CONTENTS

FINAL REPORT SUMMARIES

APPLICATIONS

STATE PROJECT REPORTS

NOTES AND ANNOUNCEMENTS

This issue is dedicated to the memory of Jack Estes

Jack Estes, one of the giants of remote sensing, passed away Friday, March 9, in Santa Barbara after a month-long battle with cancer. Jack has been a driving force in the advancement of remote sensing science, technology, and applied program development worldwide for the past three decades. In addition to being instrumental in the development of Gap Analysis, he was a major asset to the USGS, the International Geosphere-Biosphere Programme (IGBP), NASA, and many similar organizations. He directed the Remote Sensing Research Unit at the University of California-Santa Barbara and taught in the department of geography. Of the many books, book chapters, and journal articles he authored, perhaps he will be best remembered for his contribution to the well-known Manual of Remote Sensing (1983, ASPRS). In late 1999 Estes and others published "The Way Forward" in Photogrammetric Engineering and Remote Sensing (65:1089-1093), an evaluation of the prototype and vision for a continuously updated global 1 km earth cover data set.

In "A Perspective on Trends in Conservation, GAP, and a Vision for the Future of Biodiversity Managed Areas" (Scott, Tear, Davis, eds, 1996, ASPRS), Jack articulated some of the challenges that GAP would face, such as politics and political influence, lack of agreement among scientists concerning conservation priorities, lack of program support, lack of public awareness, and the institutional loss of sight of the GAP mission. He was right about these and other issues, and his loss leaves a gap that cannot be filled.

"The vision I hold for the future of GAP is global in scale and comprehensive in scope. It is for an integrated partnership of national and international agencies, non-governmental organizations, and private industry. It has a small but efficient, integrated management structure with supporting advisory panels. It has an effective operational support organization with an adequate budget. A funded, prioritized supporting science program is also in place. Global GAP has acceptable standards for data acquisition, network communications, processing, output products, and storage and archiving. It is part of a comprehensive global spatial data framework of linked, distributed databases. Databases where all interested parties are able to communicate in an effective and efficient fashion, and acquire and validate the data/information they require for their application. A future where advanced satellite survey, airborne inventory, surface sampling and ancillary digital data acquisition procedures are applied in an integrated fashion to measure, map, monitor, model, and manage conservation areas. A future where we know the levels of accuracy and understand more fully the potential pitfalls associated with the data/information decision processes in which we are engaged. A time where neither governments, their militaries, private industries, or any other special interest groups use national security, national sovereignty, copyright or proprietary rights as an excuse to inhibit the open, unrestricted flow of environmental information. A future where the infrastructure exists to use GAP data/information to make wise choices/decisions that will lead to improved conservation strategies and an effective network of biodiversity managed areas for the benefit of the world community.

I'll close with the words of the pop poet/songwriter John Lennon: 'You might say that I'm a dreamer; but I'm not the only one.' "

Jack Estes, 1996

NATIONAL NOTES

KEVIN GERGELY
National Gap Analysis Program, Moscow, Idaho

The big news this past year is the GAP budget. A major addition was made to the Department of the Interior funding bill in the final stages of the appropriations process. This was a compromise proposal, which was aimed at meeting some of the needs identified in CARA proposals, but at the same time kept the annual funding under control of the Appropriations Committees, instead of making it permanent and automatic.

The fiscal year 2001 Interior spending bill included an "authorization" of $1.6 billion for environmental programs, and it included actual "appropriations" of $1.2 billion towards that authorized level. This amount is made up of base funding for ongoing programs, totaling over $500 million, plus a brand-new program called the Land Conservation, Preservation and Infrastructure Improvement program. Nearly $700 million of new funds were provided for environmental initiatives, primarily for the major federal lands agencies–the Fish and Wildlife Service (FWS), the National Park Service (NPS), and the Forest Service (FS).

While the GAP funding increase is a very small portion of a $1.6 billion dollar concept, it has major implications for us. First, it will speed the completion of the Lower 48 data set, which is our primary goal. Second, Congress directed us to spend at least $2 million on Gap Analysis of aquatic resources. Over the past few years, only small amounts of money were spent on aquatic GAP, but the idea has been extremely popular. Many of our cooperators want to expand their projects to include similar analyses of aquatic resources. We have struggled to keep a few prototype projects under way and have been frustrated at the number of requests we have had to turn down simply because no funds were available. Finally we have an opportunity to do more.

More importantly, I hope this funding increase is a signal that GAP has taken a major step towards being recognized as a vital component of conservation planning and management.

I remember being asked about the GAP budget at our National Meeting in San Antonio. At the time, it seemed Congress was likely to approve $500,000 of new funds out of the requested increase of $4 million. I replied that I believed that the U.S. Geological Survey managers had shown a great amount of vision to request more than a 100% increase for GAP, because we certainly needed the funds and could quickly use them for very high priority work. However, I was not surprised that Congress initially took an incremental, conservative approach. I was thankful for even a little financial help. I thought there was a big difference between getting a small operational increase and getting a relatively huge programmatic expansion. The former took a little commitment on the part of those that knew about GAP and were influential in the budget process. The latter took a leap of faith. I would like to say thanks to those that had the faith and helped us get such an increase.

So is this it? Was this last year a major turning point for the Gap Program? Have we received status and recognition from the policy world? Do we now have our mandate?

Sometimes it seems like the word on GAP has spread everywhere. In this past year, we have been in contact with scientists from Japan, Australia, the Netherlands, South Africa and Brazil, and various other parts of the world, all interested in or involved in GAP-like analyses. The Chinese have taken on a major project to use GAP to identify potential reserves in the Yunnan Province, and they sent a team of scientists to the States last year for training on developing GAP data. Our partnership with Mexico to jointly map the Rio Grande region as a means of technology transfer has also picked up steam this past year. There seems to be commitment to developing a system of national reserves in Mexico, and several states–including Nuevo Leon and Tamaulipas–seem ready to invest in GAP for use in reserve identification and selection.

On the other hand, when working with our most likely federal partners, such as the FWS or the Bureau of Land Management (BLM) we still find a need to do basic education about GAP, what the program does, and how our data can be incorporated into a comprehensive analysis of biodiversity. On specific projects, we have some major accomplishments to show. We are working on a prototype decision support system using GAP data to help the FWS ecosystem team in eastern North Carolina make decisions about land acquisition and restoration projects. We are also working on a partnership with BLM and the FS to take regionalized GAP data from western states and revise them to help evaluate future conservation needs for shrub-steppe habitats and for long-term protection of the sage grouse. We need to turn these types of projects into success stories that will help us become better integrated into federal land management.

How can this disparity exist? Are we really world leaders in conservation, having developed an operational model that is practical, applicable, and a meaningful extension of the core concepts in the conservation biology literature? Or, are we just a little more data for the mix–one of many partial solutions to complex conservation problems? How much impact can we make?

The next year or two will tell us much. This program has held together over time. With the end of this past year, we have fulfilled the long-held vision of getting projects under way in every state in the Lower 48. The continued hard work of our cooperators is paying off, and it seems like each day another state is sending us their completed data sets. We have set out a plan in the National Office to begin regionalizing data sets–something we have known many of our users want, but that has been just beyond our reach. Now we have received a vote of confidence from Congress through the appropriations process.

We'll show them, I'm sure, that it is the best money they ever spent!

Enhancing the GAP Organization

LIEF HORWITZ, JOHN MOSESSO, AND ROB DIETZ
USGS/BRD Biological Informatics Office, Reston, Virginia

Since its inception eleven years ago, GAP has evolved from a way to examine the correlation between Hawaiian bird species and conservation areas into a national program with projects completed in 19 states and under way in all the other states with the exception of Alaska. Working with limited resources and faced with the challenge of transferring a visionary concept into a functional program, GAP has emerged as an innovative approach for collecting biodiversity information. Resource managers, land stewards, policy makers, elected officials, educators, and the general public are the beneficiaries of GAP products–land cover, species range and stewardship maps, as well as corresponding analytical resources–that provide them with valuable tools in the pursuit of understanding the status of biodiversity protection across the nation.

From the beginning, GAP has been clear in purpose and cognizant of the elements needed to carry out that purpose. The program provides national biodiversity information through a bottom-up organization that maximizes use of local interests and expertise. Funding projects at the state level ensures local control and “ownership” and draws upon the scientific expertise and other resources needed to make an efficient and successful state project.

More recently, regional approaches have created new efficiencies in the science and methodologies of GAP. Just as the focus of GAP is dynamic, with technologies and approaches that are constantly in flux, the organizational structure of GAP is adjusting as well in pursuit of improvement and innovation.

A renewed realization of the value of the program by Congressional and Departmental contacts, coupled with the increased importance of timely and comprehensive biodiversity data for a wide variety of GAP data users, have brought about a crucial increase in our fiscal year 2001 budget. Strong advocacy has provided the program with an opportunity to accelerate the completion of ongoing projects, expand the aquatic component, and examine how to best proceed with our ultimate objective of making data and tools widely available on a national scale. Consideration of these objectives and the desire for an aggressively planned and focused program have spawned a new organizational approach.

With the understanding that any successful organization must invest in itself, the program has been restructured. Five distinct components have been identified–operations, research and development, information technology and data dissemination, program development, and education and participation. Each component has a coordinator who has developed a working plan that delineates its purpose and scope. Funding opportunities for specific proposals within each component were made available in this budget cycle. This approach allows the operations component to dedicate its energies to the task of completing and updating state projects while other components can focus on gathering specific expertise and support for increased use of GAP products. The objectives of the five components follow.

Operations is focused on initiation, administration, and management of state projects; approval of products delivered by contractors; regionalization and analysis of data; and other supporting projects. With recent budget increases, the aquatic element of GAP is expanding under this component. This expansion is crucial to allowing GAP to become a truly comprehensive biodiversity tool. Development of an aquatic "approach" will present the operations component with a series of challenges ranging from establishing methodologies to the determination of scope and priorities.

Research and Development is examining innovations that will help to carry out the main components of GAP–the characterization of land and water environments, modeling and predicting species distributions, delineating land stewardship, accuracy assessment techniques, etc. In addition, research and development is needed to identify and incorporate socioeconomic issues associated with the status of biodiversity, create new tools for resource managers and planners, and further build upon the scientific basis needed to support the conservation-through-information mission of GAP.

Program Development includes activities such as out-year budget initiatives, building consensus among GAP cooperators and users, creating new and strengthening old coalitions of GAP supporters, organizing an outside-of-BRD steering committee, developing a strategy for gaining Congressional support for GAP, and exploring ways of integrating Gap Analysis with other USGS activities. Program development activities will include consideration of other Biological Informatics Office (BIO) programs in order to strengthen all areas of BIO interest and to allow presentation of more complete information packages to relevant parties.

Information Technology and Data Dissemination will focus on keeping the electronic infrastructure updated and capable of serving the ever-increasing amount of GAP data. Specifically, as the quantity of and demand for data increases, attention must be paid to Web site operations, hardware and software systems upgrade and maintenance, and GAP data and information dissemination systems and processes.

Education and Participation is aimed at increasing the awareness, value, usability, and usefulness of GAP data. This includes identifying and serving user needs and requirements, increasing citizen and student participation, and developing educational programs and products.

Crucial to the success of these plans is active support from program cooperators, GAP data users, and others associated with the program. Participation of all of those involved in GAP is necessary to move from plans to practice. Much could be accomplished through the voices and actions of five hundred cooperators and numerous users by providing us with feedback and diligent advocacy.

GAP has been identified and embraced as a way to understand the status of our biological heritage and as a tool for making scientific resource decisions. The time has come to go beyond the collection and compilation of data to focus more intently on the distribution and usability of GAP data. It is in access and application that GAP will meet its goal as a premier program for assessing national biodiversity and supporting wise resource management decisions.

For questions concerning the specific components please contact the following:
Operations: Kevin Gergely, gergely@uidaho.edu, (208) 885-3565
Research and Development: Maury Nyquist, maury_nyquist@usgs.gov, (303) 202-4217
Program Development: John Mosesso, john_mosesso@usgs.gov, (703) 648-4079
Information Technology: Mike Frame, mike_frame@usgs.gov, (703) 648-4164
Education and Participation: Lief Horwitz, lief_horwitz@usgs.gov, (703) 648-4099

Partnering in Great Plains Regional GAP

GLENNIS KAUFMAN[1], JACK CULLY[2], GEOFFREY HENEBRY[3], JONATHAN JENKS[4], KEVIN KANE[5], ERVIN KLAAS[6], JAMES MERCHANT[3], VICKIE SMITH[4], AND LARRY STRONG[7]
[1]Division of Biology, Kansas State University, Manhattan
[2]Kansas Cooperative Fish and Wildlife Research Unit, Kansas State University, Manhattan
[3]Center for Advanced Land Management Information Technologies, University of Nebraska, Lincoln
[4]Wildlife and Fisheries Science, South Dakota State University, Brookings
[5] GIS Support and Research Facility, Iowa State University, Ames
[6]Iowa Cooperative Fish and Wildlife Research Unit, Iowa State University, Ames
[7]Northern Prairie Wildlife Research Center, Jamestown, North Dakota

Partnerships and Matching Funds from the Great Plains States

Partnering within the Great Plains states has been very important to the success of the Great Plains Regional GAP project. Over $3.5 million have been received in monetary and in-kind support from partners for the direct funding of basic layers of gap analysis as well as spin-offs of the GAP projects important to partners in the Great Plains (Table 1). Successes in basic gap analysis efforts would not have been possible without the direct and financial support of our many partners in the Great Plains. In addition to the financial aspects of partnering, contributions of partners have demonstrated their interest in our work and the value of creating high-quality, state-of-the-art products. Our partnering support, both in direct and in-kind financial aspects, also has stimulated several spin-off projects within the basic GAP effort, thereby facilitating future partnering with various agencies and organizations.

Background on the Formation of the Great Plains Regional GAP Group

The Great Plains Regional GAP project originated as a two-pronged effort; one effort was focused on land cover and the other on vertebrate modeling. The desire to produce a seamless land cover map within EPA-Region 7 brought together the four states of the region (Iowa, Kansas, Missouri, and Nebraska) in 1996 to form the MidAmerica Remote Sensing Consortium to work on this common initiative. The Consortium expanded to include South Dakota in 1997. In contrast, the vertebrate group was brought about partially by the recognition that the ranges of many vertebrate species crossed state boundaries. Also, significant to the formation of the vertebrate group were repeated observations of the continuing successful cooperation of the land cover group. Further, the spatial arrangement (north-south) of the region's major grassland types (tallgrass, mixed-grass, and shortgrass prairies) made it highly likely that many vertebrate species would be shared among the Great Plains states. Individuals within the vertebrate group indicated their interest in pursuing common goals at the National GAP meeting in Reston, Virginia, in August 1997.

Great Plains Regional GAP Meetings and Partnerships

The first formal meeting of the Great Plains Regional GAP group was hosted by the KS-GAP project at the University of Kansas in Lawrence in October 1997. States participating were Iowa, Kansas, Missouri, Nebraska, Oklahoma, and South Dakota. North Dakota joined the regional group in spring 1998. Since that time, the group has held semi-annual meetings in the spring and fall. Oklahoma and Missouri discontinued participation in the regional group in spring 1998 and spring 1999, respectively.

The spring and fall meetings have facilitated numerous interactions between the land cover and vertebrate modeling groups in addition to providing time to discuss the "nuts and bolts" of GAP tasks in separate breakout sessions. Joint sessions have included six-month progress reports for each state project as well as discussions of funding opportunities and successes (Table 2). In breakout sessions, the land cover group has discussed the challenges of distinguishing among grassland types. They also have worked to design a common regional protocol for conducting accuracy assessment of each state's land cover map. Likewise, the vertebrate group has considered issues that are related to development of vertebrate distribution maps and wildlife habitat relationship models. At the spring 1999 meeting, KS-GAP demonstrated a Microsoft Access database expert system that they developed to assist modeling habitats of vertebrates in Kansas. Subsequently, the five states decided to use the same database expert system with some modifications. This decision was made to ensure that all vertebrate species and vegetative alliances occurring in the Great Plains states would be included in the database, which would allow vertebrates to be modeled across the region.

Our last regional meeting occurred on 24-25 October 2000 at EROS Data Center. Our focus has now moved from intrastate land cover classifications to interstate evaluations of land cover classes (cross-walks) and how state modifications in vertebrate mapping will impact regional vertebrate models. Although these questions eventually surface in all GAP projects, regional meetings have allowed GAP project personnel to anticipate problems and to have potential solutions or recommendations at hand. Furthermore, discussions have begun to address rules for development and cross-walking of state stewardship layers, which will allow cross-walking of stewardship categories and processing of a regional stewardship map.

Breakout sessions also fostered discussions about types of in-kind support in each state that partners were providing for land cover mapping, vertebrate modeling, and stewardship mapping. For example, in-kind support has included waiver of indirect costs by universities on grants and contracts funded to support producing land cover and vertebrate maps, Landsat Thematic Mapper scenes, and metadata on museum voucher specimens (Table 3). In-kind support has been very valuable to each state both in terms of services provided as well as monetary values associated with these services (Table 4). Although we have placed a dollar value on in-kind services and support, some of these estimates for in-kind support undoubtedly are undervalued. For example, museum records of specimens useful to GAP projects have been valued at $1 per record, but total costs would be in the millions of dollars were these specimens to be collected today.

Table 1. Total support (monetary and in-kind) of the Great Plains states over GAP I funding period.

State	Monetary	In-kind	Total
Iowa	$142,000	$193,000	$335,000
Kansas	$810,402	$800,349	$1,610,751
Nebraska	$620,017	$99,000	$719,017
North Dakota		$800,500	$800,500
South Dakota	$20,000	$142,000	$162,000
Total	**$1,592,419**	**$2,034,849**	**$3,627,268**

Table 2. Financial partners (excluding funding by the Biological Resources Division) of the Great Plains states over GAP I funding period.

State	Partner	$$ of Support
Iowa	Iowa Department of Natural Resources	$42,000
	U.S. Environmental Protection Agency	$100,000
Kansas	Kansas Department of Wildlife and Parks	$266,041
	Kansas Water Office (GIS State Policy Board)	$178,023
	Kansas Army National Guard	$304,238
	U.S. Environmental Protection Agency	$45,000
	U.S. National Park Service	$10,000
	USDA Natural Resources Conservation Service	$7,100
Nebraska	Cooperative Hydrology Study (COHYST)	$ 87,000
	U.S.D.I. Bureau of Reclamation	$250,765
	U.S. Environmental Protection Agency	$ 45,000
	USDA Forest Service	$227,252
	Nebraska Game and Parks Commission	$ 10,000
North Dakota		
South Dakota	U.S. Fish and Wildlife Service	$20,000

Table 3. Nature of in-kind support that the Great Plains states have received from universities, museums, federal and state agencies, nongovernmental organizations, and individuals during GAP I funding period.

State	**In-Kind Support or Services**
Iowa	Waiver of indirect costs; Phase I land cover map; research and field biologists time; mapping research and assistance; mammal records; faculty and staff research and expertise; intern
Kansas	Waiver of indirect costs and lab fees; 44 TM images; >55,000 vertebrate records; mid-size and large mammal survey
Nebraska	Expert review, technical advice, and observational data; assistance in training field crews, conducting field work, conducting land cover map accuracy assessments; accessing voucher specimens
North Dakota	TM images and land cover classifications; vectors for refuges, waterfowl production areas, and easements; existing digital land cover, vegetation and vertebrate databases, and land ownership data; databases and vertebrate records in non-electronic format
South Dakota	Waiver of indirect costs; office space; computers; equipment; TM images

Table 4. In-kind partners of the Great Plains states over GAP I funding period and estimated value of services or support provided.

State	Partner	Value of In-Kind
Iowa	Iowa State University	$100,000
	Iowa Department of Natural Resources	$53,000
	Drake University	$5,000
	Iowa Association of County Conservation Boards	$5,000
	John Bowles, Mammal Research	$25,000
	Iowa Natural Heritage Foundation	$1,000
	Iowa Nature Conservancy	$4,000
Kansas	Kansas State University (Office of Research & Sponsored Programs)	$108,188
	Biological Resources Division	$106,744
	Kansas Department of Wildlife & Parks	$133,339
	Kansas Army National Guard	
	University of Kansas	$119,914
	Center for Research Inc.	$118,564
	Kansas Biological Survey including KARS	$133,000
	National Aeronautics & Space Administration	$4,000
	Kansas State University-Konza Prairie LTER Program	$33,000
	Museum of Natural History, University of Kansas	$21,600
	Sternberg Museum of Natural History, Fort Hays State University	$22,000
	Kansas Department of Wildlife and Parks	
Nebraska	Nebraska Game and Parks Commission	$15,000
	Nebraska Natural Heritage Program	$15,000
	USDA Natural Resources Conservation Service	$40,500
	Nebraska State Museum	$18,500
	University of Nebraska-Nebraska Research Initiative	$10,000
North Dakota	U.S. Fish & Wildlife Service	$100,000
	Ducks Unlimited	$100,000
	U.S.D.I. Northern Prairie Wildlife Research Center	$100,000
	U.S.D.I. Bureau of Reclamation	$20,000
	U.S.D.I. Bureau of Land Management	$20,000
	U.S.D.I National Park Service	$50,000
	U.S.D.I. Bureau of Indian Affairs	$20,000
	USDA Natural Resources Conservation Service	$15,000
	USDA Forest Service	$50,000
	U.S. Army Corps of Engineers	$20,000
	North Dakota Natural Heritage Program	$50,000
	North Dakota Geological Survey	$20,000
	North Dakota Game and Fish Department	$10,000
	North Dakota Agricultural Statistical Service	$50,000
	North Dakota Department of Transportation	$50,000
	North Dakota State Land Department	$75,000
	North Dakota Public Service Commission	$500
	North Dakota State University	$5,000
	University of North Dakota	$5,000
	3 Affiliated Tribes	$40,000
South Dakota	South Dakota State University	$135,000
	EROS	$7,000

LAND COVER

Collection and Processing of a High Volume of Field Data for the Missouri Land Use/Land Cover Mapping Project

DAVID D. DIAMOND, TAISIA M. GORDON, AND KAN HE
Missouri Resource Assessment Partnership (MoRAP), University of Missouri, Columbia

Introduction

The Missouri Resource Assessment Partnership (MoRAP), a cooperative of natural resource agencies, mapped land cover for Missouri using Thematic Mapper (TM) satellite data. We developed a field sampling scheme based on spatial segmentation of individual TM scenes by ecological subsection that was designed to derive the maximum relevant information possible. Incoming data quality varied due to the diversity of individuals involved, but the spatially segmented sampling scheme, large data volume, and final expert review ensured that the biases of any individual had negligible impact on the final land cover product. In order to efficiently process the large volume of incoming data, we developed the Missouri Land Cover Ground Verification Tool–a Microsoft Visual Basic application with data management, analysis, and mapping functions that bridges Microsoft Access and ESRI's ARC/INFO software.

Classification Approach

An unsupervised multispectral image classification for Landsat TM data was used as the core land cover mapping approach. We first merged two dates for each of 15 scenes and used three bands from each date to derive 60 spectral classes per scene using ISODATA (Tou and Gonzalez 1977, Jensen 1996). MoRAP then produced two distinct versions of Missouri land cover based on the level of ground verification. Phase I involved the assignment of 60 spectral classes per scene to land cover classes using NAP photos and ecological expertise. Phase II incorporates the information from more than 11,500 on-site visits to polygons that represent large clusters of 30-meter pixels within different, individual spectral classes. Whereas these two stages are logically connected and are mentioned for context consistency, this paper will emphasize the details of the field verification process.

Sampling Design and Preparation of Field Materials

Efficient collection and management of accurate on-site land use/land cover information is critical to the success of a land cover classification from remotely sensed data. MoRAP designed an ambitious sampling scheme with the goal of collecting several on-site data points for each spectral class derived from each TM scene within every ecological subsection that the scene intersected. Ecological subsections were used because land cover is more homogeneous within versus among subsections.

The on-site field data collection effort involved more than 150 individuals, and we planned to get information from more than 11,500 polygons within one year. Hence, we developed a set of field materials that were easy to understand and interpret and were relatively easy to produce. After a trial run, we settled on a final set of materials consisting of:

1. the Missouri Phase II Land Cover Classification Scheme;
2. a field data recording sheet (Table 1);
3. a brief explanation of the materials and instructions for filling out the data form;
4. a Land Cover Quadrangle Map with numbered polygons (Figure 1 - see Web version of Bulletin at http://www.gap.uidaho.edu/Bulletins/9); and
5. a USGS Quadrangle Map with numbered polygons (Figure 2 - see Web version of Bulletin).

Development of field materials for ground verification involved three major steps. First, we clipped each TM scene by ecological subsection or, in some cases, land type association (Bailey et al. 1994, Keys 1995, Schroeder et al. 1998) (Figure 3). In this way, Missouri was spatially subdivided into 38 major ecological subunit polygons. Second, we selected target USGS 7.5-minute quadrangles based on (1) their spatial position in relation to the boundary of TM scenes and ecological polygons, and (2) visual inspection of the diversity of spectral clusters within the quadrangle. Diverse quadrangles were selected over more uniform ones, and quadrangles entirely within a single TM scene or ecological polygon were selected over those that were not. Finally, we created and numbered sampling polygons that represented large spatial clusters of 30-meter pixels of uniform ISODATA spectral classes (Figure 4). The minimum sampling polygon was approximately one hectare (11 pixels), and we attempted to choose polygons that were accessible via public roads or public lands. These numbered polygons were in turn outlined on two maps based on the boundary of a USGS 7.5-minute quadrangle, one with classified land cover and one Digital Raster Graph of the same quadrangle. These maps were then printed from a large-format plotter. Field personnel used the familiar Digital Raster Graph to navigate to sites, which had clearly marked and numbered polygons to visit. The numbers on the polygons (Figure 1 and 2) corresponded with numbers on the field data collection form (Table 1).

Capture and Processing of Incoming Data

We developed a Microsoft Access database designed to facilitate initial data entry and analysis. The Access database contains 21 fields that uniquely identify and describe each polygon visited on the ground (Figure 5). Among those 21 fields, 15 have one-to-one relationships between the record and record item, whereas six have a one-to-many relationship. For the sake of speed and efficiency, we divided the database into four linked tables. The master table contains all one-to-one relationship fields, and three ancillary tables hold fields with one-to-many relationships.

We developed a Microsoft Visual Basic application, the Missouri Land Cover Verification Tool (Figure 6). Visual Basic's built-in Data Access Object (DAO) allows easy management of the Access database (Microsoft Corporation 1998). ARC/INFO's Open Development Environment (ODE) allows access to GIS functionality through a custom-created Visual Basic interface (Potts 1998). Through the data-centric application development environment of Visual Basic, the Missouri Land Cover Verification Tool provides fast, comprehensive data access and data analysis, visualization, and mapping capabilities. Hence, the overall complexity of data management and analysis is much reduced from using Access and ARC/INFO independently. Integrity of the field data was ensured with this tool by making data transcribed from field forms read-only after initial entry. All ground verification data were summarized per spectral class within at least three spatial contexts: TM scene-based, ecological subsection-based, and USGS

7.5-minute quadrangle-based. These types of summaries facilitate the analysis of each spectral class within each TM scene, ecological subsection, or small region (quadrangle). Ecologists from MoRAP partner agencies used these summaries to complete in-lab expert reviews of all data in order to detect obvious errors. The tool's built-in GIS functions were used to intersect GIS data layer values (ancillary data) with spectral class data from the field by TM scene and by ecological subsection. The use of ancillary data was thus restricted to small areas or to single spectral classes. Hence, the final product was improved where possible, but any errors related to the overapplication of ancillary data were avoided.

Results and Discussion

More than 11,500 ground points were visited, the data recorded and processed, and summary statistics calculated. Initial accuracy of the classification ranged from 64% to 88%, and visual examination of the revised classification (e.g., no “seams” are apparent between ecological subsection polygons) indicates significant improvement for the final product. Validity and accuracy of ground data is always a central focus in attempts to limit error propagation in land cover mapping.

A large volume of sampling data has a better chance of truthfully representing the target population (Cochran 1977). In Missouri, the opportunity to collect a large volume of field data came with the caveat that a large number of people would be involved. We elected to pursue this course rather than collect a much smaller volume of data in a more “controlled” way. We then needed to overcome the problems of high data volume and variation in the quality of field data. We were successful in developing a field form and protocol that was used with little apparent difficulty by more than 150 field biologists. These forms were delivered in person, with accompanying verbal explanations, to 15 different natural resource agency field offices. Fewer than 10 calls for clarification were received from the field. Likewise, the development of the Missouri Land Cover Ground Verification Tool allowed us to successfully deal with the high volume of data generated.

Involvement of many different people with different backgrounds and dispositions directly impacted the quality of our field data. In this regard, data were used for an unsupervised classification in which TM scenes were subdivided by ecological section. Therefore, errors associated with any individual were limited to relatively small areas (generally less than 15% of one TM scene) on the final map. In addition, some field checking errors were detected and corrected based on (1) review of the field data records by ecologists in the office and (2) review of “suspect” information using NAP aerial photos. For example, several biologists in one region reported that grassland patches were all warm-season grasses. This result seemed in error according to ecologists involved in review of the final map product, and quick field revisits confirmed the error: they were all cool-season grasslands.

Perhaps the most compelling reason to involve a large number of people in collection of a high volume of ground data is related to buy-in and practical use of the finished land cover map. Results of the statewide classification and mapping should be used by natural resource agencies and planners at all levels of government. Policy decisions such as where to locate new development, new parks, highways, conservation areas, etc. can be facilitated with this land cover data layer in combination with other information. However, decision makers will only use the information if they have confidence in its accuracy and validity. Involvement of many people from different agencies helps ensure that as many people as possible have ownership and confidence in the results of Missouri's land cover mapping effort. Use of the Missouri land cover map applied towards conservation issues is our primary measure of success, and we believe that involvement of so many people in its development will ensure the widest possible use.

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Table 1. Field data recording sheet

Principal Data Collector: ___________________ Contact Phone Numbers: ___________________
Organization: ________________________ Collecting Date: ____________________

USGS 1:24,000 Quadrangle *Name* and *location*: **Tiff Quadrangle, Washington & Jefferson Counties, Missouri**

Site ID	Land Cover Type on map	Verification Method*	Ground verified classification and site description
01	Deciduous Forest Agree? Y / N	site visit___ windshield ___ experience___ other_______	More Detailed or Alternative Class(es)**__________________________ Dominant Species/Structure____________________________________ Changes since 1991-1993?__________________________________ Other comments:
02	Eastern Red Cedar Forest Agree? Y / N	site visit__ windshield ___ experience___ other_______	More Detailed or Alternative Class(es)**__________________________ Dominant Species/Structure____________________________________ Changes since 1991-1993?_________________________________ Other comments:
03	Eastern Red Cedar Forest Agree? Y / N	site visit__ windshield ___ experience___ other_______	More Detailed or Alternative Class(es)**__________________________ Dominant Species/Structure____________________________________ Changes since 1991-1993?_________________________________ Other comments:

*Please check one. A field level observation of the site is highly preferred, but close inspection of the entire site is not needed. If you cannot gain access, but can see the site remotely or have experience on-site, please indicate.
**From Phase II Land Cover Scheme.

Figure 3A. Figure 3B.

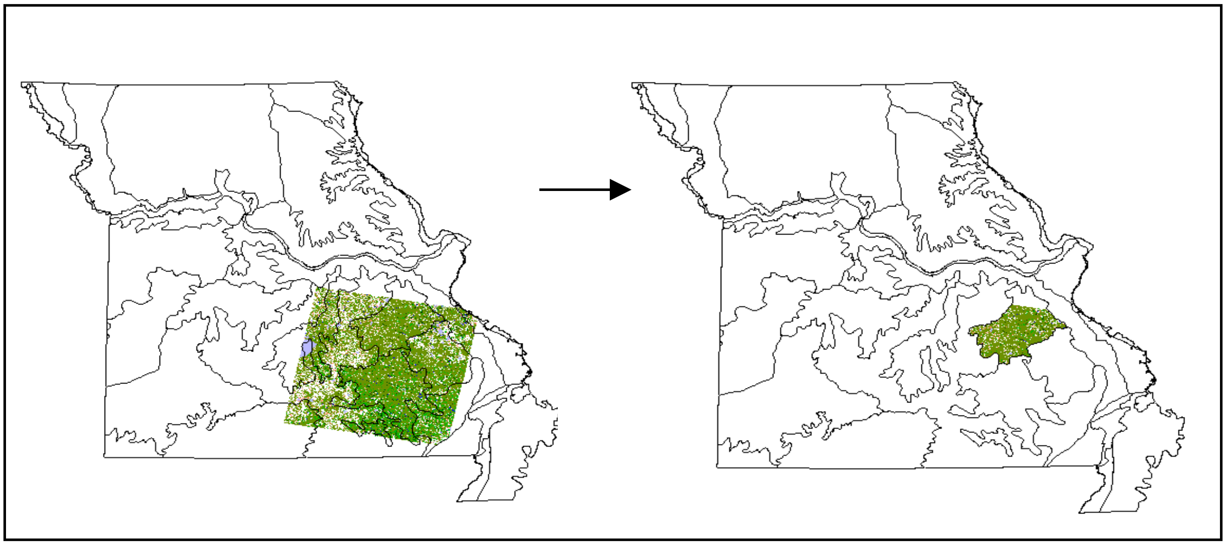

Figure 3A. A classified TM scene overlaid with ecological subsection polygons.
Figure 3B. Part of the classified TM scene clipped by ecological subsection.

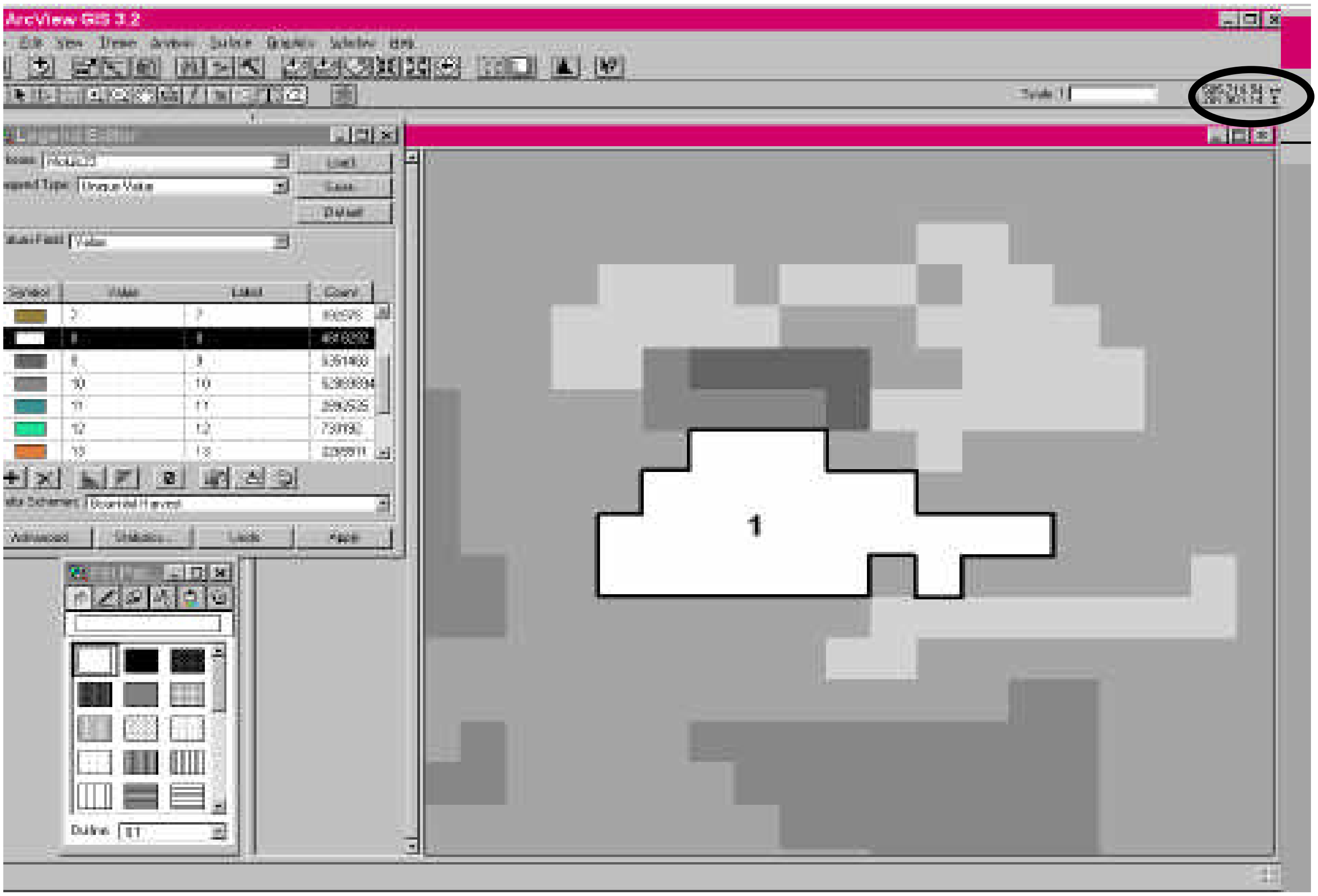

Figure 4. A polygon is created around pixels representing the same spectral class. The X and Y coordinates (circled) of the center of the polygon are recorded for data analysis.

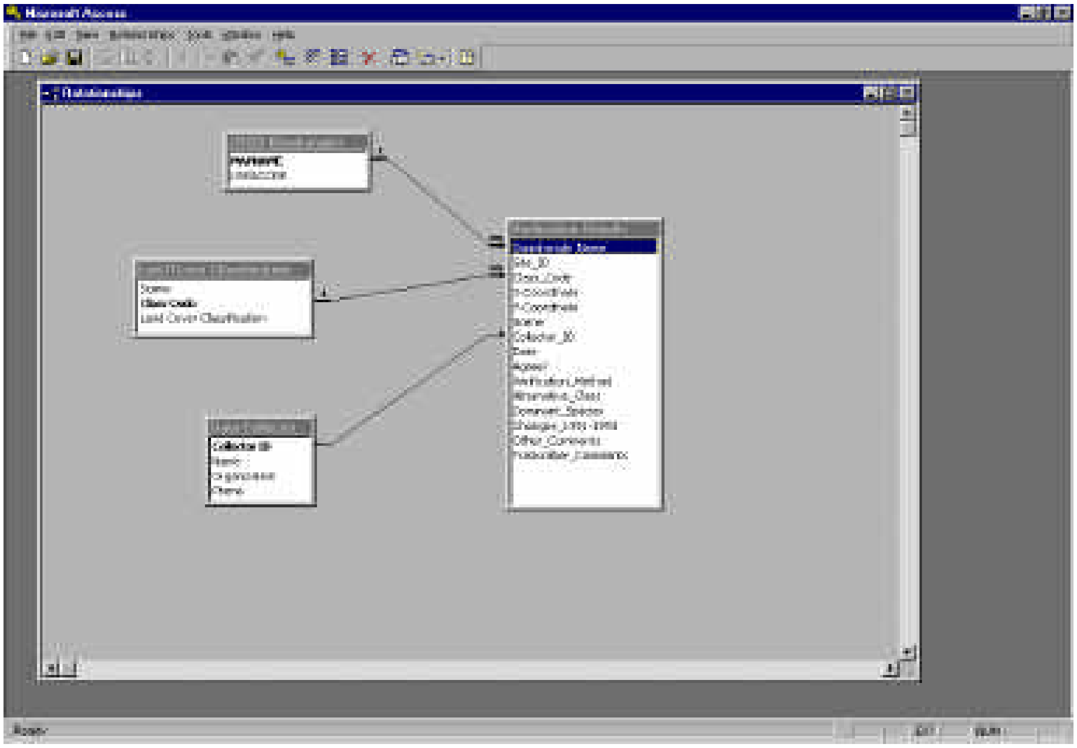

Figure 5. Microsoft Access tables demonstrating one-to-one and one-to-many relationships.

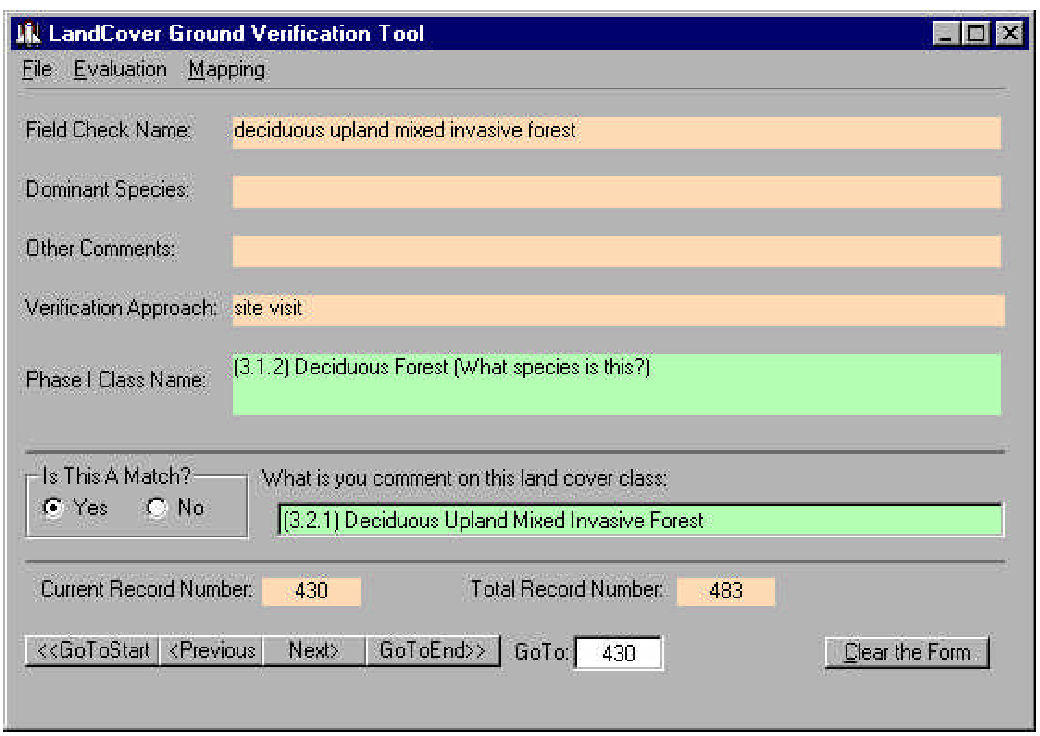

Figure 6. Initial interface of Missouri Land Cover Ground Verification Tool.

Using Ecological Systems as Land Cover Map Units for GAP

SHANNON MENARD[1] AND CHRIS LAUVER[2]
[1]Association for Biodiversity Information, Minneapolis, Minnesota
[2]Kansas Biological Survey, University of Kansas, Lawrence

The U.S. National Vegetation Classification (USNVC), which is maintained by the Association for Biodiversity Information (ABI), is used by the Gap Analysis Program (GAP) as the classification standard for mapping existing vegetation. In the past, GAP projects have used many methods to derive map units, from mapping associations (finer than alliances) to combining alliances into coarser units that encompass different upper physiognomic units. Different states may choose contrasting methods of combining alliances, which can lead to problems when cross-walking map units across state borders.

One approach to potentially solve these problems is the use of Ecological Systems. While mapping alliances continues to be the goal for vegetation classification for GAP, in some instances this will not be possible. The use of ecological systems is being developed to maintain consistency with the USNVC and to facilitate regionalizing GAP data across states. Use of ecological systems is not a substitute for the alliance-level goal, and the finer-level alliance data will always be retained as part of the GIS data sets.

Ecological Systems have recently evolved from several years of work by ecologists from ABI, The Nature Conservancy, and the Natural Heritage Network. Systems are currently defined as conceptual vegetation units, unified by similar ecological conditions and processes (e.g., disturbance), environmental features (e.g., soils, geology), environmental gradients (e.g., elevation, latitude), and broadly similar plant species composition. Ecological Systems can form spatially contiguous units and provide a standardized classification structure for combining associations or alliances that share ecological processes. Ecological Systems alleviate inconsistent aggregation from state to state. They are similar in concept to “complexes” and “compositional groups” but provide richer context and data because they are more directly linked to alliances and associations. They are more intuitive and so will be readily understood by outside partners and clients. The use of Ecological Systems in an individual state usually results in fewer units compared to associations or alliances. For example, there are approximately 250 Ecological Systems for the Great Plains, Midwest, and Southeast regions (25 states), compared to about 800 alliances and 2000 associations. The ecological construction of Systems renders them as ideal map units for GAP projects that use remotely sensed satellite data or aerial photography. Systems integrate ecological elements such that many animal and plant species will be limited to one or a few Ecological Systems. Other vertebrates that use a wider variety of Ecological Systems can be easily modeled using Systems. Thus, Systems provide a way to “regionalize” these maps while still maintaining conservation units that are ecologically meaningful.

Significant progress has been made towards the conceptual development and implementation of Systems in the Midwest and Great Plains regions. However, the utility of Systems in developing spatial units for projects such as GAP needs to be addressed in more detail. To that end we hope to evaluate the use of Ecological Systems with the current Kansas GAP land cover map. Ecological Systems could be a valuable tool in unifying state GAP maps across a region by developing more ecologically meaningful map units.

The Development of Mapping Zones to Assist in Land Cover Mapping over Large Geographic Areas: A Case Study of the Southwest ReGAP Project

GERALD MANIS[1], COLLIN HOMER[2], R. DOUGLAS RAMSEY[1], JOHN LOWRY[1], TODD SAJWAJ[1], AND SCOTT GRAVES[3]
[1] Utah State University, Remote Sensing and GIS Laboratories, Logan, Utah
[2] EROS Data Center, Sioux Falls, South Dakota
[3] Ducks Unlimited, Sacramento, California

Introduction

Spectral classification of satellite imagery to map land cover across large landscapes involves the effective identification of spectral gradients resulting from the variability of physiographic and phenologic variables, ground variability, as well as solar and atmospheric influences within and between remotely sensed imagery. A common method of identifying spectral gradients is to stratify landscapes into subregions of similar biophysical characteristics. This process is not new to remote sensing and has been widely used as a postprocessing method to improve accuracy (Pettinger 1982, White et al. 1995). Lillesand (1996) refers to this process as "stratifying" the study area, and the resulting stratification units are called "spectro-physiographic areas" or "spectrally consistent classification units (SCCUs)."

This paper outlines the development of similar stratification units, which we refer to as "*mapping zones*." Our study area is comprised of the five states in the Southwest ReGAP Project (Arizona, Colorado, Nevada, New Mexico, and Utah), covering approximately 530,000 square miles and encompassing a wide variety of ecosystems.

By partitioning the five-state study area into mapping zones, we hope to maximize spectral differentiation within areas of uniform ecological characteristics. From a project management and logistical standpoint, mapping zones will facilitate partitioning the workload into logical units. Finally, we anticipate that the development of mapping zones will simplify postclassification modeling and improve classification accuracy. Based on previous work by Bauer et al. (1994) overall classification accuracy could be improved by 10 to 15% using physiographic regions.

Background

The underlying concept of mapping zone delineation is to divide the landscape into a finite number of units that represent homogeneity with respect to landform, soil, vegetation, spectral reflectance, and overall ecological physiology. Ancillary data such as Digital Elevation Models (DEMs), existing imagery, soils, and/or geologic data are the primary source of quantitative information guiding the delineation of mapping zones. However, the most critical component is a familiarity with the study area and an intimate knowledge of the biophysical features of the landscape. Delineating mapping zones requires a degree of subjective decision making to strike the balance between affordable economic units, optimal ecological units, and reasonable spectral units. The concept of economy helps determine mapping zone size. A large number of small zones become uneconomic since quasi-independent mapping efforts are required for each zone.

To delineate mapping zones for the five-state Southwest ReGAP project we focused on an iterative process using a number of factors to partition the landscape into ecological units. We created boundaries for land type associations using topography, soils, geology, spectral uniformity, and economics. A land type association is a grouping of related units with similar biophysical features. Ecological units may be designed for different scales of analysis depending on the objective (McNab and Avers 1994). Land type association boundaries in the Intermountain West tend to be reasonably identifiable, characterized by features such as prominent escarpments, the foot slopes of large mountain ranges, or the edges of vast lake basins.

Methods

Developing mapping zones for the five-state area was a collaborative effort involving input from representatives of each of the five participating states. Through the course of discussion the five-state group determined that approximately 75 mapping zones for the region would be optimal to define ecologically distinct areas and be affordable. Refinement of the mapping zone boundaries was achieved by introducing additional ancillary information and through periodic consultation and input from SW ReGAP state collaborators.

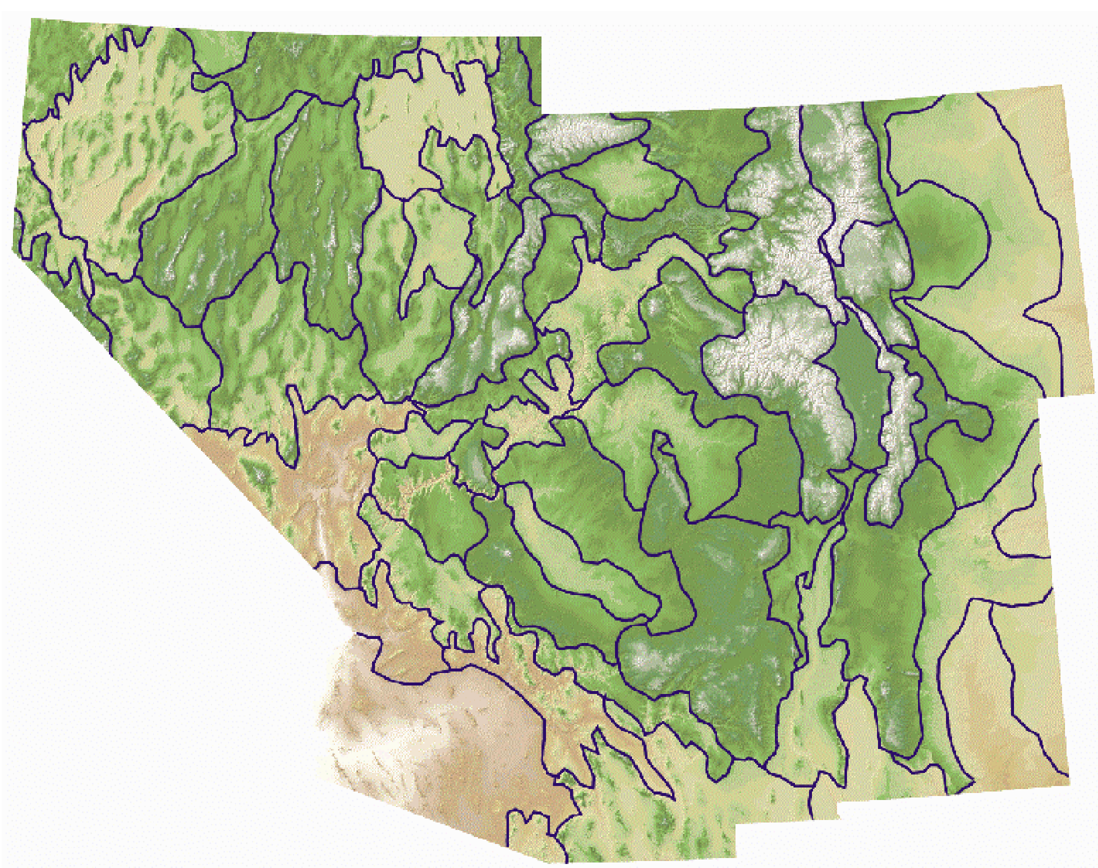

Figure 1. Color-contour shaded-relief map with refined Bailey lines.

Initial research into an ecological evaluation of the region focused on ecoregions defined by Bailey et al. (1994) and Omernik (1987). These sources provided an overview of the landscape with consideration to climate, vegetation and landform. Bailey's ecoregion sections provided an initial "starting point" for mapping zone boundaries. To refine the boundaries, a GIS coverage of Bailey's ecoregions was plotted over a high-resolution, color-contour shaded-relief base map created from a 3-arc second DEM (Figure 1). The resulting map was an interpretation of land type zones guided by Bailey's section boundaries and was used as a starting point for discussion with SW ReGAP collaborators.

Following comment from state collaborators, a second draft of mapping zones was created using existing Landsat TM images to help identify major life zones. This phase of the refinement process accounted for the spectral characteristics of the landscape. Interpretation of imagery improved the delineation of major physiographic "seams," such as escarpments and/or clear geologic formation boundaries.

Most mapping zone boundaries are boundaries between landscape features that appear to best define life zone boundaries. In areas that lack clear distinction between life zones, an attempt was made to identify approximate boundaries by identifying spectral patterns that could be related to vegetation communities and or geology. For example, major agricultural areas were used as a surrogate for natural vegetation patterns and became mapping zone boundaries in some areas to assist in the separation of natural vs. man-made environments.

A third phase of refinement involved the use of soils data. Soil is an integral component of the landscape/vegetation relationship and provides great potential in guiding mapping zone delineation. A soil map reflects not only edaphic conditions, but climatic conditions as well, reflecting elevation and latitude gradients over large areas. The State Soil Geographic (STATSGO) database is a nationwide digital (state-level) soil geospatial database. While the Soil Survey Geographic (SSURGO) database is more accurate and detailed than STATSGO, complete coverage for the five-state region is not available.

The original STATSGO GIS coverage for the five-state region contains approximately 2,100 soil mapping classes, each with multiple soil components. With a goal of 75 mapping zones for the five-state region, the STATSGO database clearly had to be simplified to be useful for delineating mapping zone boundaries. To simplify STATSGO, we developed a protocol for aggregating soil mapping classes. The protocol can be summarized as follows:

1. Component soils were re-classified based on a hierarchy of soil temperature regime, soil order, soil rooting depth classes, wetness classes, flooding regime, and broad soil texture groups. This established a reasonable evaluation of which soil types were similar in their capacity to support vegetation.
2. General soil classes were sorted based on composition of similar soils, similar range of slopes, and similar range of non-soil components, i.e., rock outcrop, badlands, playas, etc.

3. Logical aggregations were evaluated by viewing the polygons over TM imagery, with subsequent adjustments of slope limit and soil component differentia to preserve the most definitive delineations while merging the least definitive. Aggregations that were of small size, except those of unique value like dunes or playas, were merged with the adjacent, most similar aggregation.
4. A table was developed to describe each aggregated class, such as the range of soil great groups, slopes, major life zones, nonvegetated landscape features, soil textures, and a simplified mapping unit description.

Following this protocol, we generated 58 “generalized land type” classes based on soil characteristics. The aggregated 58-class STATSGO data layer was first used as an informal “test” of mapping zone boundaries derived in phases one and two. We found that the derived STATSGO data layer could be used to improve the delineation of some of the more problematic mapping zones. This was most important in areas with little topographic relief such as the plains of eastern Colorado and New Mexico.

As a result of the refinement phases, the mapping zone GIS coverage consisted of 129 polygons. While this reflected a reasonable stratification of the landscape, it still exceeded our target of 75 mapping zones. We compared this coverage to earlier drafts of the mapping zones and Bailey’s ecoregion sections. The smallest polygons were merged into adjoining polygons, based on the distinctive qualities of the surrounding polygons and a general agreement or disagreement with Bailey’s ecoregions. The final mapping zone coverage contained 74 polygons (Figure 2).

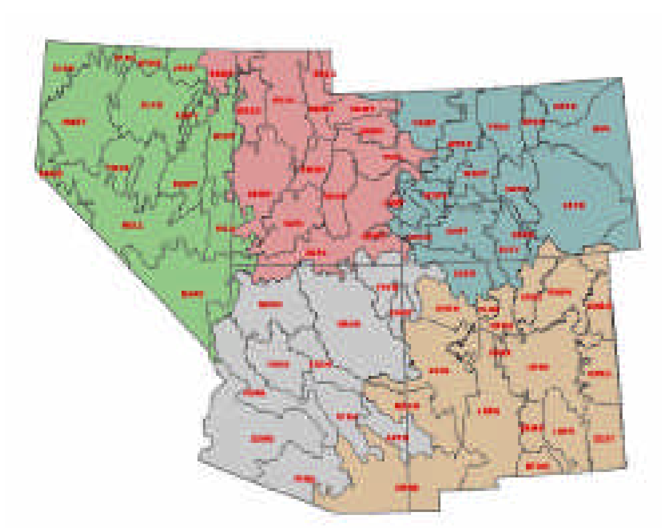

Figure 2. Final mapping zones for the SW ReGAP region.

Discussion

The southwest United States provides a unique landscape with discrete mountain ranges and complex structural geology and soils, which helped provide a basis to delineate mapping zones. A possible limitation of using geomorphic boundaries to identify mapping zones is that the coincidence of microclimatic and soil factors controlling vegetation will not always coincide with geomorphology. Certain landscapes such as cuestas tend to be problematic because long dip slopes imply an unbroken elevation gradient. We have tried to resolve disagreement between landscape boundaries and apparent vegetation boundaries by deferring to vegetation, as interpreted on existing TM imagery, as the primary criteria. However, positive geomorphic boundaries took precedence over small-scale or uncertain vegetation patterns.

The amount of effort placed in deriving the soils GIS coverage from the STATSGO database was significant and alone did not substantially help in defining the mapping zone boundaries. In fact, a state-level geology coverage could very well be used as a surrogate for the soils data produced from STATSGO. What the derived STATSGO data provided was ancillary information useful in verifying and refining some of the more problematic mapping zoning boundaries. The effort to aggregate the STATSGO database was not wasted as it holds great potential as a postclassification modeling layer.

We anticipate that well-defined mapping zones will improve image classification and, ultimately, land cover mapping. One of the important lessons learned from this effort is that delineating mapping zones for the five-state region is an iterative process involving input from collaborating participants and refinement using multiple ancillary data sources. In addition, a significant amount of personal and collective knowledge and a sound understanding of the general mapping process is required to interpret the ancillary data in a way that is meaningful.

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Managing Land Cover Map Units Among States, Regions, and the USNVC

SHANNON MENARD
Association for Biodiversity Information, Minneapolis, Minnesota

The U.S. National Vegetation Classification (USNVC) is the standard for mapping vegetation for the Gap Analysis Program (GAP). The objective for mapping vegetation units is the alliance level of the USNVC. The Association for Biodiversity Information (ABI) maintains the classification system. Many state projects conducted their land cover mapping prior to establishment of the NVC or complete identification of alliances for their region. Commonly, states have not been able to map all individual alliances across the entire state and so have created mosaics of alliances or mapped at the formation level (the physiognomic level above alliance in the USNVC). Some states are able to map some units at the association (a finer floristic unit than alliances in the USNVC).

The variation in map categories among states and regions has created a need to develop cross-walks to the classification standard. In order to develop regionally consistent, ecologically meaningful map units, ABI ecologists are working with individual projects to link different state data through a common platform. To this end, ABI scientists are creating Access databases that will contain map units from several states cross-walked to alliances, which will give GAP a common unit to produce regional maps.

I created an Access database to manage state classification/map units in relation to USNVC alliances in the Great Plains and Southeast. This database links directly to USNVC data and will update each time USNVC is revised. I received alliance and map category information from several Great Plains states (SD, ND, KS, NE, MO, and IA). Data from other states in the Great Plains (and the Midwest) will be solicited and added to the database during the next year. Data from some southeastern states have been incorporated (TN, NC), and Milo Pyne (Vegetation Ecologist, Southeastern Region, ABI) is in the process of gathering data from the rest. This database can be used to update the information provided by state GAP projects (some projects had out-of-date USNVC information), locate map units not cross-walked to the USNVC, and identify alliances defined by states that are not currently defined in the USNVC. Reports linking data from several states can list state information/data in various formats. These reports can be sent to state/regional projects once data have been finalized for those states. This database will continue to efficiently track and manage the alliance data, compositional groups, and ecological complex data needed to develop multiscale land cover mapping units across the regions and can be used to develop regional map units. Using this database as a template, a similar database is also under development in the West to manage information from the Southwest ReGAP project. In the future, these databases can be combined to track the GAP map units and their relationships to the USNVC nationwide and thereby help GAP define regions for remapping or regionalizing.

Challenges in Land Cover Classification in Areas of Rapid Urban Expansion

LINDA SCHWAB
Illinois Natural History Survey, Champaign

The Chicago region in northeastern Illinois is an area of rapid urban expansion. Areas that were once agricultural fields and mining sites have been converted to residential and commercial properties, many of which include man-made drainage ponds. New roads have been built to link new development to older urban centers, providing a causeway for more urban expansion. As a result, open grassland and woodland habitat has been lost to a highly fragmented landscape. Landsat imagery covering the Chicago area also encompasses diverse rural areas, including farmland, forest preserves, parks, beaches, and wetlands. This wide array of landscape types required a way to separate significantly diverse spectral regions.

To understand what changes have occurred in this urban landscape, we studied the expansion of the Chicago region. Our first challenge was found in creating an urban mask in a region of explosive urban growth. An all-inclusive urban mask of high-density urban areas was essential in separating urban spectral properties from vegetative spectral properties. The most recent regionwide roads coverage was ten years old. Much development had since taken place in the Chicago region, which made creating an urban mask directly from the roads coverage impractical. A conventional classification of imagery to create the mask would have been inconclusive because older urban residential areas appear as "woodland" and do not indicate road density.

We solved this problem with a two-part approach. First, we followed methods outlined by Morisette et al. (1996). The theory is to account for areas of high road density, which is a measure of urban density.

Part I involved four steps performed in ARC/INFO GRID, v. 7.2:

1. the road vector coverage to grid format using LINEGRID.
2. Increase the road zone by five pixels (150 meters total) using EXPAND.
3. Reduce the encompassed area of high road density using SHRINK.
4. Convert Increase the encompassed area once again to produce an area of urban density using EXPAND.

Part II of the process involved on-screen digitization of urban expansion areas not encompassed by the area expanded from the roads zone. On-screen digitizing was performed in ArcView 3.2 with the July 1999 Landsat TM image displayed as background. This process captured new residential and commercial developments that did not have high-density road networks when the roads coverage was created. In addition to adding in urban areas, on-screen work was used to eliminate rural areas that had a high density road network but were not true urban areas, such as farmsteads, state parks, and interstate cloverleaf exchanges. The benefits of using the road density approach to creating an urban mask were that it captures roads in older urban residential areas and the amount of time spent performing on-screen digitizing of urban expansion was greatly reduced.

Once the urban mask was generated, we were able to run two separate unsupervised classifications on the Landsat imagery–one for "urban" areas and one for "non-urban" areas. We are confident that this extra effort led to better accuracy in our classification in both the urban and non-urban areas. As an example, we were able to capture small urban parks as well as older tree-lined neighborhoods within the Chicago metro area, which may have been lost otherwise. In this urban landscape, these "green pockets" provide critical habitat for wildlife that live and migrate through this area.

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Expert Review for Land Cover: Integrating Information from Specific Comments and Evaluating the Results

GEOFFREY M. HENEBRY[1], JAMES W. MERCHANT[1], JUSTIN W. FISCHER[1], AND DOUGLAS GARRISON[2]
[1]Center for Advanced Land Management Information Technologies, University of Nebraska, Lincoln
[2]USDA Natural Resources Conservation Service, Lincoln, Nebraska

Introduction

The Landsat TM data used to generate the base land cover map for Nebraska were acquired nearly a decade ago in the early 1990s. This situation poses a challenge for evaluation of the accuracy of the land cover product. Land cover changes subsequent to image acquisition result in temporal decorrelation that is interpreted as classification error in a formal accuracy assessment, if the ground data for the accuracy assessment are not collected concurrently with image acquisition. As we did not have concurrent ground data, we sought a procedure to not only evaluate the accuracy of our draft land cover map but also to increase its relevance to a potential user community.

To solicit expert assessment of the draft land cover map, the Nebraska Gap Analysis Project and the Nebraska State Office of the Natural Resources Conservation Service (NRCS) sent out relevant county-level maps to district conservationists at NRCS offices during late 1999 and early 2000. The district conservationists coordinated review of the hard-copy maps, utilizing staff from 81 NRCS offices statewide. Local experts reviewed the draft maps and identified misclassifications by annotating the hard-copy map with a series of general and specific comments. As of December 15, 2000, 75 of 93 county maps had been returned, a response rate of over 80%.

Methods

Of the 75 maps returned, 65 were annotated with specific comments and 10 indicated no change. General and specific comments were recorded from each map. Specific comments, defined as comments noting misclassification of particular groups of pixels, were then tabulated into a special confusion matrix reporting only misclassification errors; thus, all elements of the matrix were located off the principal diagonal (Table 1).

Misclassifications identified on the draft land cover map were then compared against a subsequent version of the map that incorporated additional sources of information, viz., a thematically simplified subset of NWI polygons, fallow agricultural lands generated by an independent project, and urban land cover classes pulled from the USGS National Land Cover Data. A second special confusion matrix was generated to determine whether misclassifications had been corrected by incorporation of multiple data sources (Table 2). Remaining misclassifications deemed significant were manually recoded. The decision to recode pixels into the “Agricultural Fields” class was made on a case-by-case basis. Adjustments were made by comparing the latest draft with the National Land Cover Data product, relevant DOQQs, and a map of Nebraska’s native vegetation. A third special confusion matrix was then generated (Table 3).

Table 1: Special confusion matrix based on original draft land cover map. Matrix elements correspond to total numbers of comments made by reviewers. No elements occur on the diagonal.

	Expert Review															
Original Data	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	**T**
1. Ponderosa Pine										1	2				1	
2. Deciduous Forest/Woodland	3				1			26			2	12	133		11	
3. Evergreen Forest/Woodland	1					4		22			1		11		1	
4. Sandsage Shrubland					1							1	8			
5. Sandhills Upland Prairie								2					182			
6. Lowland Tallgrass Prairie													180			
7. Upland Tallgrass Prairie					1	1							37			
8. Little Bluestem-Grama Mixedgrass Prairie													73			
9. Western Wheatgrass Mixedgrass Prairie												1				
10. Western Mixedgrass Prairie					1								5			
11. Barren/Sand/Outcrop					5		2			4			185			
12. Bulrush-Cattail Wetland													5			
13. Agricultural Fields					2	19	2	14			1	4				
14. Urban						1										
15. Open Water													20			
TOTALS	**4**	**0**	**0**	**0**	**11**	**25**	**4**	**64**	**0**	**5**	**6**	**18**	**839**	**0**	**13**	

Table 2: Special confusion matrix based on subsequent draft land cover map incorporating additional data sources. Diagonal elements correspond to corrected comments. Off-diagonal elements correspond to comments that were not corrected with additional data.

	Expert Review															
Revised Data	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	**T**
1. Ponderosa Pine										1	2					
2. Deciduous Forest/Woodland	3				1			26				3	21			
3. Evergreen Forest/Woodland	1					1		21			1		9		1	
4. Sandsage Shrubland					1											
5. Sandhills Upland Prairie								2					143			
6. Lowland Tallgrass Prairie						6							168			
7. Upland Tallgrass Prairie					1								37			
8. Little Bluestem-Grama Mixedgrass Prairie								11					26			
9. Western Wheatgrass Mixedgrass Prairie																
10. Western Mixedgrass Prairie					1					4						
11. Barren/Sand/Outcrop					5		2						178			
12. Bulrush-Cattail Wetland											2	15	3			
13. Agricultural Fields					2	17	2	4			1		254			
14. Urban						1										
15. Open Water															12	
TOTALS	**4**	**0**	**0**	**0**	**11**	**25**	**4**	**64**	**0**	**5**	**6**	**18**	**839**	**0**	**13**	

Results

The inclusion of additional data sources took care of 302 (31%) of the specific comments. Manual editing of the significant misclassifications took care of 241 (35%) remaining comments. The two-stage revision eliminated 543 (55%) of the specific comments made by the expert reviewers. Of the remaining 446 misclassifications, 372 (83%) were identified by the reviewers as “Agricultural Fields”. The classes contributing to most of this remaining error were “Barren/Sand/Outcrop” (144 or 39%) and “Lowland Tallgrass Prairie” (124 or 33%). The second-most confused class was “Little Bluestem-Grama Mixedgrass Prairie” at 53 (12%) remaining comments. Two woodland classes contributed to most of the error remaining after revisions: “Deciduous Forest/Woodland” (26 or 49%) and “Evergreen Forest/Woodland” (21 or 40%).

Table 3. Special confusion matrix following manual recoding of significant misclassifications. Diagonal elements correspond to corrected comments. Off-diagonal elements correspond to comments that were not corrected with additional data.

							Expert Review								
Revised and Recoded Data	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	**T**
1. Ponderosa Pine	4															
2. Deciduous Forest/Woodland					1			26				3	19			
3. Evergreen Forest/Woodland						1		21					9			
4. Sandsage Shrubland																
5. Sandhills Upland Prairie					1			2					55			
6. Lowland Tallgrass Prairie						24							124			
7. Upland Tallgrass Prairie					1								10			
8. Little Bluestem-Grama Mixedgrass Prairie								11					8			
9. Western Wheatgrass Mixedgrass Prairie																
10. Western Mixedgrass Prairie					1					5						
11. Barren/Sand/Outcrop					5		2				3		144			
12. Bulrush-Cattail Wetland											2	15	3			
13. Agricultural Fields					2		2	4			1		467			
14. Urban																
15. Open Water															13	
TOTALS	**4**	**0**	**0**	**0**	**11**	**25**	**4**	**64**	**0**	**5**	**6**	**18**	**839**	**0**	**13**	

Discussion

Inclusion of additional data significantly improved the land cover map. Further revision by manual recoding yielded a reduction of misclassification by 55% from the original draft map. Most of the misclassifications identified by the field experts were agricultural fields. Increasing agricultural activity across Nebraska has resulted in new lands going into production. Most of the remaining misclassifications involved grassland-woodland confusion. It is important to keep in mind that the comments referred to specific groups of pixels that varied widely in size; thus conventional map error analyses and metrics were inappropriate. While the results of the expert review did not yield a formal pixel-centric accuracy assessment, it did yield a land cover map more in accordance with the understanding of local experts. This classification post-processing has better prepared us to conduct a conventional accuracy assessment and interpret the results in the light of land cover changes subsequent to image acquisition.

Animal Modeling

An Exploratory Look at Combining Vertebrate Models from Several States: An Overview of Vertebrate Modeling in the Western States

REE BRANNON
National Gap Analysis Program, Moscow, Idaho

Introduction

The eleven western states have completed their first round of mapping for GAP. The Gap Analysis Program has always had the objective of moving beyond state boundaries to create regional maps and making regional, and ultimately national, assessments. Beyond reporting, regional and rangewide maps provide a frame of reference for more in-depth analyses of individual species or vegetation types across their range.

I selected several species for the taxa (mammals, birds, reptiles, and amphibians) from the eleven western states. The GIS coverages were converted to a common projection and cell resolution and then merged. Some patterns emerged and are particularly relevant to the work done by Karl et al. (1999). The authors conducted a review of primary literature (peer-reviewed journals) to assess how many articles had been written on selected species in three categories and how many of those articles described habitat. I used their three groups (game species, species of special interest, and species that have general habitat requirements) and added one more "species that have special (e.g., microhabitat) requirements". I compared the merged model outputs from the eleven states with availability of habitat information as per Karl et al. (1999).

Game Species

Karl et al. (1999) found numerous articles on elk (*Cervus elaphus*), 30 of which had descriptions of habitat. Figure 1 shows the merged state models with consistent mapping across state boundaries. This suggests that, for the most part, there were fairly similar ideas about elk habitat. In contrast, the models for chukar (*Alectoris chukar*), another game species, do not match well and, interestingly, there was only one article found in the primary literature

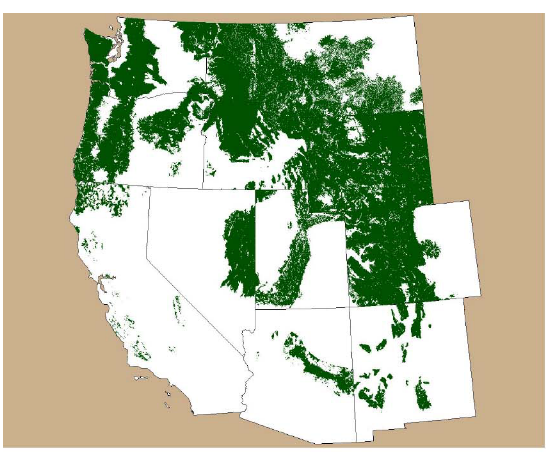

Figure 1. Predicted distribution of Elk habitat (*Cervus elaphus*)

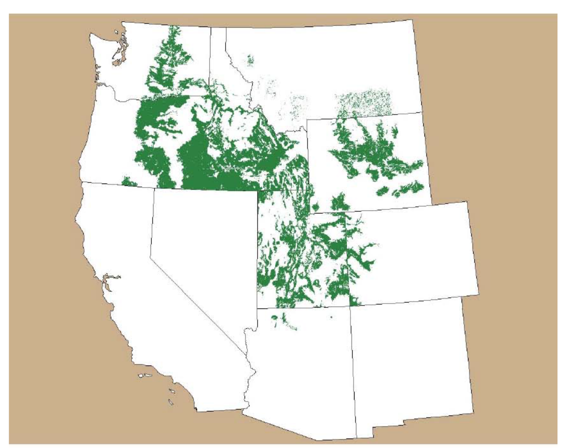

Figure 2. Predicted distribution of Chukar habitat (*Alectoris chukar*)

referencing habitat (Figure 2). Elk habitat is generally described as coniferous forest, alpine meadows, marshy meadows, and shrub steppe. These are all components that are fairly commonly mapped in land cover. Components of chukar habitat range from mountain slopes of grassy vegetation to deserts with sparse grass, barren plateaus, and rocky hillsides. These are not categories that are commonly included in land cover mapping from one state to another and may contribute to some discrepancies across borders. Therefore, two possible explanations for the discrepancies seen here for chukar are: 1) because of a lack of habitat information for a species, there are varying ideas of habitat preferences from one state to the next, or 2) even if we have a common understanding of habitat, it may not be mapped consistently in the land cover from one state to the next.

Species of Special Interest

The species in this category are experiencing declining populations, most commonly as a result of declining habitat. Two examples are southern red-backed vole (*Clethrionomys gapperi*) and the fringed myotis (*Myotis thysanodes*). The southern red-backed vole had 20 references to habitat in the primary literature, whereas the fringed myotis had zero. Figures 3 and 4 illustrate the model outputs. The vole's habitat preferences are cool, moist deciduous, mixed, or coniferous forests whereas the fringed myotis prefers desert, grassland, and woodland habitats.

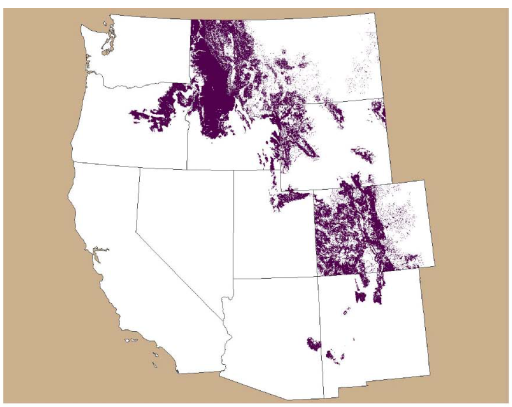

Figure 3. Predicted distribution of Southern Red-backed Vole habitat (*Clethrionomys gapperi)*

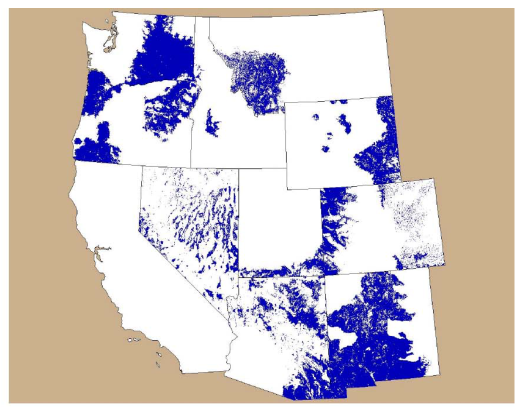

Figure 4. Predicted distribution of Fringed Myotis habitat (*Myotis thysanodes*)

The agreement for the vole suggests an underlying agreement in habitat and land cover elements, but the myotis map shows more discontinuities. Typically, grasslands and woodland have been very difficult to map using satellite imagery. Moreover, without descriptions available in the primary literature there may be inconsistencies in the understanding of habitat use from state to state as seen for the fringed myotis.

Species with Special Habitat Requirements

I consider microhabitat features to be small features such as wetlands, snags, rocks, and down woody debris, or linear features such as streams. These features are not generally mappable from satellite imagery. Figure 5 shows the American beaver (*Castor canadensis*) and Figure 6 the bald eagle (*Haliaeetus leucocephalus*), two species not surveyed by Karl et al. (1999). Both species require a component of water, either adjacent to woods for the beaver or snags for the eagle. Clearly, these are components that have been mapped quite differently from one state to the next. Table 1 summarizes the mapped water categories by state. The states varied dramatically in their thematic resolution for this component. Some indicate floristic composition (cottonwoods or willows) while others show structure (tree vs. riparian) and elements such as wetlands and vernal pools.

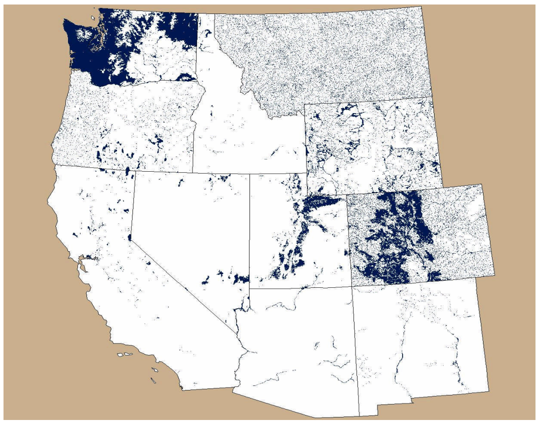

Figure 5. Predicted distribution of American Beaver habitat (*Castor canadensis*)

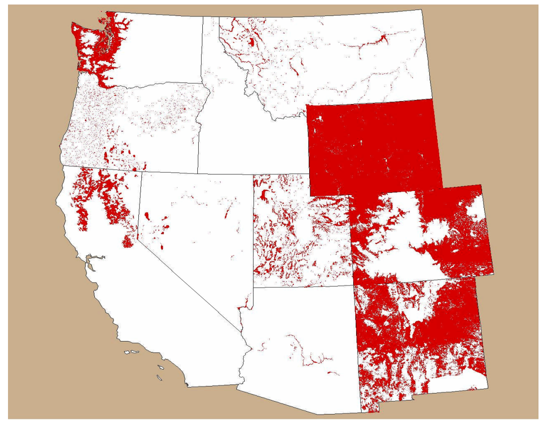

Figure 6. Predicted distribution of Bald Eagle habitat (*Haliaeetus leucocephalus)*

Table 1. Numbers of categories of riparian, wetlands or marsh mapped by each state.

	Riparian Structure	Riparian Elevation	Riparian Composition	Meadows	Wetland Structure	Wetlands Composition	Lacustrine/ Marsh/wetland	Vernal	Coastal
Arizona			21						
California			25	1			9	4	2
Colorado					4				
Idaho	4		3	1			2		
Montana	6								
Nevada		2		1		1			
New Mexico						4			
Oregon				1			6		2
Utah		2		1			1		
Washington	1				4		7	1	1
Wyoming	3					1			

Other habitat requirements difficult to delineate at this scale are orchards, city parks, shade trees, and agricultural features such as irrigated crops. The thematic resolution varied from state to state as seen in Figures 7 and 8 and Table 2 for species that use these features.

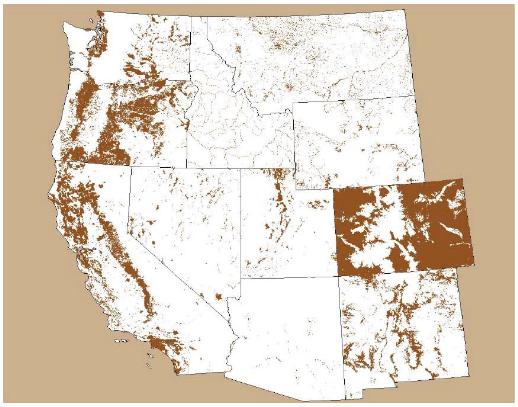

Figure 7. Predicted distribution of Northern Oriole habitat. (*Icterus galbula*)

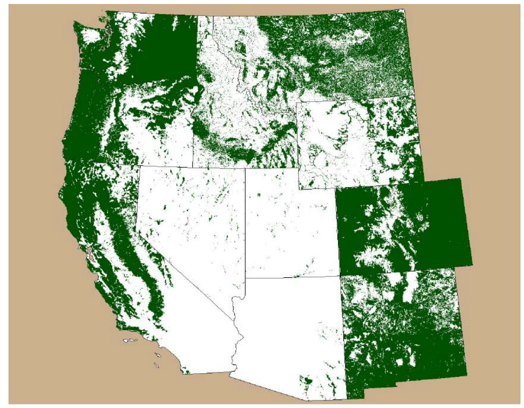

Figure 8. Predicted distribution of Barn Swallow habitat (*Hirundo rustica)*

Table 2. Number of categories of agriculture mapped by each state

	Agriculture	Irrigation	Pasture	Orchards	Crops
Arizona	1				
California	1	3	1	4	2
Colorado	1	2	1	1	
Idaho	1				
Montana		2			
Nevada	1				
New Mexico		2			
Oregon	1				
Utah	1				
Washington		2	2	1	2
Wyoming		2			

Wide-Ranging Species with General Habitat Requirements

This category of species had some surprising results. Intuitively, one would expect ubiquitous species to show the most continuity in mapping. Figures 9 and 10 contradict this assumption. Karl et al. (1999) found 51 articles addressing habitat for mule deer (*Odocoileus hemionus*) and 14 for the black-capped chickadee (*Parus atricapillus*). Despite the wealth of information, there is still quite a bit of discrepancy between state model outputs for each. Both species have habitats that have been noted earlier for inconsistency in mapping (woodlands, parks, brushlands).

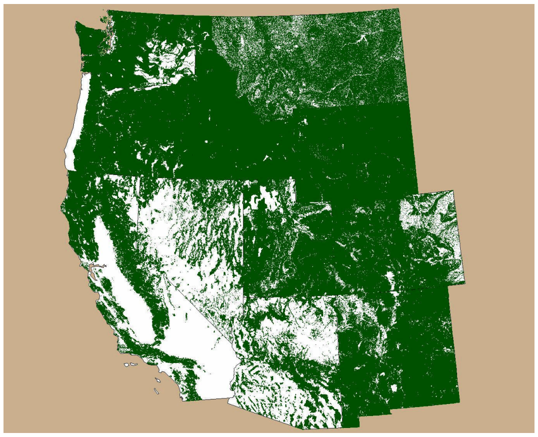

Figure 9. Predicted Distribution of Mule Deer habitat (*Odocoileus hemionus*)

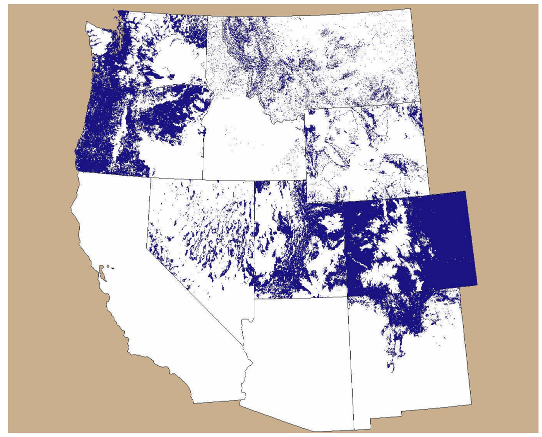

Figure 10. Predicted distribution of Black-capped Chickadee habitat (*Parus atricapillus*)

Conclusions

A cursory examination of merged vertebrate models for the western states reveals some interesting results. Continuity, or the lack of it, across state boundaries is influenced by several factors:

5. available information about the habitat preferences for the species,
6. mappability of habitat elements as land cover or ancillary layers, and
7. seamless minimum mapping unit, thematic resolution and mapping categories of base data for modeling vertebrate distributions.

The GAP projects continue to test methods to increase mappability of features, and we have moved to more consistent minimum mapping units (two hectare to single, 30 meter pixel). Because description of habitats for species is largely unavailable in primary literature, it would behoove us to access, and to contribute to, secondary sources such as biological Web sites (e.g., the Fish and Wildlife Information Exchange), the National Biological Information Infrastructure (metadata serving of information), NatureServe (Association for Biodiversity Information or ABI) and Ecological Archives (appendix and supplemental materials to Ecological Society of America publications).

Acknowledgements

Thanks to Derek McNamara for his assistance in processing the state coverages and for summarizing the tabular data.

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Regional Approaches to Modeling Animal Distributions: Status of Current Projects and Outlook

PATRICK CRIST
USGS Gap Analysis Program, Moscow, Idaho

GAP has long recognized that post-modeling regionalization of state-based predicted animal distributions would be problematic (Csuti and Crist 1996; Crist and Jennings 1997). In a gap analysis of terrestrial vertebrates in the western U.S., Crist and Karl (in preparation) joined existing state GAP maps and graphically assessed them for consistency among states. The results for herpetofauna and some mammals were fairly good (Figure 1), but many widely distributed mammals and most birds showed only a fair to poor match among states (Figure 2). This suggests that for regional analysis, many species will have to be re-modeled using regionally consistent base GIS coverages (e.g., land cover, soils, hydrography, topography) and regionalized habitat association models that can account for true regional differences in associations. Such a task will be time-consuming and expensive.

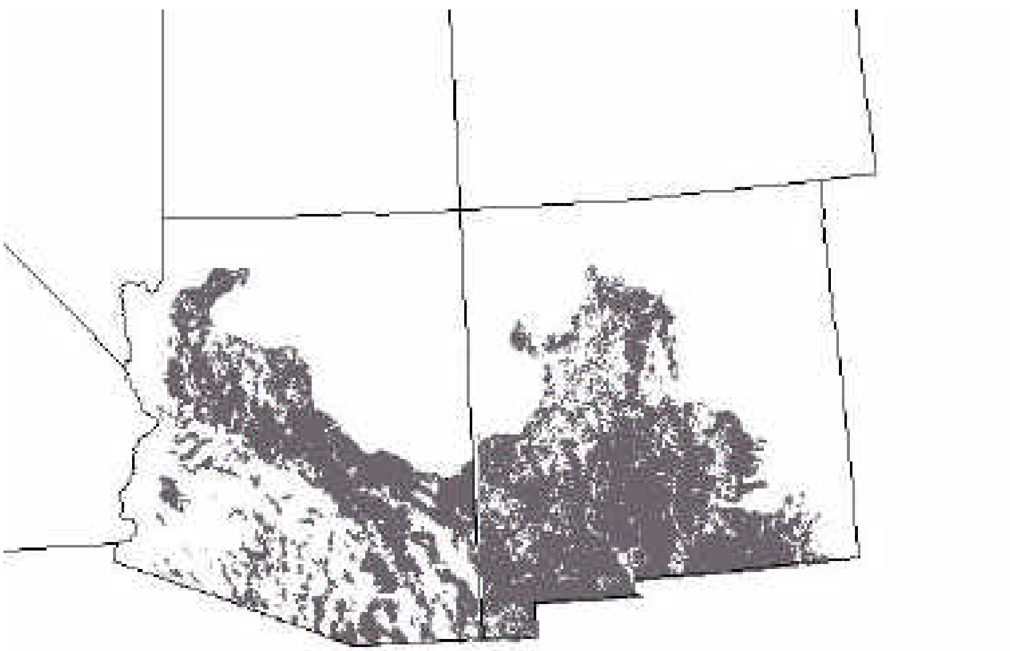

Figure 1. Map-joined distribution of blacktail rattlesnake *(Crotalus molossus)* indicating excellent match between two states.

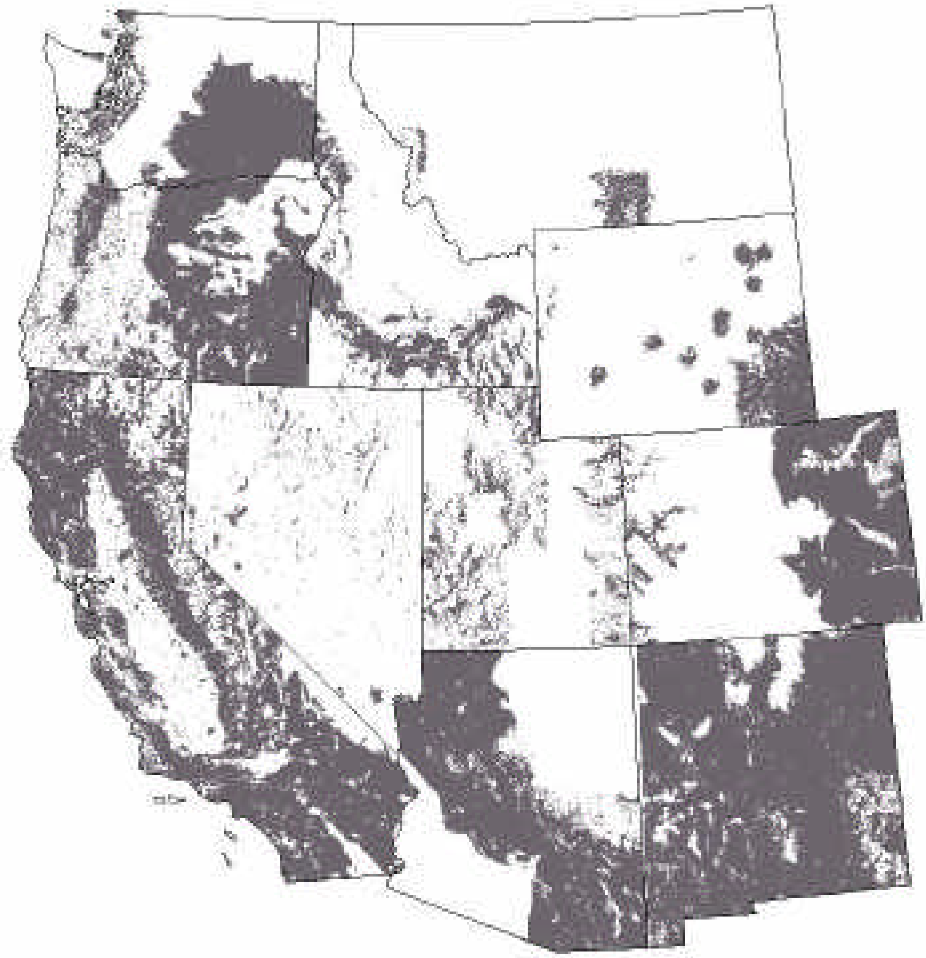

Figure 2. Map-joined distribution of barn owl *(Tyto alba)* distribution showing mismatch of both range extent and spatial pattern.

In response, four multistate regions within GAP have initiated coordinated approaches to regional animal distribution modeling. These range from fairly loose cooperation to obtain consistency in range limits to full coordination of all modeling tasks. In only one case (Southwest ReGAP) was regional modeling part of the original project objective. In the other regions (the Great Plains, Southeast, and Upper Midwest) state GAP projects are voluntarily coordinating their efforts. Following are reports on the methods, status, and outlook for each effort.

Regional Coordination of Animal Modeling in the Southeast

JEFF WALDON
Fish & Wildlife Information Exchange, Virginia Tech, Blacksburg

The Southeast Regional Working Group has discussed coordination of animal modeling at several times in recent years and developed Web-based tools to aid coordination on range extent mapping, model sharing, and discussion.

Coordination of the animal range maps was initiated by the Virginia GAP Project. An ArcView Internet Map Server application was developed that can read lists of EMAP hexagons and display them interactively over the Web. This approach would allow animal modelers to look for disjunct ranges and other anomalies prior to applying the habitat relationship data to the model. A similar effort was successfully completed for the mid-Atlantic GAP states a few years ago. This system is still available, but to date few states have established databases of EMAP hexagons that can be accessed by the regional mapping system. The NC-GAP Project has received hex species range data from TN, KY, LA, NC, and VA and is planning on combining and comparing these ranges.

Steve Williams of NC-GAP developed a matrix approach (Microsoft Access) for coordinating animal modeling and proposed it to the group approximately three years ago. To date this approach has been adopted by individual GAP projects, but it has not been used to compile and compare modeling data, a useful step towards edge-matching potential distribution maps. Although not intended as a coordination mechanism, several GAP projects got their start in animal modeling by acquiring habitat relationship data from other GAP projects or surrounding state fish and wildlife agencies and/or natural heritage programs. These sources were typically modified with local information, new references, and local expert opinion. By using the same base data, states in close proximity to others probably have very similar animal models.

Finally, the Southeast group has been using a listserver set up specifically for the group for some time. This mechanism has made it possible for the group to easily communicate regarding coordination issues. To further communication, they hold regular coordination meetings where animal modeling issues are addressed.

We feel that coordination of the animal modeling information is crucial for edge-matching the species potential distribution maps regionally and to allow for comparison of gap recommendations among states. As with most other data coordination efforts, this will require time and funding committed to the process. One of the major problems in coordination is the widely varying start dates for various states in the region. The status of state projects in the Southeast region varies from AL starting in 2000 to TN, VA, FL, and others being completed this year. This has led to differential degrees of participation among the states and prohibited true regional modeling of animal distributions.

Regional Coordination of Animal Modeling in the Upper Midwest

DANIEL FITZPATRICK
USGS Upper Midwest Environmental Sciences Center, LaCrosse, Wisconsin

The Upper Midwest Gap Analysis Program (UM-GAP) was organized to avoid duplicating efforts while meeting the diverse information needs of the participating state and federal cooperators. Coordination efforts have gone well with land cover classification efforts that are now nearing completion. This regional land cover mapping approach has always been considered a necessary prerequisite to a uniform and consistent predicted vertebrate distribution mapping effort.

Regional coordination of predicted vertebrate distribution modeling began in fall 2000 with a meeting of partners at the Upper Midwest Environmental Sciences Center in La Crosse, Wisconsin. In attendance were representatives from the Illinois Natural History Survey, the Michigan Department of Natural Resources, Michigan State University, and the Minnesota Department of Natural Resources.

Proposed state species lists were compared, and the criteria for inclusion into a uniform regional list were discussed. Initial discussions also explored ideas such as stratifying species models by Bailey's Ecoregion Provinces. Along those lines, Minnesota is planning to collaborate with the Great Plains regional animal modeling coordination effort for the western or Great Plains portion of the state. Although this was only the initial meeting, a general consensus was reached that the regional partners will collaborate to produce regionwide species range maps based on EPA hexagons. Individual species distribution modeling responsibilities will probably then be shared among states that share the range for that species.

UM-GAP has always been organized with the belief that cooperation in the development of uniform and consistent landscape-scale GIS layers will, in the long run, prove to be more cost-effective if applied at the planning and development stage of the data layers rather than as an after-the-fact effort to edge-match incompatible GIS layers.

Regional Coordination of Animal Modeling in the Great Plains

JACK CULLY, T. HOERNEMANN, AND G. KAUFMAN
USGS Cooperative Fish and Wildlife Research Unit, Manhattan, Kansas

At the 1998 Great Plains Regional Gap Analysis Program meeting, the Kansas Gap Analysis Project (KS-GAP) illustrated the database expert system that we were developing for use in vertebrate modeling in Kansas. The expert system was an Access database program that tracked the literature and other sources of information used to attribute land cover classes and range distributions to each vertebrate species within the state. Following the presentation and workshop that employed the expert system, Nebraska, South Dakota, North Dakota, and Iowa decided to adopt the modeling. KS-GAP also had developed a partial list of vertebrates for the Great Plains, which suggested that regional modeling could considerably reduce the number of species that had to be modeled by each state. In addition, this regional effort would reduce future problems of edge-matching predicted vertebrate species distributions across state boundaries.

Initially, regionalization required extra work, because species lists had to be made for all vertebrates across the five state region, and lists of vegetation association descriptions had to be found and compiled across the five states. Following these steps, the database expert system had to be expanded to include both vertebrate species that occurred in the Great Plains and vegetation alliances found in the five-state region. Additionally, this information needed to be searchable and linkable to habitat descriptions in the literature for all developed species models. Because the vegetation association descriptions were not standardized across the five-state region, we had to develop criteria by which the vegetation association could be cross-walked to each state's land cover categories. This was further complicated because the five states were using different mapping methods for their land cover layers. Compiling lists across the region and cross-walking the land cover categories across the states were the most complicated aspects of our regionalization.

The development of the regional expert system required approximately one year of time, but we believed the effort was justified by reducing our share of species modeling by 40%. The original concept that distributing the species modeling responsibilities would reduce everyone's costs could not be realized, however, because the five participating states were at different levels of completion, and because KS-GAP was scheduled to finish before the other states. South Dakota, North Dakota, and Iowa were in similar stages relative to vertebrate modeling when the Great Plains Vertebrate Database was completed, so these states are using the database to develop interstate models for vertebrate species they share. In the meantime, Nebraska decided to try a different statistical approach to model its vertebrates where adequate specimen records are available. However, Nebraska will be able to use the database and completed models from Kansas, Iowa, and South Dakota to help model those species that could not be modeled by using statistical approaches.

We believe that the initial costs in time spent both to develop the database program and the interstate cooperation will be repaid easily during the current phase of gap analysis on the Great Plains. We also are in an excellent position to proceed with GAP II as the five states plus Minnesota finish their initial GAP projects. Because we have a common methodology and a common language built into the database, we can proceed to develop truly regionalized vertebrate distribution and habitat models. With encouragement from the National Gap Analysis Program, we hope to see a regional land cover map and stewardship layer developed with the same level of interstate cooperation as has occurred in modeling vertebrates. When these coverages are available, we will have a truly integrated regional gap analysis of the northern Great Plains.

Approach to Regional Animal Modeling in the Southwest

BRUCE THOMPSON AND KEN BOYKIN
USGS Cooperative Fish and Wildlife Research Unit, Las Cruces, New Mexico

Animal modeling in SW-ReGAP is in a very early stage because initial effort is devoted primarily to land cover mapping (through 2001). Nonetheless, several early coordination steps are under way in the regional animal modeling lab at the New Mexico Research Unit. Early development emanates from a January 2000 Animal Modeling Workshop. At that workshop the group decided that two key concepts would guide the project. First, habitat association and model development for each species would be distributed among the states according to expertise or largest proportion of species range and second, GIS modeling tasks would be conducted at a central lab at the New Mexico Research Unit. The first two steps of the work have been initiated.

For the first step, we are preparing a taxonomic decision rule base to guide all projects in jointly selecting taxa that are to be modeled across the region. The draft rule was distributed to all members of the regional project in December 2000 for review, revision, and ultimate acceptance across the region.

The second step is to assign individual species modeling responsibilities to specific projects within SW-ReGAP. This approach ensures that species models evolve from available information and enhances the likelihood that species model information are derived from local expert knowledge. Further, this approach will realistically distribute effort to provide critical help to the regional lab.

A preliminary assignment of at least 865 species among projects will be coordinated with all projects after the taxonomic rule base is completed. The assignment is based on establishing model development responsibilities with the state that encompasses the primary range or distribution of key habitat for each species. Those species with wide distribution or habitat associations will be the responsibility of the regional lab throughout. Other projects will contribute their model development to the regional lab for review and revision across the region prior to final model and map preparation by the regional lab. We believe this approach will facilitate numerous other facets of the modeling process associated with literature review, habitat association databasing, and production of seamless predictions.

Conclusions

The requirements for regional modeling are straightforward: (1) establish a common list of species to be modeled, (2) establish a consistent view of range extent for each species, (3) develop seamless regional modeling base layers (e.g., land cover, topography, hydrography), and (4) develop a regional habitat association database that accounts for subregional changes in associations. As we have seen, other regional efforts (except the Southwest) have had limited success due to differential start dates and inconsistent methodologies. They have, however, achieved much in the way of information sharing, communication, and development of useful tools and can serve as a guide for future updates in GAP. Success then is a function of the degree that the modeling integration is systematic rather than opportunistic. The Southwest ReGAP approach holds great promise in maintaining the tie to local knowledge of species location and habitat associations while increasing efficiency and assuring seamless products by centralized integration and processing. A national analog may be a national database of habitat associations by ecoregions to retain local specificity, as well as occurrence locations and range limits based on EMAP hexagons or other fixed units. A well-maintained system, accessible for input by local researchers and naturalists, would allow dynamic modeling using the most current data. Standardization of GAP models, habitat association databases, and GIS layers may be the first step to achieving national animal modeling capability.

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FINAL REPORT SUMMARIES

Colorado Gap Analysis Project

DONALD SCHRUPP, LEE O'BRIEN, AND SADIE RUSSO
Colorado Division of Wildlife, Denver

The Colorado Gap Analysis Project (CO-GAP) was initiated in 1991 as a cooperative effort between the Colorado Division of Wildlife, the Natural Resource Ecology Center (NERC/USFWS), and state, federal, and private natural resources groups in Colorado. The objectives of the project were to

1. produce databases to describe current land cover, predicted distributions of native species of terrestrial (i.e., non-fish, nonmarine) vertebrate species, stewardship responsibilities for conservation and selected public lands, and land management status for use in geographic information systems (GIS) at a scale of 1:100,000;
2. identify land cover types and vertebrate species that currently are not represented or are poorly represented in areas managed or potentially managed for long-term maintenance of biodiversity (i.e., identify conservation gaps); and
3. facilitate cooperative development and use of information so that institutions, agencies, and private land owners may be more effective stewards of the biological resources of the state.

The first GIS layer developed for CO-GAP was the land ownership base layer; digitized at the NERC/USFWS in Fort Collins by TGS, an in-house contractor. The base layer was modified for the purpose of modeling land stewardship as new land management plans for national forests and BLM lands in Colorado became available.

With funding from National GAP, 12 scenes of Landsat imagery were acquired to augment four Division of Wildlife scenes, providing in-house, statewide coverage from which a baseline map of vegetation/land cover was developed at sufficient detail to model vertebrate wildlife distributions based upon habitat relationships. Following methodology developed for Wyoming GAP (WY-GAP), attributes were assigned to each polygon describing primary, secondary, and other land cover; crown closure for forested primary types; and the types of wetlands and/or disturbance found in the polygon, if any. Polygon attributes were assigned using image interpretation, existing maps, field reconnaissance, digital reference layers from federal land management agencies, and literature sources. A formal statewide validation of the land cover map was funded by National GAP and conducted by the University of Wyoming. The results of this accuracy assessment are summarized in this report, and the assessment report is included in our appendices.

Individual distributions for 597 vertebrate species were predicted using habitat associations linked to the vegetation/land cover base layer, constrained by data on elevation ranges and confinement to the east or west side of the Continental Divide from known occurrences of individual species in Colorado. Point localities and thematic distribution maps were used to evaluate preliminary distribution maps, and later as a guide in developing the county-level distribution masks used to constrain occupancy to likely areas of predicted habitat. County-level masks were developed by cross-reference to locational databases providing 101,068 field/museum records of species localities. After synthesizing this information for modeling efforts, the modeled maps predicting species range based on habitats were reviewed by 16 local experts. Comparisons of species predicted to occur at nine field sites to species lists generated from the CO-GAP predictive habitat/distribution maps indicated an overall accuracy of 64%. A special submodel was developed to account for riparian species distribution, given the importance of this habitat and the minor extent to which it was observable based solely on the Landsat imagery.

GAP uses a scale of 1 through 4 to denote the relative degree of management for biodiversity maintenance for a particular tract of land, where “1" represents the highest, most permanent and comprehensive level of maintenance, and “4" represents the lowest or unknown status. Status codes were assigned to public lands with state and federal agency input based on legal and intended management, using a key developed by the New Mexico Gap Analysis Project (NM-GAP). Most private lands were assigned Status 3 or 4 depending on the availability of information on their intended long-term management. After land stewardship was modeled using the land status base layer, the derived layer was overlaid on the vertebrate species habitat/distributions to provide the tabular output essential to a gap analysis of Colorado biodiversity. These tables show the distribution of species habitats across the major land ownership categories and are further partitioned by hectares (and percent) of the species' habitat distributed by the land stewardship categories. Land cover types and vertebrate species were generally considered underrepresented in areas managed for biological diversity if less than 1%, or less than 50,000 hectares of available cover type or occupied habitat was found within Status 1 and 2 lands.

Barely over 10% of Colorado is classified as Status 1 and 2 lands, concentrated in four national parks or monuments (Rocky Mountain National Park, Mesa Verde National Park, Dinosaur National Monument and Great Sand Dunes National Monument), with the rest distributed mostly in Forest Service wilderness areas, scattered high in the Rockies along the Continental Divide and other major Colorado mountain ranges. Following WY-GAP's lead, we considered land cover types and vertebrate species as underrepresented (i.e., “gaps”) in management areas if <1% or <50,000 ha of the land they occupied or their habitat in Colorado fell within Status 1 and 2 lands.

Twenty-two (52%) of the 42 natural (non-anthropogenic) land cover types have <1%, or <50,000 ha, in Status 1 and 2 lands. In fact, 11 of those classes each had less than 10,000 ha in Status 1 and 2 lands. The highest priorities for further protection are wetland/riparian types (grass/forb-dominated wetlands, shrub-dominated wetlands, and forested wetlands), a number of grassland types (sand dune complex-grasslands, tallgrass prairie, midgrass prairie, and shortgrass prairie), Rocky Mountain bristlecone pine, and sandy areas. Of additional highest priority but restricted in management opportunity to predominantly public lands are xeric upland shrubs. Bitterbrush shrub, if considered a high priority, presents management opportunities on BLM lands as well as some limited opportunity on private lands. All but the grassland types are restricted in both overall occurrence in the state and representation within Status 1 and 2 lands, yet offer management opportunities on existing, predominantly state-owned, public lands. Grasslands under private management present other possibilities. While grassland types cover many hectares in Colorado, they are truly underrepresented on Status 1 and 2 lands. Other types with little reported area in Colorado and in Status 1 and 2 lands were Wyoming big sage, white fir, blue spruce, and limber pine. Their consideration for having less than 50,000 ha in Status 1 and 2 lands may be more a function of their detectability due to our land cover mapping methodologies, but the question of their consideration as biodiversity gaps should be further investigated.

Mesic upland shrubs, greasewood fans and flats, desert shrub, saltbrush fans and flats, and foothill/mountain grasslands were identified second in priority. Mesic upland shrub management opportunities are limited with less than 100,000 ha of combined public/private lands not in Status 1 and 2. Management opportunities for desert shrubs are available, with land area not in Status 1 and 2 about equal in public/private stewardship. Management opportunities for greasewood fans and flats and foothill/mountain grasslands are largely on private lands, while management opportunities for saltbrush fans and flats appear more abundant on combined BLM, tribal, and state lands than on private lands. Third priority for further protection are mountain big sage, mixed conifer, and deciduous oak vegetation types. Mountain big sage and mixed conifer's seeming scarcity in Colorado may be an artifact of difficulties in delineating them with our land cover classification methodologies. Management opportunities for these two types on current Status 3 and 4 lands are limited but about equally associated with public (BLM/USFS/state) and private lands. Management opportunities for deciduous oak appear abundant on both public (BLM/USFS) and private lands.

On average, reptiles had the smallest percentage of their potential habitat (3.13%) in Status 1 and 2 lands, followed by birds (6.24%), amphibians (7.25%) and mammals (10.95%). Habitats of 5 (28%) amphibians, 19 (40%) reptiles, 70 (17%) birds, and 16 (13%) mammals were identified as gaps of the highest priority based on both criteria (<1% in Status 1 or 2 lands, and <50,000 ha of habitat under Status 1 and 2 lands) for identifying underrepresentation in management areas. An additional 2 (11%) amphibians, 8 (17%) reptiles, 40 (10%) birds, and 6 (5%) mammals were identified as a secondary level of priority because they met the one "gap" identification criteria of having < 50,000 ha of their habitats in Status 1 and 2 lands, though they have >1% (but <10%) of their habitats protected in Status 1 or 2 lands. A third level of habitat prioritization would be for species with <50,000 ha of their habitat in Status 1 or 2 lands, but greater than 10% of their habitats protected. Species in this third level of priority are all avian species tending to be associated with open water habitats, which are of limited availability statewide.

Three important efforts have already benefited from the completion of Colorado's initial Gap Analysis efforts. Habitat/distribution information on 190 key species derived from CO-GAP has been provided for presentation in Colorado's Natural Diversity Information Source (NDIS; http://ndis.nrel.colostate.edu). NDIS provides information for use by the general public, educators, and decision-makers. The information is used in land use and conservation planning as well as in public education. Secondly, habitat/distribution information for all 597 terrestrial vertebrate wildlife species modeled by CO-GAP (as well as the geographic information system coverages underlying the analysis) have been made available to all interested citizen scientists on the Web (http://ndis.nrel.colostate.edu/cogap). Lastly, the Colorado Division of Wildlife has begun efforts to develop baseline profile information on Colorado habitats on a biome basis (grassland/shrubland/forestland) for use in Species Conservation Program planning. Additionally, CO-GAP information has already been applied to CDOW's Land and Water Acquisition Plan (LWAP) development, which will help identify fee-title and easement acquisition priorities for Division funding and possible cost-sharing with Great Outdoors Colorado (GOCO) and other potential partners.

Florida Gap Analysis Project

LEONARD PEARLSTINE[1], SCOT E. SMITH[2], AND WILEY M. KITCHENS[3]
[1]Dept. of Wildlife Ecology and Conservation, University of Florida, Gainesville
[2]Dept. of Civil and Coastal Engineering, University of Florida, Gainesville
[3]USGS Florida Cooperative Fish & Wildlife Research Unit, Gainesville

The Florida Gap Analysis Project (FL-GAP), initiated in 1993, is one of the state or regional projects designed to provide overviews of the distribution and status of biodiversity across the Nation. These projects, conducted under the auspices of the National Gap Analysis Program (GAP) of the U.S. Geological Survey, have the objective of providing critical information to land and resource managers regarding location and spatial distribution of key elements of statewide biodiversity. In addition to biotic distribution, GAP projects map the extent and location of lands in various states of conservation ownership. Contrasting these distributions provides a method of identifying the degree to which native animal species and natural communities are or are not represented in existing conservation lands. The intent is to proactively identify areas of potentially high biodiversity occurring outside protected boundaries as “gaps" in the existing network of conservation lands. Application of this process provides a necessary step toward informing agencies and landowners of potential opportunities to conserve biodiversity and avoid environmental crises.

FL-GAP was conducted as a cooperative effort among several national, state, and nongovernmental organizations (NGOs), with the Florida Cooperative Fish and Wildlife Research Unit of the U.S. Geological Survey and the University of Florida principally responsible for assemblage and assessment of the information. The objective was to provide broad geographic information on the distribution of terrestrial plant communities, vertebrates, butterflies, skippers, and ants and their respective habitats in order to address the status of biological diversity conservation in Florida. The inclusion of the approximately 400 species of invertebrates was a departure from the protocol previously reported by Scott et al. (1993). It was deemed necessary due to the high fragmentation of natural habitats in Florida resulting in a landscape mosaic of small islands of natural habitat in a matrix of partially to completely modified land cover types. The rationale was that while many of these areas may be too small to support a large variety of terrestrial vertebrates, they would nonetheless be species-rich, containing high numbers of plants and invertebrates.

The first step in the process was the development of a statewide spatially explicit land cover database of vegetation types based on the hierarchical National Vegetation Classification

Scheme (NVCS) developed by The Nature Conservancy. The scheme was adapted to constraints posed by the uniqueness of Florida and other states in the Southeast, resulting in the addition of compositional groups and ecological complexes to augment the alliance level structure of the NVC. Landsat Thematic Mapper imagery (1992-1994) was used as the base for mapping vegetation and classifying land cover types to the level of dominant or co-dominant species. The image processing scheme was custom-designed to maximize accuracy by incorporating ancillary data at critical steps in the process. For example, ancillary data such as wetland distributions (National Wetlands Inventory), soil maps, other aerial imagery, existing land use/land cover maps, and extensive on-the-ground survey data were employed to provide data masks to facilitate classification. The final product was a seamless composite mosaic of 14 Landsat TM scenes with a 30-meter by 30-meter minimum mapping unit representing 71 categories of vegetative land cover varying from open water to mixed evergreen cold deciduous hardwood forests. Assigned cover types were compared to low altitude aerial imagery for ground-truthing. In summary, the Florida landscape is very heterogeneous. Approximately 53% of the state was classified as forest (mesic-hydric pine forests, 18%; forested swamps, 14%), and shrub (xeric shrub, sandhill, and sand pine, 4%), with no other category occupying more than 23% of the land area. Other major categories included agriculture (pasture and crop, 23%), marsh (8%), developed (8%) and surface water (3%). Overall accuracy was 73%. Most of the error could be explained by the fact that the satellite imagery was taken at a different time and different hydroperiod than the aerial videography and digital camera imagery. A second factor was the high degree of heterogeneity within the 30-meter by 30-meter minimum mapping unit.

The next step in the process was to construct spatially explicit databases of potential distributions of native species of terrestrial vertebrates, skippers, butterflies, and ants. This effort was accomplished by first mapping species ranges to the county level, utilizing museum records for mammals, the Florida Breeding Bird Atlas for birds, and statewide databases for herpetofauna. Butterfly distributions were determined from published county dot maps and ants from published and unpublished data from the U.S. Department of Agriculture. Habitat association data were used to build a species by habitat matrix for each group mapped. Resulting county-level maps were reviewed by experts. These data were joined with EMAP hexagons. Maps for individual species were based upon suitable habitat being available within a given hexagon. The final product represents the potential distributions of 56 mammals, 76 species of herpetofauna, and 234 species of birds, as well as over 400 species of invertebrates (butterflies, skippers, and ants). Highest species richness is associated with swamp forest and sandhill land cover types. In southern Florida, pine communities provide habitat for the largest number of species. Overall species richness follows the pattern of most of the individual groups (mammal, birds, herpetofauna, and selected insects) with swamps, mixed pine-oak, sandhill scrub, longleaf pine, and pine flatwoods all contributing to the species richness of the area. For many of the taxa, this region is an area of overlap of species with northern affinities and species with southern affinities. In south Florida, forested classes also appear to support the highest diversity with the exception of the insect taxa. Xeric scrub is an important component in central Florida and unfortunately is underrepresented in the cover classifications.

The conservation lands of the state were mapped by the Florida Natural Areas Inventory (FNAI) from ARC/INFO GIS coverages maintained in their files. Approximately 26.4% of the state's lands are maintained in some legal status of conservation. The remaining 73.5% is held in private ownership. The following summarizes the relationship between taxonomic group diversity or richness and conservation stewardship:

Mammals – Lands in Eglin Air Force Base, the Ocala National Forest, and the Withlacoochee State Forest have the highest mammalian species richness in the state. Unprotected areas of high species richness include both coasts of North Florida and the Panhandle, the lands between Eglin Air Force Base and the Blackwater River State Forest as well as the lands between Osceola National Forest, Camp Blanding Military Reservation and the Ocala State Forest.

Birds – State and federal lands including Eglin Air Force Base, Withlacoochee State Forest, Osceola National Forest, Apalachicola National Forest, Fakahatchee Strand State Park, and the Big Cypress National Preserve protect a high diversity of avian species. Unprotected areas of avian diversity, in order of species richness, exist along both coasts of North Florida, east-central Florida, and the pasture lands of the Immokolee Rise (southwest Florida) and north of the Caloosahatchee River.

Herpetofauna – Eglin Air Force Base, Apalachicola National Forest, and the Big Bend Wildlife Management Area are examples of some of the highest herpetofauna diversity in protected areas. The bottomland and wet forests areas of the Gulf Coast appear to be best opportunities for additional protection of species richness.

Ants – The highest species richness of ants is within xeric central Florida sandhill and sand pine communities protected by the Ocala National Forest and Withlacoochee State Forest. The highest unprotected diversity is in forested land cover of North Florida.

Butterflies and skippers – Across the state, areas of high butterfly diversity appear to be within the confines of conservation lands. The highest areal extent of diversity is in South Florida.

In summary, lands with pine flatwoods, xeric pine, and xeric scrub communities in Florida are major contributors to the biodiversity of the state. These lands also are some of the most threatened because of changing fire regimes and their suitability for development or pine plantation agriculture. The unique pine rocklands of South Florida are threatened by exotic invasive vegetation. In North Florida, the sandhill scrub and longleaf pine habitats of Eglin Air Force Base are protected by an aggressive resource management plan that includes restoration.

Finally, GAP tools–while useful in identifying potential areas for conservation–are but one of many tools that need to be used in concert with other supporting information to ensure adequate assessment of biodiversity distribution and conservation.

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Louisiana Gap Analysis Project

JAMES JOHNSTON AND STEVEN HARTLEY
National Wetlands Research Center, Lafayette

The Louisiana Gap Analysis Project (LA-GAP) was initiated in 1994 as a cooperative effort between the Biological Resources Division of the U.S. Geological Survey and state, federal, and private natural resources groups in Louisiana. The major objectives of the project were to (1) produce GIS databases describing actual land cover type, terrestrial vertebrate species distributions, land stewardship, and land management status at a scale of 1:100,000; (2) identify land cover types and terrestrial vertebrate species that currently are not represented or are under-represented in areas managed for long-term maintenance of biodiversity, i.e., “gaps”; and (3) facilitate cooperative development and use of information so that institutions, agencies, and private landowners may be more effective stewards of Louisiana’s natural resources. LA-GAP is a preliminary step toward the more detailed efforts and studies needed for long-term planning for biodiversity conservation in Louisiana.

The map of actual land cover was the first GIS layer completed for LA-GAP. Ten Landsat 5 Thematic Mapper (TM) scenes, mostly from the winter of 1992, and the 1988 National Wetlands Inventory (NWI) data constituted the base data layers for the land cover map. The land cover map includes the distribution of 23 land use/land cover types. The original 25-meter-resolution TM imagery was subset into smaller manageable files to perform an unsupervised clustering of the spectral signatures. These clusters were then assigned the appropriate cover type by using on-screen visual interpretation of the TM imagery, along with 1995 aerial photography. Data were resampled from the original 25-meter pixel resolution to meet the new national standard of 30-meter pixel resolution. Aggregation of the classified minimum mapping unit (MMU) 30-meter pixel data to eight continuous pixels or approximately 2.5 ha, was done through the usage of the GigaMerge software.

Formal statewide validation of the land cover map was conducted in conjunction with the mapping effort. Field checks of 10,206 sites by different agency personnel and volunteers indicated a 84.11% accuracy of primary cover mapping.

Individual distributions of 333 vertebrate species were predicted by using both point locality records and habitat associations. Range limits of each vertebrate species were delineated for 248 U.S. Environmental Protection Agency (USEPA) hexagons (~160,200 acres/hexagon) within the state. Species distributions were modeled based on habitat affinity associations, within each hexagon, to produce a predicted distribution map based on habitat affinities of an animal for the various categories of land cover, water, and buffered water areas.

Maps of predicted distributions of terrestrial vertebrates in Louisiana should be considered as coarse depictions of probable range and relative abundance of known suitable habitats within that range. This first attempt at predicting areas of high species richness has identified more gaps in our knowledge of vertebrate distribution and habitat affinities than gaps in protection of biodiversity. No formal accuracy assessment of the predicted vertebrate distribution maps of LA-GAP was undertaken.

The Gap Analysis Program (GAP) uses a ranking system of 1 through 4 to denote the relative degree of management for biodiversity maintenance for each parcel of land, with "1" being the highest level of maintenance, and "4" being the lowest, or unknown, status. Status codes were assigned to public lands by The Nature Conservancy. Land stewardship and land management status layers were overlaid with land cover and vertebrate species distributions to conduct a gap analysis of Louisiana.

Less than 10% of the state of Louisiana is classified as public land, and less than 0.3% of that is in management status categories 1 and 2. More than 50% of status 1 and 2 lands occur in the U.S. Department of Agriculture Forest Service (USDAFS) stewardship category. With the completion of LA-GAP, it can be recommended that 1) more existing public lands should be managed for better conservation (i.e., higher management status); 2) more government programs such as Wetland Reserve Program (WRP) and Conservation Reserve Program (CRP) should be initiated to encourage the private landowner to manage for biodiversity; or 3) public land holdings should be increased to target areas of high biodiversity without management practices.

Maine Gap Analysis Project

WILLIAM B. KROHN[1], RANDALL B. BOONE[1], STEVEN A. SADER[2], JEFFREY A. HEPINSTALL[2], SANDRA M. SCHAEFER[1], AND STEPHANIE L. PAINTON[1]
[1]Maine Cooperative Fish and Wildlife Research Unit, University of Maine, Orono
[2]Maine Image Analysis Laboratory, Dept. of Forest Management, University of Maine, Orono

The Maine Gap Analysis Project (ME-GAP) was initiated in 1992 as a cooperative effort between the Biological Resources Division of the US Geological Survey (USGS) and state, federal, and private natural resources groups in Maine. The objectives of ME-GAP were to: (1) produce databases for use in Geographic Information Systems (GIS) at a scale of 1:100,000 to describe current land cover, distributions of native species of terrestrial (i.e., nonfish, nonmarine) vertebrate species, ownership of conservation and public lands, and land management status; (2) identify land cover types and vertebrate species that currently are not represented or are underrepresented in areas managed for long-term maintenance of biodiversity (i.e., identify conservation gaps); and (3) facilitate cooperative development and use of information so that institutions, agencies, and private landowners may be more effective stewards of Maine's biological resources. ME-GAP is a preliminary step toward the more detailed studies and efforts needed for the long-term conservation of biodiversity in Maine.

The system used to classify the land cover consisted of 37 types (19 upland types, 16 wetlands, 2 water). This classification was a compromise between the habitats needed to predict vertebrate distributions and those classes that could be discerned from satellite imagery and ancillary GIS databases. Landsat Thematic Mapper (TM) imagery from 1991 and 1993, in conjunction with aerial videography, was used to identify and map the water and upland types. Wetland polygons came primarily from the US Fish and Wildlife Service's National Wetlands Inventory (NWI). NWI maps of Maine were done at 1:24,000 and based on aerial photographs mostly from the mid- and late-1980s. To facilitate the predicting of vertebrate species' distributions, NWI wetland types, defined largely in terms of physiographic locations on the landscape, were relabeled so types related to the occurrences of vertebrates in terms of vegetative and structural characteristics. A comparison of vegetation and land cover types mapped from TM data to aerial videography had an overall accuracy of 88.1% at the level of superclasses. For groups of forestland classes, accuracy levels range from 45% to 80%; accuracy by types also varied geographically across the state as different TM scenes were used in various parts of the state.

A GIS database of private and public conservation lands was assembled in cooperation with the Maine State Planning Office. Conservation lands comprise less than 6% of Maine with public lands consisting of approximately 5.3%. Conservation lands are well distributed throughout the state except for the northwestern portion, which is largely without public conservation lands. In southern Maine, conservation lands are highly scattered and generally smaller than in the rest of the state. Private commercial forestlands (i.e., large blocks in corporate ownership) and Native American lands managed for forestry encompass approximately 50% of Maine. Lands were denoted as to the degree to which they are managed for maintenance of biodiversity and long-term ecological processes. The Gap Analysis Program requires use of a 1 through 4 scale to denote high to low management for biodiversity maintenance based on legal and management status. While not all lands could be unequivocally classified as to management category, less than 3% of the state occurs in management Categories 1 and 2, with almost no Category 1 lands in southern Maine (lands owned by the Maine Chapter of The Nature Conservancy are the exception). Category 3 lands made up almost 53% of the state and consist primarily of privately owned or public multiple-use forestlands. Category 4 lands occur mostly in southern Maine, along the coast, and in the northeastern corner of the state. The land ownership map should not be interpreted as a legal document, but as a representation of general ownership patterns.

The number of species (i.e., richness) of native terrestrial vertebrates that regularly breed in Maine (n = 270) is highest in coastal and southern Maine. This pattern is similar to the richness patterns of terrestrial threatened and endangered species and woody plants. In the long term, human occupation of the natural landscape is the driving force underlying habitat loss. The density of Maine's human populations in 1990 was highest in the coastal and southern portions of the state. The distribution of Maine's human population is changing (like elsewhere in the nation) with people moving out of population centers into adjacent rural areas; the redistribution of people into rural areas is most extensive in southern Maine. When looking at the distribution of conservation lands by management categories, note few Category 1 areas occur statewide. Southern Maine is clearly the area of highest richness of terrestrial vertebrates, threatened and endangered species, and woody plants, but contains only small and scattered Category 2 and 3 conservation lands. In addition to coastal and southern Maine, the northwestern part of Maine also merits special consideration in conservation planning because this region contains few reserves and provides habitat for northern species at the southern limits of their distributions.

To demonstrate the flexibility of ME-GAP data, two sets of species-specific conservation analyses of terrestrial vertebrates are presented. In set one, data related to the management of a rare forest bird (i.e., Bicknell's Thrush) and a common aquatic mammal (American Beaver) were analyzed using predicted distributions from ME-GAP. In set two, analyses were done on actual habitat data collected by Maine's Department of Inland Fisheries and Wildlife (MDIFW) for an uncommon wetland species (Bald Eagle) versus a widespread upland mammal (White-tailed

Deer). The range of issues covered by these examples clearly shows that this report has barely touched the potential of the data assembled herein to address conservation and management, as well as research, questions.

With the completion of ME-GAP, the long-term maintenance, revision, and application of the GIS databases is a concern. In addition to these data becoming part of the National Biological Information Infrastructure of the USGS Biological Resources Division, these databases will be housed and used by various state agencies. The MDIFW will continue to use the vertebrate data (i.e., range limits and habitat associations) and the vegetation and land cover map; the Maine Image Analysis Laboratory, University of Maine, will store and use the TM and aerial videography data; and the Maine Office of GIS will maintain and distribute the conservation and public lands database created by the State Planning Office and ME-GAP. In the end, the relative success of this project should be judged on how long these databases are revised and reused in the decision-making processes affecting Maine's biological resources.

Montana Gap Analysis Project

ROLAND L. REDMOND, MELISSA M. HART, J. CHRIS WINNE, WENDY A. WILLIAMS, POLLY C. THORNTON, ZHENKUI MA, CLAUDINE M. TOBALSKE, MICHELE M. THORNTON, K. POODY MCLAUGHLIN, TROY P. TADY, FOSTER B. FISHER, AND STEVEN W. RUNNING
Montana Cooperative Wildlife Research Unit, The University of Montana, Missoula

Introduction

The Montana Gap Analysis Project (MT-GAP) began in 1991 for the purpose of identifying vegetation types and areas of high vertebrate species richness in the state that may lack adequate protection under existing land ownership and management regimes. Montana is the fourth-largest state in the union and one of the least populated. When the project began, there were few statewide data sets available. Consequently, much effort was devoted to building key data layers at sufficiently fine scale and resolution for subsequent analysis. These data layers included (1) land cover and existing vegetation at a 2 ha minimum map unit (MMU), (2) ownership and management of public lands (1:100,000 scale), and (3) predicted distributions of 425 terrestrial vertebrates that occur in the state. At the completion of the project, these data became freely available with the intent that they be widely used, not only by those directly responsible for managing the state's valuable natural resources, but also by the public at large, so that everyone can be better informed. With this in mind, we emphasize that these data are dynamic and, in some places, already out-of-date. Nonetheless, the data and analyses which constitute MT-GAP represent an important first step toward planning for the conservation of biodiversity in Montana.

Database Development

<u>Land Cover</u> - The land cover of Montana was mapped by a two-stage, digital classification procedure that was applied independently to 33 Landsat Thematic Mapper (TM) images covering the state. All TM images were obtained during the growing season (mid-June to early September) between 1991 and 1994. In the first stage, data from TM channels 4, 5, and 3 were combined in an unsupervised classification, and then pixels were merged into raster polygons conforming to designated MMUs on the basis of their spectral similarity. Digital elevation

models (7.5 minute wherever available), hydrography, and ground-reference data then were used in supervised classifications to label each mapping unit (raster polygon) according to its land cover type. A total of 50 different land cover types were mapped across the state. The single most abundant type was Low/Moderate Cover Grasslands, which comprised 24.7% of the state; as a group, grasslands covered more than 37% of the state. Twenty-four percent of the state was forested; 19 different forest types were mapped, the most common of which were Mixed Subalpine Forest, Douglas-fir, and Lodgepole Pine. Shrublands comprised another 14%, and riparian types were limited to 3.9% of the state's land area. Urban or Developed Lands occupied less than 1% of this land area, but agricultural lands comprised nearly 15%. Barren types, including rock, snow, or ice, covered 4.3% of the state, and slightly more than 30,000 ha (0.08%) could not be mapped because of cloud cover in the TM imagery.

Thematic accuracy of the land cover map was assessed using a bootstrap method that did not require the collection of an independent set of reference data. Cover type classification accuracies were estimated for 45 types; these averaged 61.4% and ranged from 4.4% for Western Hemlock to 93.2% for Missouri Breaks. Interpolation of the mean error estimates at each ground reference point allowed us to map the land cover accuracy across the state. Estimated mean accuracy exceeded 80% in the southwest corner (Beaverhead and Madison Counties) and in the western portion of the Highline in Glacier, Toole, and Pondera Counties; lower estimated accuracies were associated with some of the insular mountain ranges in central Montana from Gallatin County north through Cascade and Judith Basin Counties.

Predicted Vertebrate Distributions - Distributions of 425 terrestrial vertebrate species were predicted, including 16 amphibians, 17 reptiles, 290 birds, and 102 mammals. The modeling process involved several steps. First, range limits for each species were delineated on the basis of existing information about the species' presence or absence within either a latilong grid system for birds, or the Environmental Protection Agency's (EPA) hexagon grid system for amphibians, reptiles, and mammals. Next, associations between species and habitat features such as land cover, elevation, and distance to water were researched and summarized in a Wildlife-Habitat Relationships (WHR) database. After preparing the necessary GIS layers to represent these habitat features, a raster-based modeling approach was used to combine the distributional limits and WHR databases into predicted distributions for each species at a resolution of 90 m grid cells. The actual modeling rules and preliminary maps of the predicted distributions were reviewed by nearly 50 biologists from around the state. After review, any necessary changes were made to the range limits and model rules. Once all predicted distributions were complete, species checklists from 14 wildlife refuges and other management units around the state were used to evaluate their accuracy. This involved a comparison between predicted and observed species' presence, not absence. As such, it cannot be considered a complete accuracy assessment, in part because potential sampling errors in the validation data limited our ability to distinguish between commission errors and correct predictions of absence.

Geographic patterns of vertebrate species richness indicated generally higher diversity in the mountainous regions of western Montana, and lower values in eastern Montana. Not surprisingly, the high diversity was observed along ecotones and in riparian areas, where habitat diversity was correspondingly high. Comparisons between predicted and observed species presence at 14 areas around the state indicated relatively low omission error rates (< 10%), but considerably higher rates of commission errors (24-41%). This means that the models were more likely to overpredict species distributions than to underpredict them. In the context of most management decisions, this is desirable for the same reason that Type I statistical errors are more serious than Type II errors. Failure to predict a species' presence in an area where it actually occurs may cause inadvertent harm if land-use decisions are made without that species in mind. If, however, a species is predicted to occur where it has never been recorded, it is more likely that the species will be targeted in future surveys and also considered in subsequent land-use decisions.

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

The digital land stewardship layer was created by incorporating various administrative boundaries into a base layer of land ownership obtained from the BLM, Montana State Office. The BLM produced a base layer by scanning the plates from their 1:100,000 scale Surface Management Series maps. We added some additional information to this base layer, but only for lands managed to protect some elements of biodiversity (i.e., Status 1 and 2). Each map unit in the stewardship layer was assigned a management status code. Management plans for public lands were consulted when available; otherwise agency personnel were consulted.

Lands were assigned to one of four management classes based on the relative degree to which land stewards were responsible for maintaining biodiversity values. Status 1 lands reflected the highest, most permanent level of restrictive management; such lands included National Parks, designated Wilderness Areas, state Wildlife Preserves, Nature Conservancy Preserves, and National Wildlife Refuges where grazing was not permitted. Management could be changed more easily on Status 2 lands, such as Wilderness Study Areas, Wildlife Management Areas, and National Wildlife Refuges where grazing was permitted, but it was still more restrictive than the remaining multiple use public lands, which were assigned to Status 3. Finally, Status 4 included all private lands with no irrevocable easement or mandate to preserve biodiversity values.

Public lands administered by federal and state agencies comprise approximately 35% of Montana. Most federal lands in the western half of the state are managed by the U.S. Forest Service and the National Park Service, whereas most federal lands in the eastern portion of the state are managed by the BLM. Status 1 and 2 lands occupy less than 10% of the state and are generally found at higher elevations. Status 3 and 4 lands occupy more than 90% of the state, and well over half of these are in private ownership.

Analyses

Once the requisite statewide data were assembled, the actual gap analysis involved intersecting the GIS layers of land cover and predicted vertebrate distributions with land stewardship. Generally, the results indicated that high elevation cover types and associated vertebrate species should be relatively well protected under Status 1 and 2 management regimes. But even in these areas, biodiversity elements could be threatened by disease (e.g., white pine blister rust) and the introduction of exotic weeds. Two areas in the state appear to be rich in vertebrate diversity and perhaps in need of a finer-filter analysis–the East Front of the Rocky Mountains and the Bighorn/Powder River basins in southeast Montana. The former is a very scenic area, which is rich in birds and mammals. Much of the nonforest portion of this area is privately owned, and although relatively large areas have been protected by various conservation measures during the past 20 years, more efforts likely will be required to maintain the ecological integrity of the East Front. The second area, the Bighorn and Powder River basins, are rich in mammals and reptiles. Underlying these lands, however, are massive coal deposits, which threaten the long-term viability of this area for wildlife habitat. We also note with some surprise that the longest free-flowing river in the lower 48 states, the Yellowstone, has no formal protection anywhere along its banks.

Conclusions

The land cover and vertebrate distribution data developed for Montana GAP are the most detailed ever produced for the entire state. These data are based on a 90 m^2 statewide grid, which contains more than 4.5 million grid cells. One of 50 different land cover types was assigned to each cell, and information pertaining to 425 terrestrial vertebrates was synthesized into rules for predicting species' presence and absence in each cell. The resulting data sets are large and complex, which may complicate their use by state and regional managers as well as by policy makers. Moreover, we found through the review process that the 90 m resolution was often still too coarse for many wildlife biologists whose day-to-day concerns operate at even finer-scale project levels. This may make product acceptance and use even more difficult.

In spite of these challenges, we point out that the relatively fine scale at which we mapped the state's land cover should make the data useful for considerably more than predicting wildlife distributions. For example, we have already extended this work to the dasymetric mapping of human population density (Holloway et al. 1998), median income, and median age of housing unit across 34 counties in Montana. These results, in turn, could become inputs for improving vertebrate distribution models or predicting where future conflicts are more likely to occur. With the methodologies and reference data in place, remapping or updating land cover would be a relatively straightforward process. Although 23,351 ground-truth plots sound adequate, we believe that higher accuracies would result from additional data, especially from certain areas in central and eastern Montana. We do not advocate expensive field surveys, however, but rather consideration by a consortium of state and federal agencies to fund airborne video sampling, at least across areas like the Bighorn and Powder River basins where it may be important to improve land cover mapping and to monitor changes in land use.

Validation of predicted vertebrate distributions also could be expanded by using more extensive data sets, such as those from the Forest Service's Northern Region Landbird Monitoring Program (Hutto 1995). Additional sites in eastern Montana might have to be targeted for future field surveys as well.

The vertebrate distribution models themselves also could be improved in many ways. For example, incorporating interspecific relationships into the models could yield important insights. Although competitors, predators, and brood parasites may not actually limit the distribution of other species, they certainly affect habitat quality. Greene et al. (in press) examined the predicted breeding distribution of Lazuli Buntings in relation to that of Brown-headed Cowbirds in the state; their results indicated that more than 90% of nesting buntings in Montana may be vulnerable to cowbird parasitism. Similar analyses could be carried out for many other host or prey species.

Finally, at the risk of pointing out the obvious, managers of public lands in Montana have more ready opportunities to manage for biodiversity in some landscapes than they do in others. For example, more than 90% of several cover types, including Missouri Breaks and Mixed Whitebark Pine Forest, is managed by federal agencies. Consequently, these types and any associated wildlife species ought to be easier to manage than several of the riparian cover types, the vast majority of which occur on privately owned lands. Thus, it should come as no surprise that conservation of riparian areas, and their associated species, will depend on participation from the private sector. Elected officials at all levels of government can certainly help encourage this participation through enactment of laws that make conservation more appealing than development.

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New York Gap Analysis Project

CHARLES R. SMITH
Department of Natural Resources, Cornell University, Ithaca, New York

The New York Gap Analysis Project (NY-GAP) was begun in 1993 as a cooperative effort among the Biological Resources Division of the U.S. Geological Survey (U.S. Fish and Wildlife Service at that time), Cornell University, and the NY State Department of Environmental Conservation (NYSDEC). For a list of objectives see the final report summary for Colorado on page . NY-GAP is a preliminary step toward the more detailed studies and efforts needed for the long-term conservation of biodiversity in New York.

New York ranks twenty-seventh in total area among the fifty states. However, with 20 million inhabitants, it is among the three most populous states in the United States, with a population density of 1.7 persons per hectare (0.7 persons per acre). Approximately 200 years of intensive land use have dramatically affected the natural history of New York, making a complete characterization and mapping of land cover types and other elements of biodiversity a challenging undertaking.

Land Cover Classification and Mapping

A statewide map of 29 land cover types was produced to support habitat modeling for the New York Gap Analysis Project (NY-GAP). The map was produced using 14 Landsat-5 Thematic Mapper multispectral digital images acquired during spring and summer of 1991 to 1993, inclusive. A statistical clustering program was used to produce 240 spectrally homogeneous clusters to which a land cover type label was applied based on spectral properties, ancillary data, and local knowledge. The nomenclature and procedures of the National Vegetation Classification System (NVCS) were adopted for labeling land cover types.

When all clusters of all images were labeled into a land cover type, each scene was digitally mosaicked with its adjacent image and spatially aggregated to a four-hectare minimum mapping unit. Several alternative strategies were investigated to improve the spatial and taxonomic detail of the statewide map. Ultimately, time and resource constraints limited map production techniques to trained image analysts labeling clusters derived from single-date, multispectral Landsat data.

A stratified random sample of 113 field plots was used to assess the accuracy of the NY-GAP map using both conventional and "fuzzy" accuracy assessment methods, as described in the full report. Through the summer and fall of 1998, field crews visited 9,745 map polygons and assigned a land cover type label based on visual inspection and careful assessment of the dominant cover types in the polygon. Each observed polygon was considered a point sample, which was compared to the predicted land cover type for each of the sampled polygons. If polygons were inaccessible, field crews relied on aerial photo interpretation and local knowledge to determine the appropriate land cover type of the polygon. The degree to which the reliance on aerial photo interpretation for assigning land cover type labels to sampled polygons affected the accuracy of the field data was not investigated. Contingency tables at three taxonomic levels were constructed using the field observations. Overall map accuracy at the Superalliance (NVCS), Subclass (NVCS), and modified USGS Anderson Level I classification levels were 42%, 57%, and 74%, respectively.

Application of fuzzy accuracy assessment methods using a subsample of the 9,745 polygons resulted in 19% and 23% improvement in overall map accuracy at the Subclass and Superalliance classification levels, respectively. Fuzzy functions are calculated using linguistic scores that permit greater flexibility in assigning an acceptable answer to an observed land cover type in comparison to what is predicted. There should be further investigation of the extent to which fuzzy accuracy assessment provides additional information useful for improving the quality of land cover maps developed for conservation applications, when compared to conventional accuracy assessment.

The low map accuracies obtained at NVCS Superalliance and Subclass levels have to be balanced with the spatial distribution and area summaries for each land cover type at both levels of the classification scheme. The impact of sampling field plots in close proximity to transportation routes with limited observations for less heterogeneous areas may have resulted in lower map accuracies than would be expected. Additional studies are required to evaluate the impact of the sampling design used in this project. We believe that the accuracy assessment method used in this case possibly undervalues the quality of the statewide map that was produced.

The NY-GAP map compares relatively well with other regional-scale land cover mapping efforts with regard to area and accuracy of major land cover types. Consistently low producer accuracies for agricultural land cover types are indicative of the difficulties of mapping these particular types. The spatial and spectral variation due to diverse cropping systems, rotations of row crops with hay and pasture lands, and short- and long-term abandonment of cropland contributes to the spectral confusion encountered. Improvements in mapping accuracy of these particular land cover types, which are highly dynamic in their spectral response, can be expected by developing a temporal sequence of spectral indices throughout the growing season or sequence of growing seasons to capture both intra- and interannual cropping system spectral variations.

Predicted Animal Species Distributions and Species Richness

NY-GAP created predicted distribution maps for 366 terrestrial vertebrate species, including some common, introduced and commensal species (e.g., ring-necked pheasant and house mouse). All mapped species, except for 8 non-native, introduced species, were included in the gap analysis process, for a total of 358 native vertebrate species evaluated using gap analysis procedures. Accuracy assessment was conducted for as many mapped species as possible, including introduced species. Because marine vertebrates are not included in the gap analysis process, five species of marine turtles were excluded from all analyses. Accuracies for three very rare breeding bird species (Merlin, Black Vulture, Wilson's Phalarope) could not be calculated because of a lack of species occurrence records.

Species richness for native, terrestrial vertebrates was computed for each of 249 EPA hexagons within the state. Total vertebrate richness ranged from 119 to 285 species per hexagon with a mean of 242.6 ± 27.6). The distribution of species richness values varies among species groups. Birds and reptiles follow a normal distribution, while distributions of amphibians and mammals are skewed to the left, indicating that most hexagons contain a relatively high number of amphibians and reptiles.

The state of New York exhibits some noticeable patterns in predicted species richness. Amphibians and reptiles exhibit greatest species richness values in the Hudson River Valley, with fewer species in the Adirondack Mountains, which is higher in elevation and likely too cold for these species in the winter. The opposite is true for birds, where richness is high in the Adirondack Region, especially in its outer portion (the Adirondack Transition), with somewhat lower relative richness in the Hudson River Valley area. Birds also show another diverse area in western New York in the transition area from the edge of the Appalachian Plateau to the Great Lakes Plain, where there is an abundance of open fields and grassland areas. Mammal diversity is highest the Catskills and the outer portion of the Adirondacks, both heavily forested regions. Diversity for mammals is lowest on Long Island, which is about 50% urban, as well as in the Great Lakes Plain, which is about 50% agriculture and open field.

Species richness for predicted distributions also was calculated by 90-meter grid cell, which follows the same general trends as richness by hexagon. The overall accuracy at the town level averaged for all species was 59.3%. Accuracy was highest for birds at 84.8% at the town level, reflecting the detailed coverage of the Breeding Bird Atlas data. Accuracy for mammals was approximately 31% because there were fewer observations for mammals at the town level. Amphibian and reptile accuracy fell between the other two groups, at 67% and 65%, respectively. The same methods were used to calculate accuracy at the ecozone level, with an overall average accuracy of 84.5%.

Accuracy for 33 species of amphibians was lowest for Jefferson Salamander and the Jefferson Salamander complex at 7.0%, with 93% commission error, and highest for the Eastern Tiger Salamander, with 99.2% accuracy and 0.6% commission error. Omission errors were low for nearly all species, except for the Blue-spotted Salamander at 4.6%. Accuracy at the ecozone level and 7.5' quadrangle level ranged from 9.1 - 100% and 10.3 - 96.8%, respectively, for these amphibian species.

Accuracy for 32 species of reptiles was lowest at 14.1% for the Smooth Green Snake with 85% commission error and highest for the Eastern Massasauga, Eastern Mud Turtle and Northern Diamondback Terrapin with 97 - 99.9% and approximately 1% commission error. Omission errors were low overall, ranging from 0 - 2.14%. Accuracy at the ecozone level and 7.5' quadrangle level ranged from 36.4 - 100% and 18.8 - 99.7%, respectively. Accuracy for some of the common species, such as the Snapping Turtle or Eastern Box Turtle fell in the middle of the range at about 50%.

Accuracy for 231 species of birds ranged from 35.2% for Barn Owl and Pied-billed Grebe (with 63% commission error) to 100% for several different species. In fact, more than half of the breeding birds had accuracies above 90%. Omission errors were generally low, from 0 - 1 %, and a maximum of 6.4% for the Northern Bobwhite. Accuracy at the ecozone level ranged from 9.1 - 100%.

Accuracy for 59 mammal species ranged from 4.2% for the Indiana Bat, with a 95% commission error, to 93% accuracy for White-tailed Deer and Rock Vole, with 31% and 62% commission errors, respectively. Omission errors were low, ranging from 0 - 3.6%. Accuracy at the ecozone level ranged from 27.3 - 100%. Besides the high accuracy for White-tailed Deer (93%) and American Beaver (89%), accuracy values for many of the common mammalian species were quite low. For example, the Eastern Gray Squirrel and Virginia Opossum both had an accuracy of about 8.5%. We believe that the low overall accuracy and high commission errors for mammals are a function of limitations of the species occurrence database. Our experience with NY-GAP emphasizes the need for substantial research on the distributions of smaller, nongame mammals in New York State. Overall, distributions and status for small mammals are among the poorest known of terrestrial vertebrates in the state.

Land Stewardship

A digital map of land stewardship was created for the state using data contributed from federal, state, and private organizations. GAP uses an ordinal scale of 1 to 4 to identify the relative degree of management for biodiversity protection for each land unit, with Status 1 being the most permanent, comprehensive level of protection, and Status 4 being the lowest level, or unknown.

Nearly 10% of New York State (NYS) was classified as Status 1 or 2 lands. Most of these lands (86%) are located in the Adirondack Forest Preserve and are managed by NYSDEC. Status 1 and 2 lands are disproportionately located at higher elevations, with 70% of lands above 700 m (2170 ft) elevation and 17% of lands below 700 m elevation classified as Status 1 or 2. Approximately 10% of the state was classified as Status 3 and 81% was classified as Status 4. In contrast to the Status 1 and 2 lands, Status 3 lands are well distributed across NY. State and federal government lands comprise about 14% of NY, a modest proportion compared to many western states.

Analysis Based on Stewardship and Management Status

Our analysis was based on results from intersecting the GIS coverages of land cover types and predicted vertebrate distributions with the stewardship and management status coverages. Generally, the results revealed that forested cover types are well represented on protected lands (those classified as Status 1 or 2), but nearly all shrub and grasslands are under private management and are poorly protected.

Predicted distributions for a total of 358 native, terrestrial vertebrate species were mapped for NY. Of these species, only five were not predicted to occur at all in Status 1 or 2 lands (Eastern Hellbender, Shorthead Garter Snake, Ring-billed Gull, Clay-colored Sparrow, and Yellow-throated Warbler). A large proportion (72%) of vertebrate species in the state have less than 10% of their predicted distribution on Status 1 or 2 lands. Nearly all reptile species (97%) and a majority of amphibian (75%), bird (70%), and mammal species (64%) are in this group.

There are 66 species of vertebrates currently listed as being of special concern in NYS. Among these species, nearly all (92%) of the amphibian and reptile species, 76% of the bird species, and 66% of the mammal species have less than 10% of their predicted statewide distributions within Status 1 or 2 lands. Many species that appear to be least protected are associated with grassland habitats or habitats associated with water bodies. Cover types that represent these habitats are not only uncommon, but also among the least protected areas in the state. There are a few listed species, such as Bicknell's Thrush, that prefer higher elevation areas in coniferous forest cover. Cover types representing these habitats have some of the highest proportions of occurrence in Status 1 and 2 lands, and it logically follows that nearly 90% of the expected distribution of Bicknell's Thrush is on protected lands.

Conclusions and Management Implications

More than 200 years of intensive land use by humans have created a complex landscape mosaic across NY. Widely dispersed land cover types of small size and substantial within-type diversity present an ongoing technical challenge for landscape characterization. The vegetation map of NY-GAP represents the first time in history that a digital land cover map, including an accuracy assessment, for the entire state has been created and analyzed, based largely upon satellite imagery. This map, however, represents a beginning, not an end. Only if subsequent maps are produced in the future will we be able to assess change in land cover types and extent across the state. Such land cover change detection is essential if we are going to be able to estimate the spatial nature and temporal trajectories of land cover change and evaluate conservation options in that dynamic landscape context.

The procedures of gap analysis, developed by professionals, widely tested, and thoroughly peer-reviewed, offer a protocol and template for continued collection and use of spatially referenced information about the occurrences of elements of biological diversity at the species level and above. As more management practitioners develop a better understanding of new technologies and become more familiar with applications of remotely sensed imagery, digital image processing, and geographic information systems, greater acceptance and application of these technologies can be expected. Potential applications of GAP data still can be limited by user or institutional inertia, an absence of creativity and imagination on the part of users, and an absence of adequate funding for exploratory studies and refinement of methods. For example, issues related to the propagation of errors in all phases of the gap analysis process still need to be investigated more thoroughly. Errors contained in the land cover map, habitat matrices, vertebrate models, validation data, and land stewardship maps may all contribute to the uncertainty of predictions, relationships of animals to habitats, and map products resulting from the gap analysis process.

New York is a densely populated state, with only approximately 15% of its land area represented by public lands, actually or potentially managed for biodiversity conservation. This proportion of public lands is in marked contrast to most of our large western states. We have learned that substantial observed terrestrial vertebrate biodiversity is represented within the corridor along the Hudson River, between Albany and New York City. The Hudson Valley Region, with 13.5% of the land area of the state and only 12% of the state's public lands, has 83% of the state's terrestrial vertebrate diversity, 86% of the land-cover diversity, and 54% of the state's human population. These statistics capture the essence of the challenges that face biodiversity conservation for our eastern United States in the twenty-first century.

Information from the NY-GAP database about land cover types and predicted occurrences of terrestrial vertebrates could be useful in guiding state inventory and planning efforts. Among such efforts could be open space designation, planning, and management, along with development of long-range management plans for state wildlife management areas and state forests. GAP data can be used to map land cover types and estimate land cover type areas for state lands and also offer a first approximation of expected (i.e., predicted) terrestrial vertebrate species diversity to aid in the planning and inventory process for land management units.

With completion of NY-GAP, we are poised to address a number of questions relevant to the regional content and context for elements of coarse-filter and fine-filter biodiversity within NY. It is hoped that there will be sufficient interest from agency leaders and others for these kinds of questions to be addressed in the future for a variety of regions of NY, both ecological and political. The gap analysis process and NY-GAP database provide the foundation and basic information essential for these kinds of analyses and associated planning efforts at landscape scales.

Oregon Gap Analysis Project

JAMES S. KAGAN[1], JOHN C. HAK[1], BLAIR CSUTI[2], CHRIS W. KIILSGAARD[3], AND ELEANOR P. GAINES[1]
[1]Oregon Natural Heritage Program, Portland
[2]Metro Washington Park Zoo, Portland
[3]Northwest Habitat Institute, Corvallis

The Oregon Gap Analysis Project (OR-GAP) began work in 1988 as the second GAP project started, following only the original pilot project initiated in Idaho by Mike Scott of the Idaho Cooperative Fish and Wildlife Research Unit of the University of Idaho. OR-GAP was managed by Blair Csuti of the Idaho Cooperative Fish and Wildlife Research Unit until 1997 and was completed by the Oregon Natural Heritage Program (ORNHP). It has been a cooperative venture, with the initial vegetation map completed by contract staff and the ORNHP, and the initial wildlife distributions developed cooperatively by Oregon State University, the Biodiversity Research Consortium, ORNHP, and the Oregon Department of Fish and Wildlife (ODFW). Oregon was also fortunate enough to have a separate statewide biodiversity assessment managed by the Northwest Office of the Defenders of Wildlife. This was the Oregon Biodiversity Project, which started as an effort to implement the results of the first Oregon Gap Analysis work, but wound up as an independent analysis. A second-generation land cover map was developed by ODFW, and ORNHP developed updated species distribution maps based on the second-generation land cover. Because we had access to a historical vegetation cover, we were able to model vertebrate species distributions prior to European settlement. This report outlines all of the work completed to date.

The major objectives of the project were to (1) produce GIS databases describing actual land cover type, historical land cover type, terrestrial vertebrate species distributions, land stewardship, and land management status at a scale of 1:100,000, (2) identify land cover types and terrestrial vertebrate species that currently are not represented or are underrepresented in areas managed for long-term maintenance of biodiversity, i.e., “gaps,” and (3) facilitate cooperative development and use of information so that institutions, agencies, and private land owners may be more effective stewards of Oregon’s natural resources. The OR-GAP project is a step toward the more detailed efforts and studies needed for long-term planning for biodiversity conservation in Oregon. The final (Version 2) map of actual land cover used in this analysis included the distribution of 65 land cover types, mapped as polygons with a minimum mapping unit (MMU) of 100 hectares.

Individual distributions of 457 vertebrate species were predicted using habitat associations. Range limits of each species were delineated within a grid of 441 hexagons (635 km^2) based on published range maps, locality records, and review by local experts. This hexagon database has been in existence at the Oregon Natural Heritage Program for the last 10 years and has been updated based on continual reviews and inclusion of new data. It includes information both on species distributions, the source of information for each hexagon, and the confidence in the record. Within hexagons, species distributions were modeled based on species/land cover associations and the presence of riparian areas. Comparisons of predicted species to species lists maintained for eight wildlife refuges produced variable results since the tested areas often had incomplete lists.

The Gap Analysis Program (GAP) uses a scale of 1 through 4 to denote how well each tract of land is managed for biodiversity maintenance, with "1" being the highest, most permanent, and best managed, and "4" being the lowest, or unknown, status. Status codes were assigned by ORNHP staff following GAP guidelines with review by The Nature Conservancy's Public Lands Coordinator. A total of 17.2% of the state of Oregon is classified as status 1 and 2 lands; 95% of these are found on federal ownership. Oregon has large portions of its public lands in the western portion of the state as Late Successional Reserves (LSR), and large portions of the eastern part in Bureau of Land Management Wilderness Study Areas (BLM WSA). The designation of these LSRs and BLM WSAs as status 2 lands results in high proportion of Oregon found in protected areas (status 1 and status 2 lands), although these designations do not provide as much protection as do most other status 2 designations. This is a limitation of using only four land management classes to represent a complex array of management designations when examining protection patterns for individual species as well as species richness. Land management status was overlaid with land cover and vertebrate species distributions to conduct a gap analysis of Oregon. We considered land cover types and vertebrate species as underrepresented (i.e., "gaps") in management areas if < 1% of the land they occupied or their habitat in Oregon fell within status 1 and 2 lands.

Nine (14%) of 63 natural (non-anthropogenic) land cover types have < 1% of the area they occupy in status 1 and 2 lands. The highest priority for further protection is recommended for coastal strand and hawthorn-willow shrublands, because their current protection is low and they are the most vulnerable to ongoing land management practices. Palustrine forest and south coast mixed conifer forest are also high priorities for protection if WSAs and LSRs are excluded from the analysis. Wetland and riparian types are not satisfactorily mapped at our current MMU, and further efforts are needed to provide an adequate spatial description of their location before long-term planning for their conservation can be accomplished.

Five (< 2%) of the 263 birds modeled had < 1% of their habitat protected in status 1 and 2 lands. When LSR lands are put in status 3, three additional species are added to this category. When historic distributions were compared to current status 1 and 2 lands, one fifth (57) of the birds modeled had substantial habitat loss or low habitat protection. Of these, nine are of current conservation concern. No native mammals had < 1% of its habitat in status 1 and 2 lands. When LSR lands are excluded from category 2, two mammals of conservation concern (California and Townsend's voles) fall into this category. Thirty-one (24 %) mammals (including seven conservation targets) have had substantial habitat loss or low habitat protection when compared to historic distribution. There were no amphibians or reptiles with < 1% of their present distribution in status 1 and 2 lands. When LSR lands are dropped from the analysis, one reptile, the common kingsnake, is added to this group. Thirteen (22 %) of the amphibians and reptiles have had substantial habitat losses or low habitat protection compared to historic distributions.

Using some indices developed to look at how much habitat species have lost and how well their current and historic distributions are protected, OR-GAP was able to compare species richness maps for all species, with a subset of those needing conservation action. The major centers of species richness (areas with very high species richness values) are the Klamath Basin in south-central Oregon, the Malheur Basin in east-central Oregon, and the Siskiyou Mountains in southwestern Oregon in both the all-species and the priority-species richness maps. However, areas of high to moderately high diversity change dramatically in the subset of needy species coverage, with priority areas highlighted in the western Columbia River Gorge, the Alvord Basin, and southeastern Wasco County that were not important in the overall species richness map.

In general, OR-GAP is hesitant to use the results of the analysis to make important statements about either diversity patterns in Oregon or sites where highest biodiversity most needs to be protected. However, the development of the stewardship coverage and the species distribution databases has improved the ability of others to do statewide and local assessments. Both versions of the OR-GAP land cover are uneven, with detailed mapping and classification in some areas and coarser mapping and classification in others, and neither have undergone accuracy assessment. The wildlife by habitat relationship models used in OR-GAP are in the process of being improved, but the new models were not available in time for this analysis. We believe that using higher-resolution vegetation coverages with more detailed classifications and the improved wildlife-habitat models would greatly improve the overall accuracy of the analysis. However, the OR-GAP version 2 species distribution maps are clearly the best wildlife distribution maps available and are quite useful for ecoregional, statewide, and multistate analyses.

OR-GAP has been most valuable as a focus to develop and integrate these important data sets. Using the species distribution databases and the managed area coverage with the new wildlife-habitat models and ecoregional or local vegetation maps that are currently being produced throughout the state, should provide much more accurate species lists and species distribution maps. OR-GAP intends to continually update the managed area cover and species distribution databases and to provide cross-walks between the new wildlife habitat models and any new vegetation or land cover maps which become available. We intend to try to aggregate a 1:24,000 vegetation coverage for Oregon, based on local mapping efforts, and to compare these to the coarser-scale maps based on satellite imagery. And, we intend to remain a source of biodiversity information for anyone interested in studying or protecting biodiversity in Oregon.

Pennsylvania Gap Analysis Project

WAYNE MYERS[1], JOSEPH BISHOP[2], ROBERT BROOKS[2], TIMOTHY O'CONNELL[2], DAVID ARGENT[2], GERALD STORM[3], JAY STAUFFER[2], AND ROBERT CARLINE[3]
[1]School of Forest Resources & Environmental Resources Research Institute, The Pennsylvania State University, University Park
[2]School of Forest Resources, The Pennsylvania State University, University Park
[3]Pennsylvania Cooperative Fish & Wildlife Research Unit, The Pennsylvania State University, University Park

The Pennsylvania Gap Analysis Project (PA-GAP) was initiated in 1993 with the goal of providing a landscape-level perspective on the conservation status of reproductive habitats for mammals, birds, amphibians, reptiles, and fishes. The intent has been to attain this overall goal of landscape perspective within the general framework of the national Gap Analysis Program (GAP), but with some accommodation for Pennsylvania's special blend of physiography and historical human habitation.

Pennsylvania's contemporary habitats are largely a legacy of historic human disturbance. Major modes of disturbance have included strip mining, marginal agriculture, and extensive forest clear-cutting, often followed by fire. There has been a physiographic propensity for exposed soils to be degraded by erosion, leading to abandonment of lands and their eventual reversion to the public domain. Regrowth and reforestation, along with restoration of mine spoils, have created habitats that harbor a considerable variety of wildlife.

Thus, geography, physical environment, land cover and disturbance, and wetland occurrence are major determinants of habitat in Pennsylvania. Species composition and density of vegetation are somewhat secondary as habitat factors at landscape scales in this region. For these reasons, the landscape-scale habitat models for Pennsylvania give more emphasis to the former features, whereas GAP would traditionally emphasize vegetation types.

Pennsylvania history is replete with negative human influences on waters and wetlands. These ecosystems have not been as resilient to human impacts as terrestrial systems. Erosion of exposed soils generates sediment that fills in wetlands, aggravating the loss and modification of wetlands due to development. Pollution from industry, mining, agriculture, urbanization, and transportation contributes toxic chemicals to the waters, increases their acidity, and builds up excess nutrients in lakes and ponds, which can ultimately be deadly for fish and other aquatic life. Acid mine drainage and acid rain have been especially problematic for Pennsylvania. Hydrologic engineering for transportation, flood control, cooling, and power generation has disrupted natural hydrologic patterns. The location of major urban centers in the state is strongly associated with large rivers, estuaries, and Lake Erie. Drainage divides between major river basins constitute virtually complete barriers to dispersal and recolonization by aquatic species. This multitude of long-term stresses, coupled with segregation imposed by Pennsylvania's physical geography, has put several of the state's aquatic species in jeopardy, and a number of others are apparently already eliminated from entire geographic sectors.

To tracking conservation status, GAP protocols differentiate four levels of land stewardship. On status 1 lands, human disturbance of habitat is legally prohibited and nonhuman disturbance is not controlled unless it threatens human life or property. Status 2 lands are naturalistic areas with a legal mandate prohibiting conversion to humanistic/cultural development. On status 3 lands, any further permanent conversion of lands to humanistic/cultural development is restricted by legal mandate. In Pennsylvania, a distinction was made between status 4 lands having no specific provisions for habitat conservation and lands for which conservation status could not be determined.

Examples of GAP status 1 lands in Pennsylvania are wilderness areas, natural areas, wild areas, and conservancies. Pennsylvania has less than 1% of its approximately 11.6 million hectares in status 1 lands. Status 2 lands in Pennsylvania include state parks, state forests, state gamelands, state scenic rivers, national wildlife refuges, and less restrictive private conservancies. Pennsylvania has 12% of its area in status 2 lands, with the interesting irony that a substantial share of this large area was historically degraded land that reverted to the public domain for rehabilitation. Pennsylvania's GAP status 3 lands consist mostly of national forest, national parks, national recreation areas, and national scenic and recreational rivers. Status 3 lands account for a little more than 2% of Pennsylvania's area. Therefore, the Commonwealth has approximately 15% of its land area in stewardship status 3 or better, with the more pristine status 1 lands being quite limited. Importantly, status 2 lands are concentrated in parts of the state that have been demonstrated historically to be unsuitable for intensive human development.

Generalized land cover and disturbance were mapped in several modes from Landsat Thematic Mapper (TM) digital data collected during a period from 1991 through 1994. The image data were compressed for mapping purposes so as to be compatible with geographic information systems (GIS) software. The compressed images have been made available to the public and have received considerable use in Pennsylvania as backdrops for GIS applications. An initial interpretive mapping at 100 ha resolution classified landscapes as being either *naturalistic* or *humanistic*. Naturalistic landscapes included forests, wetlands, and water. Humanistic landscapes included agricultural, suburban, and urban land uses. Nearly 70% of the state has a naturalistic (mainly forested) landscape, with approximately 65% in one large unit encompassing much of the northern third of the Commonwealth and extending through the mountains to the southern border.

Landscapes in several regions of Pennsylvania are heavily influenced by human development. Habitat disturbance due to human development was mapped interpretively in three types with no specific minimum resolution. The disturbance classes were rural, suburban (primarily residential), and urban (commercial/industrial). Pennsylvania is predominantly rural, with 1.5% of its area being intensively urbanized and another 4.1% being suburban. Much of the urbanization is due to a few large metropolitan areas.

By reference to selected digital aerial photos, eight general land cover categories were mapped through computer-assisted classification of spectral groupings in the compressed image data. These land cover categories were (1) water; (2) evergreen forest; (3) mixed evergreen/deciduous forest; (4) deciduous forest; (5) woody transitional such as bushes; (6) perennial herbaceous such as grasslands and forage crops; (7) annual herbaceous such as row crops and grains; and (8) barren/hard-surface/rubble/gravel. Combining the land cover and disturbance mappings yielded 24 classes for habitat modeling.

Habitat models were developed in tabular (matrix) form as spreadsheets, with columns representing habitat factors and rows representing species. A map of suitable habitat was then prepared for each species from the respective model by analytically combining spatial data layers for the habitat factors using computerized geographic information systems (GIS). The modeling for fishes was done on the basis of 9,855 small watersheds.

GAP analysis conventionally takes note whether a species has 10%, 20%, or 50% of its potential habitat on lands with management status 1 or 2. Pennsylvania has approximately 13% of its total land area in GAP status 1 and 2, so common species fall mostly in the 10% to 20% range for this level of conservation. Higher percentages indicate some degree of habitat restriction to conservation areas. Lower percentages indicate relative underrepresentation of habitat within conservation areas but do not necessarily reflect overall degree of statewide habitat scarcity.

There are no mammals having 50% or more of the potential habitat in status 1 and 2. The following species have 20% to 50% of potential habitat in status 1 and 2: northern water shrew, long-tailed shrew, pygmy shrew, Indiana myotis, Appalachian cottontail, snowshoe hare, northern flying squirrel, Allegheny woodrat, woodland jumping mouse, common porcupine, fisher, eastern spotted skunk, bobcat, and elk. Species having less than 10% of potential habitat in status 1 and 2 are: eastern mole, evening bat, Norway rat, house mouse, meadow jumping mouse, and least weasel. The remaining species have 10% to 20% of potential habitat in status 1 and 2.

There are four species of birds with 50% or more of potential habitat in GAP status 1 and 2: American wigeon, black tern, yellow-bellied flycatcher, and blackpoll warbler. Bird species having 20% to 50% of habitat in GAP status 1 and 2 are: northern goshawk, black-necked stilt, northern saw-whet owl, yellow-bellied sapsucker, olive-sided flycatcher, red-breasted nuthatch, winter wren, golden-crowned kinglet, Swainson's thrush, hermit thrush, blue-headed vireo, yellow-throated vireo, warbling vireo, Nashville warbler, black-throated blue warbler, yellow-rumped warbler, black-throated green warbler, Blackburnian warbler, pine warbler, worm-eating warbler, northern waterthrush, mourning warbler, Canada warbler, rose-breasted grosbeak, white-throated sparrow, dark-eyed junco, and purple finch.

Bird species having less than 10% of potential habitat in GAP status 1 and status 2 are: least bittern, great egret, snowy egret, cattle egret, black-crowned night heron, yellow-crowned night heron, mute swan, Canada goose, mallard, blue-winged teal, northern shoveler, bald eagle, northern harrier, peregrine falcon, ring-necked pheasant, northern bobwhite, king rail, Virginia rail, sora, killdeer, upland sandpiper, common snipe, American woodcock, rock dove, barn owl, short-eared owl, common nighthawk, Chuck Wills's widow, chimney swift, willow flycatcher, eastern kingbird, horned lark, purple martin, tree swallow, bank swallow, cliff swallow, barn swallow, fish crow, Carolina chickadee, sedge wren, eastern bluebird, loggerhead shrike, European starling, white-eyed vireo, blue-winged warbler, yellow warbler, magnolia warbler, prairie warbler, common yellowthroat, yellow-breasted chat, summer tanager, blue grosbeak, dickcissel, clay-colored sparrow, field sparrow, vesper sparrow, savannah sparrow, grasshopper sparrow, Henslow's sparrow, song sparrow, bobolink, red-winged blackbird, eastern meadowlark, western meadowlark, common grackle, house finch, house sparrow. The remaining species have 10% to 20% of potential habitat in GAP status 1 and status 2.

The mud salamander is the only amphibian species having 50% or more of the potential habitat in GAP status 1 and 2. The valley and ridge salamander along with Wehrle's salamander are the only species with 20% to 50% of potential habitat in GAP status 1 and 2. Amphibian species having less than 10% of potential habitat in GAP status 1 and 2 are: hellbender, seal salamander, ravine salamander, mudpuppy salamander, Woodhouse's toad, northern cricket frog, gray tree frog, mountain chorus frog, western chorus frog, northern leopard frog, and southern leopard frog. The remaining species have from 10% to 20% of potential habitat in status 1 and 2.

There are no turtle species having 20% or more of the potential habitat in GAP status 1 and 2. The wood turtle and bog turtle have 10% to 20% of potential habitat in status 1 and 2. The other 8 turtle species have less than 10% of potential habitat in status 1 and 2.

Among snakes and lizards, there are no species with 50% or more of potential habitat in GAP status 1 and 2. Species having 20% to 50% of potential habitat in status 1 and 2 are: eastern fence lizard, coal skink, five-lined skink, redbelly snake, smooth earth snake, and timber rattlesnake. Species having less than 10% of potential habitat in status 1 and 2 are: broadhead skink, Kirtland's snake, rough green snake, queen snake, brown snake, copperhead, and massasauga. The remaining species have 10% to 20% of potential habitat in status 1 and 2.

Consistent with the problematic conservation context for fishes in Pennsylvania, the majority of species in this group have less than 10% of potential habitat in GAP status 1 and 2. There are no fish species with 50% or more of habitat in status 1 and 2. Species having 20% to 50% of habitat in status 1 and 2 are: shortnose sturgeon, brook trout, redside dace, bluespotted sunfish, longear sunfish, and slimy sculpin. Species having 10% to 20% of habitat in status 1 and 2 are: Atlantic sturgeon, American eel, rainbow trout, brown trout, chain pickerel, cutlips minnow, bigeye chub, eastern silvery minnow, hornyhead chub, spotted shiner, silver shiner, ironcolor shiner, southern redbelly dace, blacknose dace, fallfish, satinfin shiner, gravel chub, white sucker, creek chubsucker, northern hog sucker, margined madtom, brown bullhead, green sunfish, pumpkinseed, bluegill, mottled sculpin, and Potomac sculpin. The remaining species have less than 10% of the potential habitat in GAP status 1 and 2.

For the Pennsylvania context, it is important to have a relatively objective way of analyzing the model results to determine which species may be particularly problematic with respect to scarcity of suitable habitat and conservation of the habitat that remains. A special mode of analysis was conceived to rank species in this regard and determine where there is notable co-occurrence among such species. A Regional Habitat Insecurity Index (RHII) was formulated which combines overall habitat scarcity with scarcity of habitat in conservation areas and scarcity of conservable habitat. It lends particular emphasis to species that couple overall habitat scarcity with low representation in conservation areas and difficulty of finding habitat outside existing conservation areas by which to enhance the level of stewardship. The RHII results were mapped on a 1 km grid having 118,218 cells in Pennsylvania. A weighted spatial index of landscape importance was determined for each of six (taxonomic) groups of species by summing the RHII values for species having suitable habitat in the cell.

The index of landscape importance was mapped separately for the portion of Pennsylvania not contained in conservation areas having status 3 or better. A threshold was then determined for the composite RHII importance index of each group of species. Cells above this threshold were designated as "leading landscapes" for conservation concern regarding that group of species. Cells occurring as small patches were suppressed in the leading landscapes map to avoid habitat fragments. The mappings of leading landscapes were also cross-compiled among groups of species to show where landscapes are important for multiple groups.

Analysis of turtles in this manner places emphasis on the map turtle, bog turtle, and eastern spiny softshell turtle. Analysis of snakes and lizards emphasizes the broadhead skink, Kirtland's snake, rough green snake, eastern massasauga, and eastern worm snake. Emphasis for amphibians is on the eastern mud salamander, southern leopard frog, green salamander, eastern spadefoot toad, ravine salamander, northern cricket frog, mudpuppy salamander, mountain chorus frog, and Appalachian seal salamander.

Analysis of mammals lends emphasis to eastern spotted skunk, evening bat, least shrew, rock vole, Indiana myotis, elk, Appalachian cottontail, northern water shrew, fisher, river otter, fox squirrel, least weasel, Allegheny woodrat, and snowshoe hare. Placement of existing conservation stewardship areas generally matches better with the needs for mammals than for other taxonomic groups of vertebrates.

The RHII approach emphasizes several bird species as given in Table 5.2 of the report, with wetland associated species and grassland species both being prominently represented. The leading landscapes for birds, likewise, show this emphasis. Not surprisingly, the fish list is largest (Table 5.6) and loaded with endangered, threatened, and candidate species. French Creek and the Ohio River are prominent in the leading landscapes for fishes.

Tennessee Gap Analysis Project

JEANETTE JONES AND SUSAN MARDEN
Tennessee Wildlife Resources Agency, Nashville

The Gap Analysis Program (GAP) is a nationwide program sponsored by the Biological Resources Division (BRD) of the U.S. Geological Survey (USGS) and is conducted at the state level. National standards ensure edge-matching between adjacent states and will eventually allow for regional and national assessments of biodiversity. Gap analysis utilizes Geographic Information Systems (GIS) technology to map the distribution of plant communities and terrestrial vertebrate animal species, and determine the degree of protection that biological reserves and conservation lands provide to species-rich areas and, hence, identify the “gaps” in representation of biodiversity (Scott et al. 1993). The geographic data layers required to conduct GAP include plant communities or vegetation types, predicted terrestrial vertebrate species distributions, and land ownership/land management status in which lands are categorized as to the current level of management for biodiversity conservation.

The Tennessee Biodiversity and Gap Analysis Program is a federal/state/private joint venture. Coordination of the joint venture was achieved through a steering committee with representatives from the following agencies: Tennessee Conservation League, Tennessee Wildlife Resources Agency, Tennessee Technological University, Tennessee Department of Environment and Conservation, Tennessee Department of Agriculture, U. S. Fish and Wildlife Service, University of Tennessee, Tennessee Valley Authority, Westvaco, and U. S. Forest Service. The Tennessee Gap Analysis Project (TN-GAP) is housed at the Tennessee Wildlife Resources Agency (TWRA).

One of the first GIS layers developed for TN-GAP was the general land cover layer. Landsat Thematic Mapper (TM) satellite imagery provided the basis of land cover mapping in Tennessee. Portions of twelve Landsat TM scenes dated 1990-1993 were used for the spectral classification of open water, pasture/grassland, cultivated crop land, deciduous forest, coniferous forest, urban, barren land, and cloud/cloud shadow. Polygons of forested and nonforested wetlands from the U. S. Fish and Wildlife National Wetland Inventory (NWI) were digitized and added to the classification file. Ancillary data sets were used to add strip mine, rock quarry, and gravel pit locations to the data file. Classes were validated using 1:58,000-scale, color infrared, National High Altitude Photography (NHAP) transparencies.

The forest classes from the Anderson Level II land cover file were further refined to create a detailed vegetation map utilizing aerial videography and other ancillary data sources. Forested lands cover approximately 49% of the state. Approximately 4000 km of video transects were flown over a representative portion of forested lands during mid-April 1995. Geographic position data were recorded with a GPS unit and related to the time encoded on the video. This coding allowed the satellite image to be related to the corresponding video image and allowed an exact location on the ground to be determined during fieldwork. A library of video prints of forest communities created from the field visits was used to interpret the remainder of the videography. Video interpretation and labeling of forest classes were performed in stages by physiographic provinces, in order to take advantage of the variation in the vegetation due to differences in geology and landform. Labeling of forested classes is guided by the *National Vegetation Classification: Alliances of the Southeastern United States* developed by the regional office of The Nature Conservancy. Classification techniques performed on the forested regions of the satellite imagery were correlated with the interpreted aerial videography. Statistical information (spectral class, slope, elevation, and aspect) surrounding the location of interpreted sites were collected. Inference rules compiled from the summary tables and additional ancillary data were used to create the detailed vegetation map. The final vegetation maps were used with habitat relationship models to predict vertebrate distributions.

Tennessee's native fauna includes approximately 62 amphibians, 56 reptiles, 71 mammals, and 170 breeding birds. Habitat data for these species resides in the generalized *Vertebrate Characterization Abstracts* (VCA) and the more specific *Tennessee Animal Biographies System* (TABS). Updated information has been incorporated into TABS from the Fish and Wildlife Information Exchange Master Species Files from Virginia Polytechnic Institute. The primary source of habitat and distribution data for birds was the *Atlas of Breeding Birds of Tennessee* and *The Land Managers' Guide to the Birds of the South*.

Distribution data from TABS and VCA databases have been incorporated into the GIS to produce range maps for all 359 species based on county, watershed, and physiographic province of occurrence. Ranges for nonbreeding wintering birds in Tennessee were not mapped. The range maps were compared to available data sources such as the *Annotated Checklist and Bibliography of Amphibians and Reptiles of Tennessee*, the *Handbook of Mammals of the South-Central States*, and the *Biodiversity of the Southeastern United States*. Comments were solicited from state biologists about the range data. The range maps were then translated into the Environmental Protection Agency's (EPA) hexagonal grid. Ecological Services of the Tennessee Natural Heritage Program provided data for rare species.

Vertebrate distributions are predicted by mapping the potential range of each species and relating habitat preference to the vegetation map within each species' range. Data sources for the habitat relationship models are TABS, VCA, the *Land Manager's Guide to Birds of the South* and the *Land Manager's Guide to the Amphibians and Reptiles of the South*. The vertebrate distribution maps are predictive and may be generalized in some cases, a major factor for the generalization being that the vegetation maps do not contain information on structure or age class. Several animal species are dependent upon this structure and age class. The final distribution maps for all terrestrial vertebrate species were overlaid and analyzed to determine areas of species richness. Analysis of species richness can be generated for each taxon based on range data and habitat preferences. Areas of species richness, when overlaid with locations of publicly managed lands can determine the protection afforded to biodiversity.

The TWRA GIS maintains coverages of major public lands and acquired wetlands in the state. The land ownership coverage includes all federally and state-owned land, as well as local and privately owned lands that are managed for conservation. To obtain an estimate of the protection afforded biodiversity, land ownership was assigned a land management status category. A subcommittee, formed to categorize the lands as to their management status, developed five categories for Tennessee. The land management status categories range from Status 1, for those lands with a management plan for providing the greatest amount of protection to biodiversity, to Status 4, for those lands not identified as functioning to conserve biodiversity. The public lands database, when overlaid with the vertebrate species distributions, can identify the "gaps" in biodiversity protection.

Public lands comprise approximately 8% of the total land area of Tennessee with 4.8% under federal and 2.7% under state jurisdiction. The U.S. Forest Service administers the largest amount of public land in the state, and this land is located in the mountainous regions of East Tennessee. TWRA administers the largest amount of state-owned land. Less than 2% of the state occurs in status 1 and 2 lands.

Approximately 52% of the state falls under the category "natural community." Of this percentage, only 8% are under federal jurisdiction and 4% are under state jurisdiction. The remainder is privately owned. All 22 natural community types are located on federal lands and all but three plant community types are located on state lands. All natural plant communities, with the exception of one type, are represented to some degree under land management status 1 or 2.

Overall species, breeding birds, and neotropical migrants have a relatively higher area containing higher species richness in status 1 and status 2. Mammals show the largest amount of area; each category predicts a species richness of 31 to 35, except for status 4 with species richness of 26 to 30. The largest area per status type for reptiles was 21 to 25 species for all status types except status 5. Amphibians show the highest area per land status at 12 to 13 species for all land status types except land status 5.

The Tennessee Biodiversity Program (established by the Tennessee Conservation League) and TWRA's GIS division are continuing to work together to provide planners and community leaders, landowners, natural resource professionals, and educators with information on Tennessee's natural resources. TWRA provides TN-GAP data and related GIS data layers as Arc View files to county planners and community leaders. *Managing Natural Resources - A Planning Guide for the Elk River Watershed of South Central Tennessee and Northern Alabama* was published by TWRA, TCL, TVA and National GAP as a planning guide for developing and carrying out natural resource conservation and management programs.

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Virginia Gap Analysis Project

SCOTT D. KLOPFER AND JULIE MCCLAFFERTY
Conservation Management Institute, Virginia Tech, Blacksburg

The Virginia Gap Analysis Project (VA-GAP) was initiated as a cooperative effort between the Biological Resource Division of the U.S. Geological Survey, and state, federal, and private natural resources groups in Virginia. The major objectives of the project were to (1) produce GIS databases describing the actual land cover type, predicted distributions of terrestrial vertebrates, land ownership, and land management status at a scale of 1:100,000, (2) identify land cover types and terrestrial vertebrate species that currently are not represented or are underrepresented in areas managed for long-term maintenance of biodiversity (i.e., “gaps”), and (3) facilitate cooperative development and use of information so that institutions, agencies, and private landowners may be more effective stewards of Virginia’s natural resources. The VA-GAP project is a preliminary step toward the more detailed efforts and studies needed for long-term planning for biodiversity conservation in Virginia.

The system used to classify the land cover consisted of 26 classes (14 forest classes, 4 herbaceous/agriculture, 3 wetland, 2 developed, 1 nonvegetated, 1 open water, and 1 mixed/unknown) and 2 forest complexes. Landsat Thematic Mapper (TM) imagery from 1986 to 1994 (mostly 1992-1993), in conjunction with aerial videography and field data collection, was used to identify and map the land cover types. The mapping of wetlands was facilitated by a direct overlay of the US Fish and Wildlife Service’s National Wetlands Inventory (NWI). Topography and phenological index (related to changes in latitude, longitude, and elevation) also were important tools for mapping diverse forest types across the state. A comparison of vegetation and land cover types mapped from TM data to the known points database gave an overall accuracy of 67.5% before spatial error correction and 87.1% after correction of potential spatial errors.

Individual distributions of 566 vertebrate species (67 reptiles, 78 amphibians, 107 mammals and 314 birds) were predicted using both county occurrence records and habitat associations contained within the Biota of Virginia (BOVA) database that was set up and is maintained by the Virginia Department of Game and Inland Fisheries. Range limits of each species were delineated based on county lines and the presence of a either a “known” or “likely” occurrence of a species within each county. Within counties, species distributions were modeled based on species/land cover associations also available in BOVA that were cross-walked with the VA-GAP land cover classification system. Southeast Virginia was found to be the most diverse area of the state. Comparisons of species predicted to occur to species lists maintained for six sites (mammals and herpetofauna on Fort A.P. Hill; birds on five eastern Virginia National Wildlife

Refuges) indicated an overall accuracy ranging from 76.8% to 96.2%. Uncertainties in modeling strategies and final species distribution maps are discussed.

A GIS database of private and public conservation lands was assembled in cooperation with the major federal, state, and private land management agencies managing land for conservation purposes in Virginia. Conservation lands mapped by VA-GAP make up 8.9% of the total state area. By far, the U.S. Forest Service is the largest land-managing entity in Virginia, with 66% of all stewardship lands mapped in VA-GAP. The Virginia Department of Game and Inland Fisheries holds the next largest amount of property with 14.5%. Of all the conservation lands used in VA-GAP, federal agencies control about 82% and state agencies 18%. Lands were denoted as to the degree to which they are managed for maintenance of biodiversity and long-term ecological processes. The Gap Analysis Program requires use of a 1 through 4 scale to denote high to low management for biodiversity maintenance based on legal and management status. Status 1 lands (primarily wilderness areas within National Forests) make up only 3.4% of all conservation lands, with 10.1% in Status 2 and 86.5% in Status 3. Conservation lands are concentrated primarily in the western mountainous portion of the state (98% of status 1 lands and 89% of status 3 lands), especially along the ridge tops, with only small portions of land in the central Piedmont region (1.2% of Status 3 lands, no Status 1 or 2) and eastern Coastal Plain (3% in Status 1-3). The land ownership map should not be interpreted as a legal document but as a representation of general ownership patterns.

Only three land cover types in Virginia have more than 10% of their areas protected under Status 1 or 2. These are the Red Spruce-Fraser Fir type (found exclusively on mountaintops) with 80% of their distribution found in National Forests; Tupelo-Red Maple type (found in extreme southeastern Virginia) with 30% of its distribution found within the Great Dismal Swamp National Wildlife Refuge; and the Coastal Shrub type with over 10% protection afforded by the Assateague and Chincoteague Island National Seashores. Montane Mesic Coniferous, and Riparian Forest, herbaceous, and wetland (especially in central and western Virginia) types are especially underrepresented in conservation lands given their overall proportion of the landscape. When Status 3 lands are included in this analysis, many types appear protected in proportion to their distribution. However, the Riparian Forest and submontane forest (particularly deciduous) types remain poorly protected.

Of the 566 species modeled in VA-GAP, more than one-third (35%) have <1% of their predicted distribution within status 1 and 2 lands. By taxon, this represents 35.9%, 43.3%, 43.0%, and 30.3% of the total number of amphibians, reptiles, mammals, and birds respectively. Sixteen species have almost no protection (<0.1%). No species were predicted to have >50% of their distributions on status 1 and 2 lands. We identified species with moderate or restricted distributions and low representation on status 1 and 2 lands to be at greater risk. Although we did not select a specific threshold for determining significant risk, we considered any species whose protected distribution (as a percentage of all protected lands) is less than its total distribution across the state (as a percentage of the total state area) to be at increased risk. Among birds, four groups of species were identified as being at risk: grassland species (e.g., Bachman's sparrow, Eastern meadowlark, upland sandpiper); agricultural/forest mix species of the Piedmont region (e.g., pine grosbeak, rough-legged hawk, rough-winged swallow); mountain species that use agricultural, open areas, or wetlands for some component of their habitat (e.g., common raven, willow flycatcher, warbling vireo); and agricultural/forest mix species with statewide distributions (e.g., barn swallow, sharp-shinned hawk, orchard oriole). Several reptile species also are underrepresented. The black racer, corn snake, mole kingsnake, and the southeastern crowned snake all utilize agricultural/open areas mixed with forest and, with the exception of the black racer, are all found in the Piedmont region of Virginia and eastward. The bog turtle and wood turtle (found in wetlands types of the mountains), eastern river cooter, and stripe-necked musk turtle (found in waterways and riparian areas of the mountains), and the red-eared slider are turtle species with low representation on conservation lands. Most amphibian species are well represented on conservation lands, with a few widespread species (e.g., gray tree frog and spotted salamander) appearing underrepresented only because of their wide distribution and presence throughout the poorly protected Piedmont region. Mammals identified at increased risk include those that utilize agricultural and open areas (e.g., eastern harvest mouse, common muskrat, common pine vole, star-nosed mole) and those with widespread distributions that utilize agricultural-forest mixed lands (e.g., meadow vole, northern white-footed mouse, Kirtland's short-tailed shrew). In summary, species that tend to use mountain wetland riparian areas or agricultural/open areas (esp. in the Piedmont) appear to be the least represented in conservation lands and are at greatest risk.

Important implications of this VA-GAP study can be drawn for each of the three physiographic provinces in Virginia. In the western mountain region, riparian and agricultural/open land is predominantly privately owned and poorly represented in conservation lands. Species requiring these lowland habitats typically do not receive concerted protection efforts and may be susceptible to changing land use practices such as urbanization, which typically are restricted to flatter, intermountain terrain. The Piedmont region in central Virginia has very little land in public ownership, regardless of the cover type, and any species or habitat type restricted to this region receives little protection. Habitat loss due to agriculture and timber production, as well as rapid urbanization, continues in this area and threatens to remove existing natural habitats. The public land on the Coastal Plain is predominantly comprised of herbaceous and forested wetlands. Very little upland is included with these properties. As a result, species requiring these habitats are not well represented in the protection network, and these species are susceptible to rapidly encroaching human development. Although this study has provided an important foundation for future land management and acquisition decision-making, it is only that–a foundation. In order to make smaller-scale decisions and fine-tune the species models, more research is needed in the arenas of species/habitat relationships, fine-scale habitat delineations, and subparcel stewardship mapping. More detailed work in defining species ranges in Virginia will also improve prediction models.

APPLICATIONS

Place Prioritization for Texas Using GAP Data: The Use of Biodiversity and Environmental Surrogates Within Socioeconomic Constraints

SAHOTRA SARKAR[1], NICK C. PARKER[2], JUSTIN GARSON[1], ANSHU AGGARWAL[1], AND SHERI HASKELL[2]
[1]Biodiversity and Biocultural Conservation Laboratory, University of Texas, Austin
[2]U.S. Geological Survey-Biological Resources Division, Texas Cooperative Fish and Wildlife Research Unit, Texas Tech University, Lubbock

Introduction

The Texas Gap Analysis Program (TX-GAP) (Gonzalez-Rebeles et al. 1997; Parker et al. 1998) has developed a Geographical Information System (GIS) containing biogeographic and localized socioeconomic data for the entire state of Texas. These data have been used to populate a set of 1,183 hexagons produced as part of the U.S. Environmental Protection Agency's Monitoring and Analysis Program (EMAP). Ignoring local topographic details, these hexagons each have an area of 649 sq. km. The attributes recorded for each cell include:

1. environmental attributes such as area, average temperature, average maximum and minimum temperatures, average rainfall, average snowfall, elevation, aspect, dominant soil type, and acreage of each of 46 soil classes;
2. biodiversity attributes such as dominant vegetation type, acreage of each of 38 vegetation types, and presence/absence of 655 animal species; and
3. socioeconomic attributes including human population density.

This data set was used to perform three tasks that are central to conservation planning (Margules and Pressey 2000):

1. Subsets of the environmental and biodiversity attributes were used to prioritize the hexagons and establish potentially reserved sets of hexagons so as to achieve a required level of representation of the attributes in a reserve network. This is called the "place prioritization problem," and the goal is to achieve the targeted representation as efficiently as possible (that is, with the least required number of hexagons).
2. Attempts were made to use small subsets of attributes, called "estimator-surrogates," to obtain the same set of prioritized places as would be obtained if larger sets (the so-called "true surrogates" for general biodiversity) were used. This is called the "surrogacy problem," and the goal is to obtain a small set of readily available estimator-surrogates (for instance, through remote sensing) for conservation planning.
3. Prioritization results were overlaid on socioeconomic data to explore the potential for conflicts between land conversion for human use and biodiversity. This is the beginning of

more general attempts to optimize the place prioritization process in the presence of multiple objectives such as biodiversity conservation and economic development (Faith 1995).

Methods

All place prioritization algorithms used here are based primarily on rarity and complementarity (Margules et al. 1988); some also incorporate adjacency requirements (where adjacent cells are preferred over nonadjacent ones). These have all been implemented in the ResNet software package developed at the University of Texas at Austin in collaboration with the Commonwealth Scientific and Industrial Research Organization, Australia (Aggarwal et al. 2000). The algorithms are initialized using: a) a set of pre-existing reserved cells; b) the cell with the rarest attributes; or c) the cell richest in attributes. The cells correspond to the hexagons of the GAP data set. The iterative procedure uses rarity, followed by complementarity (choosing the cell with the most representatives that are not yet adequately represented in the reserved set of cells), and then adjacency (if imposed). Further ties are broken randomly (by lexical order). The algorithms terminate if a predetermined level of representation of attributes in the selected cells is satisfied or cost and area constraints are exceeded. All these algorithms were run on the Texas data.

The surrogacy problem was investigated in the following way: A place prioritization was carried out, using a set of putative estimator-surrogates, and then compared to one carried out using the targeted "true" surrogates. The estimator-surrogate set used consisted of soil types, vegetation classes, average high and low temperature and average precipitation; the "true" surrogates were the vertebrate species for which there were distributional data. For a preliminary socioeconomic analysis, the most densely populated hexagons of Texas, as projected for the future, were overlaid on the hexagons that emerged with the highest priority from the ResNet runs using terrestrial vertebrate data. Human population density gives an estimate of risk for vertebrate populations; this has obvious implications in conservation planning.

Results

A total of 121 hexagons were selected when vertebrate data were used, and the target of representation was set at 10% of all presence records (Figure 1). The selection procedure was initialized by rarity.

When an environmental parameter set of vegetation classes, soil types, average high and low temperatures, and average precipitation was used for the estimator-surrogates, and terrestrial vertebrate species were targeted as "true" surrogates, a surrogacy graph was produced (Figure 2). By the time each estimator-surrogate has been represented at least once, 89.5% of the vertebrate species have been represented at least once.

An overlay of the 100 most populated hexagons, as projected for 2020, on the 100 hexagons that receive top priority using the vertebrate data was developed (Figure 3). There was an overlap for 26% of the hexagons.

Discussion

The results presented here should be regarded as preliminary and tentative and are indicative of the way in which conservation planning should proceed rather than an actual guideline for policy decisions. The most serious deficiency, which affects all the results, is that the hexagons are too large, and each hexagon is ecologically too heterogeneous, to serve as a unit for site-specific conservation decisions. A much smaller scale must be used, usually less than a tenth of the hexagon area, when land acquisition and use decisions are made by conservation agencies (Sarakinos et al. 2001). Ideally, this analysis should be repeated at those scales prior to making an acquisition. However, the analysis conducted at the EMAP scale has immediate value. The size of the hexagons (649 km^2) is about 1/3 of the size of a county in Texas. In a state where 96-97% of the land is privately owned, a tool that identifies areas 1/3 the size of a county is a valuable aid in landscape conservation. Fine detail would be needed to support acquisition or other site-specific conservation measures; however, this broader-scale analysis does not target individual landowners and thereby may minimize premature landowner opposition or speculative purchases.

The use of environmental estimator-surrogates is fraught with danger since full representation of these surrogates does not guarantee a full representation of the targeted attributes (Figure 2). Much more work needs to be done to see if there even exists a small set of readily available estimator-surrogates for this purpose. If not, there is no way to avoid the conclusion that systematic conservation planning will require detailed survey data that are hard to obtain.

Using vertebrate species as true surrogates for biodiversity, 26% of the hexagons with the highest conservation priority are at high risk because of the impact of the projected human population increase (Figure 3). This is one conclusion that is not affected by the size of the hexagons since this increased human population density will almost certainly have negative impacts on biodiversity, particularly terrestrial vertebrates, at scales smaller than, and up to, the size of the hexagons.

Product Availability

The ResNet software package can be downloaded free of charge along with a manual from the Web site of the Biodiversity and Biocultural Conservation Laboratory at the University of Texas-Austin (http://uts.cc.utexas.edu/~consbio/Cons/Labframeset.html).

Acknowledgements

We thank Clint Boal, U.S. Geological Survey-Biological Resources Division, and Robert Bradley, Department of Biological Sciences, Texas Tech University, for their critical review of this manuscript. The Texas Cooperative Fish and Wildlife Research Unit is jointly sponsored by Texas Parks and Wildlife, Texas Tech University, the U.S. Geological Survey, and the Wildlife Management Institute.

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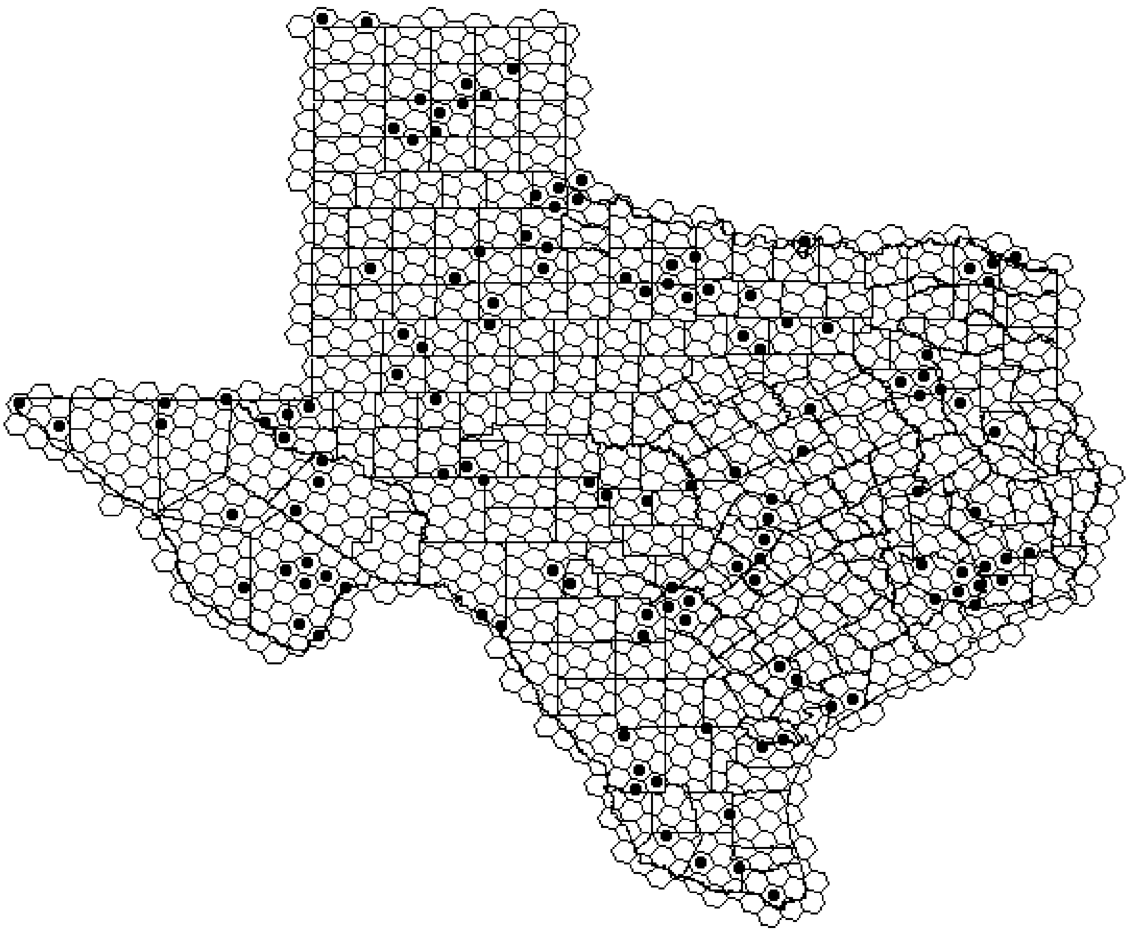


Figure 1. These are the hexagons selected if the target for each vertebrate species is set at 10% of the records. Therefore, preservation of these sites would preserve 10% of the sites containing the highest diversity of terrestrial vertebrate species. Collectively, these sites contain representatives of all terrestrial vertebrates in Texas.

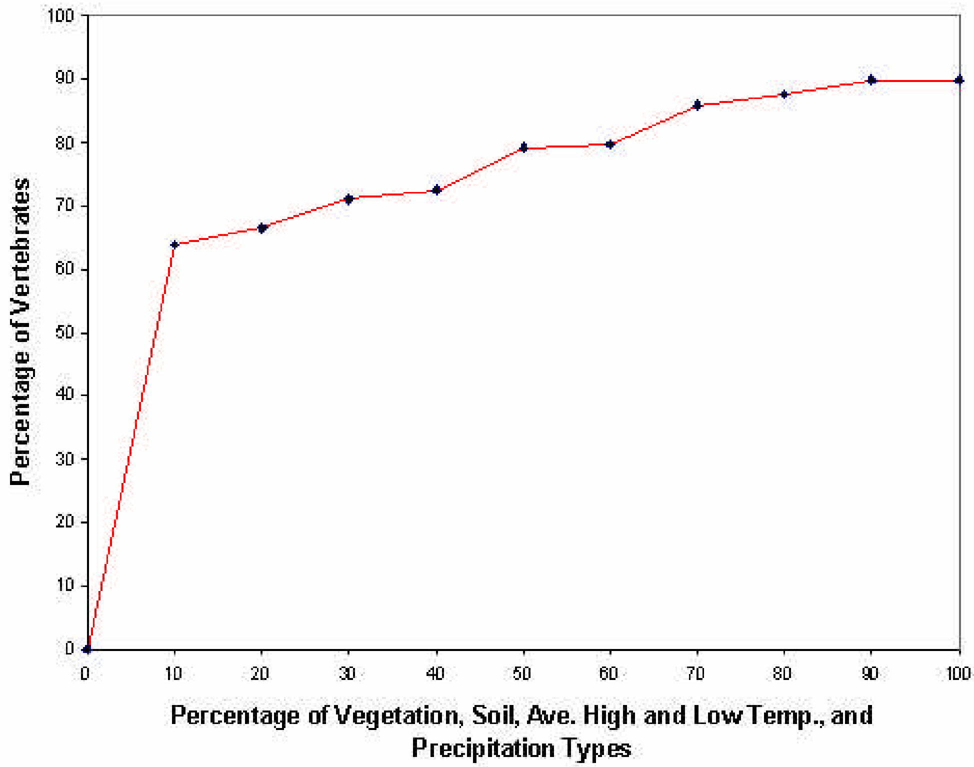


Figure 2. The percentage of terrestrial vertebrate species in Texas protected when places are selected using estimator-surrogate set consisting of soil types, vegetation classes, average high and low temperature and average precipitation. The x-axis shows the percentage of the estimator-surrogates protected at each stage.

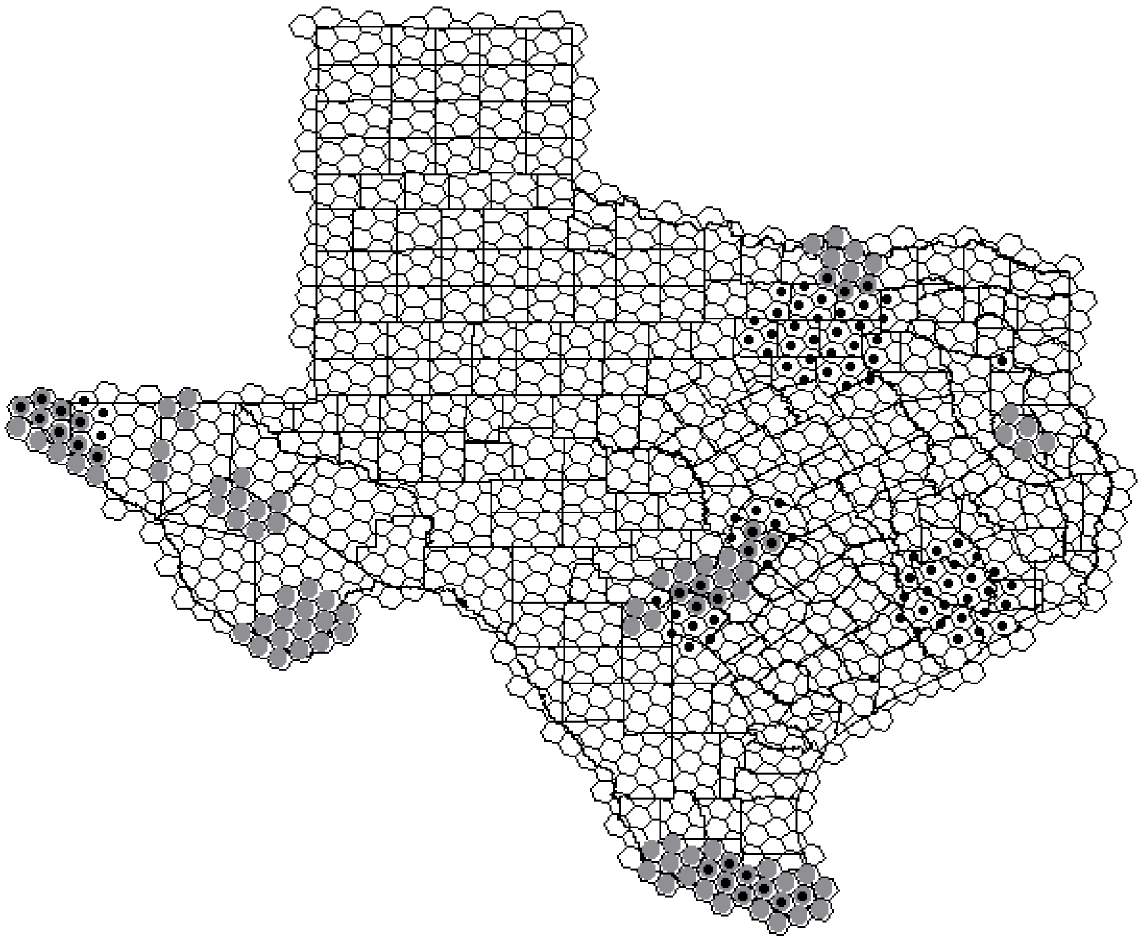


Figure 3. Identification of the top 100 of the hexagons (gray) containing the highest diversity of terrestrial vertebrate species in Texas and 100 hexagons (black dot) with the human population at the greatest density. The overlap is 26%.

An Application of a Reserve Selection Algorithm for Integrated Planning of Biodiversity and Nonfuel Minerals Exploration

REE BRANNON
National Gap Analysis Program, Moscow, Idaho

Introduction

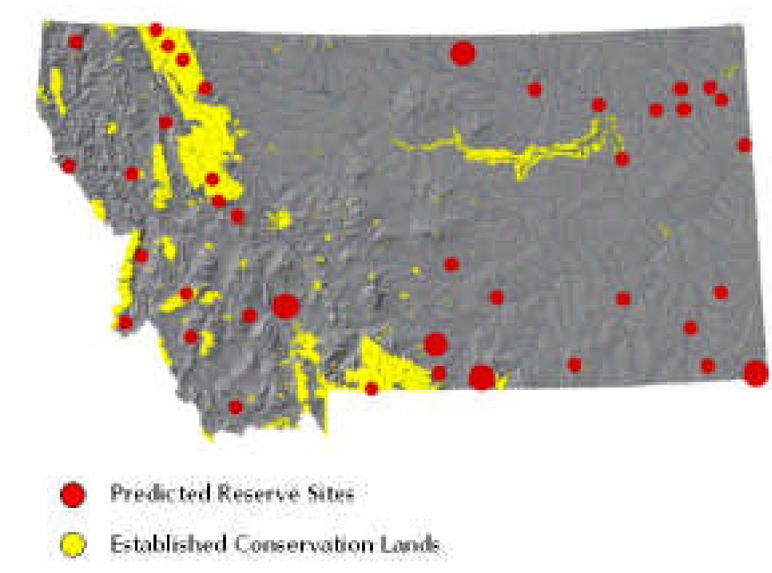
As human populations continue to increase, we see a corresponding increase in the demand for space and for consumptive uses of our natural resources (for example, timber, water, and minerals). This in turn hastens loss of biodiversity by fragmenting habitat and disrupting ecological processes. Our traditional approach to development and use of natural resources has been haphazard and conducted more by accessibility and opportunity than by careful comprehensive planning to integrate and protect other resources. During the first decade, the GAP program successfully explored technical methodologies to generate spatially explicit information for key elements of biodiversity (Jennings et al. 1999). However, information alone is not enough. It is crucial to focus future activities for the Gap Analysis Program on synthesis and interpretation of the data and to continue to apply GAP data to test new hypotheses for reserve identification, selection, and design.

Last year the U.S. Geological Survey's (USGS) Geologic Division and Biological Resources Division collaborated on a research proposal, which was subsequently funded through the Integrated Science Program as an initiative of the Director of the USGS. The Geologic Division is in the process of completing a three-year feasibility study to conduct nonfuel mineral resource assessments. Recognizing that exploration and development can have disruptive effects on biological resources, either from the direct consequences of mining or from simply opening up an area to rapid growth by other sectors, the geologists wish to integrate other sources of data on biodiversity and water resources. This practical approach would augment the comprehensiveness of their assessment and focus the exploration planning. The Spokane Field Office of the Geologic Division and the GAP Operations office in Moscow, Idaho, are working together to develop fundamental data layers from each division. Once generated, these layers can be synthesized to create a three-dimensional output of rankings for the landscape ranging from high mineral potential, strong juxtaposition of biodiversity elements and conservation status to low biological value, low mineral potential, and no conservation status.

Methods and Preliminary Results

The two divisions chose to test the process with the state of Montana because both GAP data and minerals data are available. I used an ARC/INFO Arc Macro Language (AML) script written by Jason Karl, formerly of the Landscape Dynamics Lab at the University of Idaho. The algorithm starts with areas that capture the most number of species and then iteratively selects additional areas on the landscape to add new species. This AML (called "r select") is available on our Web site at http://www.gap.uidaho.edu/Scripts/default.htm and was originally used in the Gap Analysis project for the Lewis and Clark Trail (Crist and Jennings 1999).

I resampled Montana's vertebrate grids from 90-meter to 1000-meter resolution and created hyperdistribution grids for the taxa (nonpasserine and passerine birds, mammals,



amphibians, and reptiles.) I ran the reserve AML on each hypergrid and created another grid of selected reserve sites for each group of animals. I used the entire extent of the state for the processing. I merged the grids to make one final grid of all reserve sites (Figure 1). The points in the map show the location of potential reserve areas but are not scaled to size.

Figure 1. Map of Montana with current conservation lands (Status 1 and 2) and the results of the predicted reserve sites.

The tabular results of merging the reserve grids are displayed in Table 1. Each site shows the number of cells and the number of species per taxon selected. For example, Site 4 has 147 contiguous cells and captures 25 mammal species. The zeroes for the remaining species do not mean that the animals were not predicted to occur there, simply that the site was not selected by the algorithm for those groups. The size of the selected sites range from 1 to 280 cells. The richness columns are an output of the reserve AML. The columns show the sites selected to acquire all of the species for one group. For example, 11 sites represent all mammals across the state of Montana. While approximately 2.5% of all the predicted reserve sites overlap with the conservation lands already established, there was no overlap in the sites selected for each taxon.

Discussion

Limitations to the Algorithm - The distribution of the selected reserve sites appears to be fairly well dispersed and would suggest a diverse range of environments for all species have been selected. However, this is only a first look at a very complex issue. The algorithm was designed to create a representative sample of sites to include all species. There is no decision rule for maximizing area. This is evident when comparing the output area of the sample reserve sites (1191 km^2) to the area of Status 1 and 2 land (29,078 km^2). Figure 2 illustrates one selected site. The algorithm may emphasize edge habitat and, if so, would favor common species over rare species. These would be adverse solutions for species that require continuous habitat and especially for those species of special concern that have lost critical habitat. Additionally, the algorithm is not sensitive to spatially constrained species, i.e., species that only occur in some areas and not other areas of similar habitat. It requires a closer look for sensitive, threatened, orendangered species.

Table 1. Summary of sites for all groups.

SITE	CELL COUNT	MAMMAL RICHNESS	REPTILE RICHNESS	AMPHIBIAN RICHNESS	PASSERINE RICHNESS	NONPASSERINE RICHNESS
1	1	0	0	0	0	31
2	3	0	0	8	0	0
3	4	0	0	0	0	18
4	147	23	0	0	0	0
5	2	34	0	0	0	0
6	13	0	0	6	0	0
7	6	0	8	0	0	0
8	6	0	0	0	27	0
9	13	0	0	0	19	0
10	1	0	0	0	0	21
11	4	0	0	0	0	10
12	26	0	0	0	33	0
13	1	0	0	0	39	0
14	2	0	0	8	0	0
15	1	0	0	0	0	54
16	1	33	0	0	0	0
17	12	0	0	0	60	0
18	1	0	0	0	0	43
19	1	0	0	0	66	0
20	2	0	0	0	0	22
21	1	46	0	0	0	0
22	15	0	7	0	0	0
23	1	0	0	0	0	67
24	2	0	13	0	0	0
25	33	34	0	0	0	0
26	76	29	0	0	0	0
27	17	0	0	0	3	0
28	6	0	0	0	22	0
29	208	0	0	0	18	0
30	1	26	0	0	0	0
31	7	0	0	0	0	22
32	83	33	0	0	0	0
33	36	0	0	0	0	16
34	32	0	0	0	17	0
35	1	40	0	0	0	0
36	132	0	0	0	15	0
37	2	33	0	0	0	0
38	44	0	0	0	33	0
39	59	30	0	0	0	0
40	83	0	0	0	0	12

Limitations of the GAP Data and this Process - When evaluating output, there are limitations of the GAP data which must be considered. The vertebrate distribution grids are based on the output of vegetation mapping from satellite imagery of the early 1990s. The land cover may not be current, and land uses may have altered the landscape dramatically.

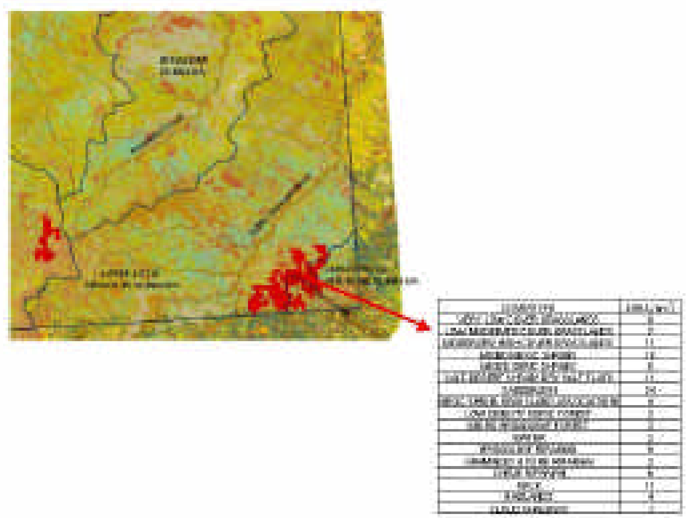


Figure 2. Example predicted reserve site in southeastern Montana. This site captures 18 passerine bird species and 17 land cover types.

GAP data predict distribution of habitat but do not evaluate the quality of it. Nor does thecurrent modeling approach provide information on which structural habitat components are mostimportant to a species' long-term viability. Accordingly, the algorithm is constrained by theselimitations to treat all patches of a given land cover equally, with no weighting for better qualityhabitat or connectivity of selected sites.

The GAP vertebrate data were processed in arbitrary groupings– mammals, birds, reptiles, and amphibians. These groupings may create output for selected sites, which is less meaningful than more thoughtfully selected groupings (habitat use, for example).

Finally, the output of the GAP vertebrate models is a coarse representation of predicted distribution of habitat. Each grid harbors some level of uncertainty for the actual occurrence of a particular species for any given set of coordinates. Consequently, the consolidation of numerous grids to conduct the analysis will intensify this uncertainty.

Future Considerations - With these kinds of limitations, what is the utility of this analysis? A coarse investigation can provide valuable insights for improvements, such as provide the context to test applications of GAP data and to explore the meaning of reserve design. (Can we partition the landscape to confidently say "here and not there" for land managing activities?). We can work with an interested user group to develop possible scenarios for exploration.

We need to work with regional experts (the Montana GAP group) to evaluate the validity of these solutions. We need to examine questions such as: Do these sites have meaning in the landscape? How much area is enough? (Does historical distribution play a role? Have we captured the natural variation of the species or the cover type?) One small portion of the range of a biodiversity element may not capture important fine-scale variation even though it would appear that it is adequately protected over its total range (Scott et al., in press, Wright et al. 2001). Do all lands have comparable potential to be converted to conservation lands? Future scenarios may include integration of qualitative assessments with electronic analysis. Stoms et al. (1998) suggested a possible triage for protection to give the highest priority to elements of biodiversity that are representative of an ecoregion and are vulnerable to expected land use and the lowest priority to elements that are better evaluated for protection in a neighboring ecoregion. It may be that the most practical approach is partitioning the landscape by ecoregions, weighting biodiversity elements by vulnerability, conservation status, and representativeness in the ecoregion, then combining with an iterative algorithm.

In conclusion, this kind of an investigation is restricted to programmatic level planning. Any site-specific activities, of course, require more detailed analysis and planning to execute. This initial attempt only evaluates diversity from the standpoint of vertebrates. Other animal taxa and plant communities should be integrated.

Acknowledgements

A hearty thanks to Jason Karl (currently with the Pacific Biodiversity Institute) for his contribution of the reserve AML and his insights on the output and limitations. The Wildlife Spatial Analysis Lab (the Montana GAP folks) developed all the base layers used here. The Spokane Field Office of the USGS Geologic Division continues to work closely with me to coordinate these data products with theirs.

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Creating a Conservation Plan for Latah County, Idaho

LEONA K. SVANCARA[1], ROBBYN J.F. ABBITT[1], GINA M. MINSHALL[1], R. GERRY WRIGHT[2]
[1] Landscape Dynamics Lab, Idaho Cooperative Fish and Wildlife Research Unit, Moscow
[2] USGS, Idaho Cooperative Fish and Wildlife Research Unit, Moscow

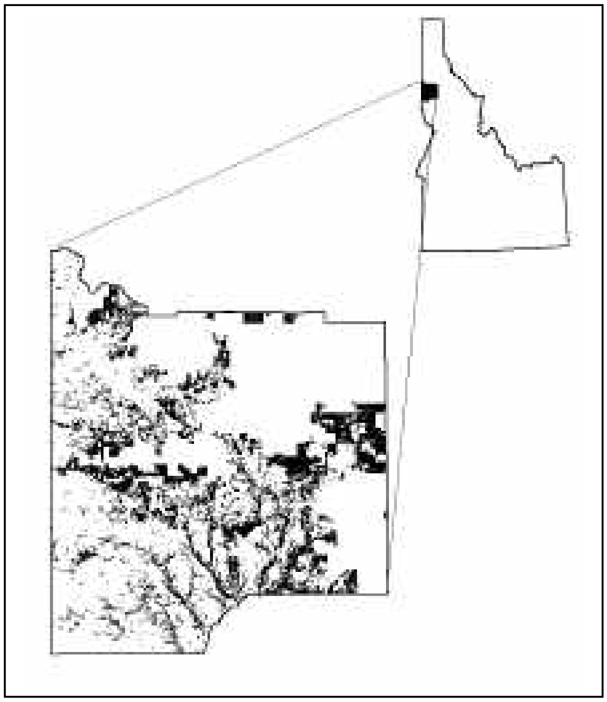


Figure 1. Areas of unprotected shrub, forest, and underrepresented cover types in Latah County, Idaho.

Recently, at the National GAP meeting in San Antonio, TX, there was much discussion about the usefulness of GAP data outside original statewide analyses. We feel one valuable application of the data and methodology is local conservation planning and are developing a county-level conservation plan for Latah County, Idaho. Located in the southern portion of Idaho's panhandle, the majority of Latah County is encompassed by the Palouse bioregion, a landscape once dominated by the Palouse Prairie. In the past century this landscape has been transformed into a wheat and legume agriculture complex. Latah County, however, is unique in that it contains the transitional area between this prairie landscape and the forested landscapes that dominate the panhandle to the east.

county. Working on behalf of the PLT, we have developed a system of criteria for identifying conservation opportunity areas in Latah County. By concentrating on lands considered most at risk of development, we identified areas in which encouraging stewardship would have the most benefit. Our study area consisted of privately owned lands (status 4), covered approximately two-thirds of the county, and contained a mixture of forest, shrub, agriculture, and urban landscapes. Understanding that little would be added to a conservation network from urban and intensively farmed agriculture lands, we removed these areas. In future analyses we plan to include agricultural lands contributing to wildlife habitat within the county, specifically those lands in the Natural Resource Conservation Service's Conservation Reserve Program. However, a complete coverage of these lands is not currently available.

We included lands containing cover types suggested to be underrepresented in statewide protection areas (i.e., those with <10% located in status 1 and 2 lands; Idaho Gap Analysis). However, since 10% is an arbitrary figure and may not represent adequate protection, we also considered all potentially at-risk cover types, regardless of statewide protection status. We identified these areas as containing important habitat features and combined them into contiguous regions (Figure 1). The resulting coverage will be used to prioritize areas that have the potential to either provide large areas of natural habitat or act as corridors between these areas.

Our efforts with this project are ongoing. We are currently working on scenarios for wetlands and riparian areas and incorporating wildlife species richness, species diversity, and sensitive species locations. We feel the methods we are using for this northern Idaho county can easily be replicated elsewhere and provide local land trusts and county governments with the tools necessary to identify and prioritize key areas for conservation.

STATE PROJECT REPORTS

(Status as of December 2000)

All completed products and reports will be available through the National GAP Web site at http://www.gap.uidaho.edu/Projects/Data.asp. Drafts and other products may be obtained from the state project PI as noted.

Alabama

Under way
Anticipated completion date: June 2005

Contact: James B. Grand
Alabama Cooperative Fish and Wildlife Research Unit
Auburn University, Auburn
grandjb@auburn.edu, (334) 844-4796

Land cover: Data acquisition is in progress. Goals for the next 12 months include:

- Developing a protocol for creating the general land cover map of the state,
- developing a preliminary land cover map,
- initiating ground-truthing, and
- refining the list of vegetation alliances to be mapped.

Animal modeling: During the coming year, we will develop the list of vertebrate species for the state and obtain species and habitat requirement lists from neighboring states for entry into a relational database. This database will be used to identify species for which habitat requirements are lacking, and to build the models for use in generating distributions maps.

Land stewardship mapping: The Alabama Natural Heritage Program is preparing a land ownership coverage that will include boundary files for all state-owned lands and available federal lands.

Alaska

Not started

Arizona

Update under way (see Southwest Regional GAP)

Arkansas
Complete (see http://www.cast.uark.edu/gap/)

California
Complete (see http://www.biogeog.ucsb.edu/projects/gap/gap_home.html)

Colorado
Update under way (see Southwest Regional GAP; see also final report summary on page)

Connecticut
(for status, contact Curtice Griffin at cgriffin@forwild.umass.edu)

Delaware
(see Maryland, Delaware, and New Jersey)

Florida
Complete (see final report summary on page)

Contact: Leonard Pearlstine
Florida Cooperative Fish and Wildlife Research Unit
University of Florida, Gainesville
pearlstinel@wec.ufl.edu, (352) 846-0630

Land cover: The final FL-GAP land cover map was completed in the summer of 2000. The final map contains 71 land cover classes.

Animal modeling: Modeling was completed in the summer of 2000 for all Florida mammals, birds, reptiles and amphibians, butterflies and skippers, and ants.

Land stewardship mapping: The stewardship map for Florida was completed in the summer of 2000.

Analysis: Accuracy assessments and comparisons of species richness to land stewardship categories were completed in the summer of 2000.

Reporting and data distribution: The final report is complete and will be released shortly. Discussions are under way for data distribution through the University of Florida Libraries.

Georgia

Under way
Anticipated completion date: April 2002

Contact: Elizabeth Kramer
Natural Resource Spatial Analysis Laboratory
Institute of Ecology, University of Georgia, Athens
lkramer@arches.uga.edu, (706) 542-3577

Land cover: The land cover mapping protocol was further refined, especially in regards to mapping suburban sprawl and delineating wetlands in the coastal plain. General land cover mapping of the state proceeded on a county-by-county basis. To date, 106 counties (out of 159) are either in progress or completed (Figure 1). Land cover maps from completed counties were edge-matched. We continued to develop an accuracy assessment protocol to be implemented after the draft of the land cover map is complete.

In cooperation with SC-GAP, flight lines were developed and used in late October and early November 2000 to fly digital video for ground-truth collection. We acquired high-resolution (1-meter) DOQQs (year 2000) of the Atlanta metropolitan area for accuracy assessment. We met with a TNC representative to further refine the list of vegetation alliances to be mapped in the state. We continue to develop rules for predicting aggregated vegetation alliances.

Animal modeling: Habitat affinity matrices for all of the vertebrates in the state continue to be developed. The general land cover affinity matrix for the state's breeding birds has been completed. Alliance level information, other environmental features, and references are being added to the matrix. The matrix is complete for all bird species and about 80 herp species that occur in the state, pending review in February or March 2001. A preliminary matrix for mammals has also been completed.

Development of methods for predicting salamander habitat is under way. We are developing and testing vertebrate models in the counties for which the land cover has been completed. Three part-time vertebrate technicians were hired to enter point locations from various data sources. Approximately 70% of the records that will be digitized have been completed. While inspecting the Georgia Museum of Natural History collections, we discovered a 1976 record of *Tantilla relicta neilli* (Central Florida crowned snake), which was previously not recognized as occurring in the state. This extends the range of the species approximately 29 km NNE of the previous northernmost known site, which was in Florida.

Aquatic Gap Analysis: We continued protocol development.

Other accomplishments and innovations: Methods for using the GAP products in greenspace planning are being developed in cooperation with county governments and city planners. We are developing a protocol for the Georgia Land Use Trends Program that will use the land cover map in a 30-year land cover change detection analysis for the state.

We began forging relationships with the Coastal Division of Georgia Department of Natural Resources, the FWS, and the Corps of Engineers to update them on the progress of the GAP data sets and possible applications for coastal resource management.

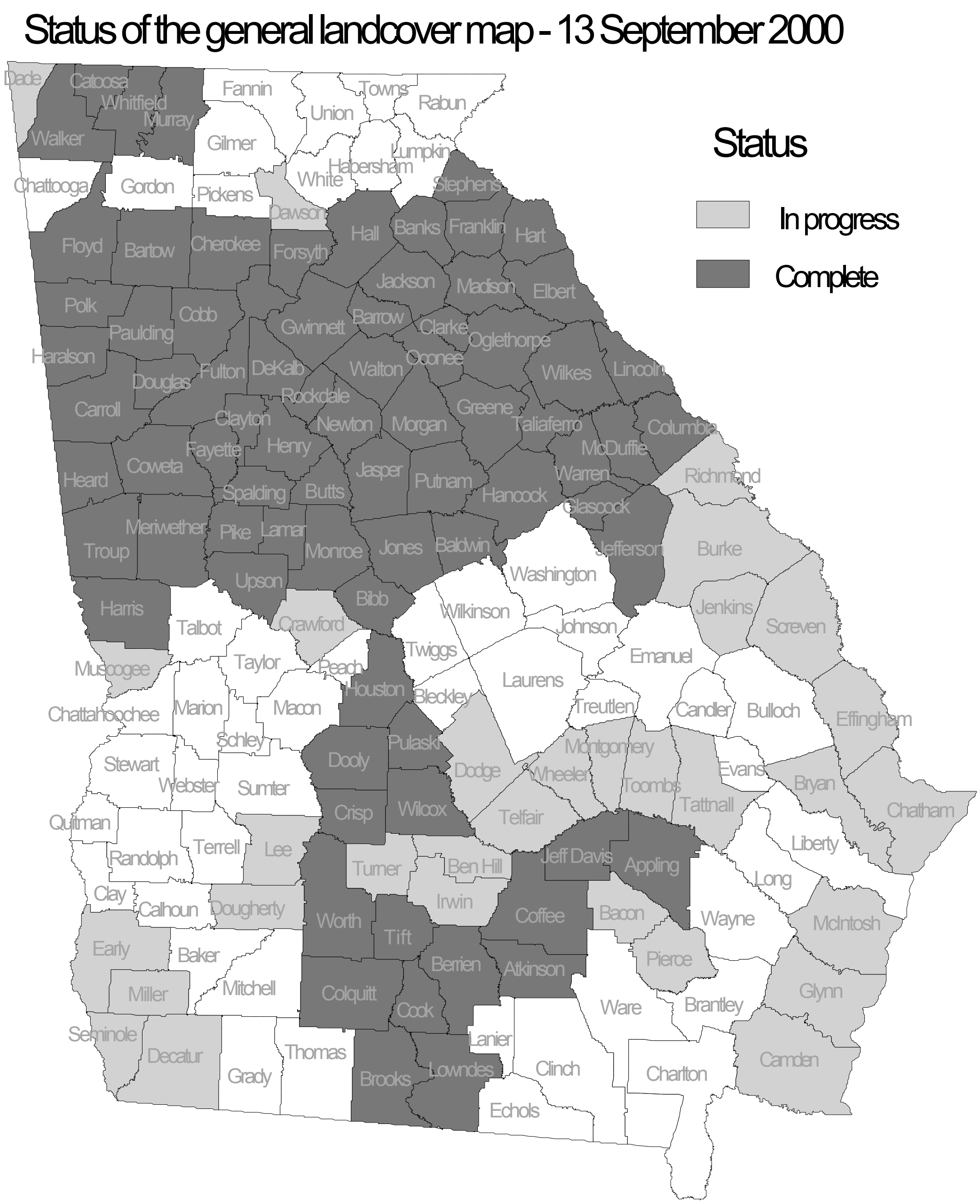


Figure 1. Status of the general land cover map for Georgia.

Hawaii

Under way
Anticipated completion date: December 2004

Contact: Samuel M. Gon III
The Nature Conservancy of Hawaii, Honolulu
sgon@tnc.org, (808) 537-4508 x241

GAP has finally returned to Hawaii, where it all began. The coalition of agencies co-sponsoring HI-GAP is quite extensive and includes The Nature Conservancy of Hawaii, The University of Hawaii, The Hawaii Heritage Program, The Department of Land and Natural Resources, U.S. Fish and Wildlife Service, USGS Biological Resources Division, and the Bishop Museum. This broad-based coalition brings some of the best biologists, remote sensing/GIS specialists, and land managers in the state together under the GAP umbrella and provides us with the opportunity to produce products with a high degree of credibility and agency buy-in.

HI-GAP began in earnest in October with the hiring of a full-time project coordinator, Don Robinson, who brings mapping, modeling, and project management skills to the effort. The HI-GAP office was established at the University of Hawaii and is collocated with the Hawaii Natural Heritage Program and the University of Hawaii's Center for Conservation Research and Training.

Land cover: HI-GAP will be proposing several additions and revisions to the NVC to accommodate anticipated major vegetation mapping units. Of particular interest will be several extensive alien-dominated alliances and associations present in Hawaii.

Co-PIs Dr. Sam Gon III (TNC-Hawaii) and Ron Cannarella (DLNR) attended the 2000 National GAP Meeting in San Antonio, where they were joined by Steve Raber, Manager of NOAA's Coastal Remote Sensing Program. One of NOAA's major initiatives in Hawaii is mapping the land cover of the major islands through the Coastal Change Analysis Program (C-CAP). (All lands in Hawaii are considered the "coastal zone" by NOAA.) Like GAP, C-CAP uses the latest Landsat imagery but produces final map products with fewer land cover classes than does GAP. At San Antonio, HI-GAP and C-CAP decided to join forces by sharing data and expertise in their respective mapping projects. Our first collaboration came in November. The C-CAP team and GAP staff jointly collected field data and refined the first set of draft C-CAP land cover maps utilizing Landsat 30 m imagery. When completed in early 2001, the C-CAP land cover maps will be used by GAP to form the foundation for the more detailed analysis required by HI-GAP.

Several other agencies are initiating mapping projects in Hawaii that are also potentially complementary to our GAP efforts, and we are pursuing cooperative efforts with them. Land cover mapping is our primary objective for year one.

Animal modeling: Mapping for endangered forest birds was completed by Hawaii Natural Heritage Program. Contacts with species experts are being initiated.

Land stewardship mapping: Major land ownership patterns for the state have been determined. Agricultural and urban land classes will be derived from complementary work of C-CAP and NRCS.

Idaho

Update near completion
Anticipated completion date: May 2001

Contact: Leona K. Svancara
Idaho Cooperative Fish and Wildlife Research Unit, Moscow
leonab@uidaho.edu, (208) 885-3774
http://www.wildlife.uidaho.edu/idgap.htm

Land cover: The Idaho land cover layer and final report chapter are complete. The Idaho land cover classification recognizes 81 cover types and is mapped at a resolution of 0.09 ha with a 2 ha MMU. The land cover data, metadata, and final report chapter can be obtained at the URL above or by contacting the Idaho Cooperative Fish and Wildlife Research Unit.

Animal modeling: Second-generation wildlife habitat relationship models have been completed for 373 terrestrial vertebrates in Idaho. The models are stored as georeferenced TIFF images with a native resolution of 0.09 ha. The models and all documentation may be obtained by contacting the Idaho Cooperative Fish and Wildlife Research Unit.

Land stewardship mapping: The revised Idaho land stewardship database is also complete. This data set represents a significant improvement over the original Idaho land stewardship layer by increasing spatial resolution to a 2 ha MMU and incorporating many of the smaller managed areas in Idaho. This data set, its metadata, and final report chapter are available for download at the URL above or by contacting the Idaho Cooperative Fish and Wildlife Research Unit.

Analysis: Analysis of the protection status of Idaho's land cover types and wildlife habitat distributions is complete. Current analyses include accuracy assessments of the wildlife habitat models and identification of conservation opportunity areas.

Reporting and data distribution: The final report for Idaho Gap Analysis is awaiting the results of current analyses. Final updates are being made to the metadata. All data, metadata, and documentation are currently available via download at the URL above or by contacting the Idaho Cooperative Fish and Wildlife Research Unit.

Other accomplishments and innovations: We have conducted a gap analysis of geomorphologic and climatic features in Idaho and will compare the results of this analysis with those from land cover and wildlife habitat analyses. We have developed programs that create hypergrids (grids containing the distributions of all input grids in condensed, binary form) in order to facilitate the identification of conservation opportunity areas that satisfy multiple selection criteria including species richness, species protection status, size of area, and contiguity of area.

Recent GAP-related publications include:

Scott, J. M. 1999. Vulnerability of forested ecosystems in the Pacific Northwest to loss of area. Pages 33-42 in J.A. Rochelle, L.A. Lehmann, and J. Wisniewski, editors. Forest Fragmentation: Wildlife and Management Implications. Brill, Leiden, The Netherlands.
Karl, J.W., N.M. Wright, P.J. Heglund, and J.M. Scott. 1999. Obtaining environmental measures to facilitate vertebrate habitat modeling. *Wildlife Society Bulletin* 27:357-365.
Karl, J.W., P.J. Heglund, E.O. Garton, J.M. Scott, N.M. Wright, and R.L. Hutto. 2000. Sensitivity of species habitat-relationship model performance to factors of scale. *Ecological Applications* 10:1690-1705.
Karl, J.W., L.K. Bomar, P.J. Heglund, N.M. Wright, J.M. Scott. In press. Species commonness and the accuracy of habitat-relationship models. In J.M. Scott, P.J. Heglund, et al., editors. Predicting Species Occurrences: Issues of Scale and Accuracy.

Illinois

Under way
Anticipated completion date: September 2002

Contacts: Patrick Brown, PI
Illinois Natural History Survey
pbrown@mail.inhs.uiuc.edu, (217) 244-4289

Tari Weicherding, Coordinator
Illinois Natural History Survey
tweicher@uiuc.edu, (217) 265-0583

Land cover: Classification to the community/alliance level has been completed for southern Illinois including the St. Louis region and has been delivered to the regional coordinator. We have obtained ancillary data such as DEMs and forest inventory information. The northeastern scene for 1999 in Illinois, which includes Chicago, has been completed to the natural community level. Classification has begun on the northwestern portion of the state. The rest of Illinois will be classified to the level of natural communities. We have been working cooperatively with the Illinois State Geological Survey, USDA-NASS, and the Illinois Department of Agriculture to obtain 1999 and 2000 imagery and to include more detail in the agricultural classes.

Animal modeling: We have completed mapping the amphibians and reptiles and have begun to produce hexagon maps for expert review. We are continuing to map the mammal records and have completed a few predicted distributions for species occurring in southern Illinois. We are well along with our habitat associations database for amphibians, birds, mammals, and reptiles. Information gathered for the Illinois Fish and Wildlife Information System has been and will continue to be helpful in developing habitat associations. We have bird data from the Illinois Breeding Bird Atlas, USGS Breeding Bird Survey, USFWS Bird Banding Laboratory, Illinois Spring Bird Counts, Natural Heritage database, and the Audubon Society. These data will be used to create predicted species distributions for birds in Illinois.

Land stewardship mapping: We have developed a land stewardship map for Illinois, attributed general ownership categories, and assigned management status levels. The GAP coding scheme for land units has been assigned to each property. The database includes federal, state, and county properties. The data are currently being reviewed and updated and, once complete, a draft version of the database will be delivered to the regional coordinator.

Analysis: We have completed some preliminary analyses using amphibian, bird, mammal, and reptile locational data to create species richness maps using the EMAP hexagons. We have also conducted preliminary analysis of predicted distributions for species that occur in southern and northeastern Illinois. We will continue to do more analyses as our species and vegetation mapping progresses.

Reporting and data distribution: We have started writing some portions of the final report and will continue as our project progresses.

Other accomplishments and innovations: The USDA's National Agricultural Statistics Service and the Illinois Department of Agriculture have joined the Illinois Gap Analysis Project (IL-GAP) as cooperators. They have helped us obtain 1999 and 2000 TM imagery as well as classify some of the agricultural areas in Illinois.

Presentations on IL-GAP were given at the Midwest Fish and Wildlife Conference, Chicago, Illinois, in December 1999, 10th Annual National Gap Analysis Program meeting, San Antonio, Texas, in August 2000, and the Wildlife Society Conference, Nashville, Tennessee, in September 2000. In October, representatives from Illinois, Michigan, Minnesota, and Wisconsin attended a vertebrate modeling meeting in Wisconsin. The objective was to start sharing data such as species lists and hexagon maps among adjoining states in order to build predicted distribution models for the whole Upper Midwest region.

Listed below are projects that are using the land cover database of Illinois as well as other data that were developed as part of the Illinois Gap Analysis Project.

- Habitat modeling of eastern wild turkeys in Illinois. T. Van Deelen, P. Brown, J. Aycrigg, D. Greer, M. Joselyn, T. Maples, and J. Garver.
- Fox and coyote ecology in central Illinois. T. Gosselink, T. Van Deelen, R. Warner, and P. Mankin.
- Deer in the urban ecosystem. D. Etter, T. Van Deelen, and R. Warner.
- Identification and classification of critical wildlife habitat. P. Brown, J. Aycrigg, and L. Suloway.
- Map Illinois. J. Aycrigg, D. Stigberg, J. Westervelt, and M. Joselyn.
- Use of spatial technology to assist with the ecological risk assessment process. J. Aycrigg, J. Levengood, T. Weicherding, S. Lavin, L. Schwab, and L. Suloway.

Indiana

Near completion
Anticipated completion date: September 2001

Contact: Forest Clark

U.S. Fish and Wildlife Service, Bloomington
forest_clark@fws.gov, (812) 334-4261 x206

Land cover: This data layer is complete and available through the Upper Midwest Environmental Sciences Center.

Animal modeling: An original set of models is complete; however, internal review suggested the need for revisions, which are in process.

Land stewardship mapping: This data layer is complete except for minor metadata components.

Analysis: The project has taken preliminary steps to start the analysis. We propose to have the analysis finished in the next six months.

Reporting and data distribution: Some data are now available through the Upper Midwest Environmental Sciences Center. Many clients have already used data generated by the project.

Iowa

Under way
Anticipated completion date: December 2001

Contacts: Kevin Kane, Co-PI
Director, GIS Support and Research Facility
Iowa State University, Ames
kkane@iastate.edu, (515) 294-0526

Bruce W. Menzel, Co-PI
Professor and Chair, Department of Animal Ecology
Iowa State University, Ames
bmenzel@iastate.edu, (515) 294-7419

The Iowa Gap Analysis Project (IA-GAP) is beginning its fourth and final year in 2001. The IA-GAP home page is accessible at http://www.iowagap.iastate.edu/.

Land cover: Land cover mapping is 85% complete. Only far western Iowa needs to be updated from phase I to phase II. The final land cover map will be finished by February 2001; final analysis operations will begin then. Final accuracy assessment will take place in summer 2001. Current classification is shown in Figure 1 (see Web version of Bulletin at http://www.gap.uidaho.edu/Bulletins/9/).

Animal modeling: Draft vertebrate models have been completed for about 2/3 of all species (Figure 2). Iowa is a cooperator in the Upper Midwest vertebrate modeling initiative along with North and South Dakota. Initial distribution maps (Figure 2) are being shared with cooperators via the Web to obtain feedback. Final models will be started in February 2001 and finished by July 2001, when final reporting begins.

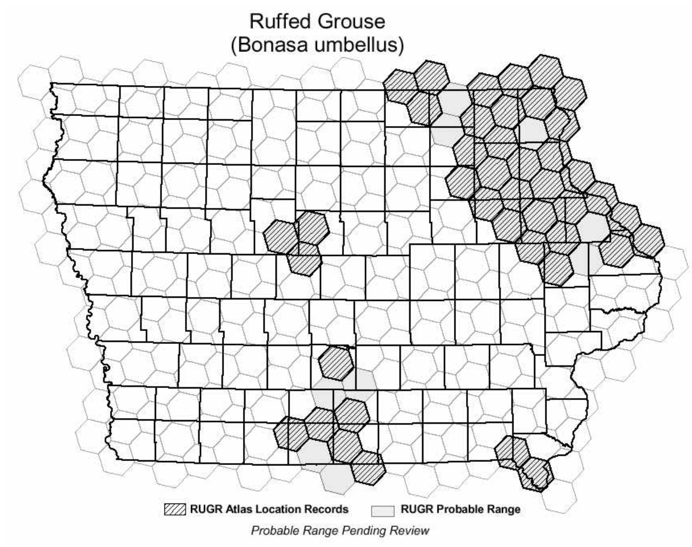


Figure 2. Draft vertebrate range map.

Land stewardship mapping: Stewardship mapping is 95% complete. Managed area boundaries are being edited with the help of the Iowa Geographic Image Server available at http://ortho.gis.iastate.edu/. The IA-GAP stewardship mapping image map server (Figure 3) can be accessed at http://baykal.gis.iastate.edu/gapims/. Addition of some county conservation board lands and federal reservoir lands will be complete for analysis by February 2001.

Figure 3. Stewardship status from Internet Map Server.

Analysis: Preliminary analysis is proceeding with draft data sets to develop final models. All draft and final analyses are expected to be finished by July 2001.

Reporting and data distribution: Documentation for the project is being compiled as we go. There has been no attempt at this point to finalize this documentation. Draft data sets are available to cooperators on-line. Documentation of the project will proceed as we enter our analysis phase. Final documentation will be compiled starting around July 2001. All data will be submitted with the final report and also be available on-line via ftp by the end of 2001.

Aquatic Gap Analysis: The Iowa Rivers Information System (IRIS) project started with Iowa DNR as partner. Funding for a 3/4-time position was established through 6/02. Staff attended a National Hydrologic Dataset (NHD) training session in Austin, TX, in December 2000. Figure 4 shows some of the data being developed for Iowa Aquatic GAP. More information can be found at http://mombasa.gis.iastate.edu/Present/IRIS%20Plus/index.htm.

Goals for 2001 are to:

- build the spatial database for IRIS with the DNR's GIS Section using the NHD;
- collect and add specific data attributes to the IRIS spatial structure;
- integrate IRIS into a GIS environment where queries can be done for location or attribute information from a user's desktop. This will involve writing programming code in an ArcView environment using Avenue, Visual Basic, or C++.

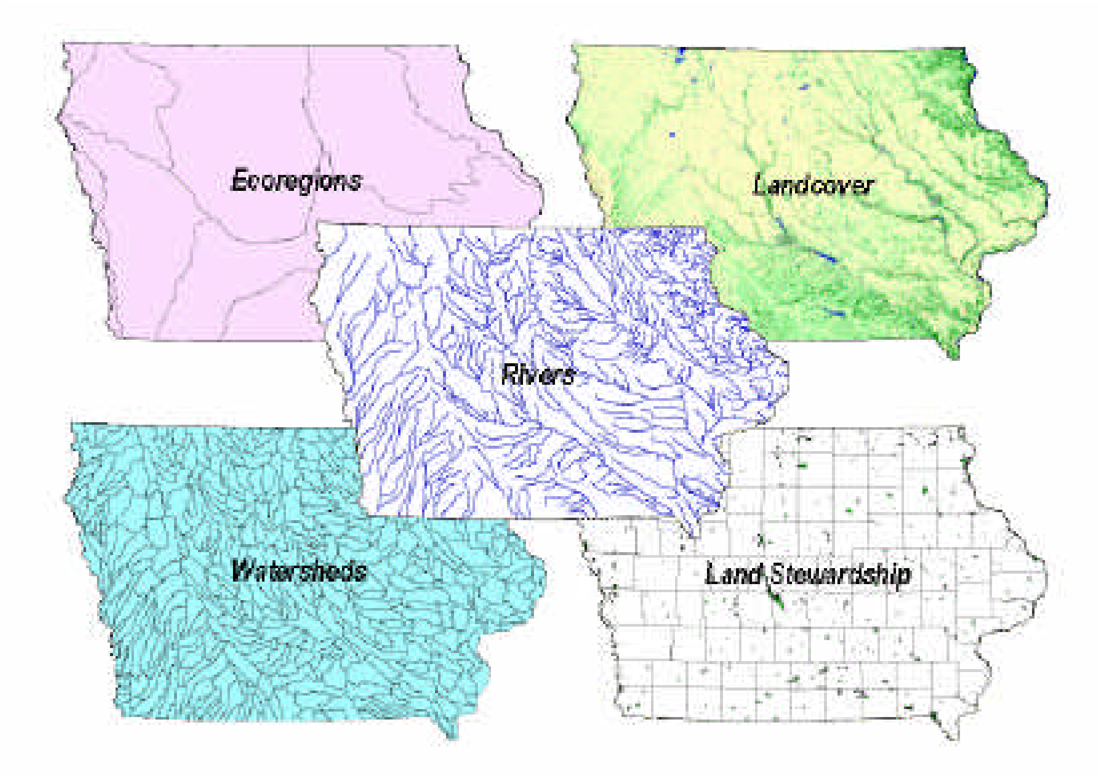
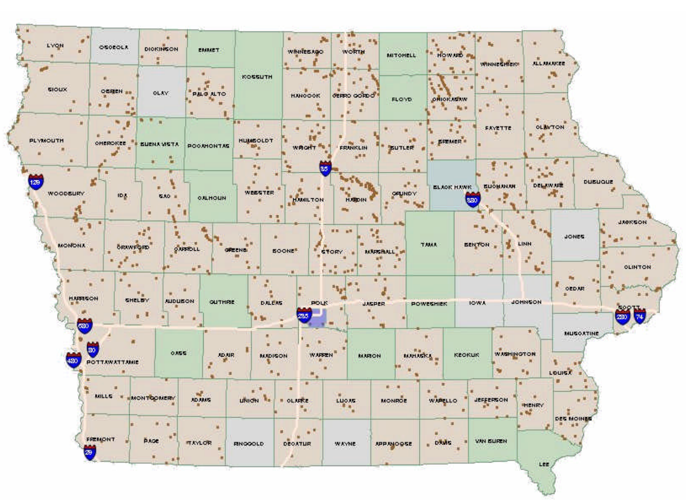


Figure 4. Primary data sets for Iowa Aquatic GAP.

Other accomplishments and innovations: The final report on land cover accuracy assessment was submitted to EPA Region VII. The report can be viewed on the IA-GAP home page (http://www.iowagap.iastate.edu/). We will be assessing the accuracy of our land cover classification this summer. If funding is available, we will be following guidelines from Sarah M. Nusser, et al. 2001. Survey Design for Iowa GAP Accuracy Assessment Pilot Study. Department of Statistics and Statistical Laboratory, Iowa State University, funded by Region 7 EPA. In the absence of funding, we will conduct our accuracy assessment through comparison of previously collected data points.

Iowa is the third state to implement the NatureMapping program in the U.S. Phase I of Iowa NatureMapping was funded by a Resource Enhancement and Protection–Conservation Education Program (REAP-CEP) grant (state allocated funding). Current efforts include forming a statewide steering committee for the project, preparing a NatureMapping Web site, developing and conducting beginner-level workshops across the state, and receiving data on Iowa's terrestrial vertebrates (birds, mammals, reptiles, and amphibians). Goals for 2001 are to begin advanced training for NatureMappers; further develop the NatureMapping Web page to improve database management to allow



electronic checking of data prior to submission; and work with the DNR's Wildlife Diversity Program and the IOWATER program to link similarities in these programs and to share volunteer efforts.

The Iowa Geographic Information Image Server is up and running and serving orthophotos, topographic maps, and other Iowa grid data from http://ortho.gis.iastate.edu (Figure 5). This service is being heavily used by IA-GAP as well as many other Iowa users for a variety of applications. In 2001, storage will be updated to provide data at higher resolution and serve more data, including integrated vector data.

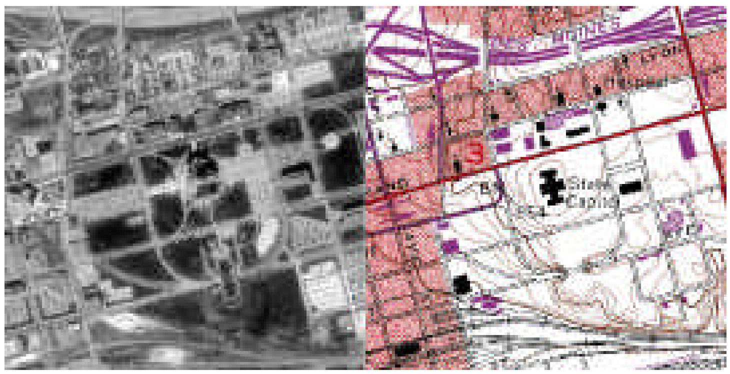


Figure 5. Example of orthophoto and 24k topo coverage at 2-meter resolution.

Kansas

Under way
Anticipated completion date: July 2001

Contact: Glennis Kaufman
Kansas State University, Manhattan
gkaufman@ksu.edu, (785) 532-6622

Land cover: The land cover layer was completed in September 2000. Currently, the land cover map is undergoing accuracy assessment; 75% of the assessment points have been entered into the database. Figure 1 demonstrates current progress (see Web version of Bulletin at http://www.gap.uidaho.edu/Bulletins/9/).

Animal modeling: An Access database expert system has been developed both for KS-GAP and the Great Plains Regional GAP effort to assist in modeling vertebrates relative to habitats and range distributions (see article on page). We continue to upgrade the system with a ProCite and Word97 interface for on-line, user-friendly review by experts. The database is complete. We have completed draft and final models for 50% and 15%, respectively, of the vertebrate species (*n* =422) in Kansas. Currently, 35% of the models are either in review by experts or in revision. We anticipate that six months may be required to complete remaining draft models, conduct expert review, revise, and finalize models. Wintering birds may not be mapped as originally proposed due to time constraints. Vertebrate layers are expected to be completed within the next 4-6 months.

Land stewardship mapping: The stewardship boundary layer is 98% complete relative to land unit boundaries. A survey was conducted to obtain information from agencies and organizations to attribute a spreadsheet that will assist in assigning status codes to public and private conservation lands. Currently, the stewardship survey is 97% complete. We anticipate assigning status codes within the next 1-2 months. The stewardship layer should be complete by February 2001.

Analysis: Analysis will be completed within the next eight months.

Reporting and data distribution: Reporting and data distribution are expected to be completed within the next eight months.

Other accomplishments and innovations: We have created a stewardship survey form that can provide information for evaluating the suitability of lands for conservation of species. Information collected from the survey can be used in conjunction with the dichotomous key provided in the GAP manual to assign stewardship status codes. The stewardship survey is available as part of the GAP handbook at http://www.gap.uidaho.edu/handbook/Stewardship/kssurvey.pdf.

Kentucky

Under way
Anticipated completion: June 2002

Contacts: Keith Wethington, PI
Kentucky Department of Fish and Wildlife Resources, Frankfort
keith.wethington@mail.state.ky.us, (502) 564-7109 x.405

Tom Kind, Co-PI
Murray State University, Murray
tom.kind@murraystate.edu, (270) 762-3110

Land cover: Our main goal for 2000 was achieved, as draft vegetation maps for each of the state's six physiographic regions were completed by year's end. If necessary, additional modeling will continue until May 2001, when we expect to publish our final land cover map. The draft map will be used when testing the animal models. If feedback from state experts and/or preliminary results from animal modeling indicate land cover errors, this information will be used to refine the map. Approximately 10,000 ground-truth points for 30 map units have been gathered; however, we have retained enough flexibility to be able to revisit the field should it become necessary.

A considerable effort to map crops and pasture was undertaken during fall 2000. Good results were achieved in most areas of the state. A poster detailing progress was presented at the GAP conference in San Antonio, and the methods and results will be documented in the final report. The land cover portion of the project will end with the completion of the final map. We will use the remaining time in winter and spring of 2001 to gather metadata and write the land cover portion of the final report.

Animal modeling: The majority of the vertebrate modeling work involved finalizing the range maps, habitat associations, and Wildlife/Habitat Relationship Model (WHRM) for each species. After the review and editing process, we posted the final ranges of terrestrial vertebrates in Kentucky on our Web page (www.kfwis.state.ky.us/kygapweb/index.htm, Vertebrate Mapping Update). The database of habitat associations for each species has been completed. A Web page was constructed for the habitat association review with the aid of the Kentucky Department of Fish and Wildlife Resources (KDFWR). The review process of the habitat association database proved to be a time-consuming task for both the reviewers and us. We recently completed the editing required after the review process. The WHRMs for each species were completed and are being tested on a rough draft version of the vegetation map in western Kentucky. We incorporated vegetation, elevation, National Wetland Inventory (NWI) wetlands, forest size, and edge associations into the KY-GAP models.

We continued the analysis of species richness of terrestrial vertebrates in Kentucky. In addition to mapping species richness in the ecoregions and physiographic provinces, we analyzed the value of some abiotic variables in predicting species richness in Kentucky and presented our findings at the National GAP meeting in San Antonio, TX, and the Kentucky Academy of Science in Lexington, KY.

Upon completion of the vegetation map of Kentucky, all vertebrate distributions will be mapped in 2001. Predicted distributions maps will be reviewed and edited as needed. After the distribution maps are complete, we will assess the accuracy of the predicted distributions for all species. Once the accuracy assessment process is finished, the predicted distributions will be prepared for the final gap analysis.

Land stewardship mapping: As of the spring of 2000 the inventory and acquisition phase of properties to be included in the stewardship layer was complete. A total of 80 potential property owners within Kentucky were contacted for data; 23 responded. Some agencies either had no data on property boundaries or were unable to share. While the current stewardship layer is lacking some potentially eligible properties for gap analysis, we did obtain complete coverages for federal, state, and NGO entities with conservation mandates. Work during the summer and fall of 2000 concentrated on merging all data to a common projection and datum and resolving sliver and overlap issues. We now have in place a single, merged coverage of all stewardship lands. Currently we are gathering metadata in order to assign stewardship categories to properties. Our goal is to have the stewardship layer completed during January 2001.

Analysis: The gap analysis is scheduled to begin in the fall of 2001, pending completion of the animal modeling layers, and will be completed in early 2002.

Louisiana

Near completion (see final report summary on page)
Anticipated completion date: March 2001

Contacts: Jimmy Johnston, Project Leader
USGS/National Wetlands Research Center, Lafayette
jimmy_johnston@usgs.gov, (318) 266-8556

Steve Hartley, Coordinator
USGS/National Wetlands Research Center, Lafayette
steve_hartley@usgs.gov, (318) 266-8543

Land cover: Complete.

Animal modeling: Complete.

Land stewardship mapping: Complete.

Analysis: Complete.

Reporting and data distribution: The final report is complete, editing of report is in progress as per National GAP recommendations. Final data distribution CDs were delivered to National GAP; no changes were requested.

Maine

Complete (see http://wlm13.umenfa.maine.edu/progs/unit/gap; see also final report summary on page)

Maryland, Delaware, & New Jersey

Near completion
Anticipated completion date: June 2001

Contact: Ann Rasberry, PI (land cover)
Maryland Department of Natural Resources
arasberry@dnr.state.md.us, (410) 260-8558

Rick McCorkle (animal modeling)
Delaware Bay Estuary Project
U.S. Fish & Wildlife Service
richard_mccorkle@fws.gov, (302) 653-9152 x17

Land cover: During 2000, land cover mapping was completed for Maryland, Delaware, and New Jersey. Accuracy assessment started with Delaware, and the gap analysis of the mapped classes has begun. Completion of metadata and preparation of data for delivery to the national office are under way. We plan to complete these activities by 31 March 2001.

Once the rest of the GAP project is completed, we will try to import our aerial video into a GIS format. This will enable us to use additional video in the classification process where GPS capture was intermittent during video flights (e.g., over the mountains in western Maryland). We will use this additional information for an update after data delivery.

Animal modeling: In 2000 we identified landscape metrics (e.g., percentage of forest cover within 250 m of breeding ponds) for amphibian modeling and developed GIS approaches to incorporating those metrics into the modeling. Landscape metrics were also identified for grassland birds, and GIS approaches to including metrics in models for area-sensitive, forest-dependent birds were fine-tuned.

The modeling software has been updated to allow for three different approaches to mapping distributional limits (i.e., range within project area). There are two hexagon-based approaches for common species, one of which relies on the existing species-hexagon association database, and the other allowing for additional hexagons to be added (e.g., for a species that an expert reviewer considers more widespread than reflected in the existing range map). The third approach, for extremely rare or endangered species, relies on a species-quad (USGS 7.5-minute quadrangle) association database. A controlling table determines which approach is used for a particular species.

With the completion of the land cover, the process of cross-walking the land cover classes to habitats (i.e., the habitats listed in the species-habitat association tables) was initiated. The first set of draft models and distribution maps will be sent to expert reviewers shortly.

Land stewardship mapping: During 2000 the stewardship layer for the project was completed. Quality control checks and last-minute changes are nearly complete.

Analysis: GAP investigators expect to complete analysis of the protection and management status of biodiversity by 31 March 2001. The determination of the statistics for the land cover classes has been completed, and further assessment is under way. We will conduct the analysis for the vertebrate modeling in 2001.

Reporting and data distribution: Final report writing for Maryland, Delaware, and New Jersey has begun and should be completed by 31 March 2001. The GIS layers will be distributed in ARC/INFO/ArcView format, with associated data tables in Microsoft Access format and dBase format on CD-ROM. The status and availability of these products will be reported via the GAP Web page.

Other accomplishments and innovations: The mid-Atlantic GAP data have been distributed to several partners, including the New Jersey Natural Heritage Program and the Maryland Chapter of The Nature Conservancy. TNC is using the data to aid in their ecoregional planning of the Chesapeake Lowlands Ecoregion in Maryland and Delaware. Staff in the Maryland Department of Natural Resources have been using the data for ecoregional planning, identifying viable plant and animal corridors for connecting other habitats, and targeting forest land parcels for conservation instead of, or in addition to, timber management.

Massachusetts

(for status, contact Curtice Griffin at cgriffin@forwild.umass.edu)

Michigan

Under way
Anticipated completion date: September 2002

Contact: Mike Donovan
Michigan Department of Natural Resources
Land and Mineral Services Division, Lansing
donovanm@state.mi.us, (517) 335-3445

Land cover: Land cover mapping follows the Upper Midwest GAP protocol at ftp://ftp.umesc.usgs.gov/pub/misc/umgap/98-g001.pdf. Mapping of the southern Lower Peninsula will continue this fiscal year and should be completed by the end of September 2001. Almost all fieldwork was completed in fiscal year 2000; this year's effort will be focused on image classification, accuracy assessment, and metadata development.

Mapping of the Upper Peninsula and revision of the northern Lower Peninsula will start this year in cooperation with the DNR's IFMAP project. This year's effort will concentrate on the collection of training sites and the refinement of the vegetation classification system. A major effort to cross-walk the classification to the NVCS is planned for 2001, pending GAP support for collaboration with TNC/ABI.

Animal modeling: Research faculty in the Wildlife Division at Michigan State University (MSU) will continue working with the Michigan Natural Features Inventory (MNFI) and other Wildlife Division staff on a species distribution modeling project. Almost all program funding received from Upper Midwest GAP for fiscal year 2001 will be applied toward this work.

During fiscal year 2001, work will continue on the integration of existing species habitat databases into the GAP modeling process. Further refinement of the databases will occur with additional literature review. Initial distribution/occurrence models will be developed for some species.

Land stewardship mapping: The stewardship layer should be delivered to UMESC by mid-January 2001.

Reporting and data distribution: Draft land cover data for the northern Upper Peninsula is available from the USGS Upper Midwest Environmental Sciences Center. Additional land cover data and stewardship data are expected to become available in 2001. Contact Daniel Fitzpatrick at (608) 781-6298 or Daniel_Fitzpatrick@usgs.gov.

Minnesota

Under way
Anticipated completion date: September 2002

Contact: Dave Heinzen
Minnesota Department of Natural Resources
Resource Assessment Unit, Grand Rapids
david.heinzen@dnr.state.mn.us, (218) 329-4449 x222

Land cover: Land cover mapping follows the Upper Midwest GAP protocol at ftp://ftp.umesc.usgs.gov/pub/misc/umgap/98-g001.pdf. The state is about 80% finished with the following classification units completed and available: North Shore, Border Lakes East, Border Lakes West, North Tamarack Lowlands, South Tamarack Lowlands, East Chippewa Plains, West Chippewa Plains, Nashwauk Uplands, Laurentian Uplands, St. Louis Moraines, Pine Moraines & Outwash Plains, Mille Lacs Uplands, Agassiz Lowlands East, Agassiz Lowlands West, Anoka Sand Plain, Blufflands and Oak Savannah and Rochester Plateau. A major effort to cross-walk the classification to the NVCS is planned for 2001, pending GAP support for collaboration by TNC/ABI.

Animal modeling: The DNR began to partner with UM-GAP last year in an ongoing state vertebrate mapping effort, and cooperation will expand in 2001. Species expert review teams have been formed, and draft habitat suitability matrices have been distributed to the teams for review. The animal modeling coordinator for the Minnesota DNR is Jodie Provost (jodie.provost@dnr.state.mn.us).

Land stewardship mapping: Stewardship mapping is essentially completed and available. The Public Land Survey (PLS) was used as a base map. The section corners are located, and the 40-acre tracts are generated from an algorithm. Each 40-acre parcel is attributed for public landowner, manager, and stewardship status. The coverage is clipped and served in 1:100k mapquad tiles. Some work still needs to be done to standardize the file naming.

Reporting and data distribution: Draft land cover data and stewardship coverages are available from the USGS Upper Midwest Environmental Sciences Center. Additional land cover data are expected to become available in 2001. Contact Daniel Fitzpatrick at (608) 781-6298 or Daniel_Fitzpatrick@usgs.gov.

Mississippi

Near completion
Anticipated completion date: December 2001

Contacts: Francisco J. Vilella, PI
MS Cooperative Fish and Wildlife Research Unit

Mississippi State University
fvilella@cfr.msstate.edu, (662) 325-0784

Richard B. Minnis, Coordinator
MS Cooperative Fish and Wildlife Research Unit
Mississippi State University
rminnis@cfr.msstate.edu, (662) 325-3158

Land cover: The land cover for Mississippi GAP has been completed. Fifty-three classes were identified to an accuracy level of 80%. Innovative analyses allowed for delineation of structural categories for several vegetation classes. Specifically, pine classes were classified into five structural categories with > 80% accuracy. Additionally, several urban classes were developed but had fairly low accuracy levels. The land cover section of the MS-GAP report will be forwarded to reviewers soon.

Animal modeling: Habitat matrices were constructed for all terrestrial vertebrate species. Range maps are completed for all species. Distribution maps are undergoing final review. Final adjustments to models will be made once the final reviews are returned. The vertebrate section of the report is well along; the first draft will be completed after final map reviews are returned. We expect to provide the report to reviewers in late spring 2001.

Land stewardship mapping: The land ownership layer has been finalized. Status 1 lands in the state are very rare (< 0.1% of the state). Status 2 is much more common (~5% of the state).

Analysis: Analysis is being conducted on animal distribution at the current time. Any models that change during the final review process will be reassessed in this process. Final analysis tables are being constructed for each species because we expect few changes in the latest round of distribution models.

Reporting and data distribution: A first draft of the final report is expected to be issued to reviewers in mid- to late summer 2001.

Missouri

Near completion
Anticipated completion date: June 2001

Contact: Timothy L. Haithcoat
Geographic Resources Center
University of Missouri, Columbia
haithcoatt@missouri.edu, (573) 882-1404

Land cover: Phase II has been completed, and land cover classes for urban areas not mapped in Phase I have also been completed.

Animal modeling, land stewardship mapping, and analysis: Complete.

Reporting and data distribution: Complete. The second draft of the final report was submitted in January 2001. Data distribution from the analyses will be posted on the Missouri Spatial Data Information Service (MSDIS) at http://msdis.missouri.edu. A link will be created on this site to the AMLs and programs written in support of this effort.

Montana

Complete (see http://www.wru.umt.edu/reports/gap/; see also final report summary on page)

Nebraska

Under way (http://www.calmit.unl.edu/gap/)
Anticipated completion date: October 2001

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: We have worked over the past year on refining the land cover product through inclusion of other data sources and an extensive county-level review by NRCS District Conservationists (see article in this issue for details). We have incorporated three additional data sources to augment the classification based on Landsat TM data from the early 1990s. First, after an extensive cross-comparison with the USGS's NLCD land cover map of Nebraska, we incorporated two of their classes: low-intensity residential and commercial-industrial-transportation. These classes enhance discrimination between the concrete and asphalt urban desert and resource-rich park and suburban habitats. We have also included select data from the Cooperative Hydrological Study (COHYST) project of the Central Platte River. These data include crop-level discrimination based on 1997 TM imagery. We aggregated these classes to active and fallow croplands, which improved discrimination between fallow fields and persistent grasslands in western Nebraska. Finally, we imported polygonal data from the National Wetlands Inventory data currently digitized for Nebraska. These data enhanced our ability to resolve wetland complexes and riparian corridors. Plans for the next twelve months include preparing metadata and publishing the land cover map as an outreach product.

Animal modeling: We have georeferenced all herpetile and mammal voucher specimens from Nebraska since 1969. We have incorporated the Breeding Bird Survey data for Nebraska since 1969. We have assembled over 100 ancillary data layers at 150 m resolution that include climate variables (means, extremes, variances), selected soils data from STATSGO, and terrain data from USGS DEMs. We are seeking appropriate data from the Natural Heritage Program on occurrence of species lacking records in our current data set. We have commenced vertebrate modeling using a recursive partitioning algorithm, related to but distinct from CART. During the coming year, we will complete assembly of the occurrence database, complete initial vertebrate models, perform accuracy assessments, solicit reviews of the models, and prepare metadata.

Land stewardship mapping: Attribution of polygons not yet complete. Plans for next 12 months: prepare metadata; finalize stewardship database.

Analysis: Analysis is pending completion of animal models.

Reporting and data distribution: Metadata assembly, data lineage and methods documentation ongoing.

Other accomplishments and innovations:

1. Continuing work with regional partners in Great Plains GAP consortium.
2. Working with Iowa, North Dakota, South Dakota, and Kansas on cooperative vertebrate modeling of regionally distributed species.
3. Cooperating with the Nebraska Research Initiative in Geospatial Decision Systems.
4. Received $49,000 from the Nebraska Game and Parks Commission to purchase 2,000 Landsat 7 ETM+ data to enhance and update land cover maps for the Niobrara River watershed in northern Nebraska.
5. We are part of a team that has received a $1.2M grant from the U.S. Environmental Protection Agency for a three-year project to develop methods for lake classification in Nebraska. This will involve characterization of lake watersheds and provide additional data relevant to GAP.
6. Cooperating with Nebraska Audubon on locating potential tallgrass prairie remnants in southeast Nebraska using Landsat TM imagery.
7. Collaborating with researchers at Oak Ridge National Lab to apply a new computational approach to “ecoregionalize” Nebraska using climate and soils data.
8. Participating in a $100,000 NSF Biocomplexity Incubation Activity project on the ecology and geology of the sandhills of Nebraska.
9. Collaborated with the UNL Conservation and Survey Division to prepare a CD-ROM containing 30-meter digital elevation data for Nebraska.

Nevada

Update under way (see Southwest Regional GAP)

New Hampshire

(see Vermont and New Hampshire)

New Jersey

(see Maryland, Delaware, and New Jersey)

New Mexico

Update under way (see Southwest Regional GAP)

New York

Completed (see final report summary on page)

North Carolina

Under way
Anticipated completion date: December 2001

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

Land cover: The current focus of the land cover mapping effort is the sandhills regions of North Carolina. While this is generally considered a subunit of the coastal plain ecoregion, the vegetation is distinct enough to warrant separate treatment. The coastal plain and outer banks have been completed, with some processing to improve the mapping in the vicinity of the Dismal Swamp planned for the early winter of 2001. A pilot study for mapping in the mountains has been completed, and a continuation of that work is scheduled for winter 2001. The land cover mapping work is scheduled for completion in June 2001.

Animal modeling: Vertebrate ranges have been developed for the 420 vertebrate species being modeled in North Carolina (75 mammals, 199 birds, 70 reptiles, and 76 amphibians). Ranges were derived using the Vertebrate Characterization Database, specimen records from the Museum of Natural Sciences collection, as well as the Breeding Bird Atlas. Expert review of the vertebrate ranges has occurred, and updates to the data set are scheduled for January 2001. Habitat associations for the mammals and birds are in draft format and ready for internal review. Following the internal review, expert reviews will be conducted in winter 2001. Arc Macro Language code for translating the habitat associations into predicted distributions have been written and tested for a subset of the species. Predicted distributions for the 420 species are scheduled for completion in June 2001.

Land stewardship mapping: In cooperation with the North Carolina Heritage Program and the Center for Geographic Information and Analysis, the land stewardship layer is nearly complete. Boundaries and ownership information of existing public lands and private conservation lands have been compiled from a variety of existing data layers. Attributing the GAP status is ongoing. Completion and external review are planned for February 2001.

Analysis: The three data layers are scheduled for completion in June 2001, leaving June through December for analysis and report writing.

Reporting and data distribution: Data will be distributed through the North Carolina Center for Geographic Information and Analysis as well as the North Carolina State University Library.

Other accomplishments and innovations: With support from the U.S. Fish and Wildlife Service, NC-GAP is developing the GAP Ecosystem Data Explorer, a decision support tool. This is an ArcView-based tool designed for the Roanoke-Tar-Neuse-Cape Fear Ecosystem for use by Fish and Wildlife Service personnel. In addition to making GAP data more accessible to refuge biologists, the explorer will have a GIS version of the Land Acquisition Prioritization System (LAPS), currently used by the USFWS. While the information required by LAPS cannot be entirely translated to a spatial framework, a good proportion of the information can. By adding the capacity for user input, the system should be able to incorporate many of the questions currently addressed by biologists in filing out LAPS questionnaires.

North Dakota

Under way
Anticipated completion date: March 2003

Contact: Larry Strong
Northern Prairie Wildlife Research Center, Jamestown
larry_strong@usgs.gov, (701) 253-5524

Land cover: The primary activity in 2000 was the construction of training data sets. Vectors were constructed for vegetation surveys conducted on thirty 28.6 x 28.6 km study areas in the summer of 1999. Three dates of Thematic Mapper imagery corresponding to polygons in the vectors were extracted and exported to S-PLUS data frames. Exploratory statistical analyses of the spectral separability among vegetation and land cover types were begun. Plant species composition and biomass data from range surveys on almost 3,500 tracts of state school land were entered from microfiche and word-processing files into a SAS data set. Linkage of the database to a vector of the state school lands is under way. Land cover maps for tallgrass prairie in Richland and Ransom counties, Theodore Roosevelt National Park, and the Little Missouri National Grasslands were acquired from cooperators, and procedures were developed for their use. Ancillary data sets constructed in 2000 included National Elevation Database, soil texture, soil depth, and soil moisture surfaces from STATSGO, and mean annual precipitation and temperature surfaces. Classification and regression tree analyses were conducted on a data set of plant species canopy cover for 180 sample units in ND to gain experience with the statistical techniques. Primary activities in 2001 will include completing the construction of training data sets and their use in land cover classification and mapping, regression trees for predicting relative biomass (%) of dominant grass species, and ordination and classification analyses of the ND State School Land Range Inventory Database. Additional land cover classes identified by this exploratory analysis will be reviewed with ABI ecologist.

Animal modeling: All vertebrate range maps are being reviewed by experts. Wildlife habitat relationship (WHR) modeling was begun in conjunction with Iowa and South Dakota GAP projects. Modeling is performed using a customized Microsoft Access database and data-entry form initially created by Kansas GAP. Regional checklists of species were examined, and species found in all three states were divided up among the three state GAP projects for literature review and model development. An on-line database search has been completed for all species and geographic areas within the region. Literature sources for each species' habitat requirements are entered into a ProCite database which can produce a species report from the Access database. North Dakota's portion of the literature reviews and WHR models have been completed for 53 bird species, 12 mammal species, and 4 herptiles and distributed to expert reviewers. Activities in 2001 will include literature review, WHR model development and expert review, development of environmental data for modeling species distributions, and development of draft species distribution maps.

Land stewardship mapping: Cooperators have continued to provide significant in-kind resources with regards to public land stewardship maps. The U.S. Fish and Wildlife Service (FWS) has almost completed a vector coverage for fee-title lands and has made significant progress on vector coverage development for easements. The ND Game and Fish Department has almost completed vector development for fee-title lands. Public land ownership data for 1:100,000 scale quads in western ND were acquired from the Bureau of Land Management. Land ownership coverages were obtained for the Fort Berthold and Standing Rock Reservations. In 2001, we will acquire the coverages constructed by the FWS and the ND Game and Fish Department and begin the process of adding land stewardship attributes.

Ohio

Under way
Anticipated completion date: May 2003

Contact: Donna N. Myers
U.S. Geological Survey, Columbus
dnmyers@usgs.gov, (614) 430-7715

Land cover: The land cover map will be produced using 1999 Landsat 7 Thematic Mapper data obtained in March 2000 from the OhioLink program. The Nature Conservancy's vegetation classification for Ohio is being used. A pilot study of classification procedures for vegetation is under way, and hiring of a vegetation classification specialist is planned for March 2001. Areal videography taken by the Ohio Department of Natural Resources in 1998 was reviewed, and it was determined that additional data are needed. The pilot study will be completed in September 2001, and the land cover map is anticipated to be 25% completed within the next 12 months.

Animal modeling:
Terrestrial vertebrate modeling: A database containing records of Ohio's terrestrial vertebrate species occurrence and distribution was obtained in 2000 from the Ohio Department of Natural Resources. The literature review of habitat preferences of Ohio's terrestrial vertebrate species is 25% complete. A database is being created from the literature review information. The database relates vertebrate species distribution to the habitat affinity information for the species. The database and literature review are to be completed over the next 12 months.

Aquatic species modeling: Ohio Aquatic GAP is using the Missouri Aquatic GAP model as a template. Valley segment classification of Ohio's perennial streams is 90% complete. The final 10% will be completed by March 2001. A database of fish species distribution containing over 6,000 records from field surveys conducted from 1976-99 was obtained from the Ohio Environmental Protection Agency (OEPA). Included in the OEPA database are data collected by OEPA, Department of Natural Resources, and Department of Transportation. Other databases reviewed for inclusion in Aquatic GAP were the Ohio Historical Society's dragonfly database and OEPA's aquatic macroinvertebrate database. The aquatic macroinvertebrate database containing species-level data for mayflies, caddisflies, stoneflies, and midges will be used in Aquatic GAP. Ohio's freshwater mussel database is not available for use at this time. A database for Ohio crayfish will be developed and completed over the next 24 months in cooperation with the Ohio Biological Survey.

Land stewardship mapping: A base map of land stewardship in Ohio was obtained from the Ohio Department of Natural Resources. The map includes all state parks, state wildlife areas, and state-owned natural areas. Over the next 12 months, federal, county, and private parks, wildlife areas, and natural areas will be added to the map from available sources. Public and private lands identified on the map will be classified by conservation status.

Reporting and data distribution: Plans are to publish a CD containing spatial data themes developed from Ohio's Aquatic GAP project during the next 12 months. These same themes will become available on the Ohio GAP home page during the next 12 months. A USGS fact sheet describing Ohio's terrestrial and aquatic GAP projects is in review.

Other accomplishments and innovations: A proposal was accepted to conduct a gap analysis of Ohio's Lake Erie wetlands. The USGS Ohio Office and the Ohio Lake Erie Commission will fund this project cooperatively. Project start date is January 2001 and end date is September 2003. The Terrestrial GAP project is working cooperatively with the U.S. EPA Office of Research and Development to map impervious surfaces in Ohio's Eastern Corn-belt Plain ecoregion. The product of this work element will be used for habitat quality assessment in the Aquatic GAP project.

Animal modeling tools were investigated. One tool is GMS (Genetic Algorithms for Prediction Modeling System) (Stockwell and Peterson 1999), an expert system that includes several statistical and nonstatistical modeling routines for spatial data analysis. GIS and Internet resources are integrated into GMS. This tool will likely be chosen for Ohio's Aquatic GAP.

Literature cited

Stockwell, D., and D. Peterson. 1999. The GARP modeling system: Problems and solutions to automated spatial prediction. *Int. J. Geographical Information Science* 13:143-158.

Oklahoma

Near completion

Anticipated completion date: May 2001

Contact: William L. Fisher
Oklahoma Cooperative Fish and Wildlife Research Unit, Stillwater
wfisher@okstate.edu, (405) 744-6342

Land cover: The land cover map of Oklahoma is complete. The map contains 39 land cover types ranging from oak-pine forest in southeastern Oklahoma to eastern redcedar-oak woodland in central Oklahoma to grama-buffalograss prairie in the western Oklahoma panhandle. Accuracy assessment is complete.

Animal modeling: Wildlife/habitat relationship models were run for 402 terrestrial vertebrate species, including 50 amphibians, 81 reptiles, 178 birds, and 93 mammals. All maps of modeled species were reviewed by state experts and revised. Accuracy assessment is complete.

Land stewardship mapping: The land stewardship map is complete. Over 94% of the land in Oklahoma is in private ownership. Status 1 lands comprise only 0.2% and status 2 lands 1.7% of the area of Oklahoma.

Analysis: Preliminary analyses indicate that because of the small percentage of status 1 and 2 lands in Oklahoma, few vegetation and animal species elements are actively managed for biodiversity conservation.

Reporting and data distribution: The draft final report is under way. The Oklahoma Cooperative Fish and Wildlife Research Unit and Oklahoma State University are handling initial distribution of the OK-GAP final report and data.

Oregon

Complete (see final report summary on page)

Pennsylvania

Complete (see final report summary on page)

Contact: Wayne L. Myers
Penn State University, University Park
wlm@psu.edu, (814) 863-0002

The final report is complete and has been produced in printed form. The 90-meter data are available on the www.pasda.psu.edu Web site. A few adjustments to the files requested in the GIS review are being addressed for production of the national CD-ROM version.

Rhode Island

(for status, contact Curtice Griffin at cgriffin@forwild.umass.edu)

South Carolina

Near completion
Anticipated completion date: December 2001

Contact: Elise Vernon Schmidt
South Carolina Cooperative Fish and Wildlife Research Unit
Clemson University, Clemson
schmidt@water.dnr.state.sc.us, (803) 734-9097

Land cover: The land cover mapping effort is nearly complete. We have completed an initial map and are preparing ancillary data. Modeling of the final land cover is completed for the coastal plain, sandhills, and most of the piedmont. We plan to finish the mountains and the piedmont by the end of January 2001. Accuracy assessment of the map began in October with collection of aerial videography for all physiographic regions. Flights and data assessment will continue until the end of 2001.

Animal modeling: The vertebrate habitat database is complete. Experts reviewed distribution maps and habitat affinities in a series of group meetings at which discussion and literature consultations were very helpful. Data for accuracy assessment has been prepared. We expect to complete vertebrate distributional modeling and accuracy assessment by March 2001.

Land stewardship mapping: The protected lands database is completed and has been through an initial QA/QC process. Final reviews of data accuracy and GAP status classification are under way and expected to be completed by March 2001.

Analysis: We will begin analysis early in 2001 and expect to complete by May 2001.

Reporting and data distribution: We expect to have the report completed by December 2001 and data ready for distribution soon thereafter.

Other accomplishments and innovations: SC-GAP cooperated in a study of imported red fire ant distribution and impact on endangered species, sponsored by Clemson University. This study will provide us with data on distribution of all ant species within South Carolina. We also assisted the U.S. Fish and Wildlife Service Coastal Ecosystems Program in producing a model of potential Red-cockaded Woodpecker habitat.

South Dakota

Under way
Anticipated completion date: May 2001

Contacts: Jonathan A. Jenks, PI
South Dakota State University, Brookings
jonathan_jenks@sdstate.edu, (605) 688-4783

Vickie J. Smith, Coordinator
South Dakota State University, Brookings
vickie_smith@sdstate.edu, (231) 946-5794

Land cover: Land cover classification was completed in early spring of 2000. We identified 35 categories, including nine grassland, three shrubland, one dwarf shrubland, two woodland, five forest, six water and wetlands, three barren or badland, and six disturbance categories. Seven alliances were identified during classification. All other categories were cross-walked to TNC alliance classifications for modeling purposes. Accuracy assessment has been completed for eastern South Dakota, resulting in an overall accuracy of 85.6%. Accuracy assessment for western South Dakota will follow.

Animal modeling: Range extent maps for 98 mammals, 31 reptiles, 17 amphibians, and 226 birds are completed. Reviews are under way for reptiles, amphibians, and birds; mammal distributions are finalized. Literature review for all species is nearly completed. Models will be created using a "Tri-state Database" designed by KS-GAP. IA-GAP, ND-GAP, and SD-GAP have partnered to create approximately 200 regional models for species shared among the three states. Remaining models will be created only for South Dakota.

Land stewardship mapping: Land stewardship mapping and classification was completed in late summer of 2000. We identified 20 land stewardship categories, including South Dakota Department of Game, Fish and Parks, U.S. Fish and Wildlife Service, U.S. Forest Service, Bureau of Land Management, and National Park Service lands. Each land stewardship category was assigned a status code according to the flow chart provided by the National GAP Handbook.

Aquatic GAP: All river-reach files have been processed with 9 of the 10 necessary attributes for predicting fish distributions. The remaining attribute, ground water potential, is expected to be completed in December 2000. Once processing in complete, attributes can be concatenated to begin modeling. Eleven-digit watersheds and Ecoregional Drainage Units (EDUs) have been created for South Dakota. The final review for these coverages is under way. Digital locations of fish have been compiled into a database for watershed-based range map creation for each species. A literature search resulted in over 1,400 citations. Approximately 15% of these have been reviewed. This habitat information along with the locations will allow the prediction of fish distributions for approximately 130 species statewide.

Analysis: Gap analysis of the land cover was completed in fall 2000. Each land cover type was evaluated by owner and by status. Of 35 categories, one land cover type (Burned Pine) had 50% of its land area in status 1 and 2 lands, or highly protected. Two land cover types were protected in greater than 10% of their land area (Vegetated Badlands and Unvegetated Badlands); two were protected in 5% or more of their land area. All other types were protected in less than 5% of their respective ranges.

Gap analysis has also been completed for 11-digit watersheds statewide. Of 510 watersheds, 11 were protected in 5-10% of their land area, 8 were protected in 10-20% of their land area, 3 were protected in 20-50% of their land area, and only 2 were protected in greater than 50% of their land area. These two areas represent Badlands National Park and the Missouri River Scenic and Wild River protection areas.

Southwest Regional GAP (SW ReGAP)

Update under way for the five-state region encompassing Arizona, Colorado, Nevada, New Mexico, and Utah. Final products for the previous versions of NV-GAP, NM-GAP, and UT-GAP are available on the GAP home page. Draft AZ-GAP products are available at http://usgsbrd.srnr.arizona.edu/nbii/. The first version of CO-GAP was completed in December 2000 and its products will be available on Web and CD-ROM soon.

Anticipated completion date: September 2004

Contacts: Julie Prior-Magee, Regional Coordinator
USGS/BRD, Las Cruces
jpmagee@nmsu.edu, (505) 646-1084

Keith Schulz, Regional Ecologist
Association for Biodiversity Information, Boulder, CO
kschulz@tnc.org, (303) 541-0356

Arizona: Kathryn A. Thomas, PI
USGS Forest and Rangeland Ecosystem Science Center
Colorado Plateau Field Station, Flagstaff
Kathryn_A_Thomas@usgs.gov, (520) 556-7466 x235

Colorado: Donald L. Schrupp, PI
Colorado Division of Wildlife, Denver
hqwris@lamar.colostate.edu, (303) 291-7277

Nevada: David F. Bradford, Co-PI
U.S. EPA, Office of Research and Development, Las Vegas
bradford.david@epa.gov, (702) 798-2681

William G. Kepner, Co-PI
U.S. EPA, Office of Research and Development, Las Vegas
kepner.william@epa.gov, (702) 798-2193

New Mexico: Bruce Thompson, PI
New Mexico Cooperative Fish and Wildlife Research Unit
New Mexico State University, Las Cruces
bthompso@nmsu.edu, (505) 646-6053

Utah: R. Douglas Ramsey, PI
Remote Sensing/GIS Laboratories
Utah State University, Logan

doug@cnr.usu.edu, (435) 797-3783

Land cover: The Remote Sensing/GIS Lab at Utah State University (USU) is acting as the regional land cover lab for the five-state southwest region. Coordination with the other four states is facilitated through a Web page that allows access to spatial data, procedural documents, and an Internet Map Server (http://www.gis.usu.edu/docs/projects/swgap). State coordination is also facilitated through the SW ReGAP Web site (http://leopold.nmsu.edu/fwscoop/swregap/default.htm).

Mapping zones: The RS/GIS Lab, in cooperation with the other four southwest states, has completed the development of mapping zones for the five-state region (Figure 1). Mapping zones define ecologically similar regions that will be used to improve spectral modeling and, ultimately, land cover classification. Mapping zones also facilitate partitioning the project into logical units independent of political boundaries. The mapping zone approach will (1) allow each team or lab to focus its efforts and specialize on interpretation of fewer, spectrally similar vegetation types; and (2) achieve a seamless, regional land cover map.

Figure 1. Final mapping zone boundaries for the five-state region.

Imagery: SW ReGAP will use Landsat 7 Thematic Mapper imagery from 1999-2001. Date selections for satellite scenes were discussed with participating states and EROS Data Center (EDC) in summer/fall 2000. Scenes for a prototype mapping zone in each state will be obtained and preprocessed by EDC in winter/spring 2000/01. The RS/GIS Lab will clip and mosaic the processed imagery for the prototype zones. They will provide this imagery and a preliminary cluster map for the prototype zone to each state in summer 2001. They will also provide initial cluster labels using existing data and first-generation GAP data later in the year. During the coming year the RS/GIS Lab will complete protocols for image classification and land cover modeling to be used throughout the five-state Southwest ReGAP effort.

Classification system: The Nature Conservancy's National Vegetation Classification System (NVCS) is being employed to develop classification consistency across the five-state area. Land cover will be mapped to the alliance level and will include exotic and semi-natural types. The southwest states are working with the Association for Biodiversity Information to refine their alliance level classification as needed. For example, the NVCS will be expanded to include undescribed vegetation alliances in Arizona, including sparse vegetation. Vegetation/environment relationship models will be developed throughout 2001 and beyond to aid in the final labeling of the land cover map.

Field data: Since May 1999 the RS/GIS Lab has refined uniform field protocols for collecting training site data across the five-state region. An electronic field form and field plot location extensions to ArcView have been developed to facilitate collection of land cover mapping field data. ArcView extensions for random selection of field plots have been developed and applied to field data collection in eastern Colorado.

In 2000 and 2001, existing vegetation data for all states is being collected and incorporated into a database. For example, in New Mexico a preliminary training site database was compiled that includes existing training sites and 723 sites obtained during 2000. This regional database will provide information for initial labeling, verification, and accuracy assessment of the land cover map.

The Colorado GAP team hosted a workshop in May 2000 to review air videography and other remote-sensing approaches to collection of ancillary data to enhance land cover classification. Air video and helicopter sampling evaluations are being considered for spring 2001.

Animal modeling: The New Mexico Cooperative Fish and Wildlife Research Unit (NM-CFWRU) in Las Cruces is acting as the regional animal modeling lab for the five-state southwest region. In January 2000 the SW ReGAP states held the first workshop to discuss the regional animal modeling process. During 2000 the states began evaluation of the Integrated Taxonomic Information System (ITIS) as a taxonomic standard for tracking model development and discussed desired spatial data themes for use in developing enhanced vertebrate habitat distribution models. A data review tool has been developed as an ArcView extension for review of range/distribution information.

NM-CFWRU drafted a preliminary taxa selection and allocation rule base for guiding decisions about selecting taxa for modeling and assignment of modeling responsibilities to different projects within the southwest region. The rule base was distributed in December 2000 to all state projects for review and revision. The final version will be directed toward a final taxonomic decision rule base to guide all projects in jointly selecting taxa that are to be modeled across the region. This rule base was preliminarily applied to a comprehensive SW ReGAP list of 865 taxa for preliminary assignment to individual state projects. A final list of taxa (species, subspecies, and exotics) to model will be completed in summer 2001. An effort to gather range and habitat data will begin in summer 2001.

Land stewardship mapping: The SW-ReGAP states will start land stewardship mapping in the spring of 2003. In New Mexico, an updated Bureau of Land Management (BLM) Public Land Survey System (PLSS) suite of maps with data current to 2000 was received, and a visual inspection was done of the surface ownership map. This PLSS land status ownership layer was compared with the layer used in the original New Mexico Gap Analysis Project. Further review of this layer is under way to understand implications of this update modification. In Utah, updates of individual management units for public and private lands will be completed in conjunction with the Utah Automated Geographic Reference Center, State of Utah.

Analysis: Analysis for SW-ReGAP will begin in the spring of 2004.

Reporting and data distribution: All products derived from SW ReGAP are scheduled for completion by 2004.

Other accomplishments and innovations:

CO-GAP: A report by Driese et al., entitled "Statistical Evaluation of the Wyoming and Colorado Land Cover Map Thematic Accuracy Using Aerial Videography Techniques: Final Report," has been submitted to National GAP.

Imagery selection: The EDC has developed an approach to optimize selection of imagery for land cover mapping using NDVI graphing functions to select for temporal differences.

Coordination: Multiyear planning documents were developed for the National GAP Office by the five cooperating SW ReGAP states, the EDC, and TNC/ABI-Boulder to identify the collaborative approach proposed to perform a regional gap analysis. Dianne Osborne, of the BLM's National Science Technology Center, is a Co-Principal Investigator for Colorado's SW ReGAP efforts and has been providing input to SW ReGAP on remote sensing technologies for use in regional gap analyses.

Soils data layer: During the past year the RS/GIS Lab at USU has developed a soils data layer, based on the STATSGO database, to be used for post-classification modeling.

Nevada outreach: The Nevada GAP team is initiating an outreach to other agencies. They plan to meet in Reno, NV, with the State Mapping Advisory Committee and a number of federal and state land management agencies, e.g., BLM and U.S. Forest Service, to review plans for the 2001 field season.

Literature citations: A searchable listing of literature citations on gap analysis/natural resources with 877 entries was compiled and posted on the SW-ReGAP Web site by the New Mexico GAP team.

Tennessee

Near completion
Anticipated completion date: January 2001
(see final report summary on page)

Contacts: Jeanette Jones, Project Coordinator
Tennessee Wildlife Resources Agency, Nashville
jjones2@mail.state.tn.us, (615) 781-6534

Sue Marden, Vertebrate Ecologist
Tennessee Wildlife Resources Agency
smarden@mail.state.tn.us, (615) 781-6637

Land cover: Completed. The final map contains 30 land cover classes with 18 forest alliance groups.

Animal modeling: Predicted species distributions and species richness data have been completed for Tennessee’s 364 terrestrial vertebrate species.

Land stewardship mapping: Completed.

Analysis: Gap analysis has been completed.

Reporting and data distribution: The first draft of the final report and data deliverables have been reviewed by National GAP. Recommended revisions are in progress. Plans are to present TN-GAP data as part of the TWRA Web page.

Texas

Under way
Anticipated completion date: June 2001

Contact: Nick C. Parker
Texas Cooperative Fish and Wildlife Research Unit
Texas Tech University
Lubbock, TX
nparker@ttu.edu, (806) 742-2851

Land cover: The land cover map for Texas has been completed; all scenes have been stitched together. Data from fieldwork, completed in all 254 counties in Texas, were used to classify the scenes. Data from 94,868 videography images were used for accuracy assessment. Overall accuracy of the classified product was about 80%. We clipped the land cover map to populate hexagons with the dominant land cover. We ranked land cover by area for each hexagon and then identified each hexagon by the dominant land cover/land use. This allows a quick classification of areas as urban, forest, grasslands, croplands, etc.. Approximately 6,000 photographs with UTM coordinates were taken in the field. These photographs are in a database and are being prepared for distribution through the Web.

Animal modeling: We have identified 665 terrestrial vertebrate species as being native to and breeding in Texas. GIS layers representing the range extents for each of these species have been developed from existing range maps. In addition, a database consisting of 34,441 location records for mammals and birds has been developed. Habitat profiles have also been prepared for all 665 species being modeled, and statewide GIS layers have been created from the following profile variables: precipitation, temperature, soil, hydrology, ecoregions, and elevation. Distribution models for herpetofauna and mammals have been completed and verified. Distribution models for birds have been completed, and about 75-80% of the models has been verified by recognized ornithologists.

Analysis: Distribution of vertebrates and land cover has been analyzed by EPA EMAP hexagon, by ecoregion, and by county. The actual gap analysis has not been done yet. Additional analyses are under way.

Reporting and data distribution: Draft maps were provided to 89 landowners in West Texas to solicit their evaluations for use in accuracy assessment. Draft maps have also been prepared for Texas State Parks, the National Park Service, the U.S. Border Patrol, USDA, and various cooperators in Texas, Louisiana, New Mexico, and Mexico.

Other accomplishments: Data prepared for West Texas have been used to prepare selected species-specific maps (e.g., prairie dog towns and Scaled Quail distribution). Data have been used to identify species in the area of a proposed pipeline and at other construction sites. In a blind study, field crews working in the watershed of a Texas river were given land cover maps based on 1993 Landsat data from TX-GAP and maps produced by another university from 1998 data and found the TX-GAP data to be superior.

The TX-GAP team hosted the 10th annual National GAP Meeting in San Antonio, TX, in August 2000. The meeting was attended by 165 registrants and featured 48 presentations and 26 posters. It was especially rewarding to have 11 scientists from Mexico participating in the meeting.

Utah

Update under way (see Southwest Regional GAP)

Vermont and New Hampshire

Near completion
Anticipated completion date: June 2001

Contact: David Capen
School of Natural Resources, University of Vermont, Burlington
dcapen@snr.uvm.edu, (802) 656-2684

Land cover: Land cover mapping for Vermont and New Hampshire is complete.

Animal modeling: Modeling is complete, although frequent revisions have been made throughout 2000 as the models have been reviewed by project personnel.

Land stewardship mapping: Complete for both states, although updates are common, and many stewardship codes have been revised as a result of reviews by cooperators.

Analysis: Most analyses will have been completed by the end of 2000.

Other accomplishments and innovations: Both Vermont and New Hampshire are in the process of identifying areas of priority for ecological reserves. Gap Analysis approaches have been used in both states, but indicators of biodiversity are more extensive than vertebrate distributions used in GAP. These efforts will provide a useful comparison of data sources and methodologies used for conservation planning.

Virginia

Complete (see final report summary on page)

Contact: Scott D. Klopfer
GIS and Remote Sensing Division Leader
Conservation Management Institute, Virginia Tech, Blacksburg
sklopfer@vt.edu, (540) 231-7348

Land cover: Complete and available for download at
http://fwie.fw.vt.edu/WWW/vagap/frames.html

Animal modeling: Complete. Hexagon species distributions are available at
http://fwie.fw.vt.edu/WWW/vagap/frames.html

Land stewardship mapping: Complete and available for download at
http://fwie.fw.vt.edu/WWW/vagap/frames.html

Analysis: Complete.

Reporting and data distribution: Final report submitted to National GAP office in December 2000.

Other accomplishments and innovations: The Conservation Management Institute continues to introduce VA-GAP data to our constituents through cooperative projects, training sessions, and on-line data delivery.

Washington

Complete (see http://www.wa.gov/wdfw/wlm/gap/dataprod.htm)

West Virginia

Near completion
(for status, contact Charles Yuill at cyuill@wvu.edu)

Wisconsin

Under way
Anticipated completion date: September 2002

Contact: Daniel Fitzpatrick
U.S. Geological Survey
Upper Midwest Environmental Sciences Center, La Crosse
Daniel_Fitzpatrick@usgs.gov, (608) 781-6298

Land cover: Land cover mapping follows the Upper Midwest GAP protocol at ftp://ftp.umesc.usgs.gov/pub/misc/umgap/98-g001.pdf. Land cover mapping is completed and available. A major effort to cross-walk the classification to the NVCS is planned for 2001, pending GAP support for collaboration by TNC/ABI.

Animal modeling: Wisconsin vertebrate mapping will be undertaken by the USGS Upper Midwest Environmental Sciences Center. A regional vertebrate mapping approach, coordinated by UMESC, was initiated in the fall of 2000. Regional species lists, range maps based on EPA hexagons, and habitat suitability matrices stratified by Bailey's Ecoregion Provinces are a few of the strategies being employed to minimize cross-state edge-matching and to reduce duplication of effort.

Land stewardship mapping: The Wisconsin DNR has completed compiling state lands and county lands and U.S. Forest Service lands. They are collaborating with UMESC to acquire coverages of DOI lands.

Reporting and data distribution: Land cover data available from the USGS Upper Midwest Environmental Sciences Center. Contact Daniel Fitzpatrick at (608) 781-6298 or Daniel_Fitzpatrick@usgs.gov.

Wyoming

Complete (see http://sdvc.uwyo.edu/wbn/gap.html)

NOTES AND ANNOUNCEMENTS

Serving GAP Data on the Web: Expanding Usability and Accessibility

One of the foremost objectives of the GAP program is to provide spatial data, supporting documentation, and Gap Analysis reports to the public. This goal serves two purposes: to provide information that summarizes the state of biodiversity, i.e., the results of the Gap Analysis, and to describe the process openly. Colleagues and researchers should have the option of either accessing data in their native format and recreating models or examining the same models with new parameters. Consequently, we designed our data distribution strategy with these users in mind. To date, we have published CD-ROM sets for seven completed states and have served the base data on our Web site (http://www.gap.uidaho.edu/Projects/FTP.htm) for nine states. We anticipate distributing an additional 10 states in the near future.

Presently, the only means to search the National Gap Analysis Program data holdings is through Clearinghouse Gateways on the Internet. To provide an easier method to search our data holdings, we are designing a relational database of all state data using Access 2000. Our goal is to create Web interfaces that will enable users to query this database for a directory of data sets. The user will be able to find not only basic GIS data layers but also a myriad of supplemental materials such as land cover manuals, vertebrate models, bibliographies, field plot information, and species richness grids. We can manage internal tracking of National Gap Analysis data holdings with this database. Finally, this database will be a comprehensive archive of all data submitted to the National Gap Analysis Program and will be updated with remapping efforts.

Our first decade of GAP, the proof-of-concept stage, was primarily an effort to test methodologies and to assemble the data. Now that we are well on our way to completing the first round of data in all the states, we are moving into a stronger application phase and recognize that our clientele represents a more diverse community. As the public becomes aware of our products, the need for access increases. Now our users include those who may not have the hardware and GIS software to view spatial data. For example, a small regional planning office that could apply GAP data to land use planning efforts may not be able to establish a GIS lab or hire the expertise for their needs. To address this issue, the USGS Center for Biological Informatics (CBI) is developing a data server to expand accessibility. The information technologists at CBI are coordinating with ESRI analysts and the GAP Operations Office in Moscow to explore new ways to display and distribute the data. A prototype ArcIMS interface is being developed that will allow users to download raw data sets from an intuitive interface, view and analyze data with Web-based GIS capabilities that are available in standard browsers, select geographic areas of interest to examine, create customized outputs that can be downloaded, and manipulate data with a nonproprietary package of map tools. Through this effort, we hope to kindle an expansion of education and outreach applications.

Ree Brannon and Derek McNamara
National Gap Analysis Program, Moscow, Idaho

Announcing National GAP Annual Meeting in South Dakota

The 11th Annual National Gap Analysis Program Meeting will be held June 17-20, 2001. This year's meeting location is Brookings, South Dakota, home of South Dakota State University. We will convene at the new Brookings Area Multiplex. The meeting is hosted by the South Dakota Gap Analysis Project and USGS EROS Data Center. A special afternoon session and panel discussion on land cover mapping will be held at EROS Data Center near Sioux Falls, South Dakota. Tours of the EROS Data Center will also be available.

This meeting should be attended by those actively working on Gap Analysis projects and their cooperators as well as potential users of GAP data, such as state and federal agencies, developers, planners, conservation groups, and others involved in management of natural resources. Concurrent sessions and workshops will focus on

- mapping and modeling science,
- partnerships and collaboration,
- socioeconomics, policy, and planning,
- aquatic GAP,
- applications and tools, and
- innovations from the Great Plains.

Additional information on the meeting can be found at http://wfs.sdstate.edu/sdgap/2001GAP.html or by contacting Elisabeth Brackney at (208) 885-3560 or brackney@uidaho.edu.

Elisabeth Brackney
National Gap Analysis Program, Moscow, Idaho

Personnel Changes at National GAP Office

Two of our long-time colleagues have left the Gap Analysis Program recently. Becky Sorbel had been our secretary/administrative assistant since 1995. She handled most of the daily operations of our office as well as budgeting, conference planning, and maintaining project files. We hired Marti VanTassell to take over most of Becky's tasks. Marti is being assisted part-time by Erin Loutzenhiser.

Patrick Crist, the National Program Coordinator since 1995, has accepted a position with the Association for Biodiversity Information. Patrick helped keep state projects on track and was instrumental in revising GAP standards. He also helped in developing decision support systems and other applications of GAP data. We have not yet identified a replacement for the National Coordinator position.

We will miss Becky and Patrick and wish them well in their new endeavors.

Elisabeth Brackney
National Gap Analysis Program, Moscow, Idaho

The Gap Analysis Bulletin is published annually by the USGS Biological Resources Division's Gap Analysis Program. The editors for this issue are Elisabeth S. Brackney, Ree Brannon, Patrick J. Crist, and Kevin J. Gergely. To receive the bulletin, write to: Gap Analysis Bulletin, USGS/BRD/Gap Analysis Program, 530 S. Asbury Street, Suite 1, Moscow, ID 83843, fax: (208) 885-3618, e-mail: brackney@uidaho.edu. A digital version of the Bulletin, containing additional graphics, is available on the Internet at http://www.gap.uidaho.edu/Bulletins/9/default.htm.

Suggested citation: Brackney, E.S., R. Brannon, P.J. Crist, and K.J. Gergely, editors. 2000. Gap Analysis Bulletin No. 9. USGS/BRD/Gap Analysis Program, Moscow, Idaho.