	4,318	2.87
Pine Types	8,363	5.56
Other Upland Conifer	1,491	0.99
Mixed Upland Conifer	817	0.54
Upland Mixed Forest	7,814	5.19
Water	3,512	2.33
Lowland Forest (Total)	17,139	11.38
Lowland Deciduous Forest	7,314	4.86
Lowland Coniferous Forest	9,301	6.18
Lowland Mixed Forest	523	0.35
Non-Forested Wetlands (Total)	10,908	7.25
Floating Aquatic Wetland	445	0.30
Shrub Wetland	6,269	4.16
Emergent Wetland	1,084	0.72
Mixed Non-Forest Wetland	3,110	2.07
Non-Vegetated Types (Total)	630	0.42
Sand/Soil	420	0.28
Exposed Rock	22	0.01
Mud Flats	0	0.00
Other Bare/Sparsely Vegetated	188	0.12
Total	150,540	100.00

Table 2. Total area (km²) and percent within each ownership category for each GAP management status level.

Owner	Status 1	Status 2	Status 3	Status 4	Total
U.S. Forest Service	0	0	11483.6 7.6%	0	11483.6 7.6%
U.S. National Park Service	570.6 0.4%	374.6 0.2%	153.1 0.1%	0	1098.3 0.7%
U.S. Fish and Wildlife Service	380.8 0.3%	0	38.1 0.0%	0	418.9 0.3%
Michigan DNR	314.6 0.2%	513.7 0.3%	17226.6 11.4%	17	18071.9 12.0%
State of Michigan	0	0	303.0 0.2%	1322.9 0.9%	1625.9 1.1%
The Nature Conservancy	61.7 0.0%	0	0	0	61.7 0.0%
Other	0	0	0	117790 78.2%	117790 78.2%
Total	1327.7 0.9%	888.3 0.6%	29204.4 19.4%	119129.9 79.1%	150550.3 100.0%

Gap Analysis

Geographic Information System (GIS) analysis of stewardship status for terrestrial vertebrates showed 60 of 214 (28 percent) birds, 19 of 61 (31 percent) mammals, 21 of 30 (70 percent) reptiles, and 7 of 22 (32 percent) amphibians have less than 1 percent of their predicted distribution in status 1 or 2 lands. One hundred forty-seven of 214 (69 percent) birds, 42 of 61 (69 percent) mammals, 9 of 30 (30 percent) reptiles, and 15 of 22 (68 percent) amphibians have between 1 and 10 percent of their predicted distribution in status 1 or 2 lands.

Only 7 of 214 (3 percent) birds, 0 mammals, 0 reptiles, and 0 amphibians have over 10 percent of their predicted distribution in status 1 or 2 lands. These 7 species all have limited predicted distributions and are associated with wetlands or Great Lakes coastal environments. Status 1 National Wildlife Refuges in Michigan are principally wetland-dominated environments, while status 1 and 2 national lakeshores protect coastal environments.

Conclusions

It is very clear from the analysis of stewardship status for terrestrial vertebrates that status 1 and 2 lands (1.5 percent of Michigan's landscape) do not afford adequate protection for the complete range of biodiversity elements in Michigan. Status 3 lands (19.4 percent of Michigan's landscape) offer the best opportunity for protecting biodiversity on public land. The Michigan DNR manages two-thirds of Michigan's status 3 lands

and the U.S. Forest Service manages almost all of the remaining. If status 3 lands are considered to offer an equivalent measure of biodiversity protection to status 1 and 2 lands, the outlook for the conservation of biodiversity in Michigan improves dramatically. Hence, the challenge for the Michigan DNR and the U.S. Forest Service in Michigan is to manage their extensive status 3 land base for the protection of the full range of biodiversity elements.

Products from MI-GAP are used across the state in a variety of research projects at universities. The Michigan DNR is using GAP products in multiple initiatives, including the development of their Comprehensive State Wildlife Conservation Strategy, the development of a biodiversity atlas, and sustainable forestry certification of their state forest lands. GAP products are also incorporated into the DNR's Integrated Forest Monitoring and Prescription (IFMAP) project. The IFMAP GIS-based decision-support system will bring GAP products to the desktop of DNR land managers throughout Michigan. MI-GAP data can be downloaded from the Michigan Geographic Data Library at <<http://www.michigan.gov/cgi>>.

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Mississippi Gap Analysis Project

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Introduction

The Mississippi Gap Analysis Project (MS-GAP) began in 1996 as an effort to assess the distribution and conservation status of biodiversity in the state under existing land ownership and management regimes. Our objectives were (1) to map vegetation types; (2) to map predicted distribution of terrestrial vertebrates; (3) to document the occurrence of inadequately represented vegetation types in special management areas; (4) to document the occurrence of inadequately represented terrestrial vertebrate species in special management areas; and (5) to make all information available to resource managers and land stewards in a readily accessible format.

MS-GAP was a highly interactive and cooperative endeavor that involved essentially all state and federal natural resource agencies, conservation organizations, and universities in the state. Further, many private landowner groups and individuals assisted by providing information and participating in working groups. The project encompassed all of Mississippi, a landscape of diverse geologic and natural history. The diverse array of biotic elements is partly attributable to a complex connection of biogeographic components from the southeastern United States, including the Mississippi Alluvial Valley, Hilly Coastal Plain, and Gulf Coastal Plain.

Data Development

Land Cover Classification and Mapping

MS-GAP used a three-stage process of development to complete the land cover. When our project began, the Stennis Remote Sensing Center (SRSC) was completing a circa 1992 land use/land cover project funded by the Environmental Protection Agency. The goal of the SRSC project was to determine the extent and distribution of wetlands within Mississippi. The final product consisted of 25 vegetation classes that approximately equated to Anderson Level 2 classes.

The development of the SRSC land cover was stage one of the process. Preparation of a statewide map of vegetation communities and other land-use cover types required a specific classification system in conjunction with interpretation of remotely sensed land cover data. We developed our land cover classification scheme in cooperation with the Mississippi Natural Heritage Program and in consultation with experts on Mississippi vegetation. MS-GAP obtained Landsat thematic mapper (TM) data (1991–93) at 30-meter pixel resolution from the Multi-

Resolution Land Characteristics (MRLC) Consortium. Additional TM data (1992–93) were acquired from the Environmental Protection Agency (EPA). In total, 18 Landsat TM scenes were used for the project. Eight scenes had two dates for analysis, one during leaf-on and one during leaf-off. This seasonal coverage aided in the differentiation of National Vegetation Classification System (NVCS) alliances and alliance groups. Moreover, we used 273 color infrared aerial photographs, representing 6 percent of the state, to aid classification of satellite images.

Stage two of the land cover development process consisted of a pilot study to refine and enhance the SRSC product. Satellite imagery data were analyzed, clustered, and classified using ERDAS software, resource agency maps, vegetation experts, and selected ground site visits. Two satellite scenes, provided by the MRLC, were used to provide temporal vegetative changes. The objective of this pilot study was to enhance the SRSC land cover product and to attempt to classify the study scene to a level of precision as close to NVCS alliances as possible. Classes that were deemed sufficiently accurate and detailed were masked out of the scene. These included agriculture or cropland class, urban classes, transportation, and water/wetland classes. The transportation class was digitized from the imagery, as it could not be separated out spectrally; included were four-lane roads and airport facilities.

Our project team decided that remaining classes could be improved so they were recombined for reanalysis. Additionally, we considered developing specific procedures that would apply specifically to Mississippi and would facilitate the classification process, instead of simply repeating the process used by SRSC or using the methods of other GAP land cover projects. For generation of the land cover we used the Mississippi Transverse Mercator (MSTM) projection. Several other GAP projects examined used some form of data subdivision to reduce the variation within the satellite data set and enhance classification levels. In each case, subsets were believed to aid the final classification process. However, no tests were conducted to verify the results.

Benefits were gained by separating the cluster classes into subsets prior to reclassification and we decided to use an approach of separation based on soil characteristics. We decided to test whether subdividing the data on some parameter would be beneficial to the overall separation of classes and what level of subdivision would prove most useful. Instead of using soils alone, we decided to test the physiographic regions and provinces. The divisions were based on soils, geography, and existing land-use practices. To test for differences within a single cluster class across physiographic regions or across provinces, pine and

hardwood were used as distinguishing classes and split into the different regions present in the scene. Separation was based on the five Mississippi provinces, rather than the three regions designated by The Nature Conservancy (TNC). The provinces further subdivided the three TNC regions into five more detailed regions. We determined the ability to separate pine and hardwood within each region, within combined regions inside the same physiographic province, and within the entire scene.

Our results showed the highest separation existed within each of the 15 physiographic regions, followed closely by separation within the three physiographic provinces. Further efforts to improve class identification involved increasing the distinction between recently harvested timber areas and spectrally similar pastures, croplands, and grasslands. SRSC classes deemed to be poor in classification or too general for use were combined for reanalysis. These classes included pine forest, mixed forest, deciduous forest, pasture, grassland, upland scrub/shrub, barren land, and other land. Based on the analysis of several parameters, we selected a total of 50 classes. The final product of the pilot project scenes had a correct classification rate of 69 percent. The lowest accuracy was low-density pine class and the highest was mixed pine/hardwood. Hardwood uplands, water, recent timber harvest area, and wetland deciduous shrub classes had the highest user's accuracy, while bottom land hardwood, elm ash cottonwood, and medium-density pine classes had the lowest. Moreover, a 15 percent increase in accuracy over the original SRSC land cover map supported our methodology and classification advancements.

We defined high-density areas as pine stands of about 5–12 years in age, medium density as stands of 12–20 years, and low-density stands represented by older trees of 20 years and older. High-density areas consisted of dense stands with many small pines of even height and very little ground vegetation. Stands characterized by more open space between stems from thinning and minimal understory vegetation were representative of medium-density pine areas, while a stand with fewer (yet larger) pine trees with open canopies and moderate understory vegetation consisting mainly of hardwoods was representative of high-density pine areas. Hardwoods were also separated according to stand structural differences and classified into medium- and high-density categories. Structural distinction was based on clusters formed and information drawn from the aerial photographs. This development was a first for GAP programs and we believe it will prove important in differentiating wildlife habitat, especially for habitat specialists.

Stage three involved the conglomeration of information found in stages one and two, and the development of the final MS-GAP land cover map. With the SRSC map as the base, alliances that could not be mapped efficiently due to inaccuracy or confusion with spectrally similar classes were collapsed. Classification for the statewide land cover was conducted on a scene-by-scene

basis, rather than on a whole state mosaic. Individual scenes were used because the satellite images across the state were taken at different times of the year and across multiple years. While MS-GAP benefited greatly from processes used or developed by other GAP projects, our project pioneered multiple techniques that not only increased the quality of the product, but contributed valuable information for wildlife habitat assessment and management. One of the major advantages discovered was our ability to accurately distinguish differences in structure within pine and hardwood types. During the pine class clustering process, three separate classes were detected. Further analysis showed a distinction between low-, medium-, and high-density pine areas.

Another development of MS-GAP was the separation of generalized urban classes into more descriptive and useful classifications. Typical GAP projects distinguish two to three urban classes. The medium-density urban class was more closely examined and reclustered into eight new urban classes with more specific vegetative land cover descriptions. We believe this advancement may increase the differentiation of vertebrate species-habitat predictions, particularly for those vertebrate species adapted to varying urban environments.

Predicted Animal Distributions and Species Richness

To develop our knowledge base for the predicted animal distributions, we initially consulted species lists of terrestrial vertebrates in Mississippi from several field guides. This list was cross-checked with the Mississippi Natural Heritage Program database for omissions and inclusions. We examined theses and dissertations available at Mississippi State University to populate our species-habitat database and supplement the information provided by field guides. We developed models for species designated as breeding in the state at least once in the previous five years.

Bird species range maps were initially delineated using available TNC information. However, we also incorporated collection records from major natural history museums around the country (e.g., the Smithsonian Institution and the American Museum of Natural History), as well as from prominent regional museums, (i.e., the Louisiana State University Natural Science Museum and the Mississippi Museum of Natural Sciences) into our avian range map database. We established a MS-GAP Bird Oversight Committee to refine species range maps and to align range maps along physiographic regions of the state, where appropriate.

The available information on mammal distribution was deficient in Mississippi as research had been limited to very few species, mostly of game management importance. The first examination of the species range was delineated from available sources in the state. Species records were then collected from museums with electronic databases and museum records were compared to available range maps. Any discrepancies were scaled to the greatest common denominator as a conservative measure. Range

maps were reviewed and edited by the MS-GAP Mammal Oversight Committee.

Extensive museum records were available for the diverse herptile fauna of Mississippi. Museum records were collected and mapped to the county level. Range maps were also selected from TNC data. Gross disparities in ranges from museum records were reported, and records were verified by museum curators for accuracy. We included all museum records in the range development regardless of date; however, records older than 30 years were excluded for a second comparison to prevent the inclusion of spurious records. Final species ranges were determined by the MS-GAP Herptile Oversight Committee.

The exponentially increasing size of intersected GIS coverages and processing time due to topological considerations involved with vector GIS greatly increased the time spent modeling animal distributions. Consequently, we intersected all coverages once, creating a hypercoverage whose polygons were unique combinations of seven land cover and physical coverages. A data file was created with rows representing hypermap polygons and columns denoting each animal's presence (1) or absence (0) for each hyperpolygon ID number. Use of a statewide hypercoverage exceeded our software capabilities so the hypermap was subdivided into three coverages. The first coverage (land cover hypermap) included all coverages except water buffers and slope. The second coverage (water hypermap) contained all data layers except land cover and slope. For these two coverages, the state was divided into nine tiles identical to the land cover map. The third coverage was statewide slope coverage. A species map was constructed by combining the three hypercoverages as pertinent.

The richest predicted areas in the state contained 223 of 306 vertebrate species, or 72.8 percent of the total. Overall, the richest areas for vertebrates in Mississippi were in the bottomland hardwood basins of the Pearl, Yazoo, and Pascagoula rivers. Herptile richness was greatest for the Mississippi coast. Accuracy for bird predictions was relatively high, especially for the De Soto and Delta National forests, approaching 80 percent. Omissions were primarily unusual species for which we had little evidence for inclusion in algorithms that intersected spatial coverages. Overall, errors of prediction for birds were a combination of edge-of-range detections and predictions of species that have relatively limited occurrence in that area. A limited historic survey of some areas of the state also appeared to influence errors.

Land Stewardship and Management Status

Land stewardship was mapped in two phases: (1) land ownership boundaries (with associated land use/land management information) were collected from various federal, state, and private sources; and (2) these boundaries were assigned one of four management status categories defined by national GAP standards as a measure of conservation afforded to biological

diversity in that land tract (Status 1 = highest conservation class). The Mississippi Department of Wildlife, Fisheries, and Parks worked jointly with MS-GAP to produce a map of land ownership categories in Mississippi. Individual private parcels were not identified; private land was mapped only as a category. This digital map formed the basis of our land stewardship data layer, with additional data about specific stewardship boundaries incorporated from federal and state agencies, land trusts, and private landholders.

Before assigning management status categories to the stewardship boundaries, we collected information on how various groups and individuals statewide viewed management classification. MS-GAP made a concerted effort to contact public and private landholders to gather pertinent stewardship information. MS-GAP also made a special effort to identify private lands subject to special conservation provisions. We recognized that many private landowners practice good stewardship, and we made a substantial effort to include them; however, only conservation backed by legal enforcement, such as legislation or conservation deed restrictions, was considered in categorizing tracts for long-term maintenance of biodiversity.

Analyses

Private lands were a prominent category of stewardship; federal stewardship was dominated by the U.S. Forest Service and the U.S. Fish and Wildlife Service. We identified four general categories of land tracts represented in management status 1 and 2 lands. These categories included an array of federal, state, and private management entities associated as stewards and information sources. We estimated distribution of management status in Mississippi as 22,759 hectares of status 1 (0.2 percent), 98,708 hectares of status 2 (0.8 percent), 622,362 (5 percent) of status 3, and 11,630,095 hectares (94 percent) of status 4.

While analyses of animal species richness provided indicators of biologically valuable areas, they also involved confusion because areas with similar or identical richness values could actually contain different individual species. Therefore, these analyses should be viewed as a general perspective on areas to focus more detailed biological evaluation. We believe it is important for all future users of these data to recognize that some species primarily distributed on status 3 and 4 lands may adequately meet their biological needs within these areas.

Thus, while the majority of vertebrates we included had a limited distribution on the highest conservation status lands, judicious evaluation will be needed to determine which ones represent actual biological gaps. These data must be regionalized with other gap analysis projects to perform biological analysis across broader geographic distributions for many of these species. Moreover, MS-GAP data were produced solely with the goal of conducting a "coarse filter" assessment on distribution and

conservation status for plant communities and selected animal species. The project was conducted in a relatively short time frame with minimal resources, thus limiting data quality to that appropriate for large regional assessments. We specified a variety of limitations on data use in the report. We believe, however, that the data and analyses will be of use to many land planners, managers, and researchers who examine the data sets in detail and observe appropriate precautions regarding scale, the accuracy of remotely sensed data, the simplification inherent to predictive models, and the dynamics of biological populations.

MS-GAP Users and Applications

The long process of data acquisition and sharing developed a strong working relationship with MS-GAP cooperators. The Mississippi Final Report and all GAP data and products are available on the GAP web site <<http://gapanalysis.nbio.gov>> and on compact discs, which can be ordered by contacting the Cooperative Fish and Wildlife Research Unit at Mississippi State University. GAP data and products provide support to agencies in terms of applying spatial technologies and existing spatial data to help solve current natural resource problems. MS-GAP data are being actively used by many cooperators in the state and in nearby states, as well as by the general public. The Mississippi Department of Wildlife, Fisheries, and Parks (MDWFP) is using MS-GAP data in the state's Comprehensive Wildlife Conservation Strategy plan. The MDWFP Law Enforcement Division has made use of MS-GAP products to assess the distribution of game violations and conservation officers' sphere of influence. The MDWFP Natural Heritage program has incorporated MS-GAP into their species' database. The Mississippi Department of Marine Resources regularly makes use of the MS-GAP land cover for coastal zone assessments. The U.S. Department of Agriculture Animal and Plant Health Inspection Service (APHIS) has used MS-GAP products in piscivorous bird research and control programs. Moreover,

MS-GAP data is being applied in species and ecosystem research and conservation efforts in the state. MS-GAP land cover data was applied to develop a spatially explicit model, derived from demographic variables, to predict attitudes toward black bear restoration in the state. More recently, MS-GAP data has been used to develop a spatial decision support system to assist county planning boards that integrates a Bayesian Belief Network with GAP data.

Conclusions

MS-GAP provided the first spatially refined data for the distribution of natural vegetation communities, animal species, and the conservation status of lands in the state. A variety of conservation assessments are now possible simply because these data now exist. However, these data sets could be further improved by (1) an updated and refined land cover map to more accurately inventory Mississippi's land surface resources and stewardship; (2) refined animal distribution predictions to differentiate between predicted potential distribution and actual distribution; and (3) a better assessment of conservation status of all lands in Mississippi that can better focus planning and management activities.

In summary, at least 50 natural land cover classes were identified in Mississippi. A small percentage of vertebrates were found having restricted occurrence on lands managed for long-term conservation of biological diversity. These restricted classes, especially wetlands and riparian areas, are under varied stewardship, including substantial private ownership. Most vertebrate species did not have substantial parts of their distribution on status 1 and 2 lands and occurred among a wide array of land stewards. Thus, the opportunity for conservation partnership is widespread, with upfront information that can easily focus attention and minimize contentiousness about what to accomplish and where.

North Carolina Gap Analysis Project

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Introduction

The North Carolina Gap Analysis Project (NC-GAP) was begun in January 1996 to assess the distribution and conservation status of biodiversity in the state under existing land ownership and management regimes. Our objectives were (1) to map the land cover of North Carolina; (2) to map the predicted distributions of native terrestrial vertebrates that use habitat in the state for breeding; (3) to map the network of conservation lands in the state; (4) to assess the conservation status of both the terrestrial vertebrates and the natural vegetative communities of the state; and (5) to provide that information to natural resource agencies so they can use it in their planning efforts.

Land Cover

A map of North Carolina's land cover was developed using Landsat thematic mapper (TM) imagery acquired in 1991 and 1992. Processing was completed on each of 13 mapping zones, which were created by intersecting the Ecoregional Provinces at the section level (Bailey et al. 1994; Keys et al. 1995) with the Landsat TM paths and rows. The Sandhills subsection was mapped independently of the larger Coastal Plain section to accommodate the relatively unique vegetation types found there. For each mapping zone, reference data were developed from aerial survey or field reconnaissance, or from existing data sets. These data were used to guide the development of decision rules for the detailed land cover mapping. General land cover types, including water, row crops, pasture, urban, and barren, were integrated from the National Land Cover Data set (USGS 1997). Throughout image processing and classification, the 30-meter (0.09 ha) resolution data were maintained. The minimum mapping unit for the land cover data set is 2 ha, approximating the area of a 5 X 5 pixel area.

The North Carolina Gap Land Cover classification includes 69 map classes, 59 of which represent natural and seminatural land cover classes dominated by vegetation. Natural vegetation map units were based on a classification system that was intermediate between the National Vegetation Classification System (NVCS) (Grossman et al. 1998) and the NatureServe Ecological Systems Classification (Comer et al. 2003). Upland forests, including deciduous, mixed, and evergreen types, represent 51 percent of the total area mapped. A fourth of the land cover is the cultivated herbaceous category, the majority of which is row crop. Ten percent of the state was classified as wetland, the vast majority being the wetland forests of the Coastal Plain region. Statewide, the two most extensive natural/seminatural cover classes are

the Piedmont Dry–Mesic Oak Hardwood Forest (7 percent) and Coniferous Cultivated Plantations (7 percent), which cover 981,400 and 966,200 hectares, respectively. The most extensive wetland forest type was the Pocosin Woodland and Shrubland, which represented 3 percent of the area.

Accuracy Assessment

Both spatial and thematic accuracy assessments were completed for the statewide land cover data set. The 95 percent confidence interval for the total spatial error in the land cover map is 20.6 ± 5 meters (Easting 38 ± 5 meters, Northing 27 ± 5 meters). Thematic accuracy was tested at two levels of thematic detail: a general classification based on cross-walking the detailed cover classes into 15 categories, and for the detailed land cover all classes were assessed. Overall accuracy for the generalized land cover was 87.7 percent with a 95 percent confidence interval of 84.9 to 90.6 percent. The calculations for per class and overall thematic accuracy are based on the known map category marginal frequencies (Card 1982), which normalizes the error calculations based on both the number of samples within a stratum and the proportion of the map represented in each cover class. The estimated accuracies in the detailed cover classes were highly variable. The overall accuracy for the full 69 class land cover map is 58.5 percent with a 95 percent confidence interval of 57.1 to 59.9 percent. This is based on the 10,620 interpreted points. The estimated Kappa statistic for the detailed land cover is 0.73.

Terrestrial Vertebrate Distributions

Potential distribution maps were developed for 414 terrestrial vertebrate species comprising 193 species of breeding birds, 75 species of mammals, 76 species of amphibians, and 70 species of reptiles. Range limits of each species were delineated on a grid of 258 hexagons encompassing the state (White et al. 1992). Point data used to create range limits included 748 point localities from the North Carolina Museum of Natural Sciences (NCMNS), 2,028 points from the North Carolina Natural Heritage Program (special concern species only), and 27,210 point localities that were newly mapped for this project. The newly mapped points include 25,001 records from the North Carolina Breeding Bird Atlas data set, along with NCMNS specimen records for birds (193 points), mammals (627 points), and herptiles (1,389 points).

The accuracy of the vertebrate potential distribution models was assessed by comparing available species lists for national wildlife refuges, national seashores, and national parks, as well as North Carolina state parks and preserves. The percent agreement averaged 78.8 percent, 64.4 percent, and 72.8 percent for birds, mammals, and herptiles, respectively. While species lists were readily available for birds throughout the state (11), very few

compiled lists exist for mammals and herptiles (3). Error rates were low for omission (5.6 for birds, 3.1 for mammals, and 2.1 percent for amphibians and reptiles), whereas commission rates were significantly higher (15.6, 32.4, and 25.1 percent, respectively).

Land Stewardship

The stewardship analysis showed that a relatively small proportion of the state is under any sort of protection to maintain its biodiversity. In fact, the North Carolina gap analysis found that approximately 10 percent of the state's area was under management, with the majority of that (7.6 percent, or 969,940 hectares) being federally managed. State management represented 2.2 percent of the state's area (277,064 hectares). A total of 37,413 hectares of nongovernmental organization (NGO) lands had been mapped through a variety of mapping projects and were included in this data set, but we know that this is an underestimate for the state and that those lands will become increasingly important for natural resource management over time. The pattern of land ownership is highly skewed across the state, with the vast majority of public lands being in the outer coastal plain and in mid- to high-elevation mountains.

Slightly over 4 percent (213,841 ha) of North Carolina's land was categorized as status 1 or 2. Federal management, specifically the National Park Service (Great Smoky Mountains National Park), the U.S. Forest Service wilderness areas, and the U.S. Fish and Wildlife Service refuges and wilderness areas accounted for the majority of the status 1 and 2 lands. Status 3 lands were managed predominantly by the U.S. Forest Service (459,081 ha) and the Department of Defense or the Department of Energy (153,363 ha).

Gap Analysis

Six of the natural cover types in the state have less than 1 percent of their distribution on conservation lands. These types include four cover types of the Coastal Plain: the Xeric Longleaf Pine Woodland, the Coastal Plain Xeric Oak–Pine Forests, the Coastal Plain Mesic Hardwood Forest, and the Coastal Plain Dry to Dry Mesic Oak Forests. The other two cover types are Piedmont types; these include the Piedmont Mixed Successional Forests and the Oak Bottomland Forests and Swamps. Another 25 natural cover types in the state have less than 10 percent of their mapped distribution in status 1 and 2 lands. The Spruce-Fir Forests have over 69 percent of their mapped distribution in status 1 and 2 lands; unfortunately, the distribution of this cover type is dwindling due to causes other than habitat conversion (acid deposition, disease). It is important to note that the gap analysis for existing vegetation does not account for the previous losses in acreage, which for some of these systems represent a severe decline in representation (Noss et al. 1995; Frost 1993).

Of the 414 species modeled, 45 have less than 1 percent of their predicted distribution on lands with long-term protection for biodiversity (GAP status 1 and 2). Thirty of these are birds, six are

mammals, and nine are reptiles. In addition, NatureServe and the North Carolina Natural Heritage Program rank 14 of the 45 species as either critically imperiled (SRank 1), imperiled (SRank 2), or vulnerable (SRank 3) in the state.

Overall species diversity is concentrated along the outer coastal plain, with other high-ranking areas including the sandhills and the Asheville basin. Diversity in the sandhills and coastal plain seems to be tied to wetland habitats, whereas the Asheville basin probably is highlighted due to the range in elevation, topography, and land use of the area. For avian species, the blue ridge escarpment and the outer coastal plain stand out as areas of high diversity. High elevations throughout the southern blue ridge represent hot spots for mammalian species diversity. Amphibian species diversity is very closely tied to the coastal plain riverine and wetland systems. This pattern highlights the role of wetland habitat in the outer coastal plain and sandhills. For reptiles, the sandhills region, as well as the xeric pine woodlands in the coastal plain, stand out as the hot spots.

Outreach

To get the information gathered as part of the North Carolina Gap Analysis Project into the natural resource managers' hands, we worked in cooperation with U.S. Fish and Wildlife Service personnel on the Roanoke-Tar-Neuse-Cape Fear Ecosystem team to build a decision-support tool. The GAP Ecosystem Data Explorer (GEDE) tool allows non-GIS-savvy users to quickly view data and conduct advanced queries with a few simple clicks. While the GEDE tool has been designed to be accessible to a broad audience, it is based on a full implementation of ArcView with Spatial Analyst, and thereby provides an advanced GIS platform for those who wish to expand the complexity of their queries and analyses. The central scripting used in the tool allows us to import our statewide data, as well as other state GAP products, into the tool so they can be used by a broad audience. In addition to the tool, an interactive web site, including download options for county, watershed, and state data sets, should facilitate the distribution to agencies and managers.

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North Dakota Gap Analysis Project

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Land Cover

A map of the land cover of North Dakota circa 1997 was prepared from the analysis of 42 Landsat-5 Thematic Mapper (TM) images acquired between August 1992 and May 1999 and digital National Wetlands Inventory data. The spatial resolution of the land cover map is the same as the TM imagery, 0.09 ha. The legend for the land cover map is hierarchical, with 8 general land cover categories at the upper level and 39 detailed land cover categories at the lower level. Approximately 118,760 km² (65 percent) of the surface area of North Dakota has been tilled at some time, with 30,543 km² of this land planted with perennial herbaceous vegetation at the time the map was made. Map estimates of the area of natural and seminatural prairie, wetlands, and shrublands are 35,681 km² (19 percent), 16,297 km² (9 percent), and 5,281 km² (3 percent), respectively. The area of woodland (natural and anthropogenic) is estimated at 4,284 km² (2.3 percent). The area of sparsely vegetated land cover including natural badlands was estimated at 1,897 km² (1 percent) and the area of developed land covers at 953 km² (0.5 percent).

A probability-based sampling design and design-based inference were used to assess the accuracy of the land cover map. The sample design was a stratified random single-stage cluster sample. Sixteen strata were defined by a combination of four physiographic regions and four anthropogenic land cover proportion classes. Observations of land cover from ground surveys and aerial photo interpretation were used to create an exhaustive land cover vector for 253 one mi² sample units. The land cover vectors were converted to 30 m grids for statistical analyses. From a preliminary analysis of data for 238 of the 253 sample units, the overall accuracy for the eight land cover categories at the upper level of the land cover map legend was 62 percent. Factors influencing the accuracy assessment include (1) temporal changes in land cover between 1992 and 1999 (when TM images were acquired) and 2002, when the data for the accuracy assessment were collected; (2) spatial registration of the map and the reference data; (3) differences in class generalizations, including definitions and inclusions arising from ground and satellite methods for observing land cover; and (4) the accuracy of the reference data. The accuracy assessment revealed that classification accuracy is spatially variable and a single number for an entire map is of limited value. One exciting outcome from our sampling design is the ability to produce maps

of the spatial distribution of the accuracy parameters by applying the estimates to the strata maps. An accuracy assessment is in progress at multiple spatial scales intermediate to the pixel and sample unit scales (1 mi²) for the 39 land cover categories at the lower level of the map legend.

Terrestrial Vertebrate Distributions

Potential distribution maps were developed for 281 terrestrial vertebrate species comprising 184 species of breeding birds, 71 species of mammals, 15 species of amphibians, and 11 species of reptiles. Range limits for each species were delineated on a grid of 635 km² hexagons using >200,000 locality records. Within the hexagons, species potential distributions were modeled based on species–land cover category affinities. The accuracy of the vertebrate potential distribution models was assessed by them with published species lists from six natural areas in North Dakota. Percent agreement averaged 94 percent (range 84–98 percent, n=5), 89.6 percent (range 86–94 percent, n=3), to 92 percent (range 85–100 percent, n=3) for birds, mammals, and herptiles, respectively.

Land Stewardship

Approximately 6.4 percent of the land in North Dakota is managed by public agencies, with 4.3 percent under federal management and 2 percent under state jurisdiction. Approximately 4.2 percent of the land in North Dakota occurs within the boundaries of lands governed by five Native American tribal governments. Lands managed by nonprofit conservation organizations account for less than half of one percent of the land in North Dakota. Private landowners are responsible for managing approximately 89 percent of the land in North Dakota.

North Dakota does not have the equivalent of national parks, wilderness areas, and other management areas that meet the requirements for status 1 and 2 lands. State wildlife areas are managed for multiple uses and often include substantial proportions on nonnative vegetation. Status 1 and 2 lands occupy 383 km² and 1566 km², respectively, in North Dakota, which combined is slightly more than 1 percent of the state and 17 percent of the area in public and private conservation lands. Federal stewards are responsible for 97 percent of status 1 and 2 lands. Seventy-five percent of federal public lands were multiple-use and assigned a status of 3. Seventy-nine percent of lands managed by state government stewards were assigned a status of 4, and the remaining 21 percent of state public lands were assigned a status of 3.

Gap Analysis

All five of the general natural vegetation land cover categories (prairie, wetland, shrubland, woodland, and sparse vegetation) have their greatest abundance on private lands. Approximately 79 percent of the prairie land cover category occurs on private lands; the U.S. Forest Service (USFS), the North Dakota State Land Department (NDSL), and the U.S. Fish and Wildlife Service (USFWS) manage 5.9 percent, 5.1 percent, and 1.7 percent of prairie, respectively. Lands governed by the Native American Standing Rock Sioux and Three Affiliated Tribes (NATAT) account for 4.5 percent and 2.0 percent of the prairie land cover category. Nine individual stewards have less than 1 percent of the prairie land cover category on the lands they manage.

Private landowners are responsible for stewardship of approximately 77 percent of the wetland land cover category. The USFWS has responsibility for 5.9 percent of the wetland land cover category, with the Native American Spirit Lake Tribe and the NDSL responsible for 2 percent and 1 percent, respectively. Thirteen stewards individually have responsibility for less than 1 percent and together 3.5 percent of the wetland land cover category. Approximately 69 percent of shrublands occurred on private lands. The USFS, NATAT, and the NDSL manage approximately 13.4 percent, 6.5 percent, and 3.5 percent of shrublands, respectively. Stewardship responsibilities for shrublands may be distorted due to the difficulty of mapping shrublands. Seventy percent of the woodland land cover category occurs on private lands. This is probably an overestimate of the proportion of natural woodlands on private lands, as many woodlands in North Dakota are planted. Stewards, in decreasing order of responsibility for natural woodlands, include the USFS, NATAT, the Native American Turtle Mountain Chippewa, the North Dakota Game and Fish Department (NDGFD), USFWS, and the U.S. Army Corps of Engineers. Twenty-five percent of the terrestrial vertebrate species have 1 percent or less of their potential habitat distribution represented on status 1 or 2 lands. Ninety-five percent of the species have 5 percent or less of their potential habitat distribution represented in status 1 or 2 lands.

Applications of North Dakota Gap Analysis Project (ND-GAP) products

The ND-GAP land cover data is used by USFWS Private Land biologists to evaluate the land cover composition of watersheds for proposed wetland creations.

The ND-GAP land cover data was used by U.S. Geological Survey wildlife biologists in the design of a survey for Richardson's ground squirrels.

The ND-GAP land cover data is used by NDGFD biologists to evaluate land cover composition for a variety of planning purposes. ND-GAP data was used in the development of the NDGFD Comprehensive Conservation Strategy.

The ND-GAP vertebrate data was used by EPA region 7 and the Missouri Resource Assessment Partnership as one input to Cplan, a reserve design algorithm, as part of the EPA's Critical Ecosystems program.

The ND-GAP vertebrate data was used by University of Illinois researchers investigating deer ticks and Lyme disease for the Centers for Disease Control and Prevention.

The North Dakota Game and Fish Department envisions using the vertebrate data in the development of wildlife conservation and restoration efforts as part of the federally funded State Wildlife Grants program.

The ND-GAP stewardship data was used by South Dakota State University in the Upper Missouri River Aquatic Gap Analysis Project.

Data Availability

The final report is under review by the national GAP office and should be available for distribution soon. In addition, the data should also be available from a USGS ftp site at [ftpext.usgs.gov](ftp://ftpext.usgs.gov/pub/cr/nd/Jamestown/ndgap) in the /pub/cr/nd/Jamestown/ndgap> subdirectory or the North Dakota GIS hub at <http://www.state.nd.us/gis>.

Oklahoma Gap Analysis Project

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The Oklahoma Gap Analysis Project (OK-GAP) was completed and published in 2005. It provides the first comprehensive GIS database of information on land cover types, ranges and predicted distributions of terrestrial vertebrates, and stewardship lands in Oklahoma. The objectives of the project were (1) to prepare a map of the current distribution of land cover types; (2) to estimate terrestrial vertebrate species distributions relative to land cover types; (3) to classify land stewardship by categories of conservation status; and (4) to identify and analyze gaps in the conservation of biological diversity from within the network of protected areas. Information from OK-GAP should benefit long-term planning efforts for biodiversity conservation in Oklahoma.

The land cover map identifies 46 land cover types based on the interpretation of thematic mapper (TM) imagery and field reconnaissance. The minimum mapping unit (MMU) is 0.81 hectares for all land cover types. Twenty-three scenes of TM data for 1991–93 obtained from the Multi-Resolution Land Characteristics (MRLC) Consortium were used to create the map. We used airborne videography from 17 flight lines flown over Oklahoma to help classify the TM scenes. Field reconnaissance was conducted to verify video classification of land cover types and verify Universal Transverse Mercator (UTM) coordinates of the flight lines. We conducted an accuracy assessment of the land cover map using data from three independent sources: field reconnaissance, an existing database, and a previous land cover map of Oklahoma. Forest and other (barren, agriculture, urban, and water) land cover types had the highest overall accuracy (78 and 85 percent, respectively), shrublands and herbaceous lands were intermediate (53 and 56 percent, respectively), and woodlands had the lowest accuracy (22 percent). Woodlands were most often misclassified as forests or other land cover types, and shrublands were typically misclassified as herbaceous types. These misclassifications most likely were the result of structural differences (i.e., vegetation height and crown density) between the land cover types, the small MMU, and the simple random sampling design we used.

Distributions of 411 terrestrial vertebrate species were mapped. Using habitat (land cover type) associations, we predicted the potential distributions of 382 species, including 75 mammals, 178 birds, 81 reptiles, and 48 amphibians. In addition, we mapped the distributions of 29 imperiled species (state and federal threatened or endangered species and species of special concern). Range

limits of each species were delineated on maps from scientific literature sources and then were reviewed by experts. The range maps were eventually converted to a presence/absence grid map consisting of 337 hexagons (635 sq km) to cover Oklahoma. Wildlife habitat relation models were developed for each of the 410 species based on their associations with individual land cover types. Accuracy of the predicted distributions was assessed for 20 species of birds; we did not assess the accuracy of any other group. Mean accuracy for the 20 species was 71 percent and ranged from 45 to 92 percent. No occurrence data were available for assessing the accuracy of mammals, reptiles, or amphibians.

The stewardship map of Oklahoma was developed from original maps of 379 public and private managed land units. We identified 14 land stewards, including eight federal agencies, five state and city agencies, and one private organization. All stewardship land areas were categorized based on management for biodiversity maintenance on a scale of 1 through 4, with 1 being the highest, most comprehensive level of management for conservation and 4 being the lowest. Ninety-three percent of the total land area of Oklahoma is composed of private, unrestricted status 4 lands. Of the remaining 7 percent of total land area, 28 percent was classified as status 1 and 2 stewardship lands, 21 percent as status 3 lands, and the remainder was either status 4 public lands (federal, state, municipal) or water.

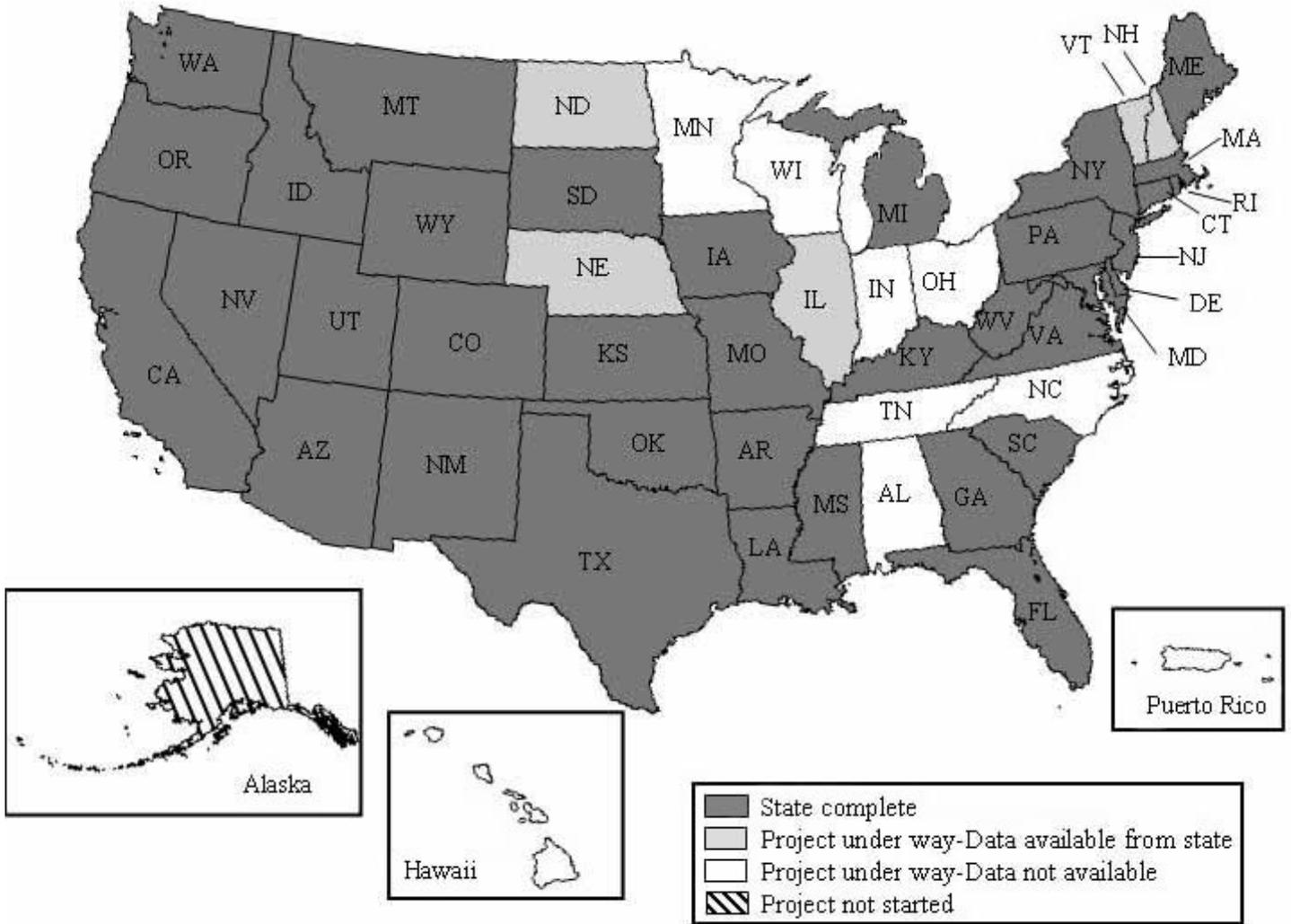
Gap analysis was conducted on all land cover types and predicted animal distributions with representation on status 1 and 2 stewardship lands. Nine land cover types had less than 1 percent representation, 32 types had between 1 percent and 10 percent representation, and two types had between 11 percent and 20 percent representation on status 1 and 2 lands. Of these, shinnery oak shrubland in west-central Oklahoma, gypsum grasslands in western Oklahoma, and dwarf white oak forests in southeastern Oklahoma were among the vegetation alliances in need of further study and possible protection. Habitats for 19 mammals, 14 birds, 8 reptiles, and 10 amphibians merit increased conservation and management attention in Oklahoma. These 51 species are designated as federal and state threatened or endangered or candidate or special concern species and, except for the small-footed myotis (mammal) and red-cockaded woodpecker (bird), have less than 20 percent of their predicted distribution on status 1 and 2 lands. Six areas distributed throughout the state support either high numbers of species or unique vegetation alliances. Our analysis revealed that the majority of gaps for biodiversity conservation occur on private lands. Therefore, conservation efforts in Oklahoma will have to focus on educating and working with private landowners.

An Oklahoma biodiversity plan was published in 1996 under the direction of the Oklahoma Department of Wildlife Conservation. The purpose of the plan was to provide information about Oklahoma's biodiversity and make recommendations on how biodiversity conservation could be included in a variety of economic and other activities. Information generated from the OK-GAP specifically addresses one of the biological recommendations of the plan: continued research to address information needs for biodiversity conservation. Although there was no immediate implementation of the Oklahoma biodiversity plan, OK-GAP data has been used for a variety of conservation

planning efforts and projects, including the Oklahoma Wildlife Conservation Strategy, waterfowl management plans, bobwhite quail management, conservation reserve land use, and a variety of other projects that have used the land cover data. The OK-GAP final report and data are available in a five-CD set distributed through the Oklahoma Biological Survey <<http://www.biosurvey.ou.edu/gap-ok.html>> and through the national Gap Analysis Program <<http://gapanalysis.nbi.gov>>. We hope that future researchers and managers will build on the information developed by the OK-GAP to help make biodiversity conservation a reality in Oklahoma.

STATE PROJECT REPORTS

(Status as of April 2005)



All completed products and reports will be available through the GAP web site at <<http://gapanalysis.nbii.gov>>. Drafts and other products may be obtained from the state project PI as noted.

Alabama

Project under way.

Anticipated completion date: December 2006

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Land cover: As part of our ongoing partnership with Southeast Regional GAP (SEReGAP), the Alabama Gap Analysis Project (AL-GAP) is responsible for all land cover mapping efforts within the East Gulf Coastal Plain (EGCP). The land cover mapping is being developed in two phases of thematic detail. In the first phase, we are creating a general land cover map in cooperation with EROS Data Center's (EDC) effort to develop a second-generation National Land Cover Data set (NLCD). For the second phase, we will refine the NLCD to create a more detailed vegetation map based on the Terrestrial Ecological Systems, described by NatureServe (Comer et al. 2003, hereafter referred



Figure 1. The East Gulf Coastal Plain.

to as Systems). This Systems map will represent the terrestrial habitat communities and provide a foundation for GAP vertebrate modeling and biodiversity assessments in the EGCP. In fiscal year 2004, the NLCD layer for the EGCP (Figure 1) was completed. In spring 2004 we initiated fieldwork and collected data for over 60 percent of the Systems found within the EGCP. In addition, in January 2005 we began to evaluate methods for developing the Systems level map, which included classification and regression tree analysis (CART), logistic regression, and spatial query analyses. We will continue fieldwork and compilation of training data for the remaining Systems within the EGCP through 2005.

Animal modeling: Development of animal models continued in 2004. As part of SEReGAP, we created regional range extents for 257 species of terrestrial vertebrates. In May 2004, we worked with project staff from the North Carolina and Georgia GAP labs to conduct an internal review and finalize range extents for the 608 species proposed for the Southeast Regional Project. In June 2004, we commenced literature reviews for generating unified habitat relationships for the region, and in the winter of 2004-05 we began developing the lists of spatial parameters and habitat relationship models for each species. The habitat modeling will continue throughout 2005 and we anticipate producing preliminary predicted distribution maps by the summer of 2005. We plan to initiate expert review workshops in fall 2005.

Land stewardship mapping: Stewardship mapping is also ongoing. Digital boundary files and ownership data have been compiled from various public and private agencies through cooperative arrangements. We will continue updating this layer for the duration of the project and will complete the final map in early 2006 to provide the most up-to-date data for our Gap analysis.

Analysis: Not applicable at this time.

Reporting and data distribution: Report writing will be ongoing through the duration of the project. Project updates and current information can be found on our web site at <<http://www.auburn.edu/gap>>.

Other accomplishments and innovations: AL-GAP has partnered with the Alabama Department of Conservation and Natural Resources, Division of Wildlife and Freshwater Fisheries to develop a map of high-priority terrestrial habitats to be used in support of the state's Comprehensive Wildlife Conservation Strategy. Also in 2004, our graduate research assistant, John Hogland, identified an innovative modeling method to classify longleaf ecosystems using polytomous logistic regression. See his paper, which describes this modeling procedure, in this *Gap Analysis Bulletin*.

Papers and posters presented in 2004:

Hogland, J. S., and M. D. MacKenzie. Determining the current distributions of critically endangered longleaf ecosystems: A

regional approach using remote sensing techniques. Poster presented at the Integrated Regional Studies for Global Sustainability Conference, Auburn, Alabama, March 22.

———. Determining the current distributions of critically endangered longleaf ecosystems: A regional approach using remote sensing techniques. Poster presented at the 5th Longleaf Alliance Regional Conference, Hattiesburg, Mississippi, October 12–15.

———. Identifying longleaf ecosystems using remote sensing and GIS: Management implications. Longleaf Alliance Report No. 8. *In progress*.

———. Using remote sensing techniques to delineate the current distribution of longleaf (*Pinus palustris*) ecosystems across Alabama, west Georgia, and east Mississippi. *Southeastern Biology Bulletin* 51 (2):186.

Kleiner, K. J., M. D. MacKenzie, and A. McKerrow. Mapping riparian wetlands from Landsat ETM+ imagery and DEM derivatives: A comparison of methods. *Southeastern Biology Bulletin* 51(2): 186.

Silvano, A. L., K. J. Kleiner, B. Taylor, E. R. Irwin, M. D. MacKenzie, M. S. Mitchell, and J. B. Grand. Alabama Gap Analysis Project: Managing biological diversity with geographic information systems. Poster presented at the Integrated Regional Studies for Global Sustainability Conference, Auburn, Alabama, March 22.

———. Alabama Gap Analysis Project: Managing biodiversity with geographical information systems. Poster presented at the First Annual GIS Symposium at Troy State University, Dothan, Alabama, May 20–21.

Literature Cited:

Comer, P., D. Faber-Langendoen, R. Evans, S. Gawler, C. Josse, G. Kittel, S. Menard, M. Pyne, M. Reid, K. Schulz, K. Snow, and J. Teague. 2003. *Ecological Systems of the United States: A Working Classification of U.S. Terrestrial Systems*. Arlington, Va.: NatureServe.

Alaska

Not started.

Arizona

Data on GAP web site <<http://gapanalysis.nbii.gov>> or CD. Remapping under way (see Southwest Regional GAP, p. 75).

Arkansas

Data on GAP web site <<http://gapanalysis.nbii.gov>> or CD.

California

Data on GAP web site <<http://gapanalysis.nbii.gov>> or CD.

Colorado

Data on GAP web site <<http://gapanalysis.nbii.gov>> or CD. Remapping under way (see Southwest Regional GAP, p. 75).

Connecticut

Data on GAP web site <<http://gapanalysis.nbii.gov>> or CD.

Delaware

Data on GAP web site <<http://gapanalysis.nbii.gov>> or CD.

Florida

Data on GAP web site <<http://gapanalysis.nbii.gov>> or CD.

Georgia

Data on GAP web site <<http://gapanalysis.nbii.gov>> or CD.

Hawaii

Project under way.

Anticipated completion date: November 2005

Contact:

Megan Laut
Hawaii Natural Heritage Program
Center for Conservation Research and Training
University of Hawaii
677 Ala Moana Blvd., Suite 705
Honolulu, HI 96813
mlaut@hawaii.edu, 808-587-8591

Land cover: Hawaii Gap Analysis Project (HI-GAP) land cover maps by island are in various stages of completion. The land cover map of the Big Island, which constitutes 50 percent of the area of the state of Hawaii, is complete (Figure 1). Drafts of Maui, Molokai, and Lanai are in semifinal stages of completion. Land cover maps of Oahu and Kaua'i are in the initial stages of development.

Over the past year, HI-GAP has developed methods of finalizing the land cover classification for each island, including manual recoding of selected areas, and the use of ancillary data to assist classification of associations characterized by the native leguminaceous tree koa (*Acacia koa*), a tree whose spectral signature is not distinguishable by the Landsat ETM sensors from its surroundings when in an open forest setting. In addition, HI-GAP is investigating the use of topographic normalization to improve classification accuracy of topographically complex areas on Oahu and Kaua'i.

HI-GAP performed a pilot accuracy assessment of an area on the Big Island to assess the cost and feasibility of collecting reference data via helicopter. Based on the results, HI-GAP has decided to explore additional methods of reference data collection for accuracy assessment.

Animal modeling: Most of the bird modeling is reliant on land cover completion, so we have almost completed Big Island bird modeling. Modeling for the other islands will be completed as land cover drafts become available. We used Pyle (2002) to identify all birds known to occur in Hawaii and categorized them according to residency status (i.e., resident native, alien introduced, or visitor species). From a total of 313 species and subspecies, we identified 49 resident native birds that represent all major taxon groups for distribution modeling (i.e., 19 seabirds, 7 waterbirds, 21 forest birds, and 2 raptors). We excluded visitor species, as they do not breed in Hawaii and no predictable pattern of distribution could be modeled. We used literature to develop a database of environment response variables (e.g., habitat type and elevation) that the species is expected to occupy. We extracted habitat associations described in the Birds of North America species accounts (see specific accounts for citations). We referenced additional sources therein and recent literature to refine general associations. These habitat associations were cross-walked to HI-GAP land cover types to generate island-specific binary matrices for element modeling.

Previous studies have shown that vegetation variables (e.g., dominance and structure) can be used to reliably predict the distribution of bird species (for example, see Seoane et al. 2004 and references therein). We therefore generated a species-specific binary matrix (element model) of associated land cover types and queried these land cover types in a GIS to produce preliminary species distribution maps. Preliminary distributions for seabird, waterbird, and raptor derived from literature-based element models did not require further model parameterization. However, preliminary forest bird element models, where elements were derived solely from the literature, typically overestimated species distributions. We further parameterized the element models to reflect island and regional differences in bird distributions. Environment variables were derived from survey data conducted between 1985 and 2005.

Species distribution modeling has been initiated for native and nonnative freshwater aquatic species of vertebrates and selected macroinvertebrates.

Land stewardship mapping: Stewardship has been completed, using standard GAP classification and a set of Hawaii-specific classifications (Figure 2). For multiple reasons, it was necessary for HI-GAP to develop a set of stewardship values we named Management Intent, which are independent of national GAP stewardship values. First, there are no designated Forest Service or Bureau of Land Management (BLM) lands in Hawaii; second, a number of key properties have no permanent designation for protection; and finally, management activities are focused on restoration, not disturbance, to regulate natural conditions. We used a dichotomous key similar to that developed by national GAP, but with the permanence of protection removed to assign Hawaii Management Intent.

GIS data will be made available on the ARC IMS web site of the Pacific Basin Information Node (PBIN) of the National Biological Information Infrastructure (NBII).

Analysis: Analysis is currently scheduled for fiscal year 2005. The gap analysis for our project is anticipated to employ standard gap analysis methods for project completion.

Reporting and data distribution: Data are available for both aquatic species survey information mapping and stewardship mapping, and land cover for the Big Island. Contact the Hawaii Natural Heritage Program or the national GAP office for details.

Other accomplishments and innovations: HI-GAP is collaborating closely with Hawaii's Comprehensive Wildlife Conservation Strategy. The products from both programs have much in common and they will both benefit from working together.

Literature Cited:

Pyle, R. L. 2002. Checklist of the birds of Hawaii—2002. *Elepaio* 62:137–48.

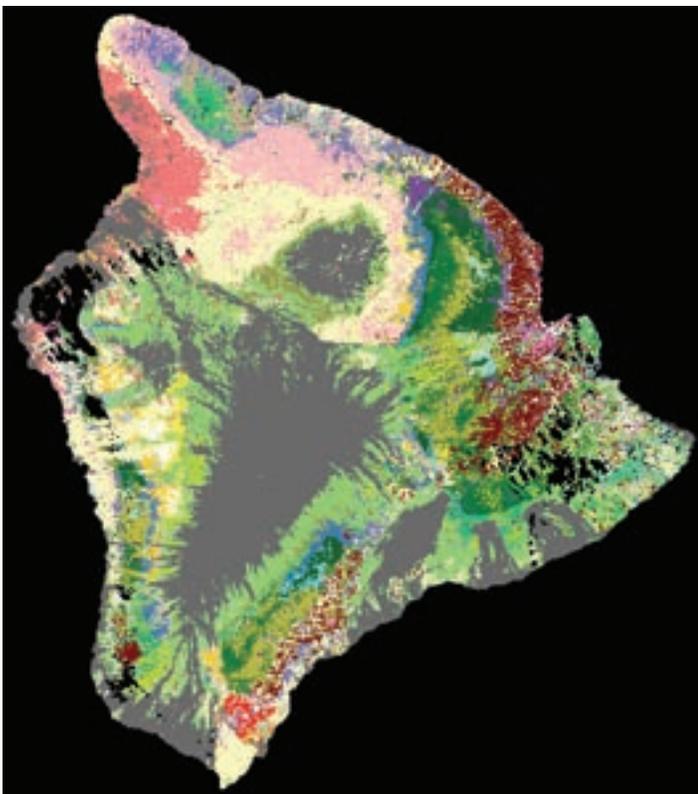


Figure 1. Land cover map for Hawaii Island.

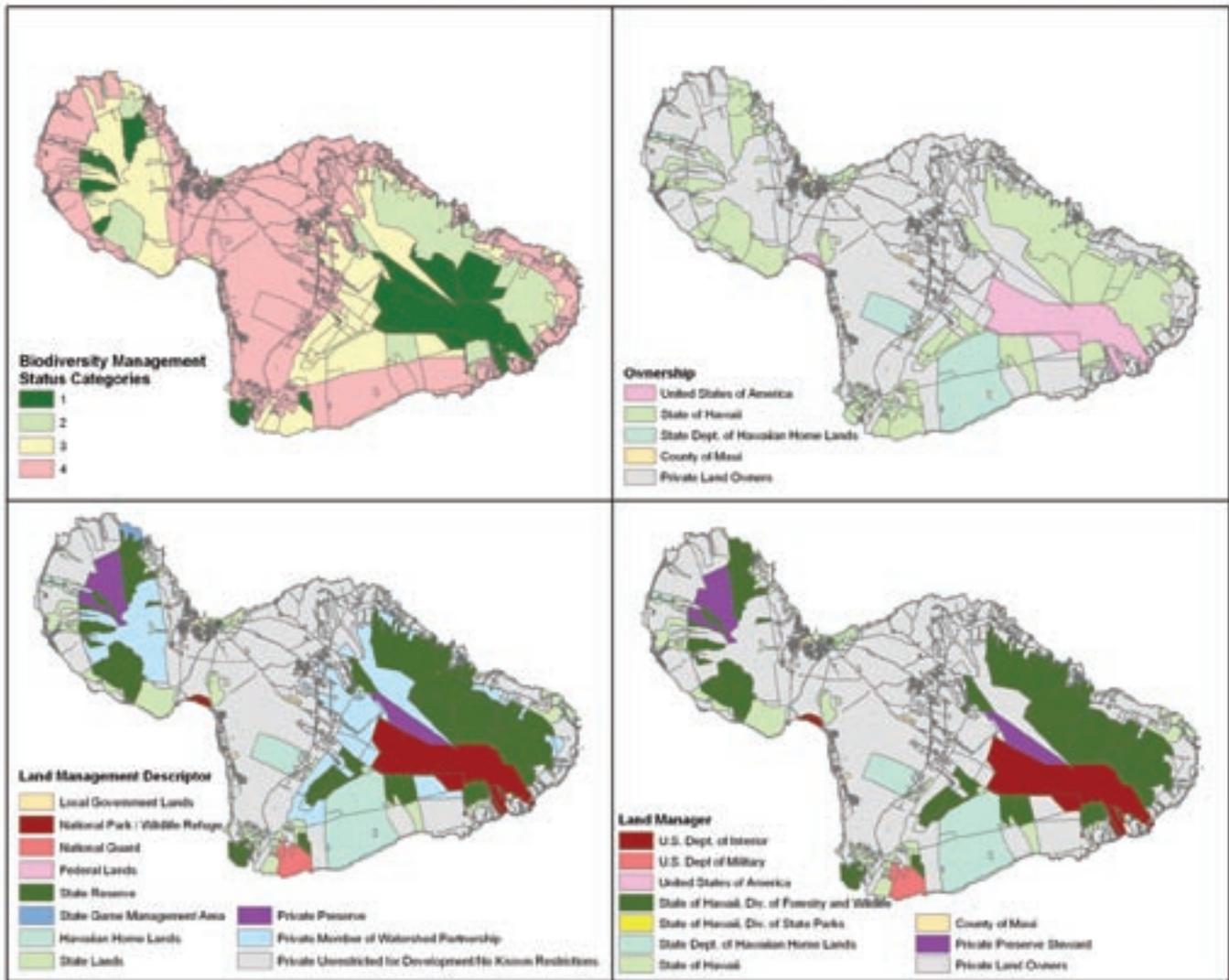


Figure 2. Stewardship maps for Kaua'i Island.

Seoane, J., J. Bustamante, and R. Diaz-Delgado. 2004. Are existing vegetation maps adequate to predict bird distributions? *Ecological Modelling* 175:137-49.

Land cover: Complete.

Animal modeling: Complete.

Land stewardship mapping: Complete.

Analysis: Complete.

Idaho

Data on GAP web site <<http://gapanalysis.nbii.gov>> or CD.

Reporting and data distribution: Digital coverages containing all Illinois Gap Analysis Project (IL-GAP) data were submitted to the national GAP office in July 2004. Initial review of the IL-GAP data was completed by the national GAP office in January 2005. The IL-GAP team is now in the process of compiling the final report and completing the necessary revisions to the data deliverables. GIS and data revisions will be submitted for peer review by June 2005. The final report will be submitted no later than December 2005.

Illinois

Draft data available from state <<http://www.inhs.uiuc.edu/cwe/gap/>>. Review under way.

Contact:

Tari Tweddle
GAP Coordinator
Illinois Natural History Survey, Champaign
tweicher@uiuc.edu, 217-265-0583

Indiana

Near completion.

Anticipated completion date: September 2005

Contact:

Forest Clark

U.S. Fish and Wildlife Service, Bloomington

forest_clark@fws.gov, 812-334-4261 x206

Land cover: The Indiana Land Cover data are complete. We are incorporating these data into our gap analysis of Indiana. The data have also been used by various Indiana GAP partners for diverse projects and provided to numerous organizations upon request.

Animal modeling: The Indiana project completed the modeling of 300 vertebrate species. Pangaea Information Technologies, Ltd., was contracted to run the final models in the autumn of 2002. We are incorporating the models into our gap analysis of Indiana.

Land stewardship mapping: The Land Stewardship map of Indiana, developed primarily under the aegis of the Indiana Department of Natural Resources, Division of Fish and Wildlife is complete. We are incorporating these data into our gap analysis of Indiana.

Analysis: A preliminary gap analysis of Indiana has been run. The initial results have been forwarded to the national GAP office for review. We will work to address the required revisions updated in February 2005 by the national GAP office.

Reporting and data distribution: We are continuing the analysis phase of the project and have begun to write the final report. We propose to continue that process through the spring/summer of 2005 and, in cooperation with the national GAP office, to make products available in the fall of 2005.

Other accomplishments and innovations: The Indiana Biodiversity Initiative (IBI), which uses Indiana Gap Analysis products extensively to identify landscape-level conservation sites, received a generous grant from the Efroymson Fund of the Central Indiana Community Foundation. The IBI finalized regional assessments, produced the Conservation Tool CD-ROM, and ran workshops distributing the Conservation Tool CD-ROM to county planners, land trusts, state and federal agencies, and private consulting firms in five of the seven modified natural regions of the state.

Iowa

Data on GAP web site <<http://gapanalysis.nbii.gov>> or CD.

Kansas

Data on GAP web site <<http://gapanalysis.nbii.gov>> or CD.

Kentucky

Draft data available from state contact. Review under way.

Louisiana

Data on GAP web site <<http://gapanalysis.nbii.gov>> or CD.

Maine

Data on GAP web site <<http://gapanalysis.nbii.gov>> or CD.

Maryland

Data on GAP web site <<http://gapanalysis.nbii.gov>> or CD.

Massachusetts

Data on GAP web site <<http://gapanalysis.nbii.gov>> or CD.

Michigan

Data on GAP web site <<http://gapanalysis.nbii.gov>> or CD.

Minnesota

Project under way.

Anticipated completion date: December 2005

Contact:

Gary Drotts

Minnesota Department of Natural Resources, Brainerd

gary.drotts@dnr.state.mn.us, 218-828-2314

Land cover: Land cover mapping followed the Upper Midwest GAP protocol <<ftp://ftp.umesc.usgs.gov/pub/misc/umgap/98-g001.pdf>>. The state Department of Natural Resources (DNR) completed classification of the entire state and, with the assistance of NatureServe, cross-walked the classification to the National Vegetation Classification System (NVCS).

Animal modeling: Hexagon species range maps have been developed for Minnesota and delivered to the U.S. Geological Survey (USGS) Upper Midwest Environmental Sciences Center (UMESC). The animal modeling coordinator for the Minnesota DNR is Jodie Provost (Jodie.provost@dnr.state.mn.us). Vertebrate distribution mapping will be completed in 2005.

Land stewardship mapping: Stewardship mapping is completed.

Analysis: Gap analysis will be completed in 2005.

Reporting and data distribution: Draft stewardship coverage is available from UMESC. Contact Kirk Lohman at 608-783-7550 x58 or klohman@usgs.gov.

Mississippi

Data on GAP web site <<http://gapanalysis.nbii.gov>> or CD.

Missouri

Data on GAP web site <<http://gapanalysis.nbii.gov>> or CD.

Montana

Data on GAP web site <<http://gapanalysis.nbii.gov>> or CD.

Nebraska

Draft data available from state contact <<http://www.calmit.unl.edu/gap/>>.

Anticipated completion date: June 30, 2005

Contacts:

Geoffrey M. Henebry, Coordinator
CALMIT, University of Nebraska-Lincoln
ghenebry@calmit.unl.edu, 402-472-6158

James W. Merchant, PI
CALMIT, University of Nebraska-Lincoln
jmerchant1@unl.edu, 402-472-7531

Land cover: The land cover map has been completed.

Animal modeling: Animal models have been completed.

Land stewardship mapping: Land stewardship mapping has been completed.

Analysis: Gap analyses have been completed.

Reporting and data distribution: Draft report, species atlases, GIS coverages, and metadata under review by state experts before delivery.

Nevada

Data on GAP web site (<http://gapanalysis.nbii.gov>) or CD.
Remapping under way (see Southwest Regional GAP).

New Hampshire

(See Vermont and New Hampshire.)

New Jersey

Data on GAP web site <<http://gapanalysis.nbii.gov>> or CD.

New Mexico

Data on GAP web site <<http://gapanalysis.nbii.gov>> or CD.
Remapping under way (see Southwest Regional GAP, p. 75).

New York

Data on GAP web site <<http://gapanalysis.nbii.gov>> or CD.

North Carolina

Draft data available from state contact. Review under way.

Anticipated completion date: August 2005

Contact:

Alexa McKerrow
North Carolina State University, Raleigh
mckerrow@unity.ncsu.edu, 919-513-2853

Land cover: Complete.

Animal modeling: Complete.

Land stewardship mapping: Complete.

Analysis: Complete.

Reporting and data distribution: The land cover, stewardship, and analysis chapters are complete and in review. The vertebrate modeling chapters are in preparation.

North Dakota

Data on GAP web site <<http://gapanalysis.nbii.gov>> or CD.

Ohio

Project under way.

Anticipated completion date: September 2006

Contacts:

Land cover, Dr. J. Raul Ramirez
The Ohio State University Center for Mapping, Columbus

raul@cfm.ohio-state.edu, 614-292-6557

Animal modeling, Troy Wilson
U.S. Fish and Wildlife Service, Reynoldsburg
614-469-6923

Land cover: The land cover map for Ohio was completed on June 30, 2004, and went through a peer review process. We incorporated the changes that resulted from the peer review process and plan to perform a quality assessment to finish the land cover map by June 2005.

Animal modeling: In 2004, we began to develop wildlife habitat models. Currently, approximately 30 percent of the species are complete. We plan to complete model development in 2005, followed by expert review, and begin draft predicted distributions upon completion of the final draft of the land cover map. In addition, the Ohio Department of Natural Resources Division of Wildlife is currently funding a study through Ohio State University that involves a statewide assessment of mammalian diversity in Ohio. We plan to incorporate these efforts to update current hexagon range information in the coming year. Draft predicted species distribution mapping began in June 2005. We anticipate completing all species distributions, along with their review, by December 2005.

Land stewardship mapping: The Land Stewardship map was completed and revised in 2004.

Reporting and data distribution: The Ohio terrestrial gap analysis and final report will be completed by June 2006.

Oklahoma

Data on GAP web site <<http://gapanalysis.nbii.gov>> or CD.

Oregon

Data on GAP web site <<http://gapanalysis.nbii.gov>> or CD.

Pennsylvania

Data on GAP web site <<http://gapanalysis.nbii.gov>> or CD.

Puerto Rico

Project underway.

Anticipated completion date: December 2005

Contact:

William Gould, PI

Geographic Information Systems and Remote Sensing Laboratory
USDA Forest Service-International Institute of Tropical Forestry,
San Juan
wgould@fs.fed.us, 787-766-5335 x302

Land cover: Our land cover layer includes spectral information from eighteen Landsat-7 ETM+ scenes (2000–2003) corrected for atmospheric distortion and cloud and cloud-shadows, and pan-sharpened to a 15-meter resolution. Pixel classification is being performed using ERDAS Imagine 8.7 and incorporates image stratification and unsupervised classification, site visits, and visual interpretation of aerial photography and Ikonos imagery. Final pixel classification will be completed in spring 2005 and will result in a set of 35–40 land cover units. Plant community descriptions are in development and are being organized into a hierarchical legend structure along gradients of climate, substrate, topographic position, and stand age as governed by disturbance and land-use history. These gradients are the key controls on plant community composition and structure in Puerto Rico. Initial pixel classification includes the delineation of urban areas based on spectral response values and visual interpretation and is followed by further classification through an analysis of patterns of development (urban pixels) and population density. From this analysis, we have developed a set of three land-use categories: urban, densely populated rural, and sparsely populated rural (Figure 1).

The developed land cover in Puerto Rico is significant and covers approximately 11 percent of the land surface. We have classified approximately 16 percent of the island as urban, with a high proportion of developed relative to vegetated pixels. The urban use category contains developed areas (Figure 2), urban forest, wetlands, and open space and these are important for both our animal modeling and for understanding the dynamics of land cover change and threats to the sustainability of biodiversity. A second important set of land cover classes are the wetlands and mangroves. We are conducting an analysis of the current and historical aerial extent of mangrove forests and other wetlands relative to the area of coastal plain in Puerto Rico. We will incorporate our land cover map with ancillary GIS layers on surface waterbodies and streams, geology, physiography, landforms, elevation, rainfall, and road networks in order to develop predicted habitat models.

Animal modeling: Our Access relational vertebrate database (PRGAP-VERT) contains an expert-reviewed list consisting of 436 vertebrate species known to occur across Puerto Rico or its offshore islands. From this total, we have identified a subset of 176 vertebrate species to initially include in the terrestrial component of the gap analysis of Puerto Rico. This subset of species includes those considered endemic, resident, or breeding migratory, or of special concern due to their establishment through human introductions or range expansion.

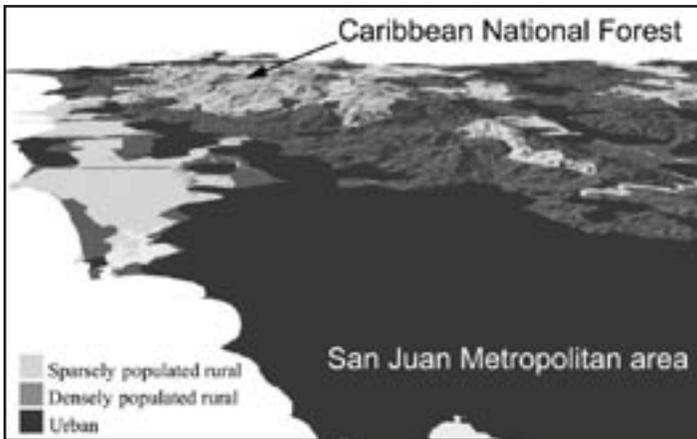


Figure 1. Using a combination of remote sensing and census data, we have developed three land use classes for Puerto Rico: urban, densely populated rural, and sparsely populated rural. In this oblique view of northeastern Puerto Rico looking eastward over the San Juan metropolitan area towards “El Yunque,” the Caribbean National Forest, urban areas in dark gray are more than 20 percent developed within a 1 km² area, densely populated rural areas are less than 20 percent developed but with population densities higher than 200 people per km², and sparsely populated areas are less than 20 percent developed and less than 200 people per km².

All 436 species can be related to the Puerto Rico Gap Analysis Project’s (PR-GAP) Vertebrate Occurrence Records (VOR) data set through either of three unique identifiers: NatureServe’s element code, the taxonomic serial number (TSN) of the Information Taxonomic Information System (ITIS), or the element code as maintained by the Puerto Rico Conservation Data Center (PRCDC). PR-GAP’s VOR data set grew from 873 element occurrence records provided by the PRCDC to over 30,000 occurrence records as a result of integrating occurrence information from sources including the USGS Breeding Bird Survey (BBS), Audobon’s Christmas Bird Count (CBC), the Institute of Tropical Ecosystem Studies (ITES), and cooperative efforts by other local agencies, organizations, and individuals. This VOR data set represents a significant resource for biodiversity research and conservation in the Caribbean.

Additionally, we are developing PRGAP-VERT with the understanding that certain aquatic and marine species are important elements of terrestrial landscape biodiversity due to their dependence on land cover types associated with a coastal-marine transition zone. The necessity of incorporating logic and methodology in our habitat modeling of terrestrial landscapes to include Puerto Rico’s proportionately significant coastal-marine habitats identifies the potential importance of conducting a combined aquatic and marine gap analysis for Puerto Rico after the completion of the terrestrial component.

We continue our collaboration with local projects to augment our VOR data set to better support island-wide species range

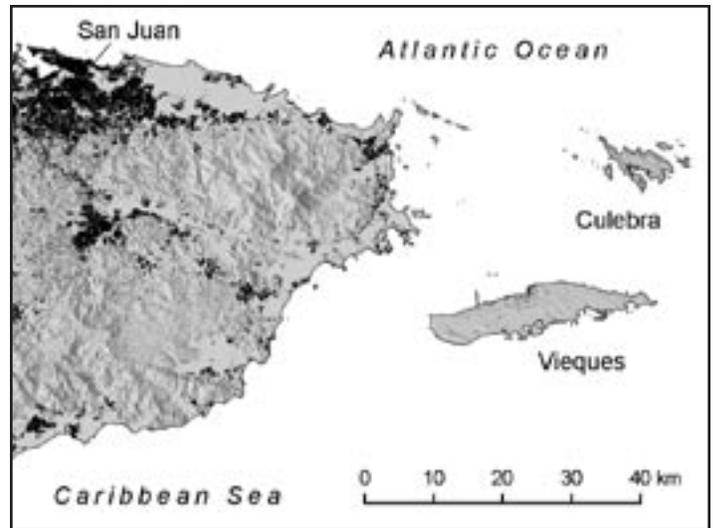


Figure 2. Black areas on map represent urban land cover in eastern Puerto Rico.

mapping efforts. Species range distributions are based on a minimum mapping unit of 24 km² represented by a hexagonal grid established by the U.S. Forest Service’s Forest Inventory and Analysis program (FIA) and modified by PR-GAP (Figure 3).

We continue to generate Access vertebrate species account reports, which, as they are completed, are submitted to experts as part of the expert review process. Each report includes the species taxonomy, conservation status, and life-history description, a concise description of the wildlife habitat relationship model (WHRM), and a range map depicting the species range distribution.

Land stewardship mapping: The Puerto Rico land stewardship layer began with the acquisition of two GIS layers representing management boundaries for most federal and commonwealth protected areas in Puerto Rico. These layers are managed by the Puerto Rico Planning Board and the executive branch of Puerto Rico’s governing administration. Using these layers as a starting point, we established an itinerary to conduct site visits with all federal and commonwealth management units to acquire additional or updated boundary information and associate management policy documents. This effort has resulted in the development of Puerto Rico’s first comprehensive land stewardship database (PRGAP-LAND) managed in an Access relational database environment. A land stewardship map (Figure 4) is one of the many products being derived from this effort.

Through this process, we are incorporating necessary quality assurance/quality control measures in response to source data set inconsistencies requiring documentation or modification, such as edge-matching with existing political and current coastline boundaries. In addition, vital land-unit management policy (and activity) is either lacking documentation and/or lacks delineation

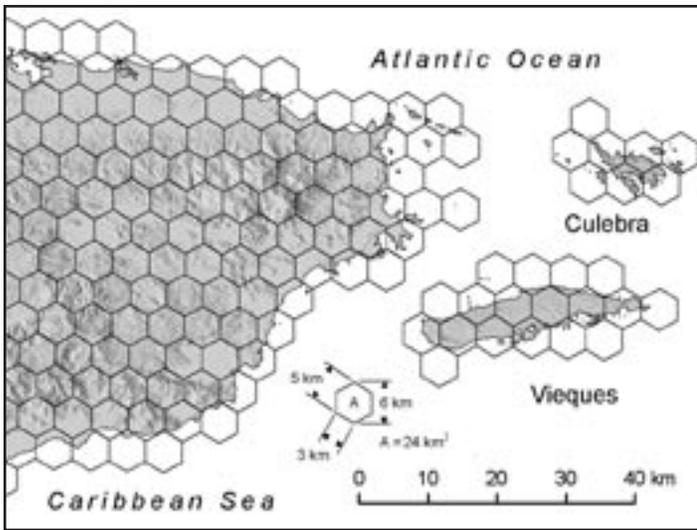


Figure 3. PR-GAP-HEX for eastern Puerto Rico.

of its management-unit boundaries, resulting in the need to create internal boundaries within a particular protected area to accurately reflect current management. Nearly completed, PRGAP-LAND contains text description and coding on land ownership and management classification, GAP management status classification and description, and protected area resources and conservation threats, as well as an annotated bibliography of related studies and publications.

Preliminary assessment of the existing protected areas identifies a total of 725 km² (8 percent) of Puerto Rico's 8,959 km² area with some level of protected status. Of this total, 60 percent is managed by the commonwealth, 28 percent by U.S. federal agencies, and 12 percent by local private organizations. To be consistent with other state-level projects, we are classifying land-unit management status according to methodology presented in the Gap Analysis Program Handbook. However, our research into the management policy of Puerto Rico's protected areas has identified a need to develop a management status classification scheme unique to Puerto Rico's commonwealth status, one we feel more realistically qualifies each protected area's management in regard to its conservation policy on the protection of biological diversity.

During site visits to protected areas, we interview each land manager directly to better assess the area's management strategies (often undocumented, or if documented, not implemented). To date, 31 of 58 site visits (53 percent) have been conducted, with an expected completion date of May 2005. By managing all this information in an Access relational database, we are able to establish entity relationships between geospatial information contained in our PRGAP-GEOD (PRGAP geodatabase) and tabular data consisting of management policies and activities, biodiversity threats, and



Figure 4. Dark grey areas show protected areas of eastern Puerto Rico.

protected area resources found at each site. As part of this effort, we are generating management area reports, maps, and posters from our information so we can provide these as a service to local area management units and for use as an educational outreach tool.

Analysis: Gap analyses will begin in the fall of 2005 following expert review of our final land cover map, vertebrate distribution models, and land stewardship layer and management status classification.

Reporting and data distribution: Reporting has been ongoing in the form of presentations and posters, both at the national and the local levels. Efforts this year include the preparation of manuscripts and maps on urban cover, physiography, and landforms of Puerto Rico. In addition, we will soon publish a color brochure describing the project that will be available in both Spanish and English.

Other accomplishments and innovations: Accomplishments by PR-GAP include the ongoing development of the PRGAP-VERT and PRGAP-LAND Access relational databases, which, when completed, will be merged into a centralized database model (Figure 5) to serve as an interface tool for exploration of PR-GAP geospatial data; report-based information on species and protected areas; and other maps and documents.

The opportunity to provide comprehensive descriptive information and maps on current land cover and land-use descriptions, species distributions and habitat associations, protected and other areas critical to biological diversity, and land management strategies and conservation threats is unprecedented for Puerto Rico. There are a number of pressing conservation issues in Puerto Rico, as well as the Caribbean, that will

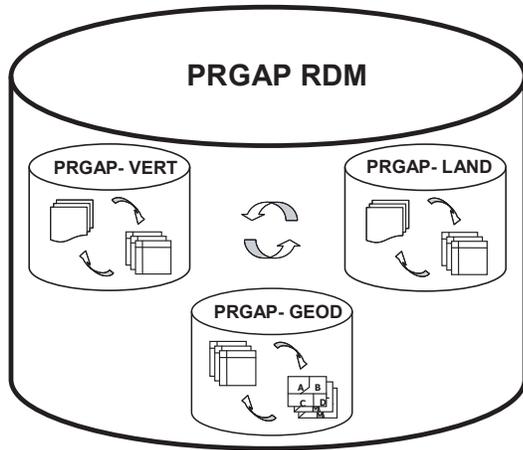


Figure 5. PR-GAP tabular and geospatial relational database model (RDM).

benefit from this gap analysis. These data are providing a good foundation on which to build long-term and comprehensive biodiversity databases for the Caribbean region.

Rhode Island

Data on GAP web site <<http://gapanalysis.nbii.gov>> or CD.

South Carolina

Data on GAP web site <<http://gapanalysis.nbii.gov>> or CD.

South Dakota

Data on GAP web site <<http://gapanalysis.nbii.gov>> or CD.

Tennessee

Draft data available from state. Review under way.

Anticipated completion date: October 2005

Contact:

Jeanette Jones
Tennessee Wildlife Resources Agency, Nashville
Jeanette.Jones@state.tn.us, 615-781-6534

Texas

Data on GAP web site <<http://gapanalysis.nbii.gov>> or CD.

Utah

Data on GAP web site <<http://gapanalysis.nbii.gov>> or CD.
Remapping under way (see Southwest Regional GAP, p. 75).

Vermont and New Hampshire

Draft data available from state contact. Review under way.

Contact:

David E. Capen
University of Vermont, Burlington
dcapen@snr.uvm.edu, 802-656-3007

Virginia

Data on GAP web site <<http://gapanalysis.nbii.gov>> or CD.

Washington

Data on GAP web site <<http://gapanalysis.nbii.gov>> or CD.

West Virginia

Data on GAP web site <<http://gapanalysis.nbii.gov>> or CD.

Wisconsin

Project under way.

Anticipated completion date: September 2005

Contact:

Kirk Lohman
U.S. Geological Survey
Upper Midwest Environmental Sciences Center, La Crosse
klohman@usgs.gov, 608-781-6341

Land cover: Land cover mapping is completed, and a draft version is available from the USGS Upper Midwest Environmental Sciences Center (UMESC).

Land stewardship mapping: The Wisconsin DNR compiled data for state, county, and U.S. Forest Service lands. UMESC acquired coverages of U.S. Department of the Interior lands and compiled the complete stewardship coverage.

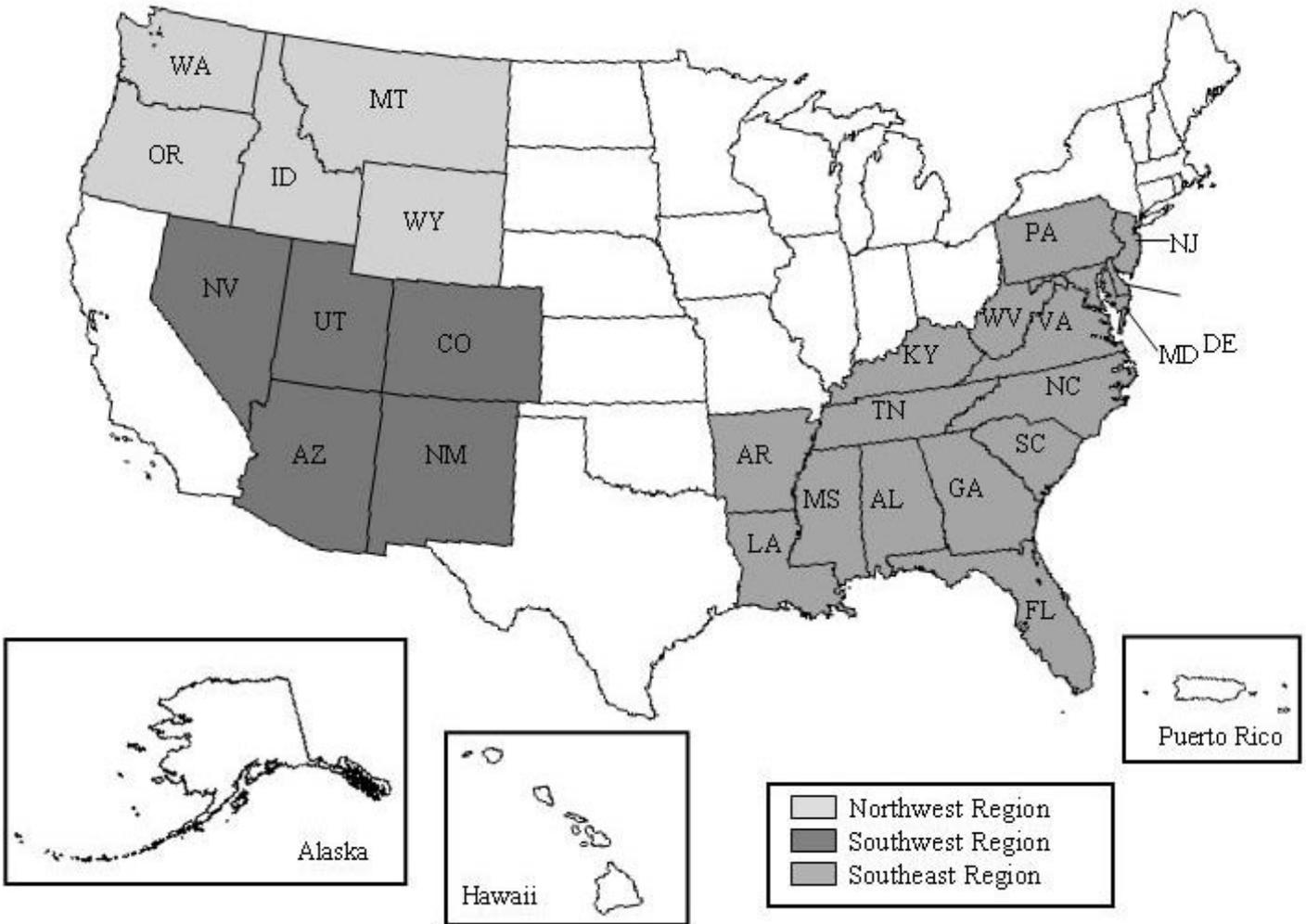
Reporting and data distribution: Land cover and stewardship coverages are available from UMESC. Contact Kirk Lohman at 608-781-6341 or klohman@usgs.gov.

Wyoming

Data on GAP web site <<http://gapanalysis.nbii.gov>> or CD.

REGIONAL PROJECT REPORTS

(Status as of April 2005)



Northwest Regional GAP (NWReGAP)

Update under way this year for the five-state region including Washington, Oregon, Idaho, Montana, and Wyoming.

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NWReGAP started in August 2004 and will be mapping the land cover, species distributions, and land stewardship for Washington,

Oregon, Idaho, Montana, and Wyoming. These data will help with conservation efforts throughout the Northwest.

Land cover: Sanborn (formerly Space Imaging) in Portland, Oregon, has been contracted to classify imagery from mapping zone 1 (Western Washington). They are working with Natural Heritage biologists to define the ecological systems occurring within this mapping zone.

To date, Sanborn staff have developed a final classification scheme using ecological systems. They have acquired numerous ancillary data from various sources, including the Washington Department of Natural Resources and the U.S. Forest Service. They have developed transitional classes for forest clear-cuts that

indicate what vegetation currently exists within mapped clear-cuts. They have obtained copious amounts of training data, which have helped them develop an Olympic National Park prototype.

Olympic National Park has been defined as one of the ecoregions within mapping zone 1, within which classification and regression tree (CART) modeling will be conducted. Based on training data obtained from the U.S. Forest Service, an initial run of the CART model has been completed for this ecoregion. The results indicated that CART broke out different ecological systems reasonably well. This prototype has helped identify issues that need to be addressed to effectively apply the CART modeling approach in the other ecoregions.

Sanborn intends to complete this mapping zone by September 2005.

Vertebrate modeling: The Conservation Biology Institute (CBI) has begun to build a species occurrence database. CBI staff have assembled a species list for the Northwest and have obtained occurrence as well as ancillary data from numerous sources. At this time, national GAP is exploring avenues for conducting vertebrate modeling over this five-state region. Since the completion of the individual state projects in the Northwest, many modeling innovations have been developed, which may improve our ability to predict species distributions.

Southeast Regional GAP (SEReGAP)

Update under way for the thirteen-state region.
Anticipated completion date: June 2006

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Land cover: Four of the seven mapping zones for which we are developing the National Land Cover Data Set (NLCD) (2001) have been submitted to EROS Data Center (EDC) for a second review (Figure 1). Those include the East Gulf Coastal Plain (46), the Southern (54) and Northern Piedmont (59), and the Coastal Plain of North and South Carolina (58). The remaining

three mapping zones are currently under way with the BaSIC lab taking the lead on the Southern Coastal Plain (55) and Interior Highlands of Tennessee (48) and NaRSAL taking the lead in the Blue Ridge and Ridge and Valley (57).

Impervious surface estimates have been completed for all but one (55) of the seven zones and that is expected to be approved and released through the NLCD web site within weeks.

Canopy closure estimates for the Coastal Plain of North and South Carolina (58) are near completion, with the East Gulf Coast (46) and the Southern Coastal Plain (55) scheduled for completion by April 2005. The remaining four zones (57, 54, 59, and 48) will be completed in a staggered fashion through the end of the project period.

We are shifting to the GAP-level detailed vegetation mapping phase of the project. The Alabama Gap Analysis Project (AL-GAP) has the majority of their field data gathered and compiled with respect to the target map units (see McKerrow and Pyne, this volume, for additional description of the classification system). For the Northern Coastal Plain, the system-level reference data collection is near completion. We are currently reviewing the point data from the North Carolina Gap Analysis Project (NC-GAP) to remove points where the land cover has shifted. For the Piedmont zones, the Georgia Gap Analysis Project (GA-GAP) and NC-GAP data and additional field data and photo-interpreted reference points are starting to be compiled now. For the remaining five mapping zones, reference data collection based on the digital photos, field visits, and existing data sets

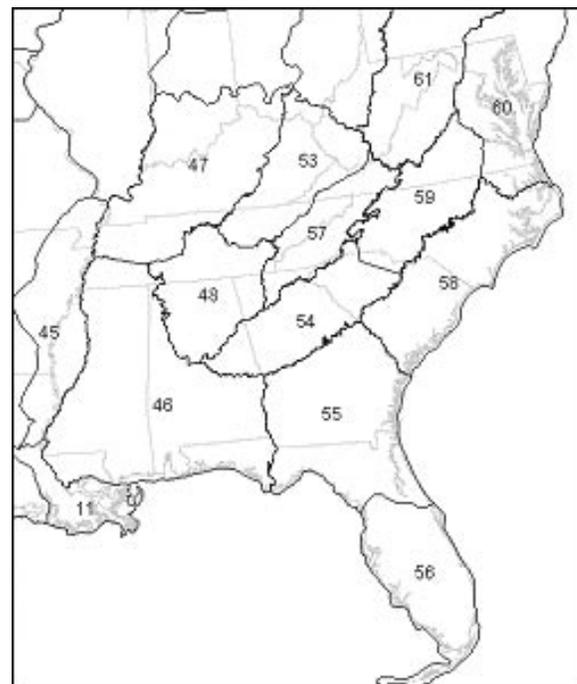


Figure 1. Mapping zones of the Southeast.

will begin in earnest after June 2005, when the first GAP-level maps will be complete. In the meantime, we have been working with NatureServe to compile a variety of existing data sets and get them cross-walked to Ecological Systems for all zones in the region. In addition to the point data collection, NatureServe has been actively delineating spatial ranges for target map units in our region. These maps are in draft format and ready for review. AL-GAP and the Alabama Heritage Program have been active in the refinement of those maps for the systems occurring in the East Gulf Coast.

The digital photo system designed for this project has been used to gather transects of photos at approximately 20 cm resolution for the majority of the region. This spring flights over the mapping zones 53 and 47 in Kentucky will be conducted to supplement the systems-level reference data collection in that area.

Ancillary data development, primarily programming and quality control on the digital elevation modeling data, has been a major focus this fall. We have been actively working with a variety of data sources to make the best available data for each of the mapping zones in the Southeast. That effort should be complete by the end of March 2005. The National Wetlands Inventory data have been vectorized for over 1,000 quads that were previously missing from our digital coverage; these quads were scanned at Auburn University and vectorized to create binary coverages at the Information Technology Outreach Services office in collaboration with the Georgia lab.

Animal Modeling: Polygonal ranges are in draft form for all

species being modeled by the SEReGAP (Figure 2). Those ranges are scheduled for review as part of the final review of the habitat affinity and distributional models. A total of 607 species will be modeled for SEReGAP (133 amphibians, 253 birds, 97 mammals, and 124 reptiles). For the full list of species being included, see the SEReGAP web site <www.segap.org>.

The habitat affinity database has been designed and is being used by the three labs to develop the species models. By April 2005, one-third of all of the species will have their models described in the database and an internal review will have occurred. Habitat affinity and ancillary parameter associations for all 607 species, along with internal reviews, are scheduled to be complete by June 2005. The final year of the project will involve incorporating the land cover project with the habitat models and conducting external reviews of the data.

Other accomplishments and innovations: This year we have continued with the SEReGAP and U.S. Fish and Wildlife Service (USFWS)/Joint Ventures Pilot project (see Williams and McKerron, this volume). We have been represented at a long list of meetings, from the national to the local level; some examples include the American Society of Photogrammetry and Remote Sensing, the Ecological Society meetings, the Department of Interior's Land Cover Summit, the Southeastern Partners in Flight, and the North Carolina Center for Geographic Information and Analysis conference. Two relevant workshops this year included the Rapid Assessment Project workshops led by the U.S. Forest Service Fire Lab and The Nature Conservancy, and the Cactus Mapping and Modeling workshop.

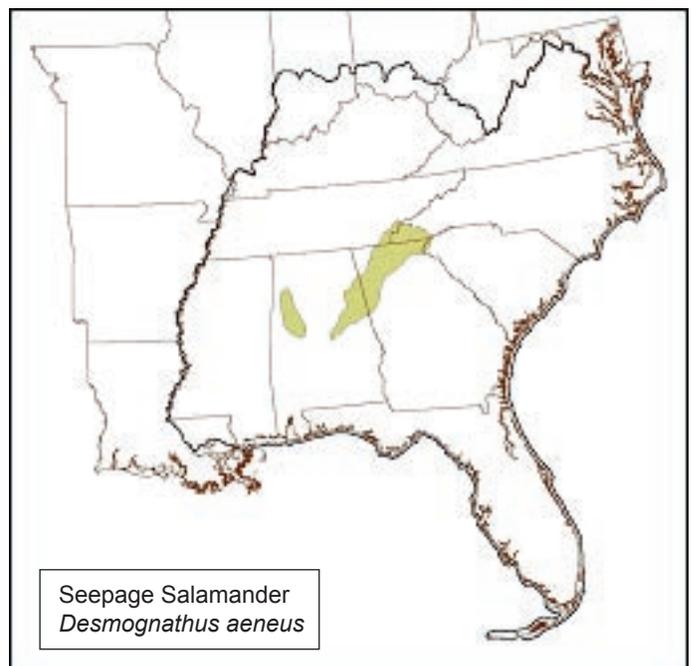


Figure 2. Examples of species range maps being developed for the SEReGAP.

Southwest Regional GAP (SWReGAP)

An update is under way for the five-state region encompassing Arizona, Colorado, Nevada, New Mexico, and Utah. State coordination for the project is facilitated through the SWReGAP web site <<http://leopold.nmsu.edu/fwscoop/swregap/default.htm>>.

Anticipated completion date: October 2005

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Land cover: The RS/GIS Lab at Utah State University is the regional land cover mapping lab for the five-state Southwest region. The regional project focused on four major objectives in 2004: (1) completing land cover modeling activities; (2) model validation; (3) producing a regional mosaic of the mapping zones; and (4) developing a data delivery system for the provisional land cover product.

The majority of natural and seminatural land cover classes were modeled using a decision-tree (DT) classifier. Advantages of

DT include the ability to use both continuous and categorical predictor data sets with different measurement scales, good computational efficiency, and an intuitive hierarchical representation of discrimination rules. Decision-tree models were validated by generating initial models using 80 percent of available samples, while withholding 20 percent of samples. Withheld samples were randomly selected and stratified by cover class. Withheld sample polygons were intersected through the land cover map to create an error matrix, presenting users, producers, and overall “accuracies.” Using the 4 km overlap region between mapping zones, a “cutline” was used to edge-match adjacent mapping areas where land cover discontinuities resulted from the modeling process. The resulting five-state region mosaic was qualitatively reviewed by the five state teams and NatureServe. Following review, a limited number of errors were “flagged” for final editing. The “edits” were determined to be relatively easy to correct with localized recoding, or a simple conditional model, and were made to the regional map.

The SWReGAP land cover data set is currently available to the public with “provisional” status from <<http://earth.gis.usu.edu/swregap/>> (see Figure 1). Because the data set encompasses such a large region, the web site allows users to download specific geographic segments of the region, such as individual states, counties, or ecoregions. Additionally, the web site offers an Internet map server from which users can interactively clip a specified rectangle in the region. The clipped data set is subsequently bundled with metadata and made available for downloading.

Animal habitat modeling: The regional project focused on six objectives during 2004: (1) collecting habitat modeling attributes;



Figure 1. SWReGAP provisional land cover data.

(2) creating region-wide modeling data sets; (3) creating a database to facilitate association compilation, expert review, and modification, and potential end-user application; (4) internal and expert review; (5) accuracy assessment; and (6) conducting a regional animal-habitat modeling workshop in Las Vegas, Nevada, in March 2004.

The region is working with an MS Access database to facilitate data collection and to compile taxa specific information for modeling purposes. The intent was to create a data set that manages information and was used to construct each taxon's wildlife habitat relationship model. Included within the database is a method for defining range limits using the eight-digit hydrologic unit code (HUC). The database also incorporates the core data layers the region had identified to be minimally addressed in each wildlife habitat relationship model. These core data layers are land cover, elevation (minimum and maximum), slope, aspect, soils, hydrology (distance to and association with permanent water), and patch size. Species were allocated to each state based on expertise and species distribution. These states were responsible for creating the habitat models for those species. The individual databases were then combined and currently any modification to the database is done through an online connection to the master database. All species data collection is complete as of this report, with modifications occurring as internal and external reviews are completed.

The region has undergone an internal review process to check consistency within the models and to provide the framework for an external review. The internal review is complete as of February 14, 2005. Expert review is beginning as of February 1, 2005, and is scheduled to be completed by April 30, 2005. The region will complete the standard gap analysis habitat modeling measure of agreement, as well as a measure of agreement with existing species occurrence records. States are currently identifying qualified species lists for the standard measure of agreement; these lists will then be provided to the regional laboratory. The Arizona project, in coordination with the regional laboratory, is identifying a procedure for using existing data to

measure the degree of concordance between habitat models and species occurrence records. This analysis will be done as models are completed, and is scheduled to be finished by July 2005.

Land stewardship mapping: The final regional stewardship and management status map is expected to be complete by June 2005. External review of stewardship mapping products began in December 2004. Nevada stewardship and management status maps have undergone the external review process, resulting in updates to internal parcel boundaries and refinements to the GAP status codes. The draft maps for Colorado are also complete and the external review is scheduled for March 2005. External reviews are also scheduled for Arizona, New Mexico, and Utah this spring. As a conservative estimate, the regional stewardship lab has collected over 300 management planning documents from various federal, state, and county entities. The process of reviewing current management plans, interviewing various land stewards, and assigning the GAP status codes is complete. In addition, most of the digital boundary information for all five states has been collected, and cooperators have been generous with providing digital parcel data layers. Currently, the regional stewardship lab is in the process of assembling the GIS database using the geodatabase format to maintain data integrity. In an effort to keep the stewardship mapping effort consistent across the region, the regional stewardship lab digitizes additional internal information when digital information is unavailable from local sources. This effort is designed to provide a consistent product across the region in both the level of mapping detail and the assignment of the GAP status codes. In addition, the detail and refinements of the stewardship product will create a better assessment in the final gap analysis.

Analysis: Analysis for SWReGAP will take place when all mapping tasks are completed. Land cover analysis and animal habitat modeling analysis will begin in May 2005.

Reporting and data distribution: All products derived from SWReGAP are scheduled to be complete by approximately October 2005.

AQUATIC GAP PROJECT REPORTS

(Status as of April 2005)

Ohio Aquatic GAP

Under way.

Anticipated completion date: September 2005

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Species modeling: Ohio Aquatic GAP predicted potential distributions for 130 fish, 17 crayfish, and 70 freshwater bivalves using either the Genetic Algorithm for Rule-Set Production (GARP) or a simple extrapolation method.

Analysis: The Ohio Aquatic gap analysis was completed in 2004. Ohio's two major watersheds, the Lake Erie and Ohio River basins, were analyzed separately. To prioritize potential conservation areas, criteria were identified for each 14-digit hydrologic unit or subbasin that maximized species richness for each taxa at each of three stream-size classes. Watersheds meeting the criteria at varying levels were identified and mapped, thus showing the best predicted areas for each taxa, as well as combinations of each taxa.

Reporting and data distribution: The Ohio Aquatic GAP final report is in review and will be ready for distribution in 2005. The report includes a discussion of watersheds identified as high conservation-priority areas using predicted species-richness values, current conservation lands, land use, and methods used to achieve these results.

The Ohio Aquatic GAP predicted-distribution data were used in a GIS-based decision support system tool designed as part of a cooperative project between the Cuyahoga River Community Planning Organization, the U.S. Geological Survey, the U.S. Environmental Protection Agency, the Ohio Department of Transportation, and the Northeast Ohio Areawide Coordinating Agency, which integrated watershed and transportation planning.

Great Lakes Regional Aquatic GAP

Anticipated completion date: September 2007

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The Great Lakes Regional Aquatic GAP project is currently in its third year, with state projects under way in Michigan, New York, Ohio, and Wisconsin, and a Coastal Pilot in western Lake Erie and eastern Lake Ontario.

Central database development: A Great Lakes Regional Aquatic GAP central relational database was developed to accommodate stream habitat characteristics, aquatic biota sample collections, and habitat affinity information for all Great Lakes Regional Aquatic GAP projects; the database is housed at the USGS Great Lakes Science Center. Fish sample collection data, including more than 57,000 sample collections from more than 25,000 different sites with data representing more than 170 different fish species, have been linked to stream segments for Michigan, New York, Ohio, and Wisconsin and loaded into the central database. Maps and expert review of the observed fish distribution data sets have been completed and the database has been revised. A web-based map application <<http://infotrek.er.usgs.gov/fishmap>> has been developed to produce dynamic species-distribution maps for Wisconsin in conjunction with a related project to update the comprehensive guide, *Fishes of Wisconsin*. Fish life-history data and habitat-affinity data have been acquired from two sources: the Ontario Freshwater Fishes Life History Database, compiled by R. J. Eakins (Eakins 2004), and a life-history database compiled by NatureServe. These data will be used to validate predicted fish distributions and analyze fish community ecology.

Stream habitat classification and modeling: Streams in Michigan, Wisconsin, Illinois, and the Great Lakes drainages of New York have been classified according to habitat

characteristics describing the channel, local riparian zone, upstream riparian zone, local watershed, and upstream watershed, and this information has been loaded into the central database. The habitat variables consist of macro-scale characteristics, including channel morphology, connection to the Great Lakes, land cover, bedrock and surficial geology, and climate. Habitat characterization is under way for the remainder of the New York drainages and for Ohio, using the same methods as the other Great Lakes Regional Aquatic GAP states. Preliminary temperature models have been developed to predict stream temperatures in Michigan, Wisconsin, and New York and will be finalized during 2005. A fish modeling workshop was held by the Great Lakes Regional Aquatic GAP team at the U.S. Geological Survey Tunison Laboratory of Aquatic Sciences in Cortland, New York, during November 2004. A number of modeling approaches have been used and compared, including multiple linear regression, linear discriminant analysis, logistic regression, classification and regression tree, and simple neural networks. The classification and regression tree, logistic regression, and neural network approaches are being tested further and pursued for analyses. Modeling of fish-environment relationships is currently under way and is a focus of Year 3 activities.

Coastal GAP pilot project: A conceptual framework for identifying and classifying coastal habitat types has been developed and applied to the western Lake Erie pilot study. A substantial amount of fieldwork was completed to help assess the efficacy of the classification framework and to collect data from unsampled and important habitat types. Habitat characteristics

that are thought to have a significant influence on the location and distribution of aquatic species include subaquatic vegetation, geomorphology, geologic formations, submerged substratum, submerged slope, and aspect, circulation, and currents. Databases of fish distributions in western Lake Erie and eastern Lake Ontario have been acquired and expert review of these data is under way. The modeling approach that has been tested in the coastal pilot project establishes a relationship between the location of the species and the characteristics of the habitat at that location before grouping similar habitat types. These groups allow for the species information to define the natural breaks in the habitat.

Outreach: Numerous papers and posters describing Great Lakes Regional Aquatic GAP progress and results have been presented at various meetings, including local American Fisheries Society (AFS) chapter meetings, the National AFS meeting, the USGS Ecological Relations with Water Quality Workshop, and the USGS National Aquatic Gap Analysis meeting. The Great Lakes Regional Aquatic GAP team continues to work closely with stakeholders in each of the Great Lakes Regional Aquatic GAP states and the coastal pilot project.

Becker, G. C. 1983. *Fishes of Wisconsin*. Madison: University of Wisconsin Press. 1,052 pp.

Eakins, R. J. 2004. Ontario Freshwater Fishes Life History Database. Version 2.56. Online database (<http://www.afs-soc.org/fishdb/index.htm>), accessed April 12, 2004.

NOTES AND ANNOUNCEMENTS

Announcing National Gap Analysis Program Meeting in Nevada

The National Gap Analysis Program Meeting will be held December 6–8, 2005, at the Silver Legacy Resort Casino in Reno, Nevada. The U.S. Geological Survey (Gap Analysis Program), Environmental Protection Agency (Office of Research and Development), Fish and Wildlife Service, and the Bureau of Land Management will host the meeting. The focus will be the Southwest Regional Gap Analysis Project (SWReGAP) in Nevada, Utah, Colorado, Arizona, and New Mexico.

Further information about the conference and registration information will be made available. For any additional questions, please contact Nicole Coffey at 208-885-3555 or ncoffey@uidaho.edu.

New Staff at National GAP Office

Three of our colleagues have left the GAP office in the past year:

- GIS Analyst Ree Brannon has returned to school at the University of Idaho to pursue a Ph.D. in conservation social sciences.
- GIS technician Joe Cullen has returned to school at the University of Arizona to pursue a Ph.D. in economics.
- GIS technician Ajay Sisodia has completed his master's degree and left us to pursue his career with GeoAnalytics in Madison, Wisconsin.

We will miss Ree, Joe, and Ajay and wish them well in their new endeavors.

We have hired new staff to take over their tasks: Jocelyn Aycrigg, Nicole Coffey, and Todd Sajwaj.

In addition to pursuing her Ph.D., Jocelyn is working half-time at the National Gap Program Office as a Conservation Biologist. She is coordinating the Northwest Regional Gap Project, which began in September 2004 and which encompasses Montana, Wyoming, Idaho, Washington, and Oregon. She is also working with various states to help them finish up their GAP projects.

Jocelyn was born and grew up in Colorado. She received her B.A. degree from the University of Colorado at Boulder in environmental biology and her M.S. from the State University

of New York College of Environmental Science and Forestry. Her thesis explored the socio-spatial behavior of white-tailed deer in the Adirondack Mountains of New York.

Jocelyn's professional experiences include working with the U.S. Fish and Wildlife Service and Pacific Gas and Electric in San Francisco Bay on a contaminant study of the bay as well as a power line bird mortality project. In upstate New York, she was a contractor with Colorado State University in the Environmental Division of Fort Drum (a military installation) doing GIS modeling and data management. She also worked with the U.S. Army Corps of Engineers Research Laboratories (USACERL) and the University of Illinois in Champaign, Illinois, modeling the impact of military training on desert tortoises in the Mojave Desert. After that experience, she worked at the Illinois Natural History Survey while she was the Illinois Gap Project leader.

Jocelyn then decided to return to graduate school to pursue her Ph.D. in wildlife population ecology. She is currently a Ph.D. student in the Department of Fish and Wildlife Resources at the University of Idaho. Her dissertation focuses on the population dynamics and genetic population structure of elk throughout Idaho. Her research question addresses whether the metapopulation concept can be applied to improve the management of elk. You can contact Jocelyn at 208-885-3901 or e-mail her at Aycrigg@uidaho.edu.

Nicole Coffey is GAP's new Administrative Officer. She has a bachelor's degree from California State University, Sacramento, and will be attending graduate school at the University of Idaho. She comes to us with seven years' experience working as an administrative assistant for a prominent law firm in California. As Administrative Officer, Nicole's responsibilities include budget and financial analysis, record keeping for all agreements, oversight of agreement closeout procedures, and agreement audits. If you have any questions related to new proposals, agreement matters, or any general questions related to the Gap Analysis Program, please contact Nicole at 208-885-3555 or e-mail her at ncoffey@uidaho.edu.

Todd Sajwaj grew up in St. Paul, Minnesota, and earned his B.S. in ecology, evolution, and behavior at the University of Minnesota. Following a period working as an itinerant field technician in Michigan, South Carolina, and California, Todd attended the University of North Dakota, where he earned an M.S. degree in biology. His thesis research focused on the thermal ecology of Blanding's turtles at the Army National

Guard's Camp Ripley Training Facility in central Minnesota. Todd then went on to attend Utah State University (USU), where he earned a second M.S. degree in geography and earth sciences, specializing in the application of remote sensing/GIS technologies to issues in landscape ecology. His thesis at USU investigated the sensitivity of a temporal sequence of landscape metrics to significant ecological disturbances at the Camp Williams Training Facility in central Utah.

Todd's professional experience began with directing land cover mapping efforts for the Nevada ecoregion of the Southwest Regional GAP Project while working for the U.S. Army Corps of Engineers. Subsequently, he went on to continue mapping land cover and developing a geospatial data browser for Lockheed Martin's Environmental Services office in Las Vegas, Nevada. You can contact Todd at 208-885-3720 or e-mail him at tsajwaj@uidaho.edu.

The *Gap Analysis Bulletin* is published annually by the USGS Biological Resources Discipline's Gap Analysis Program. The editors are Jill M. Maxwell, Kevin Gergely, Jocelyn Aycrigg, Doug Beard, Todd Sajwaj, and Nicole Coffey.

To receive the Bulletin, you may write to *Gap Analysis Bulletin*, USGS/BRD/Gap Analysis Program, 530 S. Asbury Street, Suite 1, Moscow, Idaho 83843, fax: 208-885-3618, e-mail: ncoffey@uidaho.edu. You may also contact the National Technical Information Service or the Defense Technical Information Center (see Report Documentation Page, 12, Distribution and Availability Statement). A digital version of the Bulletin, containing additional graphics, is available on the Internet at <http://gapanalysis.nbi.gov> in the Literature section. The digital version offers some graphics in color and, thereby, provides a more specific rendering of selected data and information.

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