GAP ANALYSIS

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A Geographic Approach to Planning for Biological Diversity

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DIRECTOR'S CORNER

KEVIN GERGELY
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The first thing I would like to say is thanks to everyone who has been so generous with their time and attention in my first few months of filling in as leader for the National Gap Analysis Program (GAP). I can't say enough about the professionalism that I've experienced as I've talked to people working on state projects, and I appreciate how you've helped me get up to speed on the status of your work. Also, the National GAP staff in Moscow, Idaho, is simply tremendous, and they keep this program moving ahead.

While we are more than 10 years into the process of creating a national database of biodiversity, a lot of questions remain to be resolved about the short- and long-term priorities for action. There are several reasons. One, we have already begun the second generation of GAP, taking a regional approach in the Southwest, which brings with it new challenges. Two, many of our partners are taking a hard look at the GAP products we are developing. They like what they see but are asking for more—more definition and accuracy in the data layers, more species included in the modeling, more area covered in seamless data coverages. And last, supporters in Washington, DC, are looking for us to make a big splash, to show our data in use, in order to generate support to expand the program in various directions.

With all this going on in the background, it would be easy to get pulled in several directions. We are trying to take deliberate action and are working on a five-year plan to make sure we stay on course for mapping the Lower 48 and find ways to move into the next generation of GAP that has the additional components our supporters and partners are looking for. It couldn't be more appropriate at this time to pause and think about where we've been with this program and where we should try to make it go.

In large part, the first 10 years of GAP were about integrating science into a common-sense practice of setting up nature reserves. The history of reserve identification and design has been widely discussed in the conservation literature. The basic approach relied upon philosophical or spiritual ideas of what lands should be protected. As a society, we value certain places either for their aesthetic value or because of some greater, more reverent notion. With these ideas, we developed systems of parks, refuges, and public lands that can be held up as a model for the rest of the world.

When you step back and think about it, you realize what a tremendous challenge it was for conservation-minded scientists to try to improve upon this reserve system. Yet scientific scrutiny requires us to look past our "common-sense" ideas, and to look for a scientifically credible approach to reserve identification, selection, and design. In building the GAP program, we have at the same time adopted a working theory that some level of representation of all the components of biodiversity in our reserve systems will foster their long-term viability. This has allowed us, as scientific professionals, to channel our energy into a process of classifying our natural resources and then checking at various scales how well they are represented in some form of protected status.

In the first 10 years of the Gap Analysis Program, we have taken this idea from concept initiation through multiple series of refinements. While we are still learning from the process, we are within just a few years of having a national database of land cover, vertebrate species distributions, and stewardship classifications that will allow for a level of strategic questioning about the management of biodiversity in this country that was simply not thought of before.

While we seek more scientific integrity in the reserve identification process, it may be that our common-sense approach will be our greatest asset in the next 10 years. The GAP business model (as discussed in the article by Brackney and Crist in this issue), which involves developing partnerships with academia, research organizations, public land management agencies, and interest groups, has worked exceedingly well. In some cases, other federal agencies have struggled to define an administrative model that will move their agency towards "an ecosystem approach." The GAP program, by its nature, has focused on ecosystems, and the administrative and organizational structure followed logically. It just seemed to make sense.

This approach should be important in two ways. First, we hope other federal agencies use and build upon our partnership model. We are seeing this in the Southwest regional GAP effort, in which the Bureau of Land Management and the Environmental Protection Agency hopefully will take large roles. Second, perhaps these teams will be the focus for generating support for our program from our Washington, DC, overseers and will be the hub of the network that gets information out to those who use it. After all, it is really implementation and use of GAP data that we are ultimately concerned about.

Michael Jennings and others discuss where GAP should be going in the next 10 years in their article "GAP: The Next Ten Years." Improving our scientific and technical capabilities is a big part of that vision. They also mention that the vision for the future includes "an aggressive suite of outreach and extension activities to ensure that GAP cooperators and clients are able to make full use of the program's products." Much of the discussion today in the National GAP program is about the best ways to do this. I hope our project partners will be our greatest asset in this endeavor, and that the next 10 years of GAP will be as new and as exciting as the last. With both science and common sense on our side, how can it not be?

GAP: The First Ten Years

ELISABETH BRACKNEY AND PATRICK CRIST
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Getting off the Ground

The term "gap analysis" was first used by Burley in 1988 and put into practical application in Mike Scott's now famous Hawaii project that identified the "gap" between bird distributions and conservation areas. Species distribution maps and land stewardship maps were originally produced as Mylar overlays from extensive field work, and The Nature Conservancy used these maps to establish several preserves (Scott et al. 1987a). They were the basis for creation of new National Wildlife Refuges in Hawaii. It was Jack Estes, a geographer, who suggested a Geographic Information System (GIS) approach to put the huge data set into a form that was easily usable by managers.

When Mike Scott moved to California in 1986 to head up the California Condor recovery program, it became clear to him that to avoid such costly protective measures, species had to be protected while they were still common. At a meeting in Denver, Scott discussed these problems with Blair Csuti, then a regional zoologist with the Natural Heritage Program. They drew up an outline for gap analysis, to be expanded into the seminal BioScience article (Scott et al. 1987b) that presented the concept of gap analysis.

Scott tried to sell the idea to Defenders of Wildlife and the Fish and Wildlife Service. He was able to obtain $36,000 from Idaho Fish and Game and the National Fish and Wildlife Foundation to start a gap analysis of Idaho. A breakthrough occurred when a presentation to a Congressional Working Group sparked enough interest to put $300,000 as a line item in the budget of the Idaho Cooperative Fish and Wildlife Research Unit to conduct GAP in Idaho under Scott's leadership. Csuti was hired to conduct a gap analysis in Oregon. California was the next state to start a GAP project, led by Frank Davis. Davis spent a sabbatical at the Idaho Coop Unit in 1992 and co-wrote a detailed description of the Gap Analysis Program (Scott et al. 1993). Ted LaRoe, then Chief of Cooperative Research Units, worked tirelessly on behalf of GAP and helped to substantially increase funding.

Thus, a national program was born and grew, through the incremental grassroots effort of scientists who believed in a proactive approach to conserving biodiversity in the U.S.

As GAP developed beyond the prototype stage, its status as a basic research project changed, and information collection activities began in more and more states. When the Department of the Interior science programs were consolidated into the newly established National Biological Service (NBS) in November 1993, GAP was placed in the Division of Inventory and Monitoring. Ultimately, the GAP program, along with the rest of the NBS programs, settled in the U.S. Geological Survey in 1997.

Rising Projects, Falling Budgets

Budgets rose rapidly, nearly doubling every year from 1990-1995 (Figure 1). In 1994, GAP underwent a formal peer review (Zube 1994) and an independent review funded by the forest products industry (Flather et al. 1994). Both of these critical reviews recognized GAP as a valuable tool but noted it was substantially underfunded. Increasing with the budget was the number of state projects, from the Idaho pilot in 1990 to more than 40 in 1995. The year 1996, however, saw a decline and then flattening of the GAP budget, presenting a major challenge to maintaining the multiyear projects initiated during the previous years (Figure 1). Average funding per state was reduced along with budgets for research, applications, and extension activities.

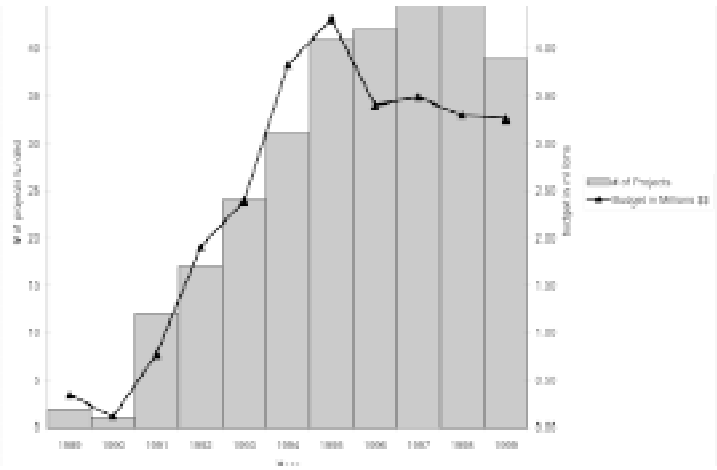

Figure 1. Number of GAP projects versus annual budget 1989-1999. Between 1989 and 1995 GAP maintained the number of projects that could be funded for approximately $100,000 each. Project numbers increased at the expected rate of budget increase, but in 1996 the budget dropped to approximately $3.4 million and leveled out, requiring a reduction in the average amount available for ongoing projects.

GAP has maintained its dedication to the state projects and, with completion of the majority of projects during 2000, it looks forward to reinstating balanced funding for regionalization, analysis, reporting, research, and extension (Figure 2). See also the accompanying article "GAP: The next ten years" on this topic.

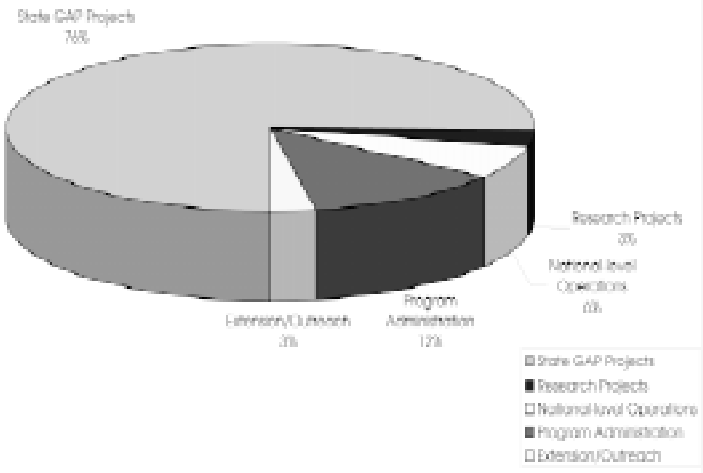

Figure 2. Example budget allocation from 1998.

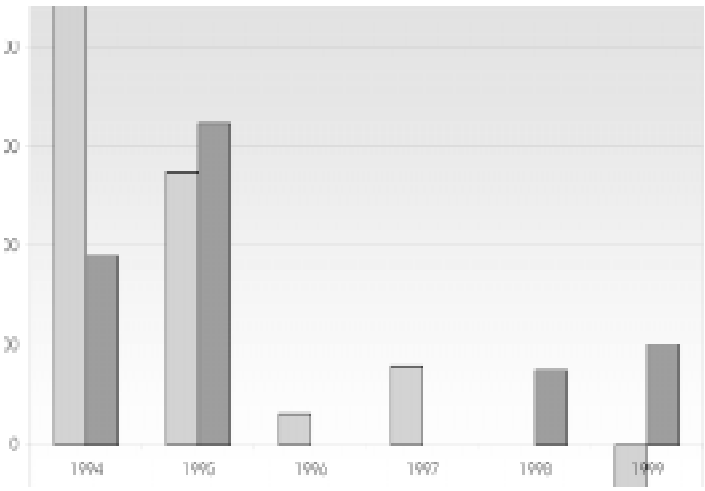

Figure 3. Funding for GAP projects received from EPA and DoD between 1994 and 1999.

Partners Make it Possible

The strong partner collaboration of GAP at the state project level is well known and certainly has been crucial in many states in providing contributions of funding and in-kind assistance. National partners have also played a critical role. Over the years, GAP has received funding from both the Department of Defense (DoD) and the Environmental Protection Agency (EPA; Figure 3). These contributions not only helped launch many state projects and aquatic pilots, but also aided GAP in the development of the Multi-Resolution Land Characteristics (MRLC) Consortium. The MRLC formed to make joint purchases of Landsat Thematic Mapper (TM) satellite imagery covering all of the conterminous 48 states. A joint purchase in fiscal year (FY) 1994 saved the government millions of dollars in direct costs as well as an estimated 30 million dollars in combined program costs (Jennings et al. 1995). The MRLC established a common set of digital land cover data across multiple levels of spatial and thematic resolution and developed a strategy for integrating the land cover data from member programs into a single national land cover database. GAP also partnered with the Federal Geographic Data Committee's (FGDC) Vegetation Subcommittee to develop federal standards for natural land cover types and was instrumental in development of FGDC metadata guidelines.

Currently GAP is working to develop core partner funding for regional mapping updates such as Southwest Regional GAP (SW-ReGAP). For example, EPA staff will act as principal investigator on the project and may contribute significantly to the total cost.

Successful Innovations

One goal of the state-based business model for GAP was to engage numerous investigators at a variety of institutions to create novel data sets on a scale never before attempted. To a large degree, this has succeeded. GAP investigators pioneered the development of airborne video for land cover mapping and accuracy assessment. The application of airborne video for GAP land cover mapping was begun by Graham (1993). Since then, Slaymaker (1996) has further improved the application of airborne video to object interpretation. A review of GAP land cover mapping protocols (Eve et al. 1998) found that the mapping effort has resulted in several positive developments, such as laying the groundwork for further advances in land cover mapping, stimulating cooperation and collaboration in mapping, increasing the acceptance and adoption of remote sensing and GIS as mapping tools, and assisting in the development of numerous new techniques for land cover mapping. In this bulletin, Homer and Crist trace the developments in land cover mapping over the past 10 years in more detail.

Sound methods were also developed for modeling predicted animal distributions, and further work by Haithcoat (Drobney et al. 1999) and Edwards (1996) continues to push such modeling toward greater thematic detail and precision. (See "Experience and Trends in Animal Distribution Modeling in the Gap Analysis Program" below). Stewardship mapping and gap analysis methods were standardized and refined but to date have seen less research and development, as discussed in the article "Identifying the Gaps, Locating the Reserves: Some Thoughts on Getting Gap Analysis into Conservation Practice" below. More recently, however, GAP project leaders and their cooperators have increased their interest

and work in analyses and application to conservation (see Capen and Stoms et al. below).

Guidelines for conducting aquatic Gap Analysis projects were developed by pilot projects in New York (Meixler and Bain 1998) and Missouri (Sowa 1998). Though GAP has not yet been able to garner core funding for the aquatic component, it continues to develop methods that will lead to national standards and protocols when a national strategy emerges.

Putting GAP to Use

Despite the fact that GAP is only this year publishing the bulk of its data, participants, cooperators, and others representing a wide spectrum of interests have made significant use of the information in hundreds of applications at a variety of scales. These uses include wildlife management, ecosystem restoration, county planning, land use planning by private corporations, basic research, generation of options for large-area designations, and environmental assessments. A typical application of GAP data is developing a prototype conservation planning process for the Columbia Plateau ecoregion. The goal of this effort is to find the most efficient method for designing and assembling a portfolio of sites to maintain all viable native species and community types within the target ecoregion. Such a method would maximize the biodiversity protected relative to the number of conservation sites or extent of land area. GAP data have also been used for more unusual applications, such as developing natural systems agricultural practices that provide habitat for birds that prey on insect pests and integrating the needs of these bird species with those of agricultural production. Another example of an ancillary application is assessing possible methods to reduce deer/vehicle accidents on Iowa highways. By evaluating land cover effects, areas that have a higher probability of deer/motorist encounters can be identified. These examples and many other GAP applications can be found on the GAP home page at http://www.gap.uidaho.edu/RA.

Where Are We Now?

GAP is now active or completed in all 48 conterminous states and Hawaii, and interest is high to initiate Alaska and several U.S. territories as funding becomes available. Updates have been conducted in Idaho and Oregon and initiated in five southwestern states. (For current status and anticipated completion dates of GAP projects in the U.S. see the map on page 58). By the end of calendar year 2000, it is anticipated that 35 states will have been completed and published on CD-ROM and the World Wide Web. These include: Arizona, Arkansas, California, Colorado, Connecticut, Delaware, Florida, Idaho, Indiana, Iowa, Louisiana, Maine, Maryland, Massachusetts, Mississippi, Missouri, Montana, Nevada, New Hampshire, New Jersey, New Mexico, New York, North Carolina, Oklahoma, Oregon, Pennsylvania, Rhode Island, Tennessee, Texas, Utah, Vermont, Virginia, Washington, West Virginia, and Wyoming.

We can also view GAP progress outside the state context and in a national perspective. For example, 75% of land cover mapping of the conterminous 48 states is complete (Figure 4).

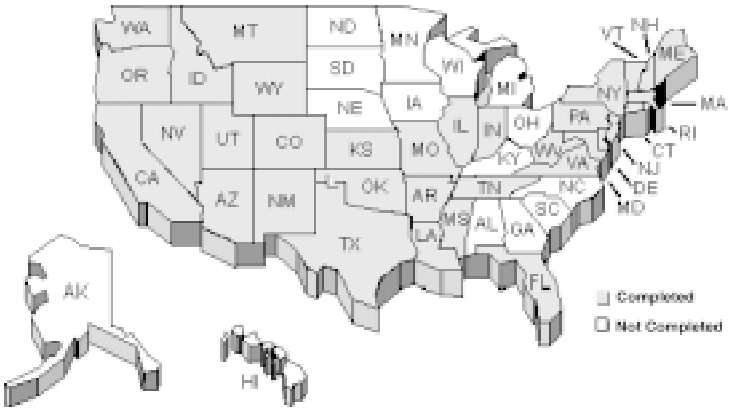

Figure 4. Current status of GAP land cover mapping across the U.S.

No one agency can claim to be GAP—it is truly collaboration on a national scale, its success the work of many. Individual GAP researchers can be proud of both their contributions to the national database and their intellectual contributions that have paved a once rocky road for current and future researchers. Still, this reflection on GAP's past ten years would be incomplete without an acknowledgement of the early leaders and researchers who made it possible. Mike Scott, Blair Csuti, Frank Davis, and Jack Estes developed the early concepts and founded the pilot projects; Steve Caicco, Tom Edwards, and Jimmy Kagan took on the daunting task of mapping the first few states with no models to guide them; Mike Jennings started and shepherded dozens of projects, guided the program through several administrative changes, and obtained the cooperation of the major national partners in the important MRLC and National Vegetation Classification initiatives. Credit is also deserved for the agency administrators, including Amos Eno, Doyle Frederick, Ted LaRoe, and John Mosesso, who worked within the bureaucracy to support GAP and keep it growing. Finally, we must acknowledge some tireless friends who guided and lobbied for GAP throughout the early years, including Sara Vickerman of Defenders of Wildlife and several folks from The Nature Conservancy including Denny Grossman, Craig Groves, Deborah Jensen, and Larry Master. There are many other guiding lights, particularly at the state level, that cannot all be listed here. However, recognition of the hundreds of dedicated graduate students is certainly well deserved.

Our discussion continues on the following pages with the thoughts of Mike Jennings and others on "GAP: The next ten years" and goes into more depth with articles on the history and future outlook for land cover mapping, animal distribution modeling, and stewardship and analysis.

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GAP: The Next Ten Years

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As human population continues to increase, and the current species extinction event involves more species and greater areas, biogeographic information that is both spatially comprehensive and of appropriate resolution is becoming more important for managing our biological resources effectively. General recognition of this tenet is recent, responding in part to conservation crises and their related large costs, and in part to emerging ecological principles and knowledge integrated across multiple levels of biotic organization. Conservation crises have become more frequent, and the costs associated with them have continued to rise. For example, resolution of the old-growth redwood forest issue in northern California has taken years of litigation and physical confrontation. It cost the State of California and the federal government about $450 million for direct acquisition of 10,000 acres—the most expensive acquisition of conservation lands in history—as well as millions in legal and other expenses to all parties. The cost of dealing with endangered species by federal and state agencies was estimated at $314 million in 1998 alone. Costs born by private, nonprofit and for-profit organizations are not known, but even if they are within an order of magnitude of this amount they make up a significant single-year cost. One can expect these amounts to increase substantially over the next decade. For example, to reach a recovery rate of 50% for endangered or threatened species would require an additional $300 million per year (Scott and others, unpublished).

Without spatially explicit data, it is unlikely that the forces causing habitat losses (e.g., invasive species, accelerating rates of resource uses, infrastructure development, recreation, etc.) can be managed effectively to reduce biodiversity loss, or that an adequate network of conservation areas can be successfully designed. Thanks to the first decade of GAP, the capability exists today to produce spatially explicit information on the distribution and status of each species and vegetation alliance, compiling and organizing the sum of knowledge we have about these elements at the same time. With this information, decisions about the myriad of activities affecting the

nation's biological diversity can now benefit from a common, widely available knowledge base. For example, the information has been used at the national level for identifying and siting new National Wildlife Refuges, at the regional level for prioritizing private acquisition of conservation lands, at the state level for mitigating new infrastructure impacts and containing environmental costs, and at the local level for county planning and land trust conservation easement acquisitions. In sum, a significantly greater level of certainty is being provided to resource users, managers, planners, and researchers.

Given a decade of experience, what should the GAP program achieve over the next ten years? The extent and complexity of our biological resources are so vast and the amount of our information still relatively small that without a cohesive approach to genetic, population, species, community, and landscape information, it seems unlikely that the Gap Analysis Program will reach its full potential. Without broad-based support for developing such information, the GAP goal of helping our clients understand a reasonable set of future scenarios affecting our biological resources would be in jeopardy.

The Gap Analysis Program is now past the proof-of-concept stage. The scientific basis, multi-organizational capability, and technical methodologies needed to fully realize the original vision have matured and are well established. We need to continue working with a framework that can expand and change with improved knowledge and information on an indefinite basis, as forcing variables such as economic trends, climate change, and population growth continue to shape the patterns of life on Earth. However, in order to continue making progress in solving the serious and complex problems of biodiversity loss, we must focus on key elements of the program, including:

- A long-term plan for updating, maintaining, archiving, and extending GAP information in each state.
- Applying GAP to the 21 phyla other than chordates. Each vertebrate species other than fish has been covered by GAP; little work has been done on species of other phyla.
- Applying the established methods for data development and analyses in aquatic environments.
- Improving the land stewardship data layer by mapping land uses that have effects on biodiversity; adopting or developing a finer-grained land stewardship and land use classification.
- Continued improvement of consistency in methods among state projects.
- Regionalizing state-level data to cover large multistate regions and conducting analyses of those data sets.
- Synchronizing second-generation state projects to achieve regional consistencies in data and analyses.
- Using the results of GAP projects to test hypotheses. For example, the species distribution data sets can be applied to explore basic issues in biogeography; important new methods for reserve identification, selection, and design can be tested. Results from such applications can then provide critical feedback for revising GAP techniques.
- An aggressive suite of outreach and extension activities to ensure that GAP cooperators and clients are able to make full use of GAP products. For example, development of a same-look-and-feel interactive digital atlas usable by educators and the public for each state, linked to rangewide element distributions for context expression.
- An international component to meet the existing and unmet demand for transferring GAP science and technology to other nations.
- Continued research and development of promising new science and technologies. There are important opportunities for developing more robust and accurate species distribution models; new concepts are emerging for dealing with accuracy assessment by graphically representing the uncertainty in the data using an intuitive display.
- Strengthening program efficacies within the U.S. Geological Survey (USGS) by taking full advantage of capabilities in the Water Resources Division, National Mapping Division, and Geologic Division.

Of course, continuity of GAP's successful partner-based organization, as well as its fundamental approach to mapping components of biodiversity, must remain central to the output of useful information. Assuring scientific credibility by using the peer-review process must continue as a critical part of how GAP does business. Over the past decade GAP has produced many hundreds of peer-reviewed articles giving the concept and the program legitimacy and recognition within the scientific community. We must continue getting the results of state projects into peer-reviewed journals *and* into the hands of users by recasting results in formats that are more quickly absorbed by the public and nonspecialists. Without these steps a project is not complete.

The extent to which each of these key elements is dealt with effectively will depend largely on the amount of funds provided, including the core USGS funding as well as cooperator funding and other forms of support. Central to this are ongoing efforts by those implementing GAP at the state level to develop support. It is especially important that their cooperating institutions actively express the value of the program to their work and the need for new initiatives that would strengthen basic and matched funding. The conceptual, science, technology, and cooperative basis to meet the need for advanced biodiversity management are in place, and we believe "smart conservation" can be accomplished with relatively modest funding. GAP has been a large and successful experiment so far. The best possible chance to avert the growing biodiversity crises is by building on the initial success of GAP. As Wilson (2000) recently stated: "Within the broader framework of ecosystem studies, community ecology in particular is about to emerge as one of the most significant intellectual frontiers of the twenty-first century. Although it still has only a mouse's share of the science funding, it stands intellectually in the front ranks with astrophysics, genomics, and

neuroscience. . . . To single-species searches and mapping can be added the already well-developed technique of gap analysis . . ."

We invite the GAP community to provide us with their suggestions, comments, and insights on GAP for the next decade.

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Land Cover Characterization in Gap Analysis: Past, Present, and Future

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Introduction

The evolution of land cover characterization in GAP over the last 13 years has been truly remarkable. Although relatively coarse by today's standards, early GAP land cover mapping was innovative and for its time represented the first detailed, statewide mapping effort. It was driven by biologists' requirements to map vegetation diversity and animal habitat covering large areas and to use existing or emerging technology to characterize the landscape. This mind-set has evolved into an ongoing theme in GAP—a constant push to characterize the landscape at improved spatial and thematic scales, resulting in rapid development of methodologies and protocols.

Past

The first land cover mapping effort conducted for GAP was a pilot project in Idaho, which began in 1987. This effort created a synthesized vegetation map based on information from existing local, regional, and state vegetation maps. The map was compared to and refined based on Landsat Multispectral Scanner (MSS) satellite image prints (Scott et al. 1993, Scott and Jennings 1997). In 1989, mapping for the Oregon GAP project utilized visual photo-interpretation of satellite image prints to locate boundaries of vegetation classes (Scott et al. 1993). Subsequent third-generation projects such as California, Nevada, and Utah mapped vegetation using some combination of digital image classification, photo-interpretation of satellite imagery, and reference to existing maps and ancillary data (Davis et al. 1995, Homer et al. 1997, Scott and Jennings 1997). By this time GAP was on its way to becoming a national program, and the state-based business model was instituted for political and practical reasons. Consciously, however, it was believed that employing the best people in each state to develop this large-area mapping process would result in significant innovation and achievement. This indeed has appeared to be the case (Eve and Merchant 1998).

Regional and national products were always envisioned and, in 1997, the 11 western states' land cover products were joined (Wright et al., in preparation). The effort was limited to cross-walking the classification schemes and joining the maps into a common data structure and projection. Despite the high variability in mapping methods and spatial and thematic detail (Eve and Merchant 1998), there were few serious boundary problems between the states. Still the variation, particularly in thematic level of detail, required much aggregation of types across the region and suggested the need for improved methods and regional cooperative approaches in future mapping.

Present

Continuing evolution of technique and technology has led to current GAP land cover characterization efforts, which are: digitally based on multi-date Landsat TM 30 m data, involve image stratification, special clustering, some form of pre- or post-classification modeling, and accuracy assessment. Each project still retains a unique mix of technical expertise, capabilities, cooperators, land cover, and goals (Eve and Merchant 1998).

Current tool and data set availability reflect a rapid evolution. Early projects constantly suffered hardware and software limitations. For example, the first digital mosaic of Utah had to be created, stored, and classified in pieces because of inadequate disk storage space and software. Agreements such as the Multi-Resolution Land Characteristics Consortium (MRLC) have helped greatly in developing base TM imagery and ancillary data sets outside of the project. Pre-MRLC projects had to spend large portions of their budgets and time in acquiring and rectifying their own imagery and building ancillary data layers from scratch before mapping could even commence.

Most importantly, expertise in land characterization, remote sensing (RS), and GIS through GAP has developed into a remarkable talent pool. GAP land cover mapping efforts have created an impressive training ground for hundreds of people (Eve and Merchant 1998). The program has served as the catalyst to introduce a wide variety of private and government collaborators to RS/GIS techniques, data sets, and capabilities. This legacy of GAP will continue to have profound positive effects in pushing the science of land cover characterization forward. Not all innovations have been in remote sensing, however. For some time, GAP researchers have

recognized the difficulty in translating between ecologically-based classification systems like UNESCO, followed by the National Vegetation Classification System (NVCS) (FGDC 1997), and the realities of remote-sensing limitations. Partnerships between GAP and The Nature Conservancy plant ecologists are increasingly addressing this issue through the addition of new map objects that are ecologically consistent with the NVCS, such as Ecological Complexes and Compositional Groups (Pearlstine et al. 1998).

The newest innovation in GAP addresses consistency by conducting mapping updates by multistate regions. The first such project is Southwest Regional GAP (SW-ReGAP) that includes Arizona, Colorado, Nevada, New Mexico, and Utah and covers an area 93% of the size of Alaska. This project will take advantage of methods developed by other projects such as the use of multi-date TM imagery that helps distinguish similar vegetation by phenological differences. It may also explore the use of airborne imagery such as videography, digital imaging, and low-elevation, multispectral cameras. The most dramatic change, however, is that mapping will be a coordinated effort where preprocessing and clustering of imagery is done regionally by EROS Data Center and Utah State University. Then state labs will label and model the land cover types based on "mapping zones" defined primarily by Bailey's section-level ecoregions rather than state boundaries (Figure 1; Figure 2 - see Web version of Bulletin at http://www.gap.uidaho.edu/Bulletins/8). The objective is a seamless, thematically consistent land cover map of the entire region.

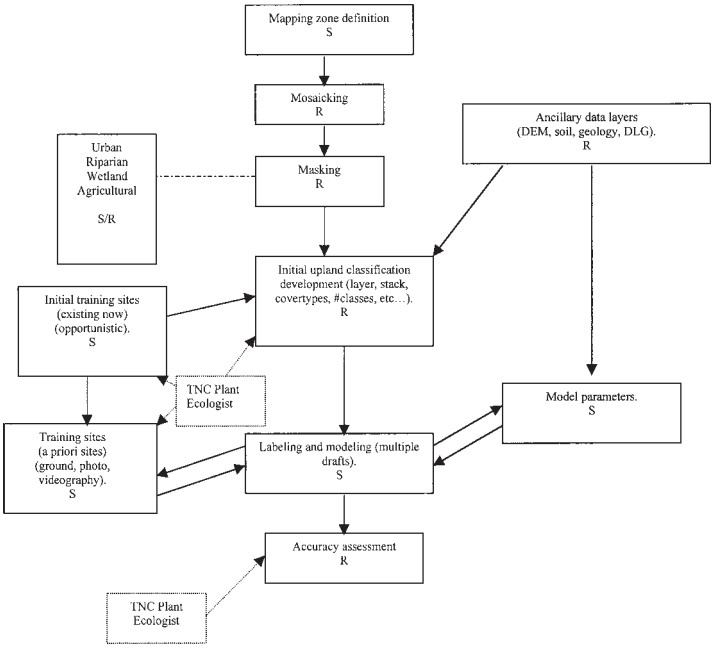

Figure 1. A diagram illustrating the land cover mapping process for the Southwest Regional Gap Analysis Project. An R following a task indicates Regional Lab (RS/GIS or EROS) responsibility. An S indicates State Lab responsibility.

Future

The increasing momentum of new data sources, refined tools and processes, and developing expertise should converge for a bright future in land cover characterization. Future efforts will be driven by improvements in several key areas:

Data - It is an exciting time as we watch the continued expansion of air- and space-borne remote sensing platforms. Several successful recent satellite launches (e.g., Landsat 7, Terra, Ikonos) will greatly expand remote sensing data availability. They provide additional spectral and spatial information at lower cost, creating new possibilities in cover-type characterization. More importantly, this increase in data will improve the ability to choose both the timing and type of data acquisition, thus enabling a deeper understanding of climate patterns, vegetation seasonality, and closer real-time comparison of imagery and field data.

However, spectral and spatial improvements will not automatically create more meaningful cover-type classes. There will always remain ambiguities between spectrally meaningful categories and human-defined meaningful categories. This means that ancillary data will continue to play a large role in successful characterization. The increasing availability of nationwide, regionally consistent information on wetlands, topography, soils, cultural features, and other data will still prove critical to successful efforts in modeling vegetation community distributions and their attributes.

Tools - The continued rapid development of software and hardware tools will allow expanded capabilities hardly imagined now. Software developments will increase functionality in visualization and manipulation of data sets, automated interpretation processes, data integration, standardized file formats, and real-time application. Hardware developments will allow increasing miniaturization, portability, capability, and affordability. Future development of other tools in spatial navigation, digital imaging, and data capture promise to revolutionize ground data analysis with remote sensing.

Process - Bringing data and tools together to create more meaningful information is probably the most critical future challenge. GAP land cover efforts, to date, have had only the resources to map simple, discrete categories of land cover. These serve as only coarse surrogates for representing wildlife habitat and vegetative diversity. Mapping efforts typically only focus on creation of the final labeled land cover layer, with intermediate, ancillary image and clustered data layers often viewed as "throw-away" steps. A key shift of the future will bring more focus on building a "data sandwich" with layers of information seen as components of a database rather than simple intermediate steps (Estes et al. 1999). These components will be applied in different combinations to supply the needed land cover derivatives of the flexible database. Derivatives can be discrete (a labeled land cover category) or continuous (a biophysical measurement). Combinations of data set derivatives could ultimately be tailored to represent each animal and plant species' unique habitat needs. For example, a generalist mammal species (i.e., coyote) might be adequately represented with broad, discrete cover-type categories, while a neotropical bird (i.e., Kirtland's

warbler) with specialized seasonal requirements might need high-resolution habitat definitions, based on habitat structure and composition continuums. Likewise, individual plant species distributions and status may be modeled (see Fertig et al. 1998) based on NVC community distribution combined with other ancillary data of land characteristics. The component-built flexible database will offer greater utility, expanded flexibility, ease of update (replace the component, not the entire set), data layer independence (components stand alone), and manageability.

Regionalization of completed, state-based land cover maps will continue, and updates in regionally coordinated projects will become the norm. Mapping zones may become institutionalized, and updates for them may become distinct from state or multistate GAP projects. Partnerships will also increase. SW-ReGAP is already planned to have an equal or greater share of the cost paid by other partners. Future mapping efforts will be planned as highly robust projects incorporating a wider variety of data sets, tools, and objectives that will involve multiple partners.

Conclusion

The convergence of better data, tools, and processes will result in capabilities that will continue to spur innovation in GAP land cover characterization. This ability to increasingly combine the tools and data in processes that characterize the landscape in more diverse and meaningful ways will provide further insight into the interplay of biodiversity and landscape ecology. Future characterization efforts will focus more on creation of a database "sandwich" capable of flexible derivatives to meet the wide array of wildlife habitat characterization needs. Components in this database can potentially be assembled and used independently. More and more of the time-consuming components of current types of GAP land characterization can be "out-sourced," leaving GAP investigators more time and resources to focus on biology-related issues and research. Because general land characterizations will be more commonly available, the real challenge of the future will not be the limitations of the tools but development of science and methods to more accurately characterize the distribution and condition of those features that represent biodiversity on the ground.

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Experience and Trends in Animal Distribution Modeling

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Introduction

Modeling the predicted distribution of thousands of animal species over large regions, but at detailed spatial resolution, represents as significant a challenge as land cover mapping, if not more so. I recall during my first few months with New Mexico GAP, that an academic scientist challenged our ability to accomplish such a task. His argument was that "you'd never be able to get the GIS data [of land characteristics] needed for the habitat associations." Our response was that we already had all the layers; what was lacking, and continues to be, is the information on species associations with those land characteristics. As I will discuss, technological progress will continue to greatly improve our ability to model animal presence/absence and even allow us to begin dealing with concepts such as abundance, viability, movement, and metapopulations. However, technology is not a replacement for knowledge, and this remains the greatest challenge for all modelers.

Past

As described in the land cover article above, Idaho was the first pilot project for animal distribution mapping in 1987. At that time, it was recognized that the two biggest challenges were gathering information on each species' habitat associations (Karl et al., in press [a]) that were mappable, and testing the accuracy of the resulting distributions. A decision was made early in the program's history to begin mapping terrestrial vertebrates and possibly butterflies (though little was done for the latter in most states). There were several reasons for this decision: they are the better studied taxa, making the modeling more tractable; they are popular targets for conservation action; and there was some suggestion that they, in combination with vegetation, would be a suitable surrogate for biodiversity in general. The latter assumption is still a largely untested hypothesis. The early state projects tended to restrict modeling to a species association with land cover, but by the early '90s projects were beginning to add other variables such as topography, hydrology, soils, climate, etc. (see, for example, Thompson et al. 1996, Edwards et al. 1995). In 1996, I had the pleasure of working with one of GAP's originators, Blair Csuti, to compile GAP's knowledge and experience to date in the form of the GAP Handbook chapter on animal distribution modeling (Csuti and Crist 1996). The qualitative process we presented is summed up by Figure 1.

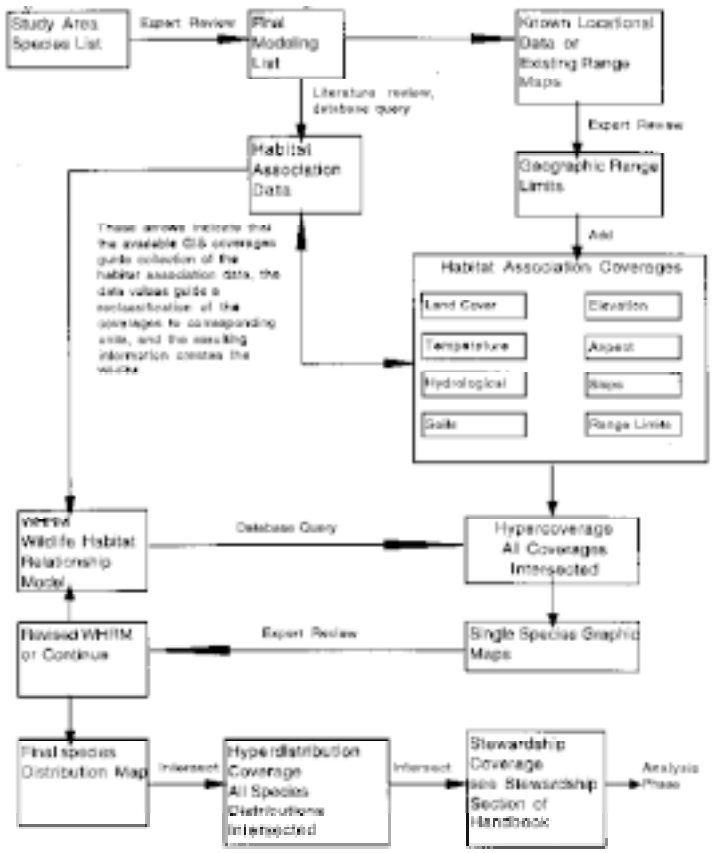

Figure 1. The animal modeling process diagram from the GAP Handbook (Csuti and Crist 1996).

Present

As evidenced from Figure 1, GAP has traditionally used a qualitative rather than quantitative process to model animal distributions. The fundamental difference between these approaches is that GAP uses known species habitat associations from the literature, existing databases, and expert knowledge to place species where the conditions are mapped to exist, whereas the quantitative process uses mapped land characteristics at known occurrence points to place species wherever such conditions exist. GAP researchers have generally believed that sampling for species occurrence has been biased and grossly incomplete; therefore, the points used in the quantitative approach may give incomplete or biased distributions. Some limited study has suggested this to be true. For relatively rare spe-

cies with good sampling, the quantitative process provides a more precise result than the GAP process, but for more widely distributed species (with which GAP is more concerned), the qualitative method provides a better model (K. Smith, pers. comm.). It is safe to say that tests of the various modeling methodologies are insufficient to draw any operational rules, but it appears likely that employing a suite of methods that can be tailored to each taxonomic group or guild will generate the most robust results.

The process described by Figure 1 has remained largely unchanged, which in some ways is disappointing. Virtually all completed assessments of GAP projects' distributions show an 80% or better accuracy when compared to checklists for managed areas (Scott et al. 1993, Edwards et al. 1996); this may suggest the process is doing an acceptable job. Unfortunately, so few independent field-based data sets exist that assessments of accuracy at finer levels of spatial resolution have been difficult; however, see Thompson et al. (1996), Llewellyn and Peterson (in preparation), and Beard et al. (1999). Work done in Idaho used field observations at 1,628 sites testing the independent influence of rarity on accuracy of model predictions. A second effort tested the change in model accuracy with increasing model complexity (Karl et al., in press [b]). Similar work is being conducted by GAP researchers in Maine (Boone and Krohn 1999).

Anecdotal evidence suggests that GAP is indeed doing well in this revolutionary first effort to map so many species over vast areas and at a cost of $100-200/species/state. Those using the traditional GAP qualitative approach are probably doing as well as quantitative modelers with species associated with well-defined environmental constraints such as minimum or maximum elevation. All modelers have problems finding realistic limits of distributions for generalists and usually do poorly with species associated with microhabitat features we cannot map, such as rock outcrops or forest snags. Species with particular movement and patch-size requirements or high sensitivity to habitat quality are also increasing our errors of commission; however, GAP has a conscious desire to err on the side of commission rather than omission.

Some GAP researchers are beginning to tackle these problems with new quantitative methods and data sets (Edwards et al. 1996) or with the use of landscape ecological principles as part of the model (Drobney 1999). It is also important to address the diversity of the taxa presently being mapped by GAP. The original decision to limit taxa to terrestrial vertebrates has generally been continued by the states, but only because of financial limitations and not lack of interest. GAP intends to be a complete biodiversity program and ultimately include all taxa. The inclusion of aquatic taxa has been a long-standing dream with some false starts and, to date, an inability to garner base funding. We have gradually been overcoming this, first through the New York watershed pilot project (Bain and Meixler 1998, Meixler and Bain 1999) followed by the Missouri statewide aquatic program (Sowa 1998, 1999). (Also see updates on these projects in this issue.) These projects have been building the methods and protocols to guide future efforts, and many GAP projects are currently including some limited aquatic aspect and garnering partner funding to do so. This bodes well for the program, but only if base funding can be provided to ensure national consistency in the methods, systems, and products.

Some GAP projects have begun incorporating other terrestrial taxa such as ants. In Florida, Craig Allen has mapped geographic distribution of ant species at the county level as determined primarily from published sources (Allen et al. 1998). In South Carolina, a sample-based approach to mapping ant diversity was taken. From the results of these sampling efforts both the county-level distribution and habitat affinity of each ant species will be determined (Allen et al. 1998).

Many of these issues were addressed at a recent symposium in Snowbird, Utah, sponsored by the USGS Idaho Cooperative Fish and Wildlife Research Unit in partnership with the U.S. Forest Service, Bureau of Land Management, U.S. Fish and Wildlife Service, and Boise Cascade and Potlatch corporations. The symposium, titled "Predicting Species Occurrence: Issues of Accuracy and Scale" attracted 325 participants from 14 countries. While most papers focused on vertebrates, other taxa such as plants, fungi, and invertebrates were well represented. Areas identified as needing more work were predicting abundance and viability. The majority of the presentations dealt with species presence/absence despite aggressive solicitation of papers on predicting abundance and viability. Tests of accuracy of model predictions using independent field data were uncommon. Finally, there is a bias worldwide towards predicting bird and large mammal occurrences. However, there is some pioneering work on predicting occurrences of plants going on in Australia. Papers from this symposium will be published by Island Press in the spring of 2001 (J.M. Scott and P.J. Heglund, eds.).

Future

I'll now use the experience from the past and present to organize some thoughts on where GAP is, or should be, heading in the next ten years to develop better distributions for more taxa.

Taxa: Clearly, an effective biodiversity program must address a broader representation of taxa (Ricketts et al. 1999) including habitat representation (aquatic) and size/life history representation (invertebrates). The research of Ricketts et al. (1999) suggests, however, that the mix of taxa used by GAP may likely be a suitable surrogate of species richness for a much broader group.

The modeling work to date has set the stage for new techniques and energized both our researchers and data users to desire such improvements. Funding is the greatest constraint, and while current interest is high for increasing GAP's budget, any foreseeable increases will still fall far short of including the breadth of taxa that should be addressed. This suggests that GAP must become even more aggressive in partnering and leveraging funds to achieve greater representation of taxa in our assessments. Alternatively, at the 1999 national GAP meeting, Malcolm Hunter noted that many countries are choosing to rely on the nonbiotic surrogate of "enduring features," believing that mapping individual taxa is impractical, too

slow, and/or a waste of resources (Hunter 1999). When asked how one determines what size or configuration to make a reserve based on these surrogates, he responded, "for that you need the animals." While it may be important for gap analysis to include enduring features, we need to expand our biotic surrogates and continue addressing the needs of individual biotic elements to ensure their survival and thus save their ecosystems.

Methods: Above I introduced the qualitative versus quantitative dichotomy, but it is certainly a false one. GAP has never had a required method for animal distribution modeling; rather we strongly advocate the use of the best available methods for producing usable products, and we certainly encourage a research dimension in every project. In the near future we will fund comparative studies, hopefully engaging other researchers and our critics to identify which models work, for which taxa, and under what conditions. We also need to pursue more robust models to incorporate viability, abundance, and metapopulation dynamics (see Vilella and Minnis, this issue). In this we will again find ourselves limited by the lack of actual knowledge of species' life histories, but just as we once believed GIS data was our limiting factor, it is important to have the tools ready when the information becomes available.

Biotic knowledge: Despite inroads in quantitative methods, qualitative information on species' life histories is critical to effective modeling, and we may find this even more so when we learn more about incorporating concepts like viability and metapopulation dynamics. GAP projects consistently find a dearth of published knowledge on species' basic habitat associations, let alone life histories required for more robust modeling. Work in Idaho indicated that the habitat association information in the literature is biased towards large vertebrate species, especially game species (Karl et al. 1999). Some projects have begun to do basic field study to establish range extents within their states (see Wall et al., this issue), but the U.S. desperately needs a systematic program for not only capturing information from ongoing field studies but new programs to study species in their habitats, particularly the poorly studied taxa. GAP is already playing an important role by compiling nearly the sum of knowledge of many species into modeling databases and the maps themselves.

Conclusion

GAP researchers and cooperators have much to be proud of. We have undertaken the largest, broadest effort in U.S. history to compile our sum knowledge of thousands of species and convert this knowledge into spatial renditions of their distributions. Assessments, though limited, are demonstrating a consistently high level of confidence for most species. In this respect the initial GAP objectives are being fulfilled, and we have the enviable position of focusing now on expanding the breadth and depth of our endeavor. Substantial success will not come as easily, however. Significant funding and partnership increases are required as well as a wholesale rethinking of the way data are collected, archived, and distributed by the entities charged with doing so. Any GAP researcher can recount visiting agency offices in search of data and being pointed in the direction of banks of filing cabinets. This must change.

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Identifying the Gaps, Locating the Reserves: Some Thoughts on Getting Gap Analysis into Conservation Practice

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Introduction

GAP seeks two objectives in mapping and categorizing the stewardship of the U.S.: 1) to map the conservation network as we define it, and 2) to report the representation of elements of biodiversity (species and plant communities) or lack thereof in the conservation network. The purpose is to characterize who the conservation stewards are, where their lands are, and the character of those lands in terms of size and intent to maintain biodiversity. The latter involves categorizing tracts of land according to the well-known four categories of biodiversity maintenance (Crist 2000) to assess the relative protection of, or risk to, the biotic elements found in or predicted to inhabit them. The result is a report, for each of the elements mapped, on the amount and percentage of their distribution found in each ownership type and protection category.

This information has proven very useful in assessing general patterns of protection afforded this country's biodiversity. For example, when the occurrence of nature reserves is mapped against elevation and soil productivity, the underrepresentation of low elevations and productive soils is very apparent (Scott et al. in press). Similarly, early results from GAP projects primarily in the West indicate that 50-85% of the mapped land cover types have less than 10% of their area in nature reserves. While 10% is a widely accepted standard of representation, it is an arbitrary standard. Protection of the full range of biodiversity may require 50-75% of the land base to include evolutionary potential of species at one end of the hierarchy to ecosystem processes at the other.

Without trivializing the monumental mapping and modeling effort to create the standard GAP information, when compared to GAP's mission, providing this information is only the initial phase of conservation planning. In the pioneering GAP monograph (Scott et al. 1993), 15 steps of the process were listed, including "13. Identify minimum areas required for . . . species and vegetation types, 14. Identify landscape corridors connecting vegetation types and centers of species richness," and "15. Design [the] reserve network." Clearly some of these tasks are now outside the responsibilities of an information program, but the U.S. lacks a government program to undertake such tasks, and the land management agencies typically do not feel mandated to do so. Thus it appears the need still exists to identify the geography of conservation need, not just tabular results (see, for example, Grue et al. and Stoms et al. below). From here I describe the context of GAP's origins to understand how we reached the current situation and where we may be or should be headed.

Past

GAP began in the U.S. Fish and Wildlife Service (FWS) to generally serve its land management and planning information needs. Specifically GAP sought to help avoid endangered species crises by aiding the FWS in the identification of elements requiring heightened scrutiny and ultimately to identify potential reserve locations for underrepresented elements of biodiversity. Work in the early and mid '90s by a variety of researchers suggested that this goal was no easy feat (for review see Csuti and Kiester 1996, Kiester et al. 1996, Merrill et al. 1995, Wright et al. 1994, also Stoms et al. below). GAP's early recommendation for using species-rich hotspots was found to be a limited surrogate for biodiversity in gen-

eral, and the computational requirements for identifying representative locations were enormous. Improvements in technology and technique combined with new concepts of "complementarity" for representing all elements (biotic and nonbiotic) emerged as more satisfying and robust answers (Pressey et al. 1997), but GAP has yet to incorporate these concepts into its standard analyses. The reasons for delay in pursuing more robust analyses range from the perennial lack of funding to support the work at either the state or national program level to the lack of demand for such information from management agencies that continue reactive management under legal duress (D. Osborne, pers. comm.).

Present

By the end of 2000, GAP will have 37 completed state projects with data sets describing and quantifying the predicted "gap" status of nearly all terrestrial vertebrates and plant communities for a large portion of the nation (74% of the area of the 48 conterminous states). This is a tremendous technical, logistical, and scientific accomplishment, but to assess our success in increasing conservation it is illustrative to look at the FWS's application of GAP. Despite legislation in 1997 that charges the FWS with guiding the future of its refuges towards the "conservation of ecosystems" (U.S. 1997) the FWS, GAP's original home and client, has not made full use of the GAP data. However, a few successful examples exist. The results from the early GAP effort in Hawaii (see Brackney and Crist, this issue) were used to create two new national wildlife refuges, and Indiana-GAP used the data to help design the Grand Kankakee Marsh National Wildlife Refuge (NWR; Clark and Slusher 2000). GAP information could significantly aid the nationwide FWS processes for identifying potential acquisition projects or the process for prioritizing them for funding. We also developed a pilot decision support system for refuge planning, "Refuge-GAP" (Herdendorf and Crist 1998), that spurred interest but has been slow to receive any FWS support for further research and development.

Perhaps the most significant block to using the results of gap analyses is that few agencies feel compelled to react to "gaps" that are not legally recognized by the Endangered Species Act (ESA) as threatened or endangered. GAP's analyses may be viewed with limited interest because we do not currently incorporate perceived short-term "real" risk in the sense of reduced abundance and clear and imminent threats such as logging of Red-cockaded Woodpecker habitat (see Vilella and Minnis, this issue). All of this reflects the fact that GAP did not emerge from national legislation as, for example, the Superfund Project did to address a widely perceived national crisis, but has instead been built from the bottom up to address the need as seen by biologists and researchers.

National GAP is rapidly developing GIS capability to both regionalize the state data sets and undertake basic gap analysis at the regional level and hopefully to engage other researchers in more robust analyses. At present, though, we need to be cognizant of how well data are being received and used by other agencies. Even sophisticated GIS users have had substantial difficulty conceptualizing how to integrate GAP's novel data into decision-making processes that have accrued over decades, using either very crude biological information or none at all. Simply publishing the information has not demonstrated that it will be used, and certainly not for the purposes for which it was created. In 1996 Crist began collaboration with the University of Wyoming GAP team on the development of decision support systems (DSS), including Refuge-GAP described above. The intent of these systems is to provide integration of GAP data in a format friendly to users' decision-making processes and not requiring either biological or GIS expertise. DSS has come of age, at least conceptually and in recognition of need, in the arena of natural resources technology but is not yet recognized as a normal funding item in most agencies.

Future

In the immediate future, GAP intends to publish a great deal of information and publicize it well. An important part of that process is publication of results by GAP researchers in the peer-reviewed literature. These are only first steps of putting the information to use, but they are important to show progress for the investment made. The next practical step will be development of other data products such as regional and element rangewide analyses (for examples see Stoms et al. [1998] and current work in Idaho to analyze gaps in the land cover of the 11 western states). Later work will identify complementarity-based reserve areas as well as development of more sophisticated DSSs for more user groups.

All of these activities will simply attempt to put current information to better use. However, it is also time to "negotiate with" as well as educate our partners. Educating them involves aiding the integration of GAP results into decision making by explaining the currently little-recognized need to consider common species and rangewide gap status. Negotiation will recognize that political realities call for us to identify those more urgent conservation issues that will continue to take precedence. Clearly our "one-size-fits-all" gap analysis requires change. Our process assumes an equal reaction of all elements to a stewardship condition, while we are well aware that some species thrive in agriculture and urbanization, and some species perish in anything less than total protection. Schemes for addressing individual element sensitivity have been suggested (Crist et al. 2000; Redford and Richter 1999; see also Gon et al., this issue) but such an approach may push the limits of our knowledge of species requirements and would require an entirely new level of partnership with primary land stewards to populate the necessary databases. We do believe the process is tractable, however, and probably necessary to provide truly useful information for the continuing "crisis planning" conducted in the U.S.

Conclusion

Recently GAP has funded socioeconomic seed grants to aid us in 1) identifying types of products and analyses needed by society, and 2) incorporating socioeconomic factors in gap analyses to address the "short-term" risk issues. GAP information has already been used for innumerable applications across the nation, and those applications will increase exponentially as we publish the gigabytes

of information pouring into the national program. Of this we should all be proud but also contemplative about why our information has yet to be used (much) for its primary purpose. Clearly institutional and societal education and changes are required as they are for all aspects of biodiversity conservation, but the greater (and more manageable) burden lies with GAP to conduct the type of analyses and create the products and tools that will better serve societal needs.

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Hawai'i: A Tropical Insular Approach to Gap Analysis

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The Hawaiian archipelago is one of the most biologically unique places in the world. This biodiversity has been greatly diminished by the impact of human activities. The loss of biodiversity is directly linked to habitat modification and loss, as well as the growing number and widespread distribution of non-native injurious species. The Hawaiian conservation community has jointly recognized the need for detailed land cover classification information and for species distribution data for key species of concern. To meet this need, the Ecosystem Data Group was formed in 1997 to coordinate information required for the conservation of Hawaiian biodiversity. The group believes that the methodology of the National Gap Analysis Program (GAP) can help to meet the needs of the conservation community in Hawai'i. By participating in GAP, Hawaii's unique biodiversity will be recognized in any national-level conservation activity efforts that evolve from the National GAP effort.

Because of Hawaii's unique geography as a tropical island archipelago, the national GAP methodology will be augmented in a few key areas. First, our analysis of biodiversity will expand the focus beyond vertebrate indicators to include representative plant and invertebrate taxa. We recognize that the spatial resolution for land cover mapping in Hawai'i will have to be at a higher resolution than on the mainland in order to capture significant areas of biodiversity, which on a per unit area basis is higher in Hawai'i than in any other place in the US. We will also expand the concept of land stewardship to include protection from emerging threats, particularly the impact of invasive non-native species. Finally, we will incorporate and integrate Aquatic GAP into our primary efforts.

Hawaiian Biodiversity and Its Loss

Approximately 90% of Hawaii's 1,000 native species of flowering plants are found nowhere else on earth (Wagner et al. 1999). It is estimated that Hawai'i has over 10,000 species of endemic insects (Eldredge and Miller 1995). All 80 species of land birds once found in Hawai'i are endemic to these islands (Jacobi and Atkinson 1995). Given the extraordinary level of endemism, Hawai'i is regarded as a globally significant "hot spot" of biodiversity.

However, with the arrival of the Polynesian explorers approximately 2,000 years ago and, more recently, with the "discovery" of Hawai'i by Westerners in 1778, major impacts have been brought to Hawaiian ecosystems and their unique biota. Today, Hawai'i is home to approximately 33% of the nation's total endangered species (USFWS 1998), and nearly 75% of the recorded extinctions in the United States have involved endemic Hawaiian species. This process continues and may be accelerating. Federal, state, and private conservation organizations currently working in Hawai'i agree that nearly all of Hawaiian native biota should be regarded as threatened.

The loss of biodiversity is directly linked to landscape alteration (e.g., agriculture, urbanization, resort development, and recreation) and the growing number of non-native, injurious species. Weeds in particular are widely regarded as posing the greatest threat to biodiversity and native ecosystems in Hawai'i. Nearly half the total land area of the archipelago is now occupied by altered landscapes or alien-dominated ecosystems that have displaced native species (Pratt and Gon 1998). Alien species now comprise nearly 20% of the overall biota in Hawai'i (Eldredge and Miller 1995).

Hawai'i GAP

The national GAP program grew out of the Hawai'i Forest Bird Survey, which was an innovative project initiated in the 1970s to evaluate the distribution, status, and threats to habitats of endangered Hawaiian forest bird populations (Scott et al. 1986, Scott et al. 1987). Since then, research and management efforts in Hawai'i have expanded to include taxa other than birds. In 1995, the Ecodata Group (EDG) was established by several federal, state, and private organizations to facilitate the sharing of environmental data and to coordinate data collection efforts statewide. EDG was instrumental in developing the Hawai'i GAP project to take advantage of its well-tested methodologies and rigorous data quality standards.

Hawai'i GAP will follow closely the standard methodology, with a couple of noteworthy innovations. Most significantly, because much of Hawaii's extraordinary biodiversity is expressed in its flora, we will be looking at the distribution of key plant and invertebrate taxa in addition to the distribution of vertebrates when developing our species distribution maps. Second, we will be mapping the biological elements in our freshwater streams. Finally, we will be mapping key threats to biodiversity, including the distribution of feral ungulates, avian disease, weeds, and fire. While we recognize the importance of the marine aspects of biodiversity in Hawai'i, our initial GAP effort will not include a marine component. In the course of the terrestrial/aquatic GAP project, we will consider the feasibility of developing coral reef and nearshore marine coverage and other important biodiversity elements.

Conclusions

Studies in Hawaiian avifauna during the 1970s contributed to the development of the current GAP framework. It is our hope that we can continue to further the process of refining the GAP methodology by including nonvertebrate taxa and environmental threats when evaluating the implications for conservation of Hawaii's biodiversity.

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LAND COVER

Predictive Modeling of Rare Plant Species

A Report on GAP Research Project #1434-HQ-97-RU-01542

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Resource managers and conservation biologists are faced with a critical shortage of information on the potential distribution of rare plant species over large areas. Predictive modeling can be a cost-effective means of identifying and prioritizing likely areas of rare plant habitat for more efficient and productive ground surveys.

Traditionally, rare plant ranges have been inferred from dot distribution maps (Figure 1), but these maps may represent only a fraction of the species' actual range or reflect sampling bias. An alternative is to model the potential range of a species by identifying correlations between the plant's known distribution and relevant environmental variables using geostatistical methods (Franklin 1995). These empirical models can be derived from herbarium or Natural Heritage Program location records and state- or regional-scale coverages of substrate, topography, and climate in a Geographic Information System (GIS).

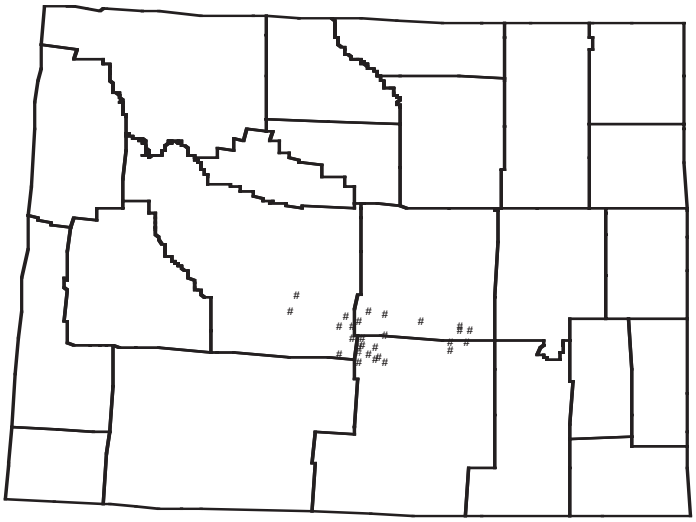

Figure 1. Dot distribution map of the known range of Physaria eburniflora in Wyoming.

To illustrate this technique, I have developed an empirical model of the potential distribution of a rare Wyoming endemic, *Physaria eburniflora* Rollins. This low-growing perennial mustard is restricted to barren calcareous ridges and granite outcrops in the North Platte and Sweetwater River drainages in central Wyoming (Figure 1). Of 29 known populations, 28 were selected for modeling because these sites could be placed within 0.1 - 2.5 km of their actual location. As absence data have not been routinely collected for this species, I used the Rocky Mountain Herbarium's (RMH) database of over 9,000 sampling points in Wyoming to identify areas where *P. eburniflora* has not been collected and is thus presumed absent. (RMH researchers have systematically established these collection sites across the state for the purpose of collecting all plant taxa present in the immediate area.) Of these putative absence sites, 1,270 were randomly selected for modeling. The combined presence and absence data set was randomly split into model-building and model-validation pools.

Environmental attributes for each presence and absence point were derived from digital coverages in ArcView version 3.1. For climate data, I used PRISM mean monthly precipitation data in 4 km raster format (Daly et al. 1994) and unpublished PRISM mean monthly temperature data in 2 km raster format. Topographic data, including elevation, slope, and aspect, were derived from 30 m Digital Elevation Model (DEM) coverages of the state. An index of landscape position for each 30 m pixel was calculated using the protocol of Fels and Matson (1996) and then reclassified into four terrain position categories based on overall slope and shape (concave, slope, flat, and convex) (Ken Driese, pers. comm.). Lastly, vector coverages of bedrock geology and GAP land cover were used.

Using classification tree analysis in S-plus version 1.1, I developed a model of *P. eburniflora* distribution using seven environmental variables as predictors (mean April and July precipitation, mean January and July temperature, bedrock geology, aspect, and elevation). Classification trees use a recursive partitioning algorithm to identify the values of continuous and categorical environmental variables that best explain the differences in predicted presence or absence of a species (Breiman et al. 1984). From the model output, I created a potential range map in ArcView by intersecting the environmental values that best predicted the presence of *P. eburniflora* (Figure 2). The model correctly classified 13 of the known presence points (93%) and 608 (95.7%) of the known absence points in the model-building data set and seven (50%) of the known presence points and 614 (96.7%) of the known absence points in the validation data set.

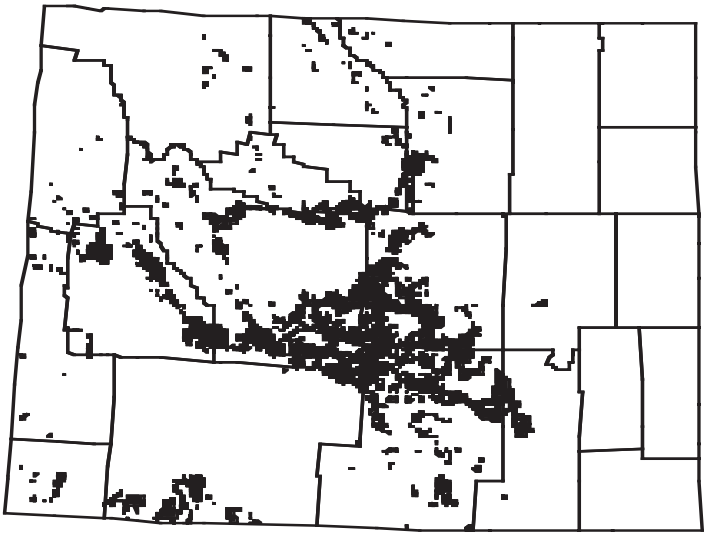

Figure 2. Predicted distribution of Physaria eburniflora in Wyoming based on correlational modeling.

According to the predicted distribution map, potential habitat for *P. eburniflora* may occur along the flanks of the Bighorn, Wind River, Owl Creek, Medicine Bow, and Uinta mountains in northern, western, and southeastern Wyoming, and on isolated buttes and valleys elsewhere in the state (Figure 2). Surveys to date have shown that other, closely related *Physaria* species occur in these areas, perhaps reflecting their superior competitive ability or localized extinction or incomplete dispersal of *P. eburniflora*.

The predictive ability of correlational models may be hampered by errors inherent in the input data sets. Imprecise location points, errors in converting map data to digital format, and horizontal and vertical errors in DEMs may all reduce prediction accuracy (Franklin 1995). Potentially useful environmental factors such as local soil pH, soil texture, or extremes in precipitation or temperature are unavailable in statewide coverages or are masked when macroclimate data are averaged over diurnal cycles and monthly periods. Equally useful spatial data sets for the distribution of pollinators, seed dispersal vectors, predators, and soil symbionts are also unavailable. Spatial autocorrelation can inflate the explanatory power of models when location points for a species are naturally clustered, although this problem may be lessened if this spatial patterning is related entirely to spatial patterning in the explanatory environmental variables (Franklin 1998). Lastly, an inadequate number of sample points may be available for some extremely rare plants to meet the minimum data input requirements for a statistically useful model. Despite these caveats, GIS-based correlational models can be a powerful tool for developing testable and ecologically meaningful distribution maps of rare species and for identifying areas of potential habitat for field surveys.

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Comparison of Satellite Imagery Interpretation Using Known Association/Alliance-Level Data

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Introduction

The U.S. Geological Survey/National Park Service (USGS-NPS) Vegetation Mapping Program was initiated in 1991 to provide national parks with information on their natural resources. Parks are classified based on the association level of the National Vegetation Classification System (NVCS) with a goal of 80% map accuracy. Classification has been completed for three national parks in South Dakota: Mt. Rushmore, Jewel Cave, and Wind Cave (Cogan et al. 1999).

These USGS-NPS maps offer a unique opportunity to evaluate the extent to which satellite imagery can be used to classify land cover based on the NVCS vegetation classification system (Table 1). Our objectives were to determine the degree to which association-level classifications could be interpreted from satellite imagery and the accuracy of these interpretations. We hypothesized that with detailed training data for association level or community type, accuracy of land cover maps would be at least 80%.

Table 1. Natural land cover classification system (Jennings 1996).

Category	Example
Class	Woodland
Subclass	Mainly Evergreen Woodlands
Group	Evergreen Needle-leaved Woodlands
Formation	Evergreen Coniferous Woodlands with Rounded Crowns
Physiognomic	
Floristic	
Community Alliance	*Juniperus occidentalis*
Community Type	*Juniperus occidentalis/ Artemisia tridentata*

Methods

Study Area - Wind Cave National Park (WCNP) is an 11,450 ha parcel in the southern Black Hills of western South Dakota. The park is a mosaic of ponderosa pine (Pinus ponderosa) stands and mixed- and shortgrass prairies. The vegetation of the park, including an approximately 2 km buffer, was classified by USGS-NPS to an association level using aerial photography (Table 2; Figure 1 - see Web version of the Bulletin at http://www.gap.uidaho.edu/Bulletins/8).

Classification Procedure - Landsat Thematic Mapper (TM) leaf-off satellite scenes for path 33/row 29 and path 33/row 30 for 1992 were acquired through the Multi-Resolution Land Characteristics Consortium. These two scenes, which encompass the Black Hills of South Dakota (including WCNP), were mosaicked and processed through an unsupervised classification with 20 iterations resulting in 255 clusters and a 30 m cell size (Lauver and Whistler 1993, Scott et al. 1993, Stoms 1996, Vogelmann et al. 1998).

GIS Summary Interpretation - GIS summary techniques were used in this study. A GIS summary calculates cross-tabulation statistics between input files (known data entered on zeroed image and clustered satellite scene) and creates an output report stating the agreement between the known data and individual clusters. GIS summaries were generated on the clustered image clipped to the WCNP boundary (GIS Summary I) and on the mosaicked scenes, containing the entire Black Hills (GIS Summary II). Methods followed Vogelmann et al. (1998).

Cluster Selection Interpretation - Using Imagine software (ERDAS), the USGS-NPS vegetation coverage was overlaid on the clipped, mosaicked satellite image. Each of the 255 clusters was selected to determine the vegetation type it represented. Labels were given to designate the present vegetation types. Once all 255 clusters had been interpreted, any cluster that was designated by only one association was assigned to that type. Clusters containing more than one association were compared and assigned to the association with the highest percent composition.

Accuracy Assessment - Stratified, random points (908) were selected for accuracy assessment based on the number of pixels in a given category (Krebs 1989, Johnson et al. 1999). A minimum of two points was assessed for small classes. Nine classes in the USGS-NPS coverage could not be assessed for accuracy because of size, accessibility, or lack of field information (Cogan et al. 1999). An error matrix was generated for the remaining classes (Table 3 - see Web version of the Bulletin at http://www.gap.uidaho.edu/Bulletins/8).

Table 2. Categories included in original USGS-NPS coverage and comparison to three methods of interpretation.

Category	USGS-NPS Coverage (ha)	Cluster Selection (ha)	GIS Summary I (ha)	GIS Summary II (ha)
Purple-3-awn – Fetid Marigold Herbaceous Vegetation	861.05	382.32	307.8	320.76
Ponderosa Pine Limestone Cliff Sparse Vegetation[1]	29.77	N/A	N/A	N/A
Redbeds Sparse Vegetation	68.53	42.12	N/A	6.48
Black Hills Rock Outcrop Sparse Vegetation[1,3]	94.62	N/A	N/A	N/A
Shale Barren Slope Sparse Vegetation[3]	70.87	359.64	29.26	32.4
White Sedimentary Rock Outcrop Sparse Vegetation	269.59	N/A	22.68	22.68
Bison Wallows[1,2]	4.35	N/A	N/A	N/A
Burned Pine	776.89	942.84	239.76	317.52
Emergent Wetland Herbaceous Complex[1]	54.35	N/A	N/A	N/A
Little Bluestem – Grama Grass / Threadleaf Sedge Herbaceous Vegetation	4259.70	3304.8	1150.2	1140.48
Western Wheatgrass – Kentucky Bluegrass Complex	10746.36	13011.84	17933.4	17677.44
Introduced Weedy Graminoid[1,3]	39.80	N/A	N/A	N/A
Needle-and-thread – Blue Grama / Threadleaf Sedge Herbaceous Vegetation	286.33	243.0	N/A	N/A
Mountain Mahogany – Sideoats Grama I	578.48	197.64	51.84	129.6
Mountain Mahogany – Sideoats Grama II[1,3]	187.97	N/A	N/A	N/A
Lead Plant	162.67	155.52	N/A	N/A
Chokecherry Shrubland	700.93	165.24	N/A	N/A
Beaked Willow Shrubland[1,3]	7.77	N/A	N/A	N/A
Western Snowberry Shrubland	757.72	758.16	N/A	N/A
Creeping Juniper – Little Bluestem Shrubland[1,2]	0.11	N/A	N/A	N/A
Plains Cottonwood – Western Snowberry Forest[3]	52.72	42.12	N/A	N/A
Boxelder/Chokecherry Forest[1]	149.64	N/A	N/A	N/A
Bur Oak Stand[1,3]	14.41	N/A	N/A	N/A
Green Ash – American Elm / Western Snowberry Forest[3]	11.58	93.96	N/A	N/A
Birch – Aspen Stand[1,3]	44.50	N/A	N/A	N/A
Ponderosa Pine Woodland Complex I	2713.99	5495.04	6207.84	6207.84
Ponderosa Pine – Little Bluestem Woodland	4224.28	1707.48	5469.12	5469.12
Ponderosa Pine – Chokecherry Forest	1001.03	N/A	3.24	3.24
Ponderosa Pine Woodland Complex II	4506.53	5585.76	2993.76	2993.76
Young Ponderosa Pine Dense Cover[1]	995.48	N/A	N/A	N/A
Transportation, Communications, and Utilities	331.31	N/A	100.44	87.48
Crop and Pasture	1744.39	1574.64	1244.16	1302.48
Other Agricultural Lands	112.06	155.52	N/A	32.4
Open Water	28.18	16.2	16.2	19.44
Strip Mines and Gravel Pits	41.49	N/A	19.44	6.48

[1]Not interpreted in any of the three classifications
[2]Removed from coverage because of size when converted from vector to raster format
[3]No accuracy assessment performed

Results

Two categories were removed from the GIS summary analysis by the gridding procedure. These classes, Creeping Juniper/Little Bluestem Shrubland and Bison Wallows, contained less than 5 ha in long, narrow corridors. A 30 m grid cell contains 0.09 ha, but neighboring spectral classes can mask small areas and remove them during the gridding process (Congalton 1997). Neither of these categories could be interpreted using the Cluster Selection method (Table 2).

Ten additional categories (less than 190 ha) were not interpreted by any of the three methods (GIS Summary I, GIS Summary II, and Cluster Selection Interpretations) listed in Table 2. Although some vegetation types less than 190 ha were interpreted, polygon size could be the factor determining whether or not the vegetation type could be distinguished.

GIS Summary Interpretations - Fifteen of the 35 NPS categories were present using GIS Summary I on WCNP (Figure 2 - see Web version of the Bulletin at http://www.gap.uidaho.edu/Bulletins/8). Seventeen of the 35 NPS categories were present using GIS Summary II on the Black Hills (Table 2; Figure 3 - see Web version of the Bulletin).

Cluster Selection Interpretation - Nineteen of the original 35 NPS categories were classified using Cluster Selection (Figure 4 - see Web version of the Bulletin at http://www.gap.uidaho.edu/Bulletins/8). The Cluster Selection method resulted in classification of six classes not found in the GIS Summaries of WCNP and the Black Hills (Table 2).

Accuracy Assessment - Based on preliminary assessment of the techniques used to classify the imagery, the Cluster Selection Interpretation resulted in the highest number of classes and most closely resembled the USGS-NPS coverage from aerial photography (Table 2). We restricted our accuracy assessment to this methodology because others would be less accurate by default. Because the USGS-NPS coverage was only 73.0% accurate, we only determined similarity between the classified satellite image and the USGS-NPS coverage.

Four hundred and twenty-nine of 908 pixels were correctly classified to association using this interpretation, resulting in accuracy of 47%. User's accuracy ranged from 0-84%, and producer's accuracy ranged from 0-63% (Table 3 - see Web version of the Bulletin at http://www.gap.uidaho.edu/Bulletins/8). However, using this association-level information does accurately separate conifer from grassland categories. When categories were grouped to the formation level, overall accuracy increased to 76% (Table 4).

Table 4. Formation-level accuracy assessment.

	Purple-3-awn-Fetid Marigold	Redbeds SV	Burned Pine	Grassland	Shrubland	Evergreen	Total
Purple-3-awn – Fetid Marigold	8	0	3	12	0	0	23
Redbeds SV	0	0	0	4	0	0	4
Burned Pine	6	0	14	1	0	18	39
Grassland	10	0	18	364	11	18	421
Shrubland	1	0	3	39	2	17	62
Evergreen	3	0	12	30	11	303	359
Total	28	0	50	450	24	356	908

Discussion

Three categories were overestimated in both of the GIS Summary interpretations; these classes were Western Wheatgrass/Kentucky Bluegrass Complex, Ponderosa Pine Complex I, and Ponderosa Pine Complex II. These three categories comprised 49.2% of all of the land classified in the USGS-NPS coverage. From these results, we conclude that using a GIS summary to interpret land cover overestimated the dominant vegetation types.

During processing, the GIS summary showed confusion between similar categories in a number of clusters. Confusion occurred within herbaceous, pine, sparse vegetation, man-made, and agricultural categories. Although recommended accuracy requirements for GAP are 80% at the alliance level, overall accuracy approached 80% only after aggregating categories to the formation level. Accuracy assessment included a comparison to the NPS classified coverage, not to actual ground-truth information; hence, accuracy of the original coverage (73.0%) may have interfered with the interpretation of satellite imagery obtained from ground vegetation. An accuracy assessment with ground-truth data from vegetation in WCNP may increase accuracy of the classified image; this information was not available at the time of the study.

Although techniques discussed were not able to distinguish accurate alliance information, additional limitations exist with these interpretations. The Black Hills contain white spruce at elevations

higher than 1,625 m. WCNP does not contain white spruce; therefore, we were not able to evaluate this vegetation type using any of the three methods. In this case, white spruce would have been classified as Ponderosa Pine in the Black Hills, resulting in additional inaccuracies in the land cover map. WCNP also is relatively small in size when compared to the mosaicked scenes of the Black Hills. Using a small area, such as WCNP (11,450 ha), as the sole training data may cause inaccuracies when applied to a large area, such as the two mosaicked Black Hills scenes (9,232,736 ha). Because of these limitations, more known vegetation types would need to be included in the Cluster Selection and GIS Summary methods to adequately represent all vegetation types present in the Black Hills.

Recommendations and Further Research

While this study found an average accuracy of only 47% using satellite interpretations to predict alliance-level information, other methods may have improved results. Ancillary data and multitemporal satellite scenes can be used to assist in the interpretation of categories that are small or that have specific habitat requirements. For example, digital soil survey information may help narrow the classification of large categories that dominate an interpretation. However, these data are not available for the Black Hills.

A second alternative that may enhance accuracy is the use of newer satellite imagery. The MRLC acquisition of satellite imagery for South Dakota dates to 1992. The ground-truth information was collected in 1997, and aerial photography was taken in 1998 to be used as ground-truth information. These temporal differences may cause inaccuracies in classification. A Landsat 7 scene from 14 October 1999 for southwestern South Dakota is currently being interpreted. Classification of this scene will likely compensate for temporal changes and will allow the use of 15 m panchromatic resolution to aid in interpretation of vegetation pattern.

Acknowledgments

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Estimating and Mapping the Thematic Accuracy of GAP Land Cover Maps

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In keeping with the research and development mission of the Gap Analysis Program, we developed an approach to accuracy assessment for land cover in Montana that did not require the collection of an independent set of reference data. Instead, all available reference data were used not only to train supervised image classifications, but also to assess the resulting classification accuracies via a bootstrap procedure. Moreover, because standard classification error matrices provide little information about the spatial variation in thematic accuracy, we used Kriging to interpolate probability estimates from each reference point to a statewide lattice, from which a contour map of thematic accuracy was produced. Although the method has withstood peer review (Steele et al. 1998), no results have been field-tested, and readers should be cautious in applying it to their areas or states. For more details about the procedure and how to construct bootstrap classification error matrices, see Steele et al. (1998); additional details about the statewide application can be found in Redmond et al. (1998).

The Montana Gap Analysis Project (MT-GAP) began before the widespread use of airborne videography. Because of the large size of the state and a lack of funds to collect new ground-reference data, we were limited to the use of whatever existing data were available. Although this amounted to 21,348 plots representing 45 cover types, this was not a sufficiently large sample for us to hold back a certain proportion (e.g., 20%) to validate the supervised classifications of 33 TM images covering the state. Thus, we devised a method of estimating the probability of misclassification at each of these reference points using a bootstrap procedure (Efron and Tibshirani 1993). This method simulated the process of sampling and classification many times (with replacement), and thereby allowed us to estimate the probability that the true cover type was correctly classified at each reference point from the number of times that the reference observation was correctly classified in all the simulations. For MT-GAP, we ran the bootstrap 100 times with replacement for each TM image classification. The resulting probability estimates then were entered into ARC/INFO (GRID module), and mean thematic accuracy was interpolated to a 1 km statewide lattice using the routine POINTINTERP (exponential option with neighborhood = 75 km, and decay = 15 km); in other words, mean accuracy was calculated for each lattice point across the state using only the reference data (cover types and accuracy estimates) that fell within a 75 km search radius. Finally, contour lines connecting lattice points of equal mean thematic accuracy were drawn at 5% intervals. Not surprisingly, the resulting map showed considerable spatial variation in mean thematic accuracy for the 45 cover types. Yet despite the utility of these results, we acknowledge that an independent validation (as recommended by Stoms et al. 1994 and Crist and Deitner 1998) would still be worthwhile, especially to detect and measure errors resulting from the possible omission or inadequate representation of cover types in the sample of existing reference data.

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ANIMAL MODELING

On Vertebrate Generations and Plant Succession: Incorporating Vegetation Structural Attributes into Vertebrate Modeling

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Species-Habitat Concept and Gap Analysis

The concept of habitat is understood, even by the lay public, as the place where an animal resides. As biologists we recognize components of habitat (i.e., cover, food) contained within this "place." MacArthur and MacArthur (1961) argued an ornithologist could determine which species were likely to occur in a given location based on the following criteria: 1) geographic location of habitat, 2) type and structure of habitat, 3) knowledge of geographic range. Similarly, Udvardy (1969) stated "the mapping of vegetation serves as the basis of correlation for animal distributions . . . (and) indicate(s) possible occurrences of animals where they have not been studied or have been overlooked." Finally, Thomas (1979) claimed "plant communities and their seral stages . . . are ecologically important as niches for wildlife species. The niches are a product of the plant community, its seral stages, and other environmental factors—including soil type, moisture regime, microclimate, slope, aspect, elevation, and temperature." It is important to specify this description refers to the Grinnellian concept of ecological niche, which focuses on factors determining the distribution and abundance of species (Grinnell 1917). This autecological approach to the concept of niche is the basis for developing the habitat models used by the Gap Analysis Program (GAP).

GAP assesses terrestrial vertebrate biodiversity by mapping the predicted distribution of terrestrial vertebrates in a given region. GAP is designed to use the association of wildlife with vegetation and/or other physical attributes to examine the potential distribution of vertebrate species and associate it with the existing distribution of lands being managed for biodiversity conservation. Data developed by GAP provide decision support for planning the protection of all terrestrial vertebrate species within a given region. GAP data sets are probably some of the broadest and most useful for this type of analysis. But, by assuming that a species occupies all suitable vegetation types within its range and that all suitable types have been included as habitat, GAP predictions will always tend to overestimate the species distributions (Smith and Catanzaro 1996). While overestimating the distribution of common species may be acceptable in some cases and is preferable to consistently underestimating distributions (Edwards et al. 1995), it may represent a problem for rare or patchily distributed species (Smith and Catanzaro 1996). Therefore, vegetation type is not the only factor influencing use by species; other environmental variables are usually incorporated to further refine a species distribution (Csuti 1996). Such factors can be either ecological or physical and may include elevation, soil type, rainfall, slope, aspect, and patch or polygon size (see Csuti and Crist [1996] for a thorough explanation of the vertebrate modeling process of GAP).

Refinement of Models

GAP has significantly contributed to the knowledge and capabilities of natural resource conservation through the use of spatial information technologies (Prendergast et al. 1998, Schwartz 1999). As GAP incorporates new software, hardware, and techniques, the original scope of GAP can be expanded. The last 10 years have seen a growth of knowledge and enhancement of techniques unparalleled in the past. This expansion of knowledge has forced GAP to continually revise and upgrade the standards for data products. For example, where once the minimum mapping unit for land cover mapping was 100 ha, today it is only 2 ha. Many states are retaining and using the 30 m pixel resolution. Similarly, where once we obtained a handful of cover classes that often included many forest alliances, we see the development of detailed techniques such as decision-rule algorithms (McKerrow 1997) for selection of detailed individual alliances or ecological complexes from the same satellite data used five years earlier.

Many GAP projects have been incorporating various factors to refine species distributions. For example, Allen et al. (in press) demonstrated the impact of incorporating dispersal distances on overall species richness in southern Florida. Mattson (1996) demonstrated the impacts of human presence and access to the potential distribution of grizzly bear (*Ursus arctos*) habitat in Idaho.

GAP is viewed as a long-term planning tool; however, there has been some acceptance of the need to continually reevaluate areas

because of a rapidly changing landscape and the impact human disturbance has on biodiversity. This being said, we ask: are GAP distributions long-term estimates or a snapshot in time? While Csuti (1996) stresses the importance of GAP distribution maps as long-term planning tools, he emphasizes the need for information management systems that allow users the ability to update this information.

While GAP is not designed to deal with the short-term need of threatened and endangered species, the examination of these species provides insight into past events that may have contributed to driving these species near extinction. Unfortunately, however, most GAP projects do not examine these species in detail. Smith and Catanzaro (1996) suggested that performing an analysis of the Red-cockaded Woodpecker (*Picoides borealis*, RCW) in Arkansas would be useless because of the rapidly changing range of the species. This seems to contradict Csuti (1996) who suggested that an analysis for a rapidly expanding species such as the Indigo Bunting (*Passerina cyanea*) would provide useful insight into the temporal dynamics of this species.

While each GAP state has their individual focus on how to improve vertebrate models, with each state learning from the success or lack of success of other states, Mississippi GAP decided to focus on the impacts of vegetation structure on wildlife habitat distributions. The state of Mississippi is a leader in timber production. The state has nearly 7 million hectares of timber land (44% of the total land base), of which on average 100,000 ha are harvested annually (Mississippi Forestry Commission, unpub. data). These figures highlight the importance of understanding the seral-stage dynamics for woodland species such as RCW and Northern Bobwhite (*Colinus virginianus*) and how timber harvest may impact habitat availability for these species. The Spatial Information Technologies Laboratory in the College of Forest Resources at Mississippi State University developed the land cover map for Mississippi GAP (Batten 1998). From the onset of the project, we determined structural components of vegetation would be emphasized in land cover mapping. A pilot study of a single TM satellite data scene revealed the ability to distinguish five structural classes of pine (Batten 1998). These classes included the following: high-density pine, low-density pine, medium-density pine, recent harvest areas, and recent revegetated harvest areas. Loblolly pine (*Pinus taeda*) comprised nearly all the pine classes in this scene, thus all pine alliances were grouped for this analysis.

These classes, in turn, correspond rather closely to pine forest seral cycles in Mississippi. Recent harvest areas refer to the stage of mature forest removal and up to the third year of pine regrowth. Revegetated harvest areas occur in the time period when pine establishes itself in the system but has not completely closed the canopy (usually 3-5 years after regrowth). High-density pine relates to the period of dense canopy cover during the sapling to pole-timber stage. Canopy cover is 100%, and little understory vegetation exists. As most pine in Mississippi is managed for timber, it is usually thinned at around 15 cm (6 in.) DBH. The period from post-thinning to final thinning relates to medium-density pine. Low-density pine corresponds to the final stages of pine development before harvest. As would be expected, there is some degree of confusion between the low- and medium-density pine classes. Even with this confusion, the product accuracy for these classes averaged 70% and the users accuracy nearly 80%.

Seral Stages and Species Associations

Stated explicitly by Thomas (1979) and implicitly by MacArthur and MacArthur (1961) and Udvardy (1969) are the potential effects that vegetation structure and seral stages exert on the presence or absence of a species. Many examples exist of species (e.g., checkerspot butterfly) that coevolved with or adapted to specific seral stages of particular vegetation types (Wahlberg et al. 1996). The Red-cockaded Woodpecker is a native, nonmigratory species endemic to mature, pyric pine communities of the southeastern United States. The distribution of the RCW has contracted, and populations have declined precipitously throughout much of its range. Population declines have been attributed to conversion of mature pine stands to young plantations, hardwood midstory invasion, habitat fragmentation, and demographic isolation (Ligon 1971). The distribution of RCW is dependent on the extent of mature longleaf (*Pinus palustris*), loblolly (*P. taeda*), shortleaf (*P. echinata*), and slash (*P. elliottii*) pine forests in the southeast. Hooper et al. (1980) give a detailed description of the life history and habitat requirements of the RCW. Because the RCW is an endangered species in Mississippi and the Southeast, a great deal of ecological information has been collected on this species in recent years. Detailed information has also been collected on habitats and species associated with RCW (Engstrom 1993).

These data can be extremely useful in expanding our understanding of the ecology of not only RCW but other species that rely on the mature, pyric pine community as well. Bachman's Sparrow (*Aimophila aestivalis*), a threatened species, nests in the wiregrass tussocks of the understory. The endangered gopher tortoise (*Gopherus polyphemus*) is a keystone species for more than 300 species of invertebrates and 65 species of vertebrates that use the underground burrows they provide (Dodd 1995). In addition to these species of concern, an additional 36 mammalian and 86 avian species have been documented as relying on this ecosystem (Engstrom 1993). These species include southeastern pocket gopher (*Geomys pinetis*), southeastern fox squirrel (*Sciurus niger*), and Brown-headed Nuthatch (*Sitta pusilla*) (Engstrom 1993).

Effect of Vegetation Structural Information on Vertebrate Models

If the structural information for pine classes were applied to the distribution model of RCW in Mississippi, we can reduce the potential overestimation of currently available pine habitat by 940,000 ha simply by eliminating recently harvested pine areas and dense young stands. Similarly, if medium-density pine proves to be unsuitable habitat for these species as well, we can reduce the available habitat statewide by an additional 1.7 million ha (Figure 1). This revised estimation of currently available habitat can have sig-

nificant ramifications for reserve design and planning. Although GAP is designed as a tool to identify unprotected regions of high biodiversity, we anticipate planning new reserves for the protection of threatened and endangered species. We feel GAP can and should provide the best available information for designation of these reserves as well.

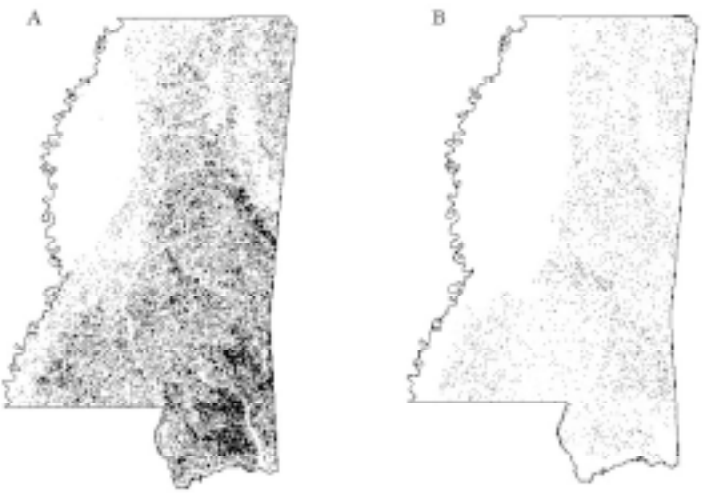

Figure 1. Estimation of available mature pine habitat for Red-cockaded Woodpeckers varies greatly depending on the classification system used. Classifying all suitable pine alliances into a single class (A) reveals 3.1 million hectares of habitat. Conversely, classification based on structural (i.e., age) classes (B) indicates 0.4 million hectares of habitat are currently available. Analysis developed from 30 m Thematic Mapper data circa 1992.

The last decades have seen a rapid expansion of the scientific basis for selection and design of nature reserves. Some of this has centered on the elucidation of conservation filters and the ability of nature reserves to capture different levels of biodiversity. Conservation at both organizational scales (i.e., coarse-filter vs. fine-filter) has been successful, and both deserve continued support (Shafer 1995). Reserves are designed to provide protected habitat for species and communities to maintain their long-term existence. Many reserves are designed to ensure population persistence for a limited number of flagship or umbrella species. While GAP is mainly concerned with animal and plant distributions and not abundance, the issue of vertebrate abundance cannot be totally ignored (Krohn 1996). Population viability should be one of the long-term objectives when planning nature reserves. During the past 30 years, studies of biogeography, particularly of island biotas, have shown habitat quantity is as fundamental to the survival of a species as is habitat type and quality (Shaffer 1996). In other words, having the proper type of habitat, even of high quality, may not assure species survival unless there is enough of it. Overestimation of available habitat for a species dependent on particular seral stages of a given vegetation type could mean the difference between species survival or extinction.

We provide an example using Noxubee National Wildlife Refuge (NWR), located in east-central Mississippi. Four major vegetation types dominate the area: hardwood bottomlands, hardwood uplands, pine, and pine/hardwood. In addition to waterfowl, endangered species play a major role in management of forest ecosystems at Noxubee NWR. Intensive management of RCW habitat is a major focus in mature pine and pine/hardwood stands (Richardson and Stockie 1995). Thinning and prescribed burning are regularly utilized in areas occupied by RCW. Let us assume Noxubee NWR has been given the resources to acquire 30,000 ha adjacent to the refuge to enhance quantity and distribution of old-growth pine habitat. If a primary concern is immediate enhancement of RCW habitat while maximizing its long-term availability, an analysis of GAP data on all sides of the refuge reveals some interesting results.

Noxubee NWR is located in fairly dense pine habitat extending west and south of the refuge. An examination of a 30,000 ha block on either side of the refuge yields slightly different results in terms of currently available habitat. To the west of the refuge, a 30,000 ha block would acquire 14,327 ha of pine of which 1,656 ha (11.5% of the total pine) would be suitable or nearly suitable habitat. Conversely, the block to the south would yield 18,829 ha of pine with 3,162 ha (16.8%) in an older state of succession. While the total area of loblolly pine was only slightly different, there was twice as much existing habitat in the south block than in the west block. Therefore, by incorporating vegetation structure into the decision process, refuge personnel can look at both current and future available habitat (Figure 2 - see Web version of Bulletin at http://www.gap.uidaho.edu/Bulletins/8). While this is a fairly simplistic example, the concepts and results are real. Not only does GAP have the potential to deal with threatened and endangered species, the data and models developed for these species can impact many other species that utilize the same habitats. Therefore, enhancing the GAP land cover to incorporate structural components would allow us to deal with short-term needs of threatened species while providing large-scale information that can be used for long-term planning.

Conclusion

The GAP approach has been, perhaps unfairly, criticized for attempting to collect species-occurrence data at coarse spatiotemporal scales for use as surrogates of community and ecosystem representation and persistence (Conroy and Noon 1996). The continual development of new reserve selection algorithms will result in more practical and realistic applications for sustainable protection regimes (Pimm and Lawton 1998). As GAP matures and spatial information technology advances, incorporation of factors such as patch size, dispersal distances (Allen et al. in press), and structure or age classes of vegetation will become vital to differentiate between currently existing habitat and potential habitat. As conservationists call for greater emphasis on management for biodiversity, it is increasingly important to develop tools for assessing the effects of a specific management strategy on a wide variety of organisms over a range of scales, both spatially and temporally. While GAP data have already proven themselves as a long-term management and

planning tool (Prendergast et al. 1998), we believe the future of gap analysis lies far beyond a mere complement to single-species management.

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EMAP Hexagon Coverage Included in South Dakota's Sportsman's Atlas

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Throughout the South Dakota Gap Analysis Project (SD-GAP), we have been working with state agencies to provide opportunities for outreach. Because of a lack of locational data for vertebrates in South Dakota, small mammals were sampled throughout the state during the summer of 1998 based on the EMAP hexagon grid. Two sites were sampled within each hexagon to obtain presence or absence information for small mammals in that particular hexagon. To coordinate the trapping effort, an ARC/INFO Macro Language (AML) program was created to build county-based maps containing all county roads (primary roads were separated from secondary roads) and the hexagonal grid, including the hexagon number for reference. Towns could easily be identified from concentrations of roads.

In an effort to maintain locational databases of various terrestrial vertebrate species, SD-GAP and the South Dakota Department of Game, Fish and Parks (GF&P) have agreed to include the EMAP hexagonal grid in the next printing of the *Sportsman's Atlas* (Figure 1). This atlas is a guide to recreational public lands, including Waterfowl Production Areas (U.S. Fish and Wildlife Service ownership), Game Production Areas (South Dakota GF&P ownership), State Parks and Recreation Areas, Federal Recreation Areas, and Water Access Areas (federal- and state-owned). The atlas is a county-based guide, covering the entire state. Nearly 1,000 copies of the atlas could be produced specifically for managers. Atlases are printed as needed and can be purchased through South Dakota GF&P in Pierre, South Dakota.

The EMAP hexagonal grid will allow managers to report observed species to the SD-GAP office by hexagon number, reducing the amount of time needed to add new sightings to the locational database. This atlas will provide a cost-effective, efficient method for gathering information on vertebrate locations, increase awareness of the public about GAP, and solicit participation in the upkeep of the distributional database for future modeling and distribution mapping efforts.

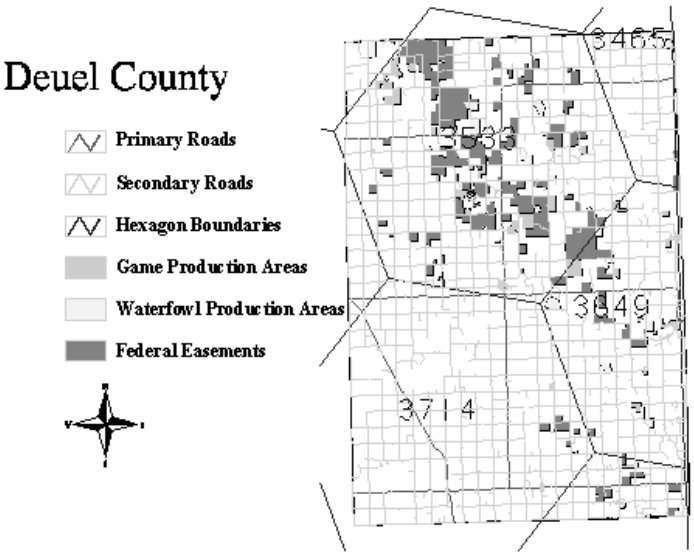

Figure 1. Sportsman's Atlas view of Deuel County in eastern South Dakota containing primary and secondary roads, hexagon boundaries, and state and federally owned lands.

For more information about the AML used to create the county-based hexagonal maps, please contact Vickie Smith at the SD-GAP office at (605) 688-5124 or by e-mail at vickie_smith@sdstate.edu. The AML may be downloaded from our FTP site at wfs.sdstate.edu. When you obtain the AML, feel free to make changes to the program to fit your state and your purposes. After making changes, please send updates to chad_kopplin@sdstate.edu.

STEWARDSHIP AND ANALYSIS

Kansas GAP: Preparing the Stewardship Layer

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With the objective of identifying gaps in biological diversity, the National Gap Analysis Program (GAP) maps managed areas, land cover, and vertebrate species distribution. The development of a spatial inventory of managed areas, collectively called the stewardship layer, is critical to meeting this objective. For the Kansas GAP project, the stewardship layer was developed using a Geographic Information System (GIS). This article outlines the process and some of the challenges in developing such an inventory in Kansas.

The development of the stewardship layer was begun by the Geographic Information System Spatial Analysis Laboratory (GISSAL) at Kansas State University in 1995. Creating a stewardship layer is a conceptually straightforward process consisting of essentially three basic steps (summarized from Crist 1998):

1) Identification of all managed areas
2) Acquisition and compilation of managed-area boundaries and subunits
3) Collection of attribute data

GISSAL researchers were able to initially identify 258 managed-area units in Kansas. Of these areas, 210 were both larger than the 40-acre minimum mapping unit (MMU) established by National GAP and had accessible and usable boundary information.

Identifying Managed Areas in Kansas

Multiple sources were consulted in order to create a comprehensive list of managed areas in Kansas. In addition to contributions made by Kansas GAP partners, phone books from the local library and the *Kansas Atlas and Gazetteer* were useful sources. An exhaustive Internet search completed our initial investigation.

Other sources of potential data include Digital Line Graphs (DLG) produced by the USGS at 1:100,000 scale and protected-area boundaries developed by the World Conservation Monitoring Centre (WCMC) in Cambridge, U.K. (Beardsley and Stoms 1993). The DLGs include administrative boundaries of national parks, forests, wilderness areas, and Native American reservations. The WCMC boundaries are being digitized into ARC/INFO and include worldwide protected areas at a MMU of 5,000 ha and at a scale of 1:1,000,000. These last two sources were not used in the Kansas GAP stewardship layer because of the availability of the Kansas National Heritage Inventory Program maps.

Acquisition and Compilation of Managed-Area Boundaries

One of the most comprehensive sources of managed-area data in Kansas was the Natural Heritage Inventory Program (NHIP) administered through the Kansas Biological Survey (KBS). This inventory became the core set of data from which much of the Kansas GAP stewardship layer was derived. The inventory contained owner and manager data, protection status designation, and 1:24,000 base maps of the managed areas.

The maps provided by NHIP were largely hand-drawn boundaries placed onto USGS 1:24,000 topographic maps and based on boundaries described either in map form or by legal description. The boundary maps were transferred to Mylar and scanned. The raster images were converted to vector form using Scorpion SRV-386 and AutoCAD software. After adding neatline and tic locations in AutoCAD, the files were converted into ARC/INFO coverages and mapjoined. Each coverage was then transformed and projected to a Universal Transverse Mercator (UTM) projection. This transformation allowed for the creation of the base set of managed-area boundaries for Kansas.

Once the initial coverage was created, the boundary areas were modified to reflect real-world boundaries. This was accomplished using 1:24,000 Digital Orthophoto Quarter Quads (DOQQs). DOQQs have a one-meter ground resolution and are useful for revising coverages generated from both Digital Line Graphs and topographic maps (DASC 1991). Used as a backcoverage, the orthophotos allowed the originally hand-copied boundaries to be adjusted to match the real-world roadways, fence lines, and water bodies that they were representing. The DOQQs greatly enhance the accuracy of the boundary information. Other researchers have used orthophotos for delimiting natural-area boundaries (Welch et al. 1995). Additional checks and improvements to boundary information are incorporated as more accurate information becomes available.

Collecting Attribute Data

The attribute data required by GAP include owner, manager, and protection status information. GISSAL has expanded these attributes to include a second owner category, county of location, and acreage per management status. The second owner category allows us to acknowledge areas that are co-owned such as the Konza Prairie Research Natural Area of which 89% is owned by The Nature Conservancy and 11% by Kansas State University (TNC 1998). The

county of location and acreage per management status variables allow us to categorize the managed areas by county or other management regions.

Collecting the attribute data is an ongoing challenge. The NHIP data set includes a protection status ranking and owner and manager information for most areas. For other areas, the information is often kept by individual managers and is not available from a centralized source. Collecting information entails contacting individual managers and translating management status categories used by the different agencies into the four GAP management categories. Coordination and communication are key aspects of accomplishing this task.

Finally, changes to management and protection status are often dynamic, and keeping tabs on changes is important. All changes affect the stewardship layer, and developing a procedure for maintaining the integrity of the database over time is a key element in establishing the GAP stewardship layer as a reliable resource.

Creative Problem Solving: A Few Examples

At each stage of the development process, challenges were encountered. In addition to the problems already discussed, two others warrant further attention. First, assessing map quality from different sources can be a significant obstacle. Most managed areas have some type of boundary delineation; however, it may vary from legal boundaries described in text to generalized, hand-drawn boundaries. Each source has its own set of problems. Kansas GAP has chosen to use only boundaries for which maps are available at the 1:24,000 scale and can be delimited on USGS topographic maps. This allows us to maintain a particular level of accuracy and reliability for the stewardship layer. The ability to rectify these boundaries to the 1:24,000 DOQQs also significantly improves our confidence in the data set.

A point coverage has been created for those areas for which acceptable maps are not available. This point coverage allows attribute data to be collected for these areas. Attribute data include the size of the area as well as ownership, management, and protection status information. GISSAL also offers agencies partnership opportunities to develop GIS databases for managed areas. KDWP, for example, has partnered with GISSAL to develop databases for wildlife refuges. Part of the development of these databases includes creating an accurate boundary layer. Both KDWP and Kansas GAP benefit from this endeavor.

A second significant challenge is maintaining an up-to-date database of attribute information. GISSAL is developing an Access database that includes key contact persons, managed-area information, dates of data acquisition, protection status by both KBS and GAP standards, and other pertinent information provided by GAP partners. In addition, all data can be related back to the stewardship coverage through ARC/INFO-generated managed-area id numbers. Converting the coverage to a shapefile allows the .dbf file to be opened in Excel. The attribute data can then be manipulated using either Excel or Access and reattached to the main stewardship coverage. The ability to move data seamlessly through these programs greatly enhances the potential uses of the stewardship coverage.

The above problems are representative of other challenges for which unique and creative solutions are necessary in order to complete and maintain a statewide stewardship layer. Kansas GAP is still developing its database of managed areas and seeking new ways to enhance the usability and reliability of the data.

Conclusion

Developing a comprehensive spatial database at the state level presents challenges for both spatial and tabular data acquisition and integration. This article outlined the basic process being utilized by Kansas GAP to develop a stewardship layer. Integrating the stewardship layer with land cover and species habitat models is the next step toward completing a spatial database and delimiting gaps in habitat protection.

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AQUATIC GAP

Status Report: The Missouri Aquatic GAP Pilot Project

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Over the last year, significant progress has been made on all of our major objectives. We are on schedule to complete our pilot project by the contract deadline of September 2001. This project is by far the most difficult but most rewarding project I have worked on. It has forced all of us working on this project to think outside the typical stream resource management "box," to educate ourselves in areas unfamiliar to most stream resource professionals, to put new meaning into the words "agency cooperation," and to overcome technical challenges that have opened the doors to a new age of aquatic resource conservation. Below is a brief update on the progress we have made on four major tasks of the project.

Defining and Mapping Assessment Units

Measures of species diversity must be expressed relative to biogeographic units of a determined spatial scale if they are to be meaningful (Levin 1981). We are currently working with The Nature Conservancy to generate a national map of biogeographic units that circumscribe relatively distinct freshwater communities. Empirical evidence has shown that both major drainages and ecoregions describe a significant amount of the variation in aquatic communities (Pflieger 1989; Angermeier and Winston 1999; Rabeni and Doisy, in press). Consequently, these biogeographic units will consist of major drainages (yet to be delineated) stratified by ecoregions (likely Bailey's Ecological Sections; Bailey 1995). We are assuming that these biogeographic units serve as "ecological and evolutionary units" with distinct genetic histories and thus serve as meaningful units for partitioning environmental, life history, and genetic variation in populations and species that have yet to be discovered through intense phylogenetic, life history, and habitat requirement research. This national map will hopefully serve as a standardized base coverage of freshwater assessment and planning units for the aquatic component of GAP, which can be refined by individual states through expert review.

To build this coverage we will be using a national fish database (and possibly other taxa) to calculate similarity coefficients for each pair of 4, 6, and/or 8-digit Hydrologic Units (HUs) and also to examine levels of endemism within each of these units. While trying to complete this same task for Missouri, we quickly realized that we needed to place our similarity coefficients in a broader context. For instance, using fish data alone, Jacaard similarity coefficients among the 66 8-digit HUs that cover Missouri ranged from around 0.2 to 1.0. Obviously, HUs that contain all of the same species (i.e., similarity coefficient = 1.0) should be combined into a single unit. However, what about HUs that have similarity coefficients of 0.9, 0.8, 0.7, or even 0.6? To answer this question we need to understand the range of similarities and the average similarity among HUs across the nation. This will allow us to generate statistical criteria for identifying HUs with relatively similar aquatic communities and ultimately produce a national coverage of major drainages that harbor relatively distinct communities. We will then intersect this "major drainage" coverage with the national coverage of Ecological Sections to generate a final coverage of freshwater biogeographic units.

We hope to have the national coverage completed by January 2001. However, before we can begin generating a national coverage of freshwater biogeographic units, the fish database has to go through an expert review, which could take six months or more.

Defining and Mapping Valley Segment Types

Valley segment types are distinct hydrogeomorphic units. Each valley segment type will be relatively homogeneous with respect to energy and nutrient dynamics, flow regime, physical habitat, and position within the drainage network. These valley segment types are the lotic counterparts of wetland types and are used in the same manner that the vegetation classes are used to carry out assessments in the terrestrial component of GAP. Our effort to classify stream networks into distinct valley segment types largely follows The Nature Conservancy's Aquatic Community Classification Framework (Lammert et al. 1997).

To date we have identified the list of classification variables that will be used to delineate valley segment types and have obtained the necessary digital data layers that will be used in the classification process. In December 1999 we finally worked out the many technical details of developing this data layer and have completed the classification process for two 8-digit HUs, the Meramec and Current River basins. It is truly exciting to see the end product of this classification process. The final digital maps provide us with a

view of these watersheds unlike anyone else has ever seen (Figure 1 - see Web version of Bulletin at http://www.gap.uidaho.edu/Bulletins/8); a continuous stream network broken down into distinct patches much like viewing a digital image of vegetation alliances for an entire ecoregion. We anticipate having a statewide 1:100,000 valley segment coverage completed in the next 12 months.

One major unresolved issue is that at the scale of 1:100,000, headwater valley segment types are grossly underrepresented. Currently, we are working with two 1:24,000 digital stream networks. While working with these higher-resolution networks, it has become apparent that there is no way to effectively deal with this problem except for actually developing the valley segment layer at 1:24,000 instead of the coarser 1:100,000. Unfortunately, 1:24,000 digital hydrography for Missouri will not be completed for another two years, and for most other states the waiting period will be even longer. The ramifications of this problem are that a) very unique headwater valley segment types will not even be identified, and b) very common headwater valley segment types will be identified as rare and underrepresented in our current network of conservation lands. At a scale of 1:100,000, the only way around these problems is to remain conscious of their existence and somehow factor this understanding into your conservation assessment.

Mapping Known Distributions

The community-sampling databases used in generating statewide known distributions are nearing completion. The fish, mussel, and crayfish databases have been populated, and each sampling location has been linked to the Environmental Protection Agency's River Reach Files. We also identified the ecological section, subsection, land type association, and the 8-, 11-, and 14-digit HUs in which each sample was located. This leaves the snail database as the only one yet to be completed.

The fish database contains 3,719 community fish samples that were collected from 2,484 different stream reaches for a total of 63,166 species occurrence records. The mussel database contains 1,156 community mussel samples that were collected from 814 different stream reaches for a total of 12,604 species occurrence records. The crayfish database contains 949 community crayfish samples that were collected from 793 different stream reaches for a total of 1,855 species occurrence records.

We are using the USGS/Natural Resources Conservation Service (NRCS) Hydrologic Units to generate our statewide distribution maps. To minimize errors of commission and omission we are specifically using 11-digit HUs for widely distributed species and the smaller 14-digit HUs for narrowly distributed species. We have finished developing the preliminary statewide distribution maps for each fish, mussel, and crayfish species (Figure 2 - see Web version of Bulletin at http://www.gap.uidaho.edu/Bulletins/8). These maps are then sent out for professional review. Professional review of the fish distribution maps has been completed, and we are currently incorporating the revisions into our sampling database and our final distribution maps. The mussel and crayfish maps are still out for professional review.

It appears that adequate statewide sampling data exist to generate detailed (i.e., using 11- or 14-digit HUs) statewide distribution maps for both fish and crayfish. Unfortunately, sampling data for mussels and snails are much more clumped, with numerous samples in certain 11-digit HUs and only a handful or no samples in others. Because of this clumped sampling distribution, it is likely that the final known distribution maps for most mussel and snail species will have to be represented at a coarser resolution (perhaps 8-digit HU).

Developing Habitat-Affinity Models

Our habitat-affinity models are used in conjunction with the valley segment coverage and the statewide known distributions to predict the potential species composition of each individual valley segment in the state. This is analogous to predicting all of the species likely to inhabit each grid cell in a statewide land cover data layer. A major difference is that we have no way of determining the environmental quality of every single valley segment. For instance, a valley segment could be of the right size, temperature, gradient, and flow for a particular species yet have serious water quality problems that make the environment unsuitable for that species. Consequently, our predictions reflect potential species composition under pristine conditions as with GAP's terrestrial vertebrate distributions.

To develop our models we are conducting extensive literature reviews to find habitat-affinity information for each fish, mussel, crayfish, and snail species found in Missouri (368 total species). We have completed the initial literature review for each species in all four taxonomic groups. More intensive reviews have been completed for both fish and mussels. We have also completed the first draft of the habitat-affinity database for fish.

In conducting the literature reviews, two major problems have been identified. First, there is simply a lack of habitat-affinity information for several species. This problem is most prevalent for mussels, crayfish, and snails but also exists for several nongame fish species. There is an obvious need for increased emphasis on, and funding for, basic life-history research of freshwater biota. The second problem is that much of the habitat-affinity information that does exist is at the "microhabitat" scale. That is, most research on the habitat requirements of aquatic species has identified the range of depths, velocities, and substrates utilized by a particular species. This would be analogous to research that documents if a bird species is primarily a ground-dwelling species or utilizes the lower, middle, or upper forest canopy without documenting the particular forest types it inhabits. Such microhabitat data are useful for predicting the distribution of an organism within a particular stream segment but not the actual stream segments it is likely to inhabit. What we need is substantially more habitat-affinity research at broader spatial scales that identifies associations between the presence of a species and factors such as stream size, temperature, elevation, permanence of flow, local and basinwide geology, soils,

and gradient.

For more detailed information on the Missouri Aquatic GAP Pilot Project contact:

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Landscape-Level Mapping of Fish for Pennsylvania Gap Analysis

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As many species living in streams and rivers of Pennsylvania are imperiled, our gap analysis commitment included a landscape-level consideration of fish fauna. Our primary concern has been to ascribe fish habitat to sectors of landscapes that are large enough to be evident in regional mapping but small enough to inform environmental and conservation analyses across landscapes. In light of exploratory work in New York and Missouri, we considered stream reaches to be inappropriately fine scale with respect to both mapping and effort. Other research work originally conducted for purposes of hydrology and fisheries provided a basis upon which to build habitat models at somewhat coarser scale for Pennsylvania.

Small watersheds constitute a next level of scale above stream reaches that can serve for purposes of landscape segmentation relevant to both hydrology and aquatic organisms. Small watersheds serve the purpose of associating aquatic habitat with portions of the landscape having most direct influence. Small watersheds also have the advantage of being mappable as area features rather than linear features, thus providing a tessellation. It has been fortuitous in Pennsylvania that the Water Resources Division of the U.S. Geological Survey undertook to digitize watersheds of all named streams within major river basins in the region. These data for the basins were integrated and harmonized in the Office for Remote Sensing of Earth Resources (ORSER) of the Environmental Resources Research Institute (ERRI) at Penn State University with funding provided by the Pennsylvania Department of Environmental Protection. Some further editing was required for purposes of gap analysis, mostly to resolve issues along the borders of the state. Our final version of this layer consists of 9,855 polygon units representing the respective small watersheds.

Geomorphology controls development of drainage networks and character of streams, with influence extending also to physical properties (e.g., turbidity) and chemical properties of water. In order to capture such differentiation of streams because of geomorphology, a layer of physiographic provinces and sections was overlaid to assign each small watershed as one of 16 physiographic sections. In Pennsylvania, these sections correspond to subregions of the interagency ECOMAP effort.

Drainage divides constitute zoogeographic barriers to movement of organisms that are wholly aquatic. The segregating effect of a drainage divide depends on the instream linkage and whether downstream or upstream passage would traverse inhospitable conditions for a particular species. Collection records in Pennsylvania establish that major drainage basins are effectively separate domains for at least some species. It was decided in this regard to recognize eight basin partitions: Erie, Allegheny, Ohio, Monongahela, Susquehanna, Delaware, Potomac, and Genesee. Accordingly, each small watershed was assigned one of these basin designations as an attribute.

Stream order can serve as a surrogate for stream size, which reflects macrohabitat for fish species. A special geographic information resource for Pennsylvania is a digital file of all blueline streams. This file originated with digitizing by the Pennsylvania Department of Transportation, but extensive editing and topological adjustment was performed by ORSER at Penn State University. The stream file was displayed over the small watersheds, and each watershed was interpretively assigned to one of four size classes. First-order (headwater) and second-order streams comprise a small-stream class. Third- and fourth-order streams comprise a medium-size class. Fifth- and sixth-order streams constitute a large-size class. Seventh- and eight-order streams are combined with lakes as the fourth size class.

A digital elevation model was used to calculate the median slope for each small watershed, with coding in three classes: low (<1%), medium (1% to 3%), and high (>3%). This variable serves to separate fish habitat along the longitudinal axis of a stream, as some fishes occupy streams of low gradient whereas others prefer higher gradients. Low-gradient streams typically have sand, silt, and clay substrates. High-gradient streams typically have cobble, boulder, and rock substrates. Medium-gradient streams often have a heterogeneous mix of substrate types.

A land cover layer was used to assign a human disturbance class for each small watershed. Human disturbance was considered to be nonforest area because of agriculture and/or development. Percentage of such area in a watershed determined its disturbance class as follows: low (<25%), medium (25% to 75%), and high (>75%). This variable provides an indication of microhabitat diversity as well as allowing for consideration of tolerance to human-induced landscape influences.

Each class for a variable was cast as a separate field (column) in a spreadsheet for habitat modeling. Models were developed as a profile for each species (row) in terms of these fields. Basin and physiographic fields were coded as either 1 or 0 for presence or absence, respectively. The size, gradient, and disturbance characteristics were designated in terms of primary habitat (1), secondary habitat (2), or unsuitable (0). Each fish species was categorized as to its highest frequency of occurrence for a given stream size, which was designated as primary habitat. If secondary habitat or stream sizes were determined, they were added to the profile as situations where the fish may occur but with lower frequency.

A large digital database of fish collection records for Pennsylvania was instrumental in developing and validating the profile models. An extra field was added for each of the small watersheds to indicate whether it had been sampled. Records from over 20,000 collection events from 1950 to 1999 were used in the analysis.

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

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Introduction

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

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

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

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

Life History of the Topeka Shiner

The ecology of the Topeka shiner is not well known. Oldest individuals are usually three years of age and have grown to about 7 cm long. Topeka shiners prey on benthic invertebrates and spawn over silt-free substrates in spring. A striking characteristic of the species is the bright reddish-orange coloration of the breeding male. In South Dakota, the shiner has been found in tributaries of the

James, Vermillion, and Big Sioux rivers east of the Missouri River (Figure 1). Topeka shiners also have been recorded from downstream portions of tributaries to the Missouri River (e.g., Grand River) in western South Dakota (Beckman and Elrod 1971).

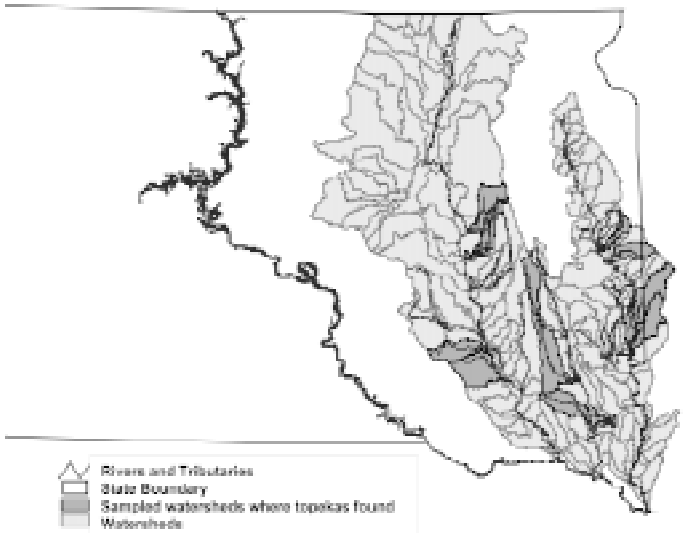

Figure 1. Watersheds where Topeka shiners were found during 1999 field season.

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

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

Methods and Progress

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

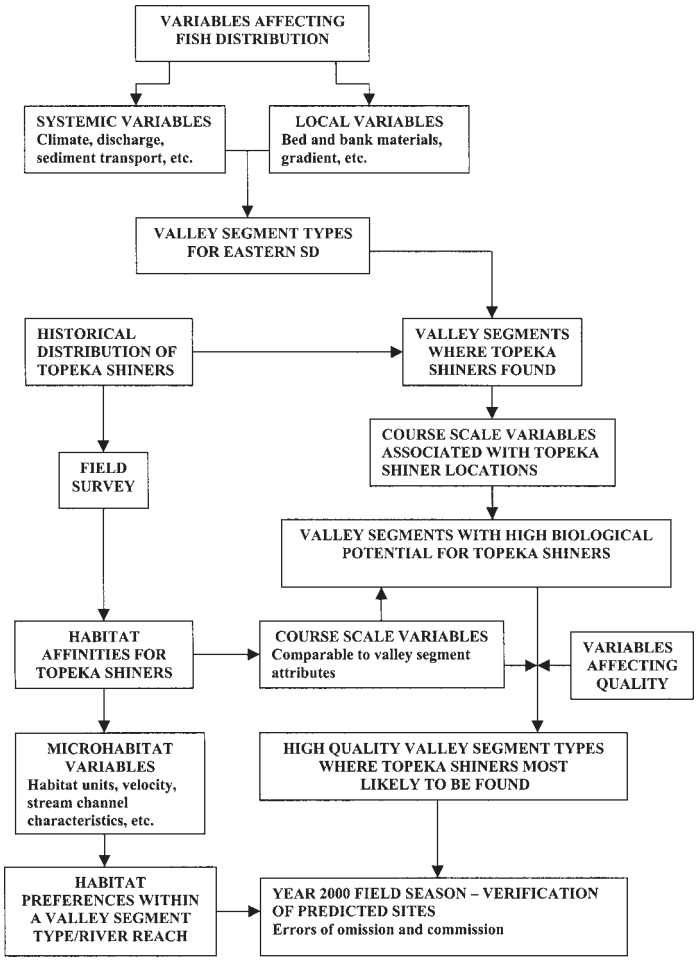

Figure 2. Diagram showing the methods to be used for modeling the distribution of Topeka shiners.

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

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

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

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

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

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

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

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

Future Plans

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

Conclusion

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

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

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Update on New York Aquatic GAP Pilot Project

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This is an update report on the pilot GIS project for aquatic systems that began in 1995 to define a methodology and determine the feasibility of predicting biodiversity distribution. Similar to gap analysis in terrestrial environments, gap analysis for aquatic systems uses remotely sensed data for habitat mapping, infers aquatic biodiversity distribution from habitat data, and provides large-scale information for targeting conservation measures. The pilot project has been a low-level effort (e.g., a one-person project) for four years. The aquatic GAP pilot project was developed in the Allegheny River, Fall Creek (1:100,000 scales), and French Creek (1:24,000 scale) watersheds of New York to study habitat classification in multiple locations throughout the state and at two spatial scales.

The basic aquatic GAP model predicts relative levels of fish and macroinvertebrate diversity and identifies stream reaches with high biodiversity without management or protection. This was accomplished by classifying stream segments into habitat types using five attributes: stream size, habitat quality, water quality, stream gradient, and riparian forest cover. Stream segments were then classified into one of eighteen habitat types for fish diversity prediction and one of eight habitat types for macroinvertebrate diversity prediction using the five attributes. The first round of habitat characterization (used 1995-1997) involved static, manually intensive classifications from topographic and Mylar land use overlay maps. In an effort to deviate from such limiting classification, we developed computerized macros to automate classification from digital elevation models, land use, road and railroad coverages (termed the automated method). This provided equal or better accuracy, increased flexibility, and enabled us to calibrate the model using previously collected data. Through extensive literature searches, fish species were associated with habitat types using information on preferences and tolerances for stream size, degree of habitat specialization, and tolerance to water pollution. Macroinvertebrate families were associated with habitat types using information on feeding guild, life habit, and tolerance to water pollution. Predictions of habitat types and associated fish species and macroinvertebrate family diversity levels were performed and gaps in protection located.

An additional method of habitat characterization (termed the calibrated method) was developed for fish diversity prediction using discriminant analysis. Five landscape attributes were added to those of the automated method: point source pollution, surficial geology, bedrock geology, depth to bedrock, and priority water status. Previously collected fish collections were used with all ten landscape attributes to statistically optimize the prediction of high fish diversity habitat on a stream segment basis. Species-specific optimizations for fish were also performed using the same methodology.

Standardized collections of habitat, fish, and macroinvertebrate data were performed at 39 stream sites in the Allegheny River watershed in the summer of 1998 for use in testing the predictions. The automated method succeeded at predicting stream size and stream gradient with accuracy, and our adaptation of the nonpoint-source pollution model was able to predict relative pollutant levels for total nitrogen but was less successful for total phosphorus, suspended sediment, and biological oxygen demand. Tests of predicted habitat quality and riparian forest cover indicated more than chance agreement with observed data. Significant correlation existed between predicted and observed fish diversity using both automated and calibrated methods in the Allegheny River watershed. Macroinvertebrate diversity predictions, only performed using automated methods, were also well correlated with observed diversity in the Allegheny River watershed. Predictions at the 1:100,000 scale in the Allegheny River watershed were uniformly higher in accuracy than those from the 1:24,000 scale in the French Creek watershed for both fish and macroinvertebrate diversity using both automated and calibrated methods. Species-specific optimizations for fish using calibrated methods revealed weak correlations with observed species occurrences, demonstrating a need for more refined methodologies for species-level predictions. It is clear that the community-level modeling procedures presented here have potential as coarse but feasible methods in identifying high-diversity habitats that should receive priority conservation attention at the watershed scale.

APPLICATIONS

Assessing Data Quality and Information Distribution Prospects for County Conservation Planning Using New Mexico Gap Analysis Data

A Report on GAP Research Project #14-45-0009-1572

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The New Mexico Gap Analysis Project (NM-GAP) was completed in December 1996. As one of the early projects to complete such data sets and analysis, we sought to evaluate the quality and utility of the resulting products, have staff available for consultation with other GAP projects and potential users, and investigate other possible uses of Gap Analysis products for conservation planning. Our objectives were to 1) assess data quality and accuracy patterns for 42 mapped land cover classes in existing digital map files, 2) provide digital files and cooperative assistance to edge-match 42 New Mexico land cover class assignments and predicted distributions for 584 New Mexico animal species relative to comparable information for Arizona, Colorado, Oklahoma, Texas, and Utah, and 3) analyze predicted distributions of 584 animal species relative to 36 classes of land stewardship, four classes of management status, and 33 county boundaries for public conservation planning applications.

Data Sharing and Edge-Matching

Early on, we contacted personnel from Gap Analysis projects in all states surrounding New Mexico. We provided technical contact information, made NM-GAP data sets available, and offered assistance in transfer and comparative analysis of mutual data sets. There was minimal response from the other projects. It appeared that those projects generally were not yet prepared to examine appreciable edge-matching questions during the time frame of our research. This remains an important communication challenge as GAP projects progress on staggered completion schedules. [Editor's note: The national GAP office continues to undertake regionalization of data. Products are available at http://www.gap.uidaho.edu/Projects.]

Data Quality Assessment

An initial assessment of the NM-GAP data set was prepared in outline form and sent to the people involved with the initial project. We also asked national GAP and the University of New Mexico Earth Data Analysis Center (EDAC) to comment on data quality. We did not receive substantive critical comments in response to these inquiries; so that document was the starting point for our database improvement. During our project, national GAP was producing NM-GAP data on CDs, but that process was independent of NM-GAP, and we were not directly involved in any digital modifications made during production. National GAP corrected some topological problems in the original vector coverages. Use of the data by others and us predictably identified some errors in the data. The most substantial was that our original coverages actually used the NAD27 datum rather than NAD83 as was reported to us by the university's Geography Department, our original partner in spatial analyses and data product development. Metadata were changed to reflect this error.

Accuracy assessment for the NM-GAP land cover map was adequate for directly describing overall quality of the map but was not adequate to identify sources of errors. We ignored spatial error during map assessment, but this probably caused problems with observers attempting to view polygons in the field because some boundaries were not distinct. We also discovered that there is substantial subjectivity to land cover designation. Different people assign different land cover types to the same parcel of land. This could be for several reasons, all unknown in magnitude and implications. Future use of the National Vegetation Classification System and mapping at finer resolution likely will ameliorate many of these problems.

The theory of development of the animal algorithm (expressing species distribution as a logical function of landscape attributes and being able to develop these relations with the advice of experts) seems to work. The execution of algorithms needs improvement. In particular, vector modeling should be abandoned. It should be

executed on one platform only, and ways to make it faster and more user-friendly should be explored.

Our review of data quality indicated a high degree of confidence in the herpetozoan and mammal distribution predictions but a lesser degree of confidence in the birds. We extensively reviewed the bird distributions (324 species year-round and 257 breeding species statewide) with two statewide experts and two graduate research assistants familiar with New Mexico birds. We focused on species for which there was consistency in suggested revisions among expert reviewers. Ultimately, we altered only 21 species' predictive algorithms (20 birds, one mammal). Most of the 21 species changes were in watersheds, not in habitat relations. The swift fox (*Vulpes velox*) algorithm was altered because of a misinterpretation of initial expert opinion that was not discovered until after the original NM-GAP report was filed.

We devoted particular attention to labeling of attributes in the stewardship map. Our original stewardship map was based on the Bureau of Land Management's Public Land Survey System (PLSS) map (1995) with additional polygons that we generated to represent special management tracts not contained in the original map. The attribute table was given to us without metadata, so it took a bit of detective work to discern that the fields indicated the original PLSS identification of landowner and management status, a description of the tract (polygon) if it was derived by our lab, and its final ownership and management status. National GAP examined the coverage for topological problems, and during this process we discovered a few corrupt polygons, some spurious quadrant boundaries, and a few polygons placed incorrectly outside the state boundary. We made the underlying vector map into two grids with the same topology as the land cover maps. In the future, the grid version should consist of one coverage that identifies the polygons as well as owner and management status.

Our stewardship coverage is useful for identifying broad categories of ownership, but specific tracts or complex land management agreements are difficult or impossible to identify. Utility of this coverage could be greatly enhanced if data structures allowed easy extraction of specific land tracts. For example, individual wilderness areas and wildlife refuges are not indicated by name or identifier in either the PLSS map or our modifications. Other difficulties exist as some tracts are subject to complicated agreements between agencies that cloud classifications to single land stewards. An example is a military installation variously composed of military land, other federal withdrawn land, and agreement or contract lands. Serious early planning is necessary to ensure such tracts are thoroughly understood and attributed properly in the GIS to extract desired land summaries later. Similar considerations apply to a variety of federal and state land holdings.

Land Cover and Animal Conservation Assessment

For the 18 most sensitive land cover classes on the New Mexico landscape, most have substantial percentages of their distribution on lands under U.S. Forest Service (USFS), Bureau of Land Management (BLM) , private, state trust, or tribal stewardship. Combinations of U.S. Forest Service, BLM, and private land stewards account for >60% of the occurrence of 16 of the 18 sensitive classes. For the sensitive wooded, higher-elevation land cover classes, USFS and private land stewards likely have the most opportunity to affect conservation of these types, whereas BLM, tribal, state trust, and private land stewards are more implicated in conservation opportunities for sensitive shrubland and grassland types. Sensitive riparian land cover classes overwhelmingly occur on private lands, with some types having appreciable occurrence on BLM and Bureau of Reclamation lands.

The 35 most sensitive vertebrate animal species, as defined by preliminary gap analysis practices, occur primarily on a combination of private, BLM, and state trust lands. The greatest percentage of occurrence is estimated to be under private land stewardship for 25 of the species and BLM for 10 species. The second greatest percentage of occurrence for 18 of the species is on state trust lands. Thus, a combination of private, BLM, and state trust lands appear implicated in appreciable conservation opportunities for these species. The frequency and extent of occurrence of the 35 most sensitive vertebrate species on refuges operated by the U.S. Fish and Wildlife Service currently are insufficient to meet conservation interests for any of the species. Of the 35 species, 15 are estimated to occur on refuges in New Mexico. Just seven species occur on more than one refuge, and none of those species has >1% of its distribution on a national refuge.

Extension to County Planners

Information on the ecological and land steward context for each county is needed to judge the merits of how conservation planning in individual counties may aid in providing benefits to the at-risk natural land cover classes and sensitive species. We provided two documents to county planners. The first, "A Proactive Approach to Conservation Planning: How New Mexico Counties Can Use Gap Analysis Project Data," provided the counties with: 1) basic information on the Gap Analysis Program; 2) factors to consider when using NM-GAP data; 3) examples of uses of GAP data at the county level; and 4) information on how to obtain NM-GAP data via the Internet and CD-ROM. The second document, "NM-GAP Data Needs Inquiry for County Planners," contained questions regarding the county's potential use of NM-GAP data. These questions related to: 1) the specific type of data the county would find most useful in its planning activities, 2) the county's interest in data for specific species or land cover classes, 3) the current mapping system used by the county (e.g., GIS program or hand-drawn maps), and 4) how NM-GAP data could be made easily available and useful to the county planning office given its technical capabilities and data needs.

We contacted 33 county planners or county officials responsible for planning. Eight counties scattered across the state responded to the data needs inquiry (Table 1). The response of county planners, while not showing enthusiastic interest in using NM-GAP data state-

Table 1. Summary of responses from eight New Mexico counties regarding prospective use of NM-GAP data products, summer 1998.

Needs Questions	County Response
What type of NM-GAP data would your county find most useful?	• Land cover, land use, hydrology, and man-made features. • Location of vertebrate species and land cover classes, and associations of animals with land cover classes. Particularly as these relate to land use or development applications and as they relate to sensitive, endangered, or at-risk species.
Would your county be interested in species-at-risk data?	• Yes, to analyze how development might impact these species and other natural resources. • Yes, to use for solid waste projects. • Would not use this information now unless required by federal or state law.
What specific species or land cover classes would be of interest to your county?	• Antelope and their native food habitat. • Grasses. • To be determined later. • In the future, will be interested in endangered species or species perceived as threatening to humans, livestock, or domestic animals. • Mule deer, prairie chicken, blue and bobwhite quail.
What mapping system is used by your county and who is responsible?	• ArcView and AutoCAD used in-house by GIS staff. • ArcInfo used by Utilities Department. • Fastmap 7000 used in-house. In the process of implementing GIS E911. • Hand-drawn maps used at present, but in 2-3 years will implement a GIS E911 system. • No computer mapping capability presently, but will work toward a county GIS system. • AutoCAD and hand-drawn maps. In the near future will have a GIS system.
How would your county prefer to access data?	• Internet and CD-ROM. • Paper maps now with the potential for future use of digital data.
Other comments.	• "I believe that natural resource assessment is the first step in good planning. I support the concept of this NM-GAP project."

wide, does show interest by selected counties with various technical capabilities. Those counties that expressed interest in using NM-GAP data particularly noted the need to integrate land cover and species data with land use and land development applications. Some counties in eastern New Mexico expressed an interest in using NM-GAP data whether or not they currently used a GIS mapping system. Those without GIS capability noted their interest in paper format data, with the possibility of using digital data in the future, when GIS systems were functional.

Considering the 33 New Mexico counties as conservation planning districts, just seven have >10% of their area in Status Class 1 and 2; 10 counties have greater than 90% of their area in Status Class 4. Of the other 16 counties, at least 11 have appreciable percentages of land in Status Class 3 that could be evaluated for opportunities to enhance conservation provisions sufficient to warrant reclassification to Status 2. Clearly such action would need to take the interests of individual land stewards into account.

We constructed an extensive set of tabulations to help county planning interests judge how their jurisdiction relates to land cover statewide, sensitive animal species, and land cover within Status Class 1 and 2. We identified the distribution of 42 land cover classes among counties that can be used to judge the relative degree to which a county can affect conservation of a specific class among counties as well as in relation to other land uses in the county. A tabulation of the percentage of habitat among counties for the 35 sensitive animal species allows county planners and others interested in county-level conservation planning to judge a county's possible contribution to conserving species habitat (e.g., Colfax County contains all of the habitat for the prairie vole *Microtus ochrogaster*, Grant County has nearly 45% of habitat for the Sonoran spotted whiptail *Cnemidophorus sonorae*). Another tabulation can extend planning further by examining the degree that various land cover classes (especially the most restricted ones) are already distributed on Status Class 1 and 2 lands in each county. All of the handily read tabulations allow for detailed understanding of how land cover classes, animal species, and stewardship can be accounted for in specific county-level conservation planning questions.

Implications

From our data review, we believe the following actions warrant attention in further work with the NM-GAP data and in the next generation of gap analysis in the Southwest.

- Specific attention is needed to derive an efficient process for managing animal algorithms, especially in attempts to consolidate predictive work among past project databases. We recommend against using vector-based processing.
- Greater specificity is needed in assigning and tracking stewardship categories. Simply compiling previous maps evolved for other purposes does not allow desired capability to extract the accurate boundaries of tracts or stewardship categories of interest.
- Critically examine how preclustering operations relate to assignment of land cover boundaries for recognizable natural features.
- Recognize how far in time and computing capability a county's planning functions are from effective use of GAP products. Similarly, recognize the opportunity that exists, at least in New Mexico, to work with counties in the formative stages of designing and delivering data products that they can immediately adapt to county-level planning operations.

Suggested Readings

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Incorporating Protection of Biodiversity into County Land Use Planning: A Gap Analysis Pilot Project in Pierce County, Washington

A Report on GAP Research Project #1434-HQ-97-RU-01583

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Background

Gap analysis is a process by which lands of high conservation priority are identified. The process uses land cover, wildlife/habitat relationship models, and other data to predict the distribution of wildlife species in a given geographic area. By overlaying land cover and vertebrate distributions onto land ownership, cover types and vertebrate species with poor representation on protected lands are identified. Gap analysis is designed to be a proactive approach to conservation, identifying important wildlife habitats or species before they become threatened by habitat degradation or loss.

A gap analysis of Washington State was recently completed by the Washington Gap Analysis Project (WA-GAP) (Cassidy et al. 1997). However, additional work is needed to make this process an effective tool for local land use planning. Although the data from WA-GAP have been summarized and analyzed at a statewide level, the analysis was conducted using ecoregions and vegetation zones, which are not easily applied to local land use planning and habitat conservation. Data must be significantly manipulated, analyzed, and reinterpreted before they can be applied to the local land use planning process.

The Department of Urban Design and Planning (UDP) at the University of Washington (through its Remote Sensing Applications Laboratory), in cooperation with WA-GAP, is conducting an ongoing program to develop procedures and materials supporting the application of WA-GAP data and methodology to local land use planning in Washington State. The intent of this work is to give local planners, elected officials, and the public the tools they need to incorporate biodiversity protection into their planning programs. The initial pilot project of the program took place in Spokane County in eastern Washington during 1997 and 1998 (Stevenson 1998, 1999; Westerlund 1998). UDP and WA-GAP identified Pierce County as an excellent location for a westside pilot project because of the county's broad range of habitat types and development densities, current conservation issues, and existing planning and GIS infrastructure. Funding and support for this project were provided by Pierce County, Washington State Department of Fish and Wildlife (WDFW), U.S. Fish and Wildlife Service, the USGS Biological Resources Division (National Gap Analysis Program and Cooperative Research Units), and the Rocky Mountain Elk Foundation.

Our Pierce County pilot project was conducted in collaboration with Pierce County and WDFW and was executed in two phases. The primary objective of Phase 1 (January - May 1999) was to review, validate, and augment the county's Open Space Implementation Committee's draft Open Space and Greenbelt Corridor Map by incorporating terrestrial biodiversity and salmonid habitat issues. The analysis and products of this phase were broad in scale and appropriate for policy-level decision making. The objectives of Phase 2 (May - December 1999) were to develop the open space and greenbelt system recommendations to a higher level of detail, present a methodology for establishing and implementing a priority system for habitat conservation and restoration, and prepare project documentation in both hard copy and digital formats.

The project team consisted of the authors and Kelly Cassidy and Karen Dvornich (WA-GAP and NatureMapping), Katherine Rose, Grant Griffin, Karen Trueman (Pierce County), and Michelle Tirhi (WDFW).

WA-GAP Conservation Priorities for Pierce County

The Puget Trough and Southwest Cascades ecoregions comprise the majority of Pierce County. The lowland vegetation zones of the Puget Trough ecoregion (Puget Sound Douglas Fir, Woodland/Prairie Mosaic, Willamette Valley, and Cowlitz River) were identified as among those with the highest priority for conservation in the state. These areas have been heavily converted to both agriculture and development. The remaining forests are now a patchwork of hardwood, mixed, and early-seral conifer forest. There are only a few small areas of moderate richness of at-risk species, because most at-risk species have been extirpated from these zones. A major priority of these zones is management of the handful of vertebrate species or subspecies that cannot "retreat" into less-impacted, higher-elevation vegetation zones.

The mid-elevation Western Hemlock vegetation zone (also found in both the Puget Trough and Southwest Cascades ecoregions) was identified as a moderately high priority for conservation. This zone has not been as severely impacted by development and agriculture as the lower elevation zones but has a low protection status and has seen extensive logging. Areas of high amphibian and mammal richness occur here, and the remaining mid- to late-seral forests support large numbers of at-risk amphibian, mammal, and bird species. Less than 10% of the zone remains in late-seral forest; an additional 20% is estimated to be mid-seral. This statewide perspective provided a framework for applying the WA-GAP data and methodology to local land use planning issues in Pierce County.

The Pierce County Project

Phase I - The objectives of Phase I were to: 1) update the WA-GAP land cover classification to a 1998 base line, 2) generate predicted species distributions for all breeding native vertebrates based on this classification, 3) identify lands in Pierce County of high conservation priority, and 4) develop a biodiversity network that included the lands identified in 3) and that complemented the Pierce County Open Space and Greenbelt Corridor Map. The study area for the pilot project included all of Pierce County plus adjacent lands within the watersheds partially contained in the county.

The original WA-GAP land cover map for the study area (based on 1991 Landsat TM imagery) was updated in a three-tier process. On-screen interpretation of unclassified 1998 Landsat TM data was used to determine large-scale land conversions resulting from human activities: new development, clearcut forests, and regenerated clearcuts. Existing county coverages facilitated interpretation. National Wetlands Inventory digital data were used to identify smaller wetlands missed during the original interpretation. The original WA-GAP classification scheme, which assigned primary, secondary, and tertiary land cover, was simplified to a single ("primary") classification. This process resulted in disaggregation of some large land cover units. The nominal minimum mapping unit for the updated classification was 40 hectares.

The predicted species distribution models (a series of AMLs developed by WA-GAP) overlaid species ranges on the land cover classification data and compared each within-range habitat polygon with the appropriate habitat matrix. The results were compiled in a data set indicating presence or absence for each species in the four taxonomic groups considered (mammals, birds, amphibians, and rep-

tiles). Presence was confined to habitat rated as "primary, core, and good quality" (Cassidy et al. 1997). This resulted in a conservative prediction of presence appropriate to the resolution available from the 30-meter resolution Landsat TM.

A value for richness for each taxonomic group (number of native species predicted to occur) was calculated for each habitat polygon. Habitat polygons with a richness value greater than one standard deviation above the mean for a taxonomic group were considered "rich" in subsequent analyses. An example of species distribution richness (in this case, mammals) is presented in Figure 1.

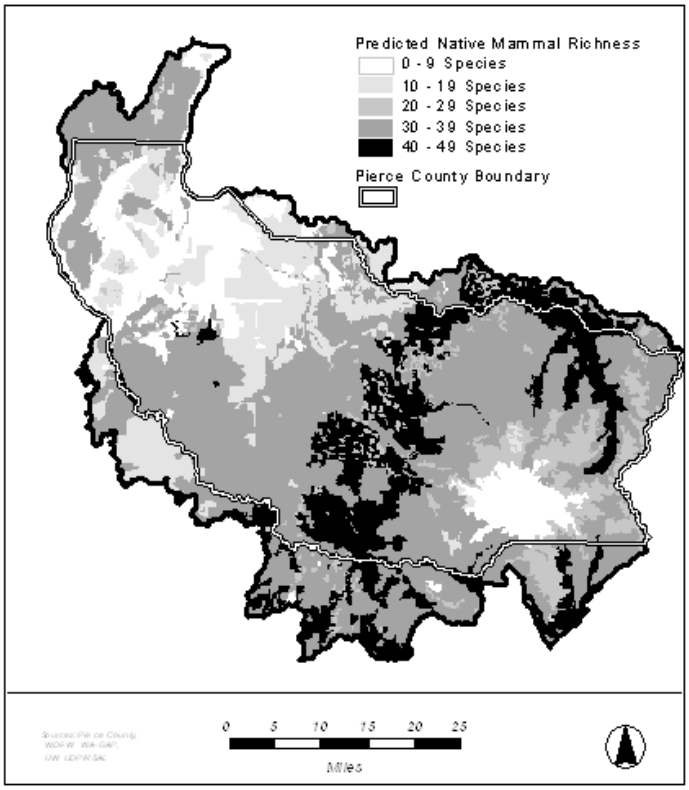

Figure 1. Predicted mammal species richness within study area.

The identification of lands important for biodiversity protection coupled the concept of richness described above with "representation." Our goal was to ensure that each species predicted to occur in the study area would be represented in a minimal set of habitat polygons. The minimal set of habitat polygons was selected through an interactive process (run as an AML) beginning with the richest land cover units and most frequently occurring species. Each iteration added a unique set of habitat polygons that provided habitat suitable for a unique set of species (e.g., mammals in Figure 2). As this process was conducted independently for each taxon, redundancy was anticipated to provide for more than the minimum selection for most species.

This representative set was examined, and areas excessively fragmented or isolated were trimmed from the set (where possible without compromising representation). The resultant set of land cover

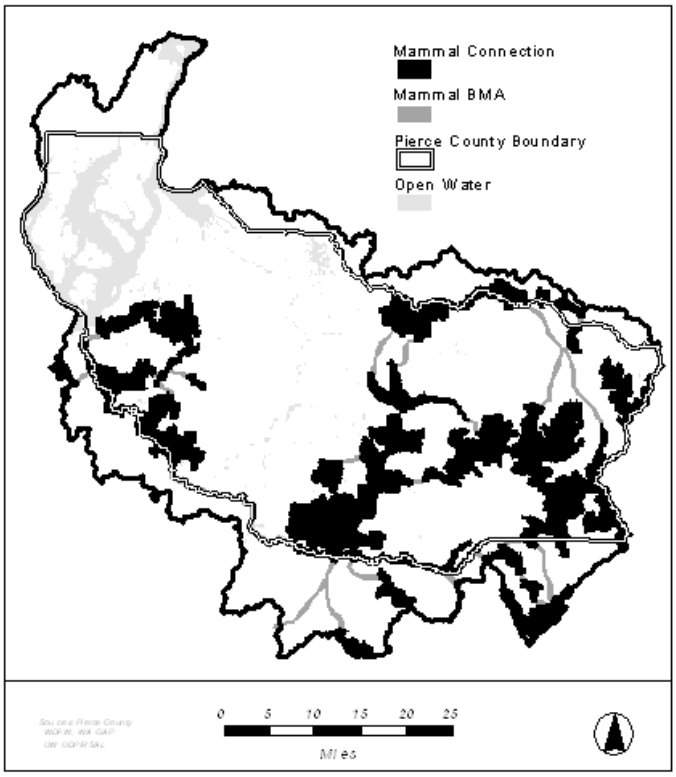

Figure 2. Core areas for mammal biodiversity protection.

units depicted the "core areas" whose preservation as functional habitat was considered essential to biodiversity protection within the study area for each taxon. Figure 3 depicts the resultant Biodiversity Management Areas (BMAs) for mammals. BMAs—the basic component of the proposed biodiversity management network—were generated by applying a 0.4 km buffer to the core areas. This buffer (based on recommendations from WDFW) was intended to isolate the core areas from adjacent land uses and possible impacts. Characterizations of the BMAs were compiled that identified the species predicted to occur (highlighting species identified by WA-GAP as being "at-risk") and the land cover types present. These characterizations were used in Phase II and will be used in future work by the county to develop land management plans and regulatory guidelines that will balance appropriate use of the areas and preservation of the essential habitat qualities.

The BMAs were integrated into a contiguous network using "connections" to provide movement corridors for large and/or migratory species and to avoid population isolation. Where possible, these connections were routed through areas of high richness. Areas of intense development (as interpreted from road and parcel data) were avoided. WDFW Priority Habitat and Species (PHS) data and the distributions of threatened salmon species were also considered (the final network contains 59% of the PHS observation points within the county). The connections were delineated independently for each taxon and then adjusted to take advantage of redundant alignments.

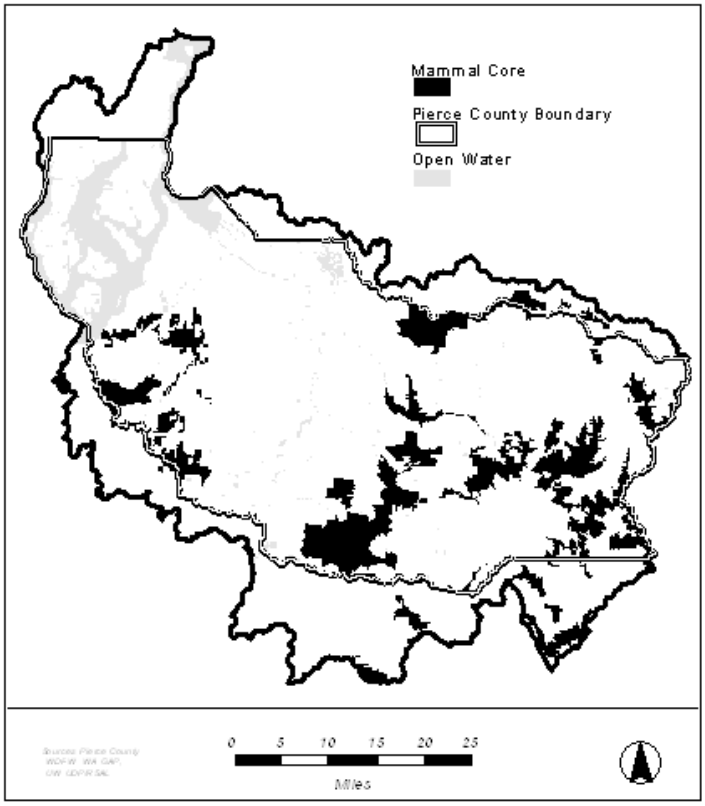

Figure 3. BMAs and connections for mammals.

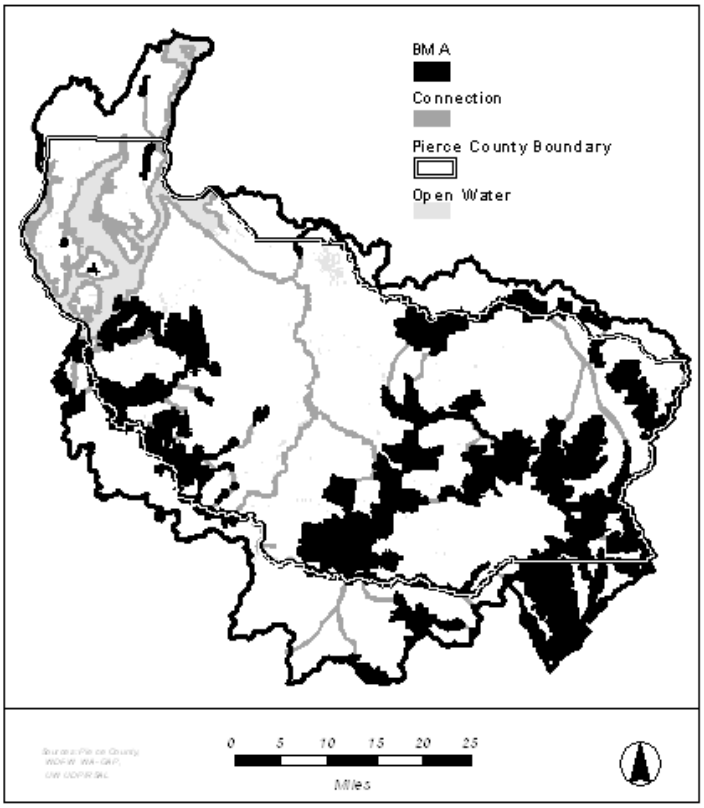

Figure 4. Biodiversity management network for Pierce County.

The final BMA network and connections (Figure 4) were reviewed by biologists (assembled by WDFW) familiar with the study area. This group verified the network and suggested additional areas for inclusion—habitats not considered by WA-GAP (e.g., critical wintering areas for some bird species) or dependent on features smaller than the resolution of the land cover data (e.g., snags for eagle nests). The additional areas were incorporated into the network as connections.

The network composed of Biodiversity Management Areas and connections was presented to the county as a recommendation for expansion of the proposed Open Space and Greenbelt Corridor Map under review. Forty-five percent of the network overlapped with the county's proposed map. The portion of the network within the county boundaries contains an area equal to 29% of the county. The network captured 60% of the remaining natural cover of the Woodland/Prairie Mosaic, rated as "highest conservation priority" by WA-GAP. Land stewardship status within the network is Status 1 and 2 (most protected) - 28%, Status 3 (extractive uses permitted) - 13%, and Status 4 (least protected) - 59%. In October 1999, the County Council adopted the revised Open Space and Greenbelt Corridor Map.

Phase 2 - In this phase of the project, we characterized the BMAs in terms of the species predicted to occur, conducted a preliminary species-viability analysis, examined opportunities to protect/enhance habitat on Status 4 (primarily private lands) using existing state and county regulations, and refined the boundaries of the BMAs within four case study areas representing varying amounts of urbanization and agriculture.

Characterizations (lists of species including salmonids and their status) were developed for each BMA to guide future specialized wildlife surveys to confirm species/habitat presence. Of particular interest were "trigger" species, the predicted presence of which governed the selection of a particular BMA during the representative set analysis (Phase 1). In addition, profiles (habitat needs and management considerations) were developed for each "at risk" wildlife and salmonid species predicted to occur within the BMAs.

The preliminary species-viability analysis was based on the acreage predicted to be available within the BMA network (excluding corridors) for each of the terrestrial vertebrates included in the pilot project. Following review by WDFW, University of Washington, and Project personnel, 11 species were identified as potentially not having sufficient acreage to maintain populations. Several of these species were identified as having only "peripheral" (as opposed to "core"; Cassidy et al. 1997) habitat in Pierce County, limited habitat remaining in the county (e.g., Woodland/Prairie Mosaic), being restricted to remote, highly protected areas outside the BMAs (e.g., Wolverine [*Gulo gulo*]), or species associated with aquatic habitats not adequately surveyed by WA-GAP or the state (e.g., River Otter

[*Lutra canadensis*]).

Redefining "Status 4" lands was important to the county, as nearly 60% of the BMA network was in private or military ownership. Our new classification divided Status 4 lands into 4-a (most highly protected), 4-b (moderately protected), 4-c (slightly protected), and Inconsequential (little or no effective protection provided) based on existing state and county regulations (Iolavera 1999). We then evaluated the existing state and county policies and regulations for habitat protection as they pertained to the redefinition of Status 4 lands. These included provisions of the Washington Growth Management Act, Shoreline Management Act, and State Environmental Policy Act; elements of the Pierce County Comprehensive Plan related to open space, shorelines, wetlands, and wildlife conservation areas; and local regulatory and incentive tools including zoning, impact fees, conservation easements, and vegetation protection ordinances. Recommendations were made for revisions and additions to these policies and regulations to enhance biodiversity protection (Iolavera 1999).

The last component of Phase 2 was to demonstrate to the county how one could refine BMA boundaries based on a higher-resolution analysis of land cover within portions of four BMAs. This is an important step in moving toward acquisition of lands for open space or the implementation of open-space designation mechanisms. We used 1991 orthorectified photographs, a 1998 high-resolution land cover classification, a restricted zoning overlay, and WDFW PHS data to primarily eliminate areas along the original boundaries of the BMAs where urban development or other land uses not compatible with habitat existed that were not visible at the resolution used in Phase 1. Similar land uses within the BMA study areas were not removed if they were surrounded by largely high-quality, unfragmented vegetative cover. These refinements resulted in reductions of 3, 14, 19, and 61% of the original size of the four BMAs within the study areas (see Figure 5). In the case of the 61% reduction between Phase 1 and 2, the area removed largely represented the 0.4 km buffer that was drawn around the core habitat in the most highly developed BMA. This suggests that, in some cases, attempts to designate buffers may require more educational outreach to private landowners than actual open space acquisition.

Copies of the Pierce County report and CD are available for purchase from the Washington Cooperative Fish and Wildlife Research Unit (206-543-6475).

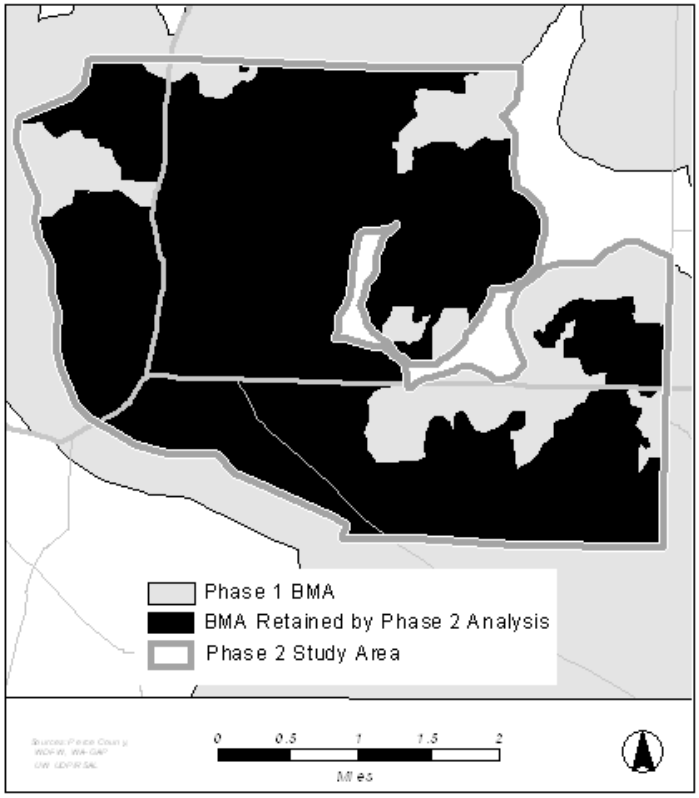

Figure 5. Phase 2 refinement of boundaries of BMA within Tanwax study area.

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Designing Regional Conservation Portfolios: Filling the Gaps

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Problem Statement

Gap analysis identifies the current level of representation of land cover types and vertebrate species in designated biodiversity management areas. That is, it helps define the identity and magnitude of the gaps. The next step is to work toward filling the gaps, which typically includes identifying a network of nature reserves. Reserve network design is a hard problem, however, because the number of conservation elements and planning units is large (typically hundreds of elements and hundreds to thousands of sites). Over the past 15 years researchers have developed computer-based approaches to make the reserve selection process more systematic and explicit. These approaches respond to the perceived need for reserve siting to be as efficient or cost-effective as possible, given the competing social and economic demands for land and resources. They also address the concern that reserve system design should be repeatable, so that the reserve systems can be readily reevaluated and modified over time as conditions change and new information is acquired. These approaches assist planners in sorting through the large volume of data to identify good initial solutions to this "hard and wicked" problem. However, at present these models remain primarily research tools, beyond the reach of most agencies and nongovernmental organizations that plan and implement reserve networks.

Recently, The Nature Conservancy (TNC) began a new planning initiative with the aim of developing "portfolios" of conservation sites for each ecoregion in the U.S., the Caribbean, and Latin America that collectively conserve viable examples of all native species and plant communities. Both the use of ecologically defined planning regions and the adoption of biotic representation as an explicit conservation objective posed many new institutional, scientific, and technical challenges to TNC, which historically has operated on a state-by-state basis and has focused on rare and threatened species and plant communities.

Based on discussions with various TNC staff involved with ecoregional planning efforts, none of the existing reserve selection approaches, in their current form, was well-suited to TNC's planning needs. From TNC's perspective, the major limitations of current tools fall into three general categories:

1. those that require high-end computing power, specialized software, and/or a high level of technical GIS expertise;
2. those with insufficient documentation and/or inadequate testing of computer code; or
3. those with overly simplistic decision rules (e.g., "greedy" or rarity-based heuristics).

In 1998, TNC funded a team of investigators (Frank Davis, Sandy Andelman, and David Stoms) at the University of California-Santa Barbara to:

- Develop a conservation siting model for regional conservation analysis that explicitly incorporates spatial design criteria into the portfolio design process.
- Test and apply the new modeling approach in a structured decision process involving local TNC staff to develop hypothetical conservation portfolios in two different ecoregions.
- Produce a training manual, including worked examples using TNC data and ecoregions, and train TNC staff in applying the regional conservation-planning tools.

The result is a "toolbox" that can solve ecoregion-sized planning problems on a Windows-based personal computer. The heart of the toolbox is a portfolio design model, written by Ian Ball and Hugh Possingham from the University of Adelaide in Australia. This software, based on a simulated annealing algorithm, has been integrated with a GIS (ArcView) interface for visualizing potential portfolios and allocating sites prior to running the model. The model has already been applied in two TNC ecoregions—the Idaho Batholith and the Northern Sierra Nevada. GAP data were used in both cases to set some of the representation goals. In addition, the model provides options for influencing the spatial configuration of an alternative portfolio. The toolbox makes it relatively easy for TNC staff to explore a range of alternatives and identify the effects of their choices in representation goals, assumptions about costs, importance of spatial clustering of selected sites, and so on. A planning team must still review the initial solutions and modify them using local knowledge, judgment, and other evidence not considered in the modeling approach.

The Toolbox

Ecoregional planning entails identifying a set of sites that collectively capture viable examples of all native species and communities from among a larger set of "planning units" within the ecoregion. The first step in applying the toolbox is to determine which conservation elements, such as cover types, are to be represented in the portfolio and at what level of representation. It is also possible to weight some elements as more important than others. Representa-

tion goals can be the specified number of population occurrences of a species or total area of a land cover type that must be included in the regional portfolio to fill the gaps.

The second step is to delineate and characterize the set of planning units in an ecoregion. There is no simple answer to what are the right spatial units to use as planning units. It is a complicated question, influenced by the size of the ecoregion, the primary ecological processes, data sources and resolution, and political issues. We have frequently used watersheds, at various hierarchical divisions, as planning units. Whatever the choice of units, data must be compiled about several variables for each unit. Data are required for the composition of cover types (such as GAP data) or other biodiversity elements and are optional for costs, length of the boundaries of planning units, and preallocations of a starting portfolio (sites required to be in or out of the portfolio). The compositional information is used by the toolbox to determine each planning unit's potential contribution toward meeting the representation goals. The cost and boundary information is used in minimizing portfolio cost and in controlling spatial clustering of the portfolio sites. Costs can be a function of area or any other units you like.

Defining the starting portfolio is an important consideration, and generally planners will want to consider several alternatives. For example, they may consider an alternative that starts by fixing existing national parks and other formally designated reserves. Element occurrences in these areas will automatically be counted towards meeting the representation goals. A different alternative would be to create a portfolio without assuming any starting reserves or to consider existing public reserves plus other planning units that are known to have significant biological resources and that planners want to make sure are included in the final portfolio. This step can be done with a word processor or through the ArcView selection tools. In each alternative the toolbox will then fill any remaining gaps.

The model seeks to minimize Total Portfolio Cost as measured by a weighted sum of actual cost (or area) of the selected set of sites, a penalty for not meeting representation goals for elements, and a measure of spatial compactness and connectivity. The actual solutions depend on how site cost is measured, on the target levels and the penalty cost for each element (these are set separately for each element), and on how heavily one weights spatial contiguity as an additional cost factor. The selection procedure uses an iterative method known as simulated annealing. The model selects a set of planning units at random and then randomly evaluates the effect of adding or deleting randomly selected planning units. After a very large number of iterations, the model converges towards a good solution. It does not guarantee to find an "optimal" solution. Typically the model is run multiple times, with a different initial random solution, and saves the best solution of those multiple runs. Another useful feature is to tally the total number of times each planning unit was selected in a series of runs, which suggests which units tend to be part of most efficient alternatives.

The graphical user interface is built on the ArcView software but has been customized for the toolbox. All actions, except for preparing the data input files, are handled through menus, buttons, or regular ArcView functionality. The reserve selection software produces output to files that can be displayed as maps, charts, or tables within the toolbox. The most basic output is the set of planning units selected for a given alternative. This can be displayed as a theme in the ArcView project, either as the best solution from multiple runs or as the total number of times each planning unit was selected in a series of runs. The summary information from a series of runs can be viewed as a table, allowing comparison of the costs, number of planning units selected, total boundary length, and the number of conservation elements that fell short of their target levels. The distribution of individual elements can be displayed in relation to an alternative portfolio to show the spatial pattern of representation for that element. Conversely, the composition of individual planning units can be examined (Figure 1) to see what they contributed (or might contribute if preallocated) to the representation goals.

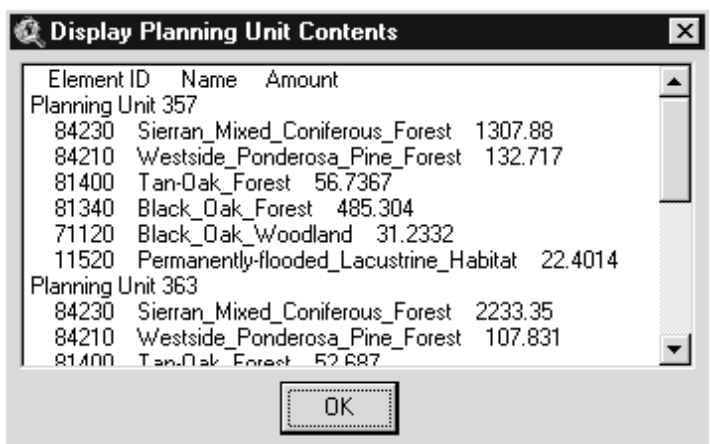

Figure 1. A tabular display of the biodiversity elements and their aerial extent in a selected planning unit.

The series of three maps below (Figure 2) shows the effect of adjusting a model parameter (BLM) on the amount of spatial contiguity, while representation goals and other parameters are kept the same. The model tries to minimize the outer perimeter length of the set of clusters of planning units. For a given total area, this is accomplished by aggregating planning units into larger, more compact clusters. The upper left map has no clustering enforced; any apparent clustering is the result of the composition of the planning units and the representation goals. The upper right and lower maps have increasing clustering enforced by increasing the value of BLM.

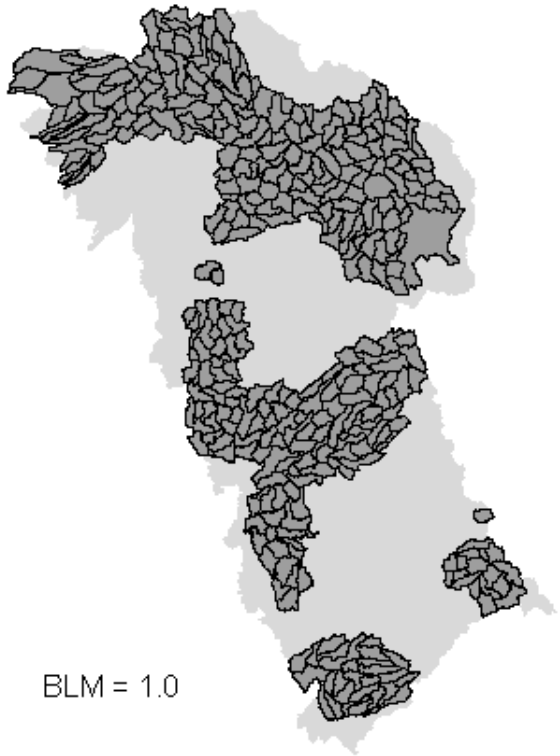

Figure 2. Maps depicting the effect of the model parameter that controls the degree of spatial clustering of selected units.

Product Availability

The software has been given to TNC and has been used in two ecoregions to date. TNC staff have been trained in the use of the toolbox so that they can train other TNC planning teams. Several other nongovernmental organizations and some governmental agencies have also shown interest. Further details about the toolbox are available at http://www.biogeog.ucsb.edu/projects/tnc/toolbox.html.

Landscape Diversity as the Basis for a Reserve Design Initiative in Vermont

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Introduction

The Vermont Biodiversity Project has been conducted hand-in-hand with the Vermont/New Hampshire Gap Analysis Project but at finer resolution and with an objective of using measures of landscape diversity as indicators of community and species diversity. There is ample rationale in the published literature for this approach. One line of support comes from evidence that biological diversity is predicted well by physical diversity, and that this relationship holds at various scales (e.g., Lapin and Barnes 1995, Burnett et al. 1998, Nichols et al. 1998). Another argument for physical diversity is that land conservation efforts should consider temporal scales that acknowledge shifts in ranges of species and communities in response to ecosystem processes and changes in climate (Hunter et al. 1988, Hunter 1991).

In the Vermont Biodiversity Project, our goal was representation. We sought to delineate a system of potential reserves that included all elements of landscape diversity. We began with an analysis of biological (tree species) and physical data (climate, geology) that led to the delineation of seven biophysical regions in the state. Within each region we then employed a methodology that assured representation by most or all elements of physical diversity.

We were constrained by the need to use data that were available for the entire state. Soils or ecological land types would have been ideal, but neither has been mapped statewide. The only consistent sources of data were digital elevation models (DEMs), bedrock geology, surficial geology, hydrography, and wetlands. From these spatial data, we derived Landscape Diversity Units (LDUs) and sampled for richness and representation.

Landscape Diversity Units

The most significant component of landscape diversity was the derivation of landforms (Fels and Matson 1997). Using 30-meter DEM data, we first derived five slope classes. We then calculated a landscape position index (LPI) for each DEM point using a focal function. This function assigns to each cell the mean of the distance-weighted differences in elevation between that point and all other elevation points within a specified radius. The LPI was "calibrated" for each region and divided into discrete classes that described recognized landforms. A matrix of slope classes by LPI classes produced 14 landform descriptions that could be mapped. Then we added four other categories from existing data, one for wetlands and three for classes of surface waters, for a total of 18 landform labels.

Also from DEM data, we defined five elevation zones with recognized links to the distribution of forest types in Vermont. Additional data came from digital maps of bedrock geology (1:250,000) and surficial geology (1:62,500). In both cases, we developed an ecologically-based crosswalk that reduced the number of classes to nine bedrock categories and eight surficial units. The final step was to overlay these four GIS coverages and to label each pixel of a 30-meter by 30-meter grid with codes for landform, elevation zone, bedrock type, and surficial class. This code—a product of four descriptors of the landscape—is referred to as a Landscape Diversity Unit (LDU). Although there are several thousand potential LDU labels, there were only several hundred actual labels in each biophysical region. The mean size for LDUs was 3.9 ha; the range was from 0.09 ha to 1,957 ha. The smallest size represented single cells that were anomalies of GIS overlays and were filtered from the database.

Representative Landscapes

We used grids of hexagonal cells to sample LDUs in each biophysical region. Each sample cell represented 5% of the area of the region, a decision based on a suggested minimum size for a functional reserve. Grid cells were custom-built for each biophysical region and were shaped to best approximate configuration of the region; they ranged from 26,000 to 60,000 ha among the regions. We used an algorithm based on richness and complementarity to select a set of hexcells that most efficiently represented landscape diversity. The first cell selected was the richest, followed by five more cells that represented the best complements, such that the six cells selected gave the most efficient representation of LDUs (Figure 1). The decision to stop at six sample cells was again related to practicalities of reserve design; here the rule was based on the notion that it would not be realistic to identify more than 30% (six cells) of the landscape as potential reserve.

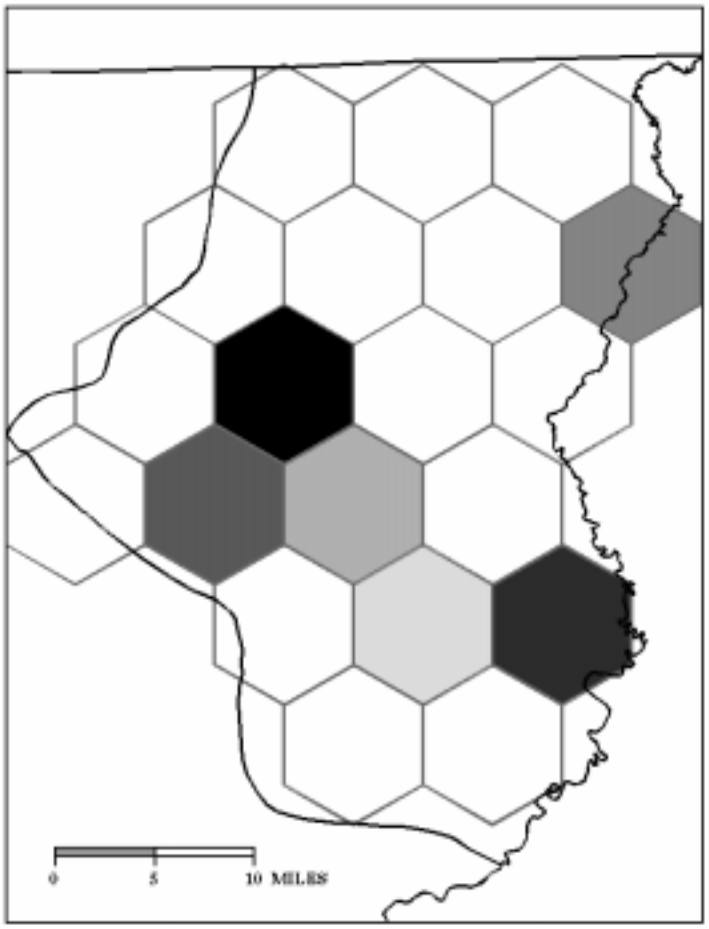

Figure 1. Six grid cells in Northeastern Highlands, Vermont, sampled to maximize richness of landscape diversity units. In this example, 477 of 586 LDUs are represented.

Figure 2. Representative landscapes of Vermont.

Hex grids overlapped boundaries of biophysical regions, so some cells were effectively smaller than others. We compensated for this by shifting the sample grid twice; thus we derived three solutions of complementary sets of cells for each region. We resolved these different solutions–and imposed a reality check on the results–by producing transparent overlays of cells selected in different runs of the algorithm and aligning these with paper maps of each of the layers comprising LDUs. That is, we sequentially overlaid different efficient hexcell solutions with maps of landforms, bedrock, surficial materials, and elevation zones. At each stage, we manually outlined polygons of significant features on these map layers; these were later digitized on screen and smoothed along boundaries of landscape features. We refer to these polygons as Representative Landscapes (RLs; Figure 2).

RLs were quite efficient in accounting for the diversity of physical features in each of the seven biophysical regions. By drawing landscape-based polygons rather than maintaining sample hexcells, we selected from 17 to 26% of each region rather than the 30% represented by six sample cells. When results from the seven regions were combined, 22% of the area of the state was featured as RLs. This area accounted for 89% of LDU richness and 95% of proportional representativeness, or similarity. By comparison, a random sample of 22% of the state, using hexcells sized as the average of RLs, accounted for only 77% of LDU richness. Fifty percent of the state would have to be sampled randomly to equal the LDU richness captured in our RLs.

Biological Representation and Applications

We have not yet been able to compare results of our landscape diversity analysis to the distributions of vertebrate species predicted by Gap Analysis and assess the degree to which physical diversity predicts diversity of vertebrate habitat. However, we have done a biological assessment using an extensive collection of atlas data on a number of plant and animal taxa. Although many of these atlas surveys were incomplete or showed sampling biases, we were able

to compare statewide records for 1,617 species referenced to the 251 towns in Vermont. Eighty-three percent of the species were represented by records that corresponded with representative landscape polygons; we captured only 76% of the species records by random samples of an equivalent area.

We believe that there are a number of ways that analyses of physical diversity such as we have described might be useful in Gap Analysis. In the eastern United States, where land cover is often shaped more by historical land use than by natural processes, landforms—as we have derived them—might serve as better predictors of habitat diversity than maps of land cover derived from Landsat imagery. Furthermore, landforms can be used as a means of enhancing interpretation of such imagery or used in combination with land cover maps to predict the location and extent of natural communities. Some preliminary efforts at such predictions of natural communities in New Hampshire have been promising (M. Anderson, TNC, Boston, personal communication).

We hope this note will encourage others to further investigate the use of physical diversity as a means of representing biological diversity. Given the dearth of information on the distribution of species and communities, the uncertainty of making predictions of these distributions, and the importance of considering long-term processes in the establishment of nature reserves, landscape diversity may be a cost-effective means for planning conservation of biological diversity.

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Digital Atlas of Idaho: A GIS Approach to Teaching Natural History

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Several products from the Gap Analysis Program are being used in a new education project called the Digital Atlas of Idaho. The primary goal of the Digital Atlas of Idaho is to integrate data from geology and biology to help Idaho students and educators learn about natural history using information specific to Idaho. This project was funded by an Idaho State Board of Education (SBOE) Technology Incentive Grant and is a joint venture between Idaho State University (ISU), Boise State University, the Idaho Geological Survey, the Idaho Museum of Natural History, and the U.S. Forest Service. In this document, we describe the Digital Atlas of Idaho and how Gap Analysis products have been used in its development.

The Digital Atlas of Idaho makes large amounts of spatial and natural history information about Idaho readily available in a Web-based form. Students and teachers will have access to the atlas through Web browsers such as Netscape Communicator and Internet Explorer, making the atlas compatible with Windows, Mac, and UNIX operating systems. A beta version of the Digital Atlas of Idaho is already viewable at http://imnh.isu.edu/digitalatlas. We are also providing the atlas on a CD-ROM to teachers, free of charge, so they can use the atlas in the classroom without an Internet connection.

Containing information about geology, biology, hydrology, climatology, and historical geography, this teaching resource is probably the single most comprehensive guide to Idaho's natural history. In the biology section of the atlas (Figure 1), species accounts are provided for over 400 species of animals in Idaho, including butterflies, amphibians, reptiles, birds, and mammals. Each account contains information about a species' range, predicted distribution, habitat, diet, ecology, reproduction, and conservation status.

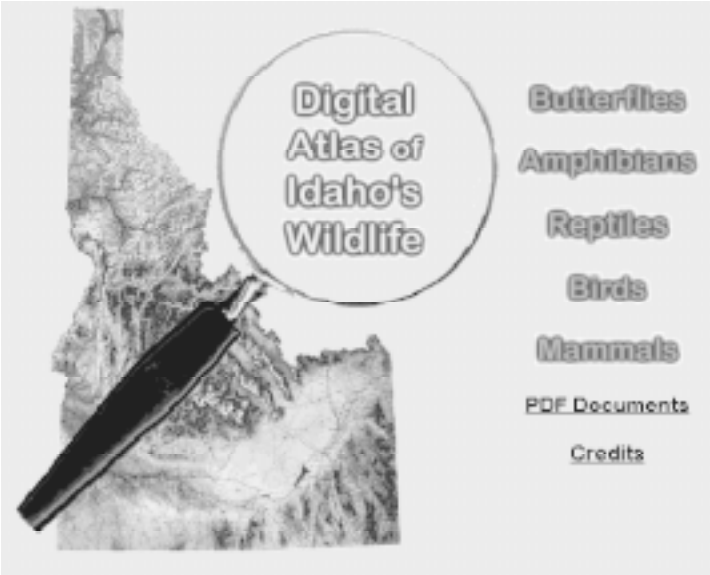


Figure 1. The biology section of the Digital Atlas of Idaho.

The vertebrate information used in the biology section of the Digital Atlas of Idaho is based on the *Atlas of Idaho's Wildlife* (Groves et al. 1997), a compilation of species accounts for the breeding fauna of Idaho that integrates Idaho Gap Analysis and Natural Heritage Program information. For the amphibian, reptile, and bird species accounts, we have added descriptive information and multimedia features, such as colored pictures and sounds (Figure 2). The predicted distributions for all of the vertebrates are currently taken from the first generation of Gap Analysis maps. In the future, we will include the second-generation predicted distribution maps from Gap Analysis. In addition, we have included the *Atlas of Idaho's Wildlife* (Groves et al. 1997) as an Adobe Portable Document File (PDF).

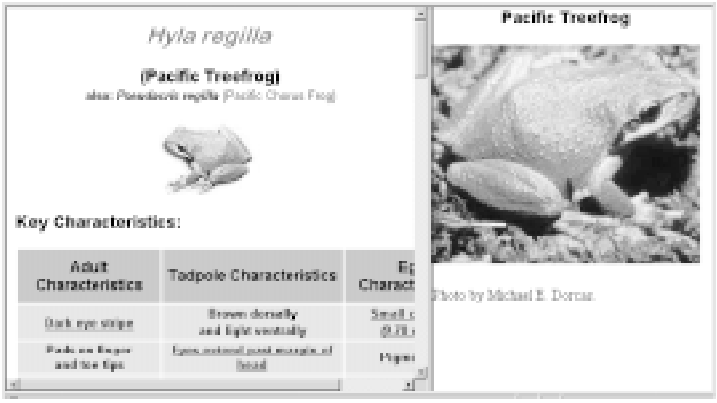


Figure 2. An example of a species account in the Digital Atlas of Idaho.

The Digital Atlas of Idaho greatly benefitted from Idaho and National Gap Analysis Program grants to the ISU Herpetology Laboratory to test and refine the Idaho Gap Analysis models for amphibians and reptiles. This funding supported the compilation of both museum specimens and observational databases used in creating the second-generation GAP models for amphibians and reptiles. Furthermore, these databases have made it possible for us to add dot-distribution maps to the predicted distribution maps in the atlas.

The Digital Atlas of Idaho also integrates spatial data, so students and educators can understand the spatial relationships between geological and biological phenomena. Much of the spatial data used in the biology section of the Digital Atlas of Idaho have been obtained from the Idaho Gap Analysis Project. Spatial data sets integrated in the atlas include cover type, ownership, and predicted species distributions. These GIS data sets, as well as others dealing with geography, surface and subsurface geology, seismic activity, and hydrology, will be linked using teaching exercises and software resources such as CADViewer, ArcExplorer, and ArcView.

The teaching exercises found on the Digital Atlas of Idaho are designed to be flexible to fit the needs of educators and to be useful for students at various levels. Students can access the spatial information by two different routes. The first route is through teaching exercises using a CADViewer plug-in that provides basic GIS functions, such as zooming, panning, and turning data layers on and off. The combination of teaching exercises using CADViewer and a GIS primer module introduces students to the fundamentals of GIS. The second route is through teaching modules that allow students to use actual GIS software such as ArcExplorer or ArcView.

The teaching exercises for the biology section of the Digital Atlas of Idaho are designed to direct students to explore questions about the spatial arrangement and ecological relationships of species in Idaho. The basis for most of these activities is the Gap Analysis predictive distribution maps for vertebrates. We have included activities such as listing potential species occurring in a given area, compiling habitat matrices for selected species, and examining factors affecting species distributions. We envision the number of exercises growing as teachers begin using them in the classroom and create activities of their own.

In 1999, we received a second SBOE Technology Incentive Grant to expand the contents of the Digital Atlas of Idaho. For the biology section, we will be using this funding to update species accounts for mammals by adding images and descriptions. We will also add species accounts for dragonflies, damselflies, and fish. Finally, we intend to include the cover-type map developed for the Idaho Gap Analysis Project and species accounts for the dominant plant species.

Many people have collaborated in developing the vertebrate biology portion of the Digital Atlas of Idaho, including John Cossel, Jr., Ean Harker, Jason Karl, and Mike Legler. Nancy Wright and Mike Scott helped by providing data from the Idaho Gap Analysis Project.

For further information, please visit the Digital Atlas of Idaho Web site (http://imnh.isu.edu/digitalatlas) or contact Stephen Burton at burtstep@isu.edu or Chuck Peterson at petechar@isu.edu.

Literature Cited

Groves, C.R., B. Butterfield, A. Lippincott, B. Csuti, and J.M. Scott. 1997. Atlas of Idaho's wildlife: Integrating Gap Analysis and Natural Heritage information. Idaho Department of Fish and Game, Nongame Endangered Wildlife Program. 372 pp.

A Gap Analysis of the Lewis & Clark Trail: Fort Peck Dam to Great Falls, Montana

PATRICK CRIST AND MICHAEL JENNINGS
National Gap Analysis Program, Moscow, Idaho

In the summer of 1999, the National GAP office was contacted by the Department of the Interior to see what type of analyses we could produce for a portion of the Lewis & Clark Trail. We previously had produced a stewardship map of the western half of the trail, and now we were charged with conducting a gap analysis and preliminary biodiversity core reserve identification project in three weeks time. The data source was Montana GAP and included land cover derived from TM satellite imagery, predicted animal species distributions, and land stewardship. The data layers were then clipped to the study area boundary, which was essentially a 20-mile buffer on each side of the Missouri River from Fort Peck Dam to Great Falls, Montana (Figure 1).

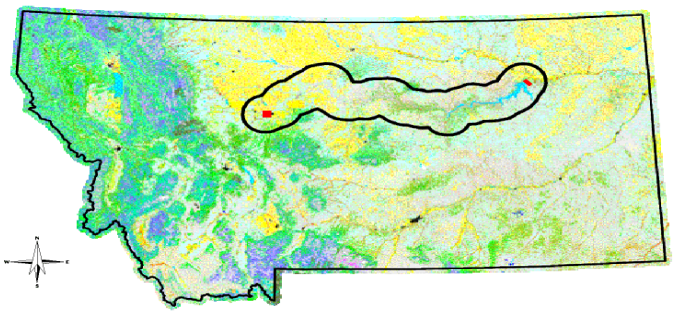


Figure 1. Study area boundary.

Because of the very limited time available, the next step was to narrow the number of species considered from the large number originally mapped for the area. The criteria for selection were:

- The species is a terrestrial vertebrate mapped by Montana GAP.
- Less than 10% of the species' distribution in Montana falls on current reserve lands (GAP status 1 or 2).
- Species are state-threatened status S–3 or lower.

Thirty-six terrestrial vertebrates were identified that met the criteria above. The species distributions were clipped to the study area boundary and then combined for the reserve selection process.

The reserve selection demonstration used an iterative "complementarity analysis" with the objective of finding the combination of places that represent at least one occurrence of every species included in each taxonomic group. Jason Karl of the University of Idaho's Landscape Dynamics Lab developed the ARC/INFO programming to conduct the analysis. This began with selection of the largest land cover patch containing the most at-risk species. Then the next largest patch containing the most at-risk species was selected, and so on until a collection of potential reserve locations was identified to represent all at-risk terrestrial vertebrates in each major taxonomic group. Time constraints did not allow further analysis that would incorporate other considerations, such as species viability, reserve connectivity and configuration for metapopulations, or socioeconomic factors. Those additional analyses would be included in a longer-term reserve selection and design process.

The three maps (Figure 2) depict the preliminary proposed reserve areas for the three taxonomic groups in relation to the four biodiversity management categories used by GAP. Status 1 & 2 areas, shown in dark grey below, are existing reserves such as national parks and wilderness areas; status 3 areas, shown in light gray, are public multiple-use lands; and status 4 areas, shown in white, have no known management for biodiversity. The potential reserves identified on these maps fall within status 3 & 4 lands. They show opportunities for avoiding possible future conservation crises by changing the management of these areas.

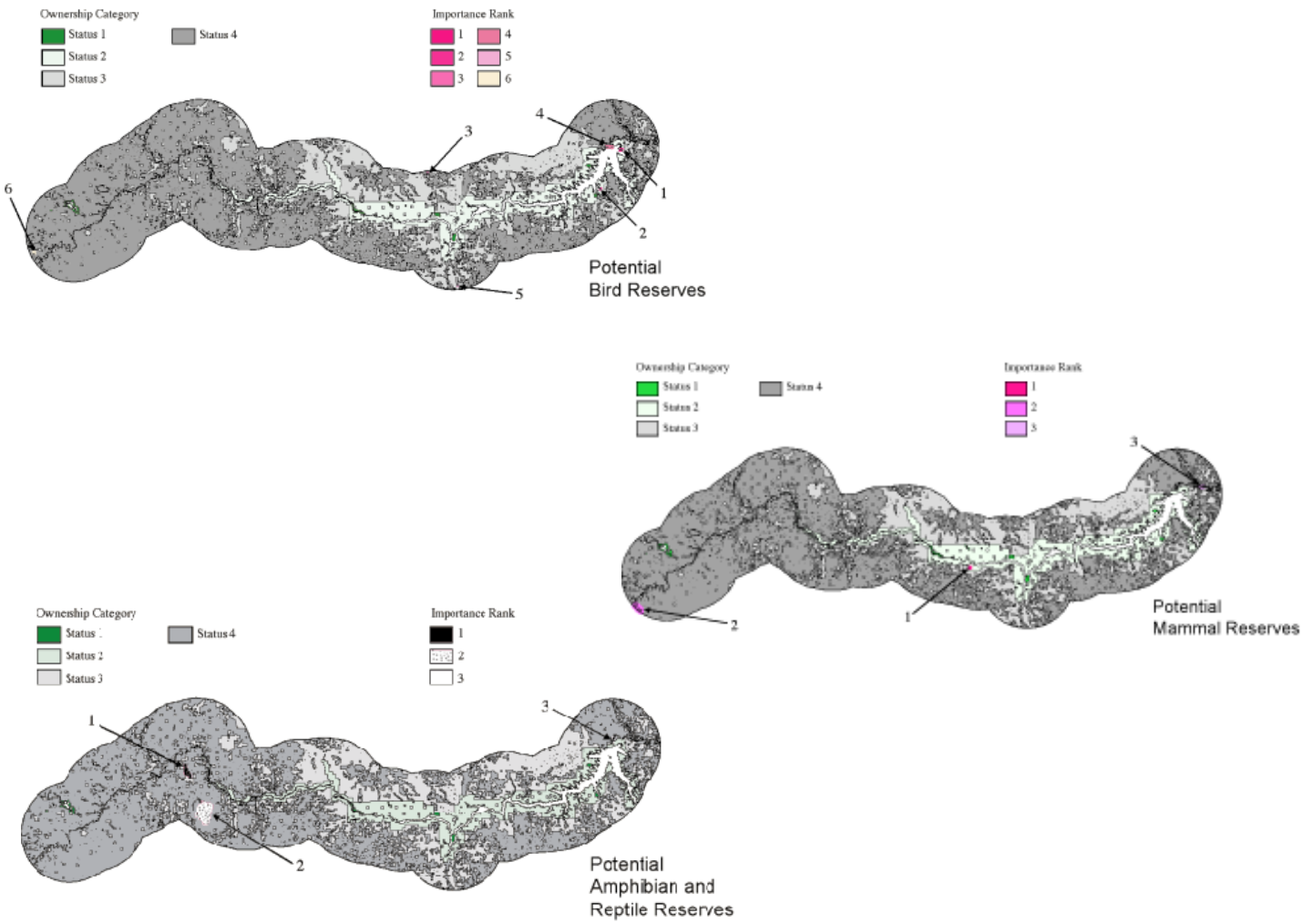


Figure 2. Potential future reserves for a) birds, b) mammals, and c) amphibians and reptiles.

Within the potential reserves identified, the U.S. Fish and Wildlife Service is the largest owner of public lands. In this case the USFWS would bear the largest agency responsibility for biodiversity stewardship. Most of the potential reserves that were identified, however, fall within status 3 & 4 lands, suggesting the need for a change in land ownership or management for these areas.

Conclusions

This project was a rapid gap assessment and reserve selection conducted over three weeks. There are many limitations to the results, but the project demonstrates the utility of Gap Analysis data and methods to evaluate current biodiversity management status, identify biotic elements that require increased management and protection, and identify potential new reserve locations. A more robust analysis would include the full complement of plant communities and species mapped by GAP as well as "enduring features" and evaluation of species viability, connectivity, and quality. Reserve selection would incorporate evaluation of parcel-level land ownership, specific management practices, and socioeconomic considerations.

Acknowledgements

Project conducted by the National Gap Analysis office in cooperation with Conservation Imaging, Inc. and the Landscape Dynamics Laboratory of the University of Idaho Cooperative Fish and Wildlife Research Unit. GAP data produced by the Wildlife Spatial Analysis Lab, MTCFWRU, University of Montana (Redmond et al. 1999).

Authors: Michael Jennings, GAP Director; Patrick Crist, National GAP Coordinator; Philip Tanimoto, Conservation Imaging; Jason Karl, Landscape Dynamics Lab; Jeremy Knudsen, GAP.

Biodiversity Impacts from Urban Growth

A Report on GAP Research Project #00HQAG0009

CHRISTOPHER COGAN
Department of Geography, University of California-Santa Barbara

The analysis of conflicts between biodiversity and urbanization requires several types of input data, collected at varying spatial scales. Urban planners working at the county level need both fine-grain data such as endangered species locations and, simultaneously, coarse-filter ecoregional information and socioeconomic indicators. Whereas much ecological research is done at relatively fine spatial scales, other work uses tools such as remote sensing to study habitats more broadly. A major problem in constructing effective decision support systems for biodiversity planning is thus the integration of data assessed over multiple spatial and temporal scales.

Work is in progress to develop a biodiversity model that minimizes scale dependencies, allowing a wide range of normally incompatible data to be integrated. Using the county as the area of analysis, sites of potential conflict between biodiversity and predicted urbanization are forecast at the landscape level. The model approach facilitates a consistent use of multiscale data and analyses.

Preliminary results are encouraging, showing that quantitative, repeatable assessments of biodiversity are possible at multiple spatial scales. Following an analysis of potential urban growth scenarios, it appears that a consistent set of species are likely to be impacted, in spite of significant variation in growth model parameters. Typically, the 50-year forecast models identify conflicts with species not currently protected under state or federal regulations. This type of local, species-specific forecasting will be invaluable to conservation biologists for anticipating and hopefully avoiding future losses of biodiversity. This work is supported by a grant from the USGS Gap Analysis Program for the integration of socioeconomic factors with Gap Analysis and biodiversity planning.

Applications of New York GAP Data

CHARLES R. SMITH
New York Cooperative Fish and Wildlife Research Unit, Cornell University, Ithaca, New York

During the last year the New York GAP Project has continued to participate in the Hudson River Estuary Biodiversity Conservation Initiative under contract with the New York State Department of Environmental Conservation. In cooperation with the NY Natural Heritage Program, a gap analysis is under way for the Hudson River Valley (HRV), and a verbal interim report was presented in May 1999.

In the context of the NY Gap Analysis Project, our work in the HRV focuses on several biodiversity content and context questions, important for evaluating the contributions of the HRV to statewide biodiversity and relevant to planning for biodiversity conservation in the HRV. Among the questions we are addressing are the following:

Comparison of HRV with the rest of New York State: 1) How many and which terrestrial vertebrates and vegetative community associations (or superalliances) are found in the HRV? 2) What proportion of the "fine-filter" elements (i.e., species) and "coarse-filter" elements (i.e., vegetative associations or superalliances) of NY biodiversity are represented in the HRV? 3) Are there any terrestrial vertebrate species or vegetative community associations (or superalliances) found only in the HRV and nowhere else in NY? If so, what are they, and where are they found in the HRV?

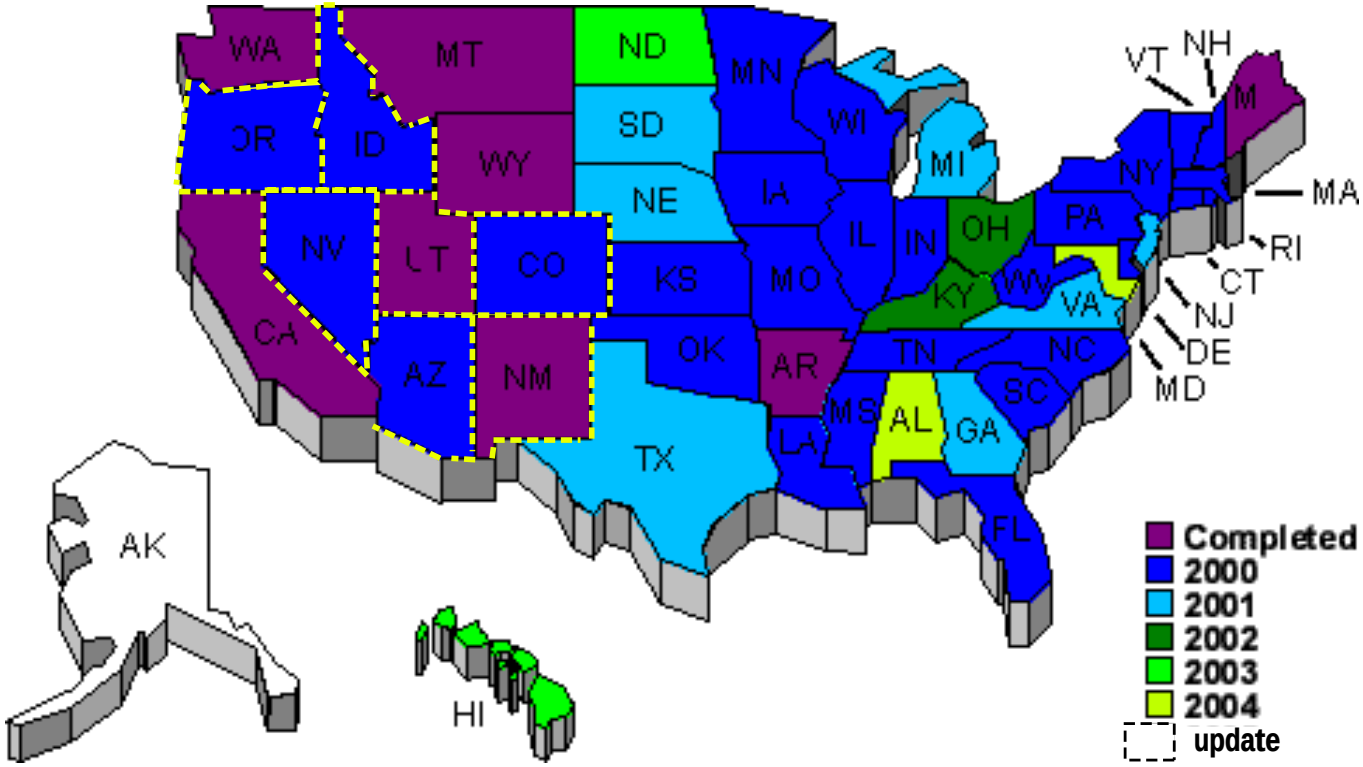
Comparison of HRV counties with each other: 1) What is the ranking of counties in the HRV for elements of biodiversity represented within their boundaries at both fine-filter and coarse-filter levels, from most diverse to least diverse? 2) Which county has the most amphibian species? reptile species? bird species? mammal species? 3) Within the HRV, which species and vegetation types are well represented on public lands, and which taxa are poorly or not at all represented on public lands? 4) What is the ranking of public lands in the HRV for the elements of biodiversity represented within their boundaries, at both fine-filter and coarse-filter levels, from most diverse to least diverse?

These kinds of questions are in addition to the traditional gap analysis questions, which also will be addressed for the HRV: 1) Where are the centers of high terrestrial vertebrate and vegetative diversity, and where are they located relative to public lands? 2) Are there "gaps" where we have regions of high biodiversity in the absence of public land status?

Additional funding was approved for new, complementary, GAP-related projects which began in April 1999. All projects are focused on applications of gap analysis and remote sensing methodologies to the HRV. These projects include development of a spectral signature and status assessment for expanses of Purple Loosestrife, an invasive, exotic plant species widely distributed in HRV wetlands; development of procedures for integrating assessment of habitat-specific relative abundance values for breeding birds within land cover types in the HRV, using the GAP land cover map; and an assessment of threats to biodiversity from urban and suburban development, based on applications of socioeconomic information derived from U.S. Census data. We also have continued to provide GIS support and analytical services for landscape conservation efforts in the HRV, including maintaining the growing biodiversity database for the region, analyzing data as required for implementation of biodiversity conservation strategies, refining the land cover map for the region, and providing information to communities in the region to aid in local conservation efforts.

STATE PROJECT REPORTS

(Status as of fall 1999)



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

Organizing

Anticipated completion date: December 2004

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A Gap Analysis Project for Alabama was initiated December 8, 1999, with a Cooperator's Workshop. The anticipated start date is March 2000.

Alaska

Not started

Arizona

Version 1 project near completion; Version 2 update under way

Anticipated completion date: June 2000; update: July 2004

Contacts: Kathryn A. Thomas, Project Leader
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Kathryn_A_Thomas@USGS.gov, (520) 556-7466 x235

Sarah R. Jacobs, AZ-GAP Update Coordinator
USGS Forest and Rangeland Ecosystem Science Center
Colorado Plateau Field Station, Flagstaff
Sarah.Jacobs@NAU.edu, (520) 556-7466 x240

Original AZ-GAP Project:

The Arizona GAP land cover map, with 54 land cover categories, is finished and is available at http://srnr.arizona.edu/nbs/gap. The as-

sessment of this map was completed through a partnership of University of Arizona and Northern Arizona University. The land stewardship map is completed and ready to be incorporated into the final GAP report. Gap analysis for Arizona has been completed; the tables and graphs are now being finalized. The AZ-GAP final report is near completion. Our anticipated date of delivery is the end of February 2000. We anticipate that all the data will be on the Web site (listed above) by the end of March.

Southwest Regional GAP Project:

Land cover: Arizona, Nevada, Utah, Colorado, and New Mexico are embarking on a multiyear project to update GAP in the Southwest as a coordinated regional effort. The Southwest regional project will develop new digital map databases, focusing first on the land cover map. A consistent approach for mapping land cover is essential for success of a regional gap analysis. Consistency across state boundaries can be accomplished by using a standardized classification system (rather than each state having a unique system) and mapping zones (rather than state boundaries).

A standardized classification system, the National Vegetation Classification System (NVCS), will facilitate use of the land cover map throughout the Southwest. The NVCS is regarded as a major step toward enhancing our ability to understand, protect, and manage the natural resources of the United States. It provides a hierarchical framework for describing vegetation and a convention for identifying and naming additional vegetation types. A description of the NVCS is available at http://consci.tnc.org/library/pubs/class/index.html. A set of preliminary alliance names have been developed in Arizona, but it is expected that the project will expand and further define alliances for Arizona.

Arizona will use satellite imagery from the latest earth satellite observation system, Landsat 7 Enhanced Thematic Mapper Plus, to delineate preliminary land cover polygons. It is anticipated that the improved spatial resolution (15 m) from the newly added panchromatic band will increase accuracy and definition in land cover mapping. Prior to classification, the imagery will undergo preprocessing and stratification at a regional laboratory.

Mapping zones will create a seamless land cover map for the Southwest by dividing the area into ecological rather than administrative units. The use of mapping zones will maximize information extraction from the satellite imagery by separating the imagery into smaller, more homogeneous areas prior to classification.

Animal modeling: Arizona will cooperate to produce a preliminary consolidated list of terrestrial vertebrate species and preliminary distribution maps for the Southwest region. The SW Gap Analysis Update five-state team met in January 2000 to develop the interstate strategy for vertebrate distribution modeling.

Arkansas

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

California

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

Colorado

Near completion

Anticipated completion date: June 2000

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

Land cover: Land cover base coverage is complete and undergoing accuracy assessment. Interpretation of air video for accuracy assessment is also complete; preliminary traditional and fuzzy accuracy estimates have been calculated for both overall map accuracy and accuracy of individual types. Interpretation of these statistics is under way.

Animal modeling: Animal models have been generated for 597 species, reviewed by cooperators, and applied to generate the species/stewardship tables for CO-GAP's final report.

Land stewardship: The land stewardship coverage for CO-GAP was finalized with edits based on Bureau of Land Management's Areas of Critical Environmental Concern.

Analysis: Standard state report tables have been generated and analyzed for the CO-GAP final report. Table information was used to prepare the analysis chapters for the final report, and the chapters were distributed for team review. Copies were distributed for final cooperator review in November 1999.

Reporting and data distribution: Development and delivery of final CO-GAP deliverables to the National GAP Office is on target for March 2000.

Other accomplishments and innovations: Materials for the CO-GAP home page (http://ndis.nrel.colostate.edu/cogap/cogaphome.html) are being developed concurrently with deliverables for the National GAP Office. The CO-GAP home page is targeted for public access in February 2000 (http://ndis.nrel.colostate.edu/cogap/cogaphome.html).

Additionally, Colorado has joined with Arizona, Nevada, New Mexico, and Utah in initiating the Southwest ReGAP project to extend state GAP project work to the landscape level for use in biodiversity planning efforts in the Southwest. Lee O'Brien will be the Colorado state coordinator for the SW-ReGAP initiative. The five states have already begun to develop a collective list of their species models and plan to meet in January 2000 to develop an integrated workplan.

Connecticut

(see Massachusetts, Connecticut, and Rhode Island)

Delaware

(see Maryland, Delaware, and New Jersey)

Florida

Near completion

Anticipated completion date: June 2000

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

Land cover: A 70-class (59 natural classes) land cover classification from 1993/94 Landsat Thematic Mapper imagery is complete. All of the classification has been reviewed by the Florida Fish and Wildlife Conservation Commission except for two Landsat scenes of the Florida panhandle that are currently under review. Accuracy assessment is also being conducted by evaluating low altitude, geocoded videography and digital photography.

Animal modeling: Habitat-affinity matrices have been completed and matched to the final land cover classification. The ARC/INFO AML programs to conduct spatial modeling of species distributions have been completed and tested. Wildlife habitat models will be run for all species and should be completed by December 1999.

Land stewardship mapping: The Florida Natural Areas Inventory (FNAI) of The Nature Conservancy Heritage Program has independently compiled GIS coverages of conservation lands for Florida. GAP ownership and management codes have been added as attributes to the FNAI coverage. FNAI is working with FL-GAP to translate their protection status rankings to the ranking scheme required for GAP.

Analysis: We are awaiting completion of the Florida land stewardship coverage to begin analysis of the land cover types. Analysis of the wildlife habitat models will be conducted as the models are completed. Expected date of completion for the analysis is late December 1999.

Reporting and data distribution: The land cover and wildlife modeling methodology sections of the final report are nearing completion. Draft products can be viewed at the FL-GAP Web site at www.wec.ufl.edu/coop/gap. As products are completed, they will be available on the FL-GAP Web site.

Publications:

Allen, C., L. Pearlstine, and W. Kitchens. (Accepted). Modeling viable mammal populations in gap analyses. *Biological Conservation.*

Georgia

Under way

Anticipated completion date: October 2001

Contact: Elizabeth Kramer
Natural Resource Spatial Analysis Laboratory
Institute of Ecology, University of Georgia, Athens
lkramer@arches.uga.edu, (706) 542-2968

Land cover: The Georgia Gap Analysis Project began in July 1998. From January 1999 to January 2000 significant progress has been made in all areas of the project. Specifically, we have:

1. Developed a protocol and progressed in creating a general land cover map of the state on a county-by-county basis. To date, 36 counties (out of 159) have been completed. Figure 1 below shows the progress of the state land cover mapping initiative.

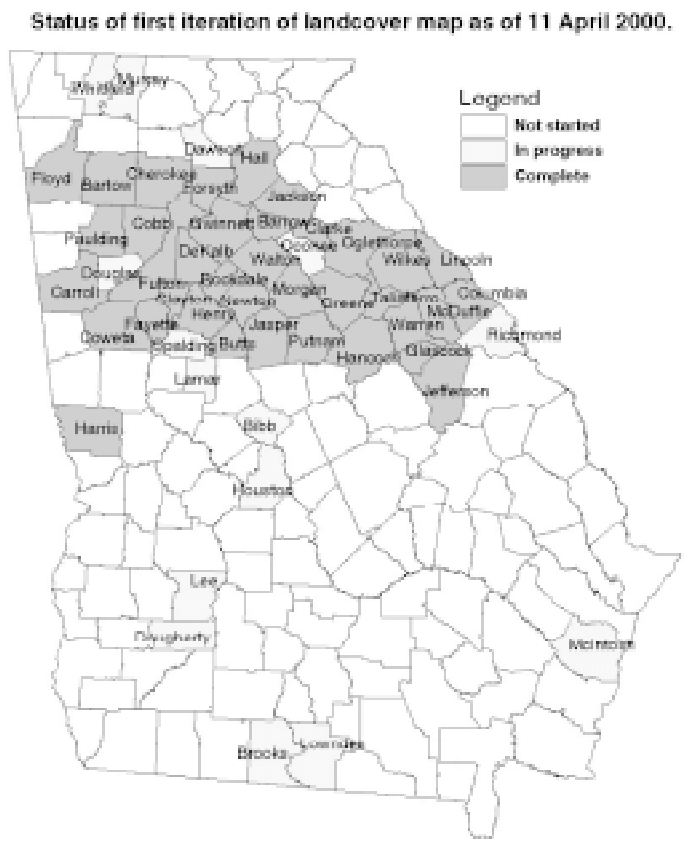

Figure 1. Status of the general land cover map for Georgia.

2. Ground-checked two of the above counties with a reported overall accuracy of 87%.

3. Continued to refine the list of vegetation alliances to be mapped in the second iteration of the land cover mapping effort. In some instances this required aggregating several alliances into a single mapping unit.

4. Began development of rules to be used in predicting aggregated vegetation alliances.

5. Continued training seven image processors to implement the vegetation mapping protocol.

Over the next 12 months, we anticipate completing the general land cover map of the state and will implement models of the distribution of vegetation alliances. Additionally, we will engage in a series of ground-truth surveys to assess the accuracy of these maps. We are also working with Dana Slaymaker of the University of Massachusetts to develop a new color infrared digital video system, which we will use to gather high-resolution land cover data in the spring/summer and fall of 2000.

Animal modeling: To date, a list of Georgia's vertebrates has been compiled, and a literature search is under way to determine habitat requirements for vertebrate species known to breed or winter in Georgia. These requirements are being entered into a relational database and will be cross-walked to the general land cover classification and, when possible, to the more detailed vegetation alliance classification. From this database, individual species models will be built to determine spatial distributions of the vertebrates in question. Locational information on rare species across all taxa will be obtained from the Natural Heritage Program's element occurrences database from the Georgia Department of Natural Resources. Additionally, agreements are being set up with the Georgia Museum of Natural History to obtain a copy of the database of distributional records for all vertebrates in their collection, including fish. GA-GAP has also implemented a pilot program focusing on the development of methods for aquatic gap analysis.

Land stewardship mapping: With funds provided by the U.S. Environmental Protection Agency, Region 4, land stewardship mapping has been completed, and a CD-ROM of the data has been provided to the National GAP office. See the section on data distribution for details on how to obtain a copy of this database. To date, 14 agencies and many individuals have requested and received copies of the Georgia Conservation Lands database.

Analysis: We have begun a preliminary analysis of the distribution and status of protected lands in the state, addressing such questions as the proportion and spatial distribution of: protected lands in each category of GAP status, protected lands in each ecoregion, protected lands that allow timber harvesting, and a breakdown of the protected lands by managing authority. This analysis will continue over the next 12 months as the land cover maps and vertebrate distribution maps are developed.

Reporting and data distribution: Maintenance of the Georgia conservation lands database has been turned over to Chris Canalos of the Georgia Department of Natural Resources, Wildlife Resources Division, phone: (706) 557-3032, fax: (706) 557-3033, e-mail: chris_canalos@mail.dnr.state.ga.us. The database and its associated metadata can be downloaded from the Georgia GIS data clearinghouse (http://www.gis.state.ga.us/) or received via anonymous FTP from the NARSAL Lab at the Institute of Ecology, University of Georgia (UGA), following these instructions:

1. ftp greer.ecology.uga.edu, 2. cd pub, 3. bin, 4. prompt, 5. mget conservation.*, 6. bye.

Other accomplishments and innovations: GA-GAP will provide the base map for the Georgia Land Use Trends analysis program (GLUT), a 1-million-dollar project funded by The Turner Foundation. The GLUT project will also be run by Dr. Elizabeth A. Kramer of UGA's Institute of Ecology in cooperation with UGA's Carl Vinson Institute of Government. The project will retroactively create a series of land cover maps for the state of Georgia representing five increments for the past 25 years to show how Georgia's rapid growth has affected land use in urban and rural areas.

Hawaii

Organizing

Anticipated completion date: December 2004

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

Land cover: Initial drafts of land cover have been completed for native vegetation. The goal is to develop more detailed units for both native and non-native vegetation. Masks for urban and major agricultural lands are planned. (Note: A graphic of Hawaii land cover can be viewed in the Web version of the Bulletin at http://www.gap.uidaho.edu/Bulletins/8.)

Animal modeling: Compilations of Natural Heritage Program occurrence records for endangered birds are complete. We intend to convene working groups to develop range maps for birds, bats, and selected native invertebrates.

Land stewardship mapping: Major land ownership patterns for the state are completed. We will develop management classes through working group meetings and assign these attributes to existing managed land units.

Analysis: We intend to adapt analysis algorithms of other states to apply to the higher resolution needed for small tropical insular systems. We will convene the analysis working group on this matter.

Idaho

Version 1 published in the peer-reviewed literature. Version 2 update near completion.

Anticipated completion date: June 2000

Contact: Leona K. Bomar
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http://www.wildlife.uidaho.edu/idgap.htm

Land cover: The ID-GAP land cover layer and final report chapter are complete. The land cover classification recognizes 81 cover types and is mapped at a resolution of 0.09 ha with a 2 ha MMU.

Animal modeling: Wildlife habitat relationship models have been completed for 375 terrestrial vertebrates in Idaho. The models are stored as georeferenced TIFF images with a native resolution of 0.09 ha.

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.

Analysis: Analysis of the protection status of Idaho's land cover types is complete. Analysis of wildlife habitat distributions will be completed in early December 1999.

Reporting and data distribution: The final report for ID-GAP is awaiting completion of the wildlife habitat distribution analysis. All data, metadata, and documentation are currently available for download from 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. We will compare the results of this analysis with those from land cover and wildlife habitat analyses.

Illinois

Under way

Anticipated completion date: December 2001

Contacts: Jocelyn L. Aycrigg, GAP Coordinator
Illinois Natural History Survey, Champaign
aycrigg@mail.inhs.uiuc.edu, (217) 244-2111

Linda Schwab, Assistant GAP Coordinator
Illinois Natural History Survey
schwab@mail.inhs.uiuc.edu, (217) 265-8425

Land cover: A general land cover classification for the state was completed in October 1995. This classification identified 19 land cover classes: four urban, three forest and woodland, three agriculture, two grassland, five wetland, and two other categories (water and barren areas). The alliance-level GAP vegetation classification is being performed by stratifying along land cover classes. Classification protocols are similar to protocols for UM-GAP (see Bulletin No. 5, p. 35). Classification to the community/alliance level has been completed for southern Illinois. We have concentrated our efforts on the western side of the state along the Mississippi River near East St. Louis. We have obtained ancillary data such has DEMs and forest inventory information, which have assisted us in our classification. We plan to classify TM scenes northward along the Mississippi River as well as in northeastern Illinois in the coming year. Furthermore, we will explore methods for conducting accuracy assessment in anticipation of completing the vegetation classification.

Animal modeling: We have created a list of amphibians, reptiles, and mammals to be mapped. We are using specimens collected by the Illinois Natural History Survey (INHS) and the University of Illinois Museum of Natural History to obtain locational records for each species. We have also obtained museum records from the Smithsonian, American Museum of Natural History, Chicago Field Museum, Kansas State Museum of Natural History, and Museum of Vertebrate Zoology at Berkeley. Furthermore, we have obtained input from wildlife habitat biologists throughout the state regarding species known to occur in their district. We have completed mapping the amphibian, reptile, and mammal collection of the Illinois Natural History Survey and the University of Illinois Museum of Natural History. We are currently mapping the mammal collections of Illinois from other museums. We plan to conduct an expert review of the amphibian and reptile range maps as well as finish up the habitat associations. We will also continue gathering habitat association information for each mammal species. Information gathered previously for the Illinois Fish and Wildlife Information System will be helpful in developing habitat associations. We will use the breeding bird survey for Illinois and the Illinois Breeding Bird Atlas to create a list of bird species to be mapped and begin delineating ranges for those species.

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 needs to be reviewed to determine if all properties have been included.

Analysis: We have completed some preliminary analyses using amphibian, reptile, and mammal locational data to create species richness maps using the EMAP hexagons. We have also started some analyses of species that occur only in southern Illinois, for which we have a completed alliance-level classification. We will continue to do more analyses as our species and vegetation mapping progresses.

Reporting and data distribution: In the coming year, we will finish the statewide alliance-level classification of vegetation and continue our work on the species modeling. We will start writing segments of the report in the coming year.

Other accomplishments and innovations: A Web page for the Illinois Gap Analysis Project has been created and can be viewed at www.inhs.uiuc.edu//cwe/gap/gapintro.html. We were able to obtain new cooperators with the assistance of the Illinois Department of Natural Resources. The U.S. Department of Agriculture's National Agricultural Statistics Service and the Illinois Department of Agriculture have agreed to work with us to obtain and classify statewide TM imagery.

Presentations on the Illinois Gap Analysis Project were given to the senior agency managers of the Illinois Department of Natural Re-

sources, the Illinois Board of Natural Resources, the Illinois Chapter of The Wildlife Society, and a University of Illinois class on Ecosystem Management.

Listed below are projects that are starting up, ongoing, or have been completed using the Land Cover Database of Illinois as well as other data developed as part of GAP.

- Modeling wild turkey habitat in the Illinois landscape. T. Van Deelen, P. Brown, M. Joselyn, D. Greer, T. Maples, and J. Garver.
- Dispersion of gray and fox squirrels. D. Rosenblatt and E. Heske.
- Fox and coyote ecology in central Illinois. T. Gosselink, T. Van Deelen, R. Warner, and P. Mankin.
- Habitat use by raccoons and opossums. E. Heske and D. Rosenblatt.
- Identification and classification of critical wildlife habitat. P. Brown, M. Joselyn, J. Aycrigg, L. Suloway, and B. Zercher.

Indiana

Near completion

Anticipated completion date: August 2000

Contact: Forest Clark
U.S. Fish and Wildlife Service, Bloomington
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Land cover: The Indiana land cover data layer is complete and is being used in numerous projects, including as a foundation data layer in the regional assessments under way by the Indiana Biodiversity Initiative. These data have also been made available on request to agencies, consultants, and NGOs. We hope to have this and the other primary data layers on the Web early in 2000.

Animal modeling: The Indiana vertebrate models were completed and integrated with the vegetation map to produce a draft product for review. A panel reviewed the models and identified those for which improvements were possible with the data available to the project. These revised models have been drafted and are currently being converted to digital form. We plan to run the entire set of vertebrate models early in 2000.

Land stewardship mapping: The Indiana land stewardship data layer is complete. Coding of stewardship types based on a matrix developed for the project is ongoing. The basic protection status coding is complete, and these data are ready for the analysis phase.

Analysis: The Indiana project will conduct the analysis over the winter 2000.

Reporting and data distribution: The Indiana project has been working on various sections of the final report and proposes to finish the first draft by late spring 2000.

Other accomplishments and innovations: The Indiana Biodiversity Initiative, which is using GAP data extensively in its assessment of biodiversity, recently received two major grants totaling over $60,000 to continue the Initiative's work. The Indiana Biodiversity Initiative functions as the implementation arm of Gap Analysis in Indiana. The Grand Kankakee Marsh National Wildlife Refuge, which used GAP data from both Indiana and Illinois in its design, was approved by the Regional Director of Region 3 of the U.S. Fish and Wildlife Service in August 1999.

Iowa

Under way

Anticipated completion date: December 2001

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The Iowa Gap Analysis Project (IA-GAP) is in its third year. An IA-GAP home page is accessible at http://www.ag.iastate.edu/centers/cfwru/iowagap/.

Land cover: Preparation of the land cover map has not progressed as rapidly as we had hoped, thus we are revising our anticipated completion date for the land cover to December 2000. Measures have been taken to speed up the unsupervised classification process by reducing the number of ambiguous cover classes that require relatively longer amounts of time to differentiate. We reduced the number of Iowa land cover classes that can reasonably be mapped to 29. Three Landsat scenes, representing about 40% of the land area of Iowa, have been mapped with these cover classes.

In 1998, we completed the aggregation of National Wetland Inventory data into five major classes of wetlands (temporary, seasonal, semipermanent, permanent, and open water). In 1999, this data layer was integrated into the Phase 1 land cover map for the entire state. Wetland vegetation is then classified using Wetland Inventory codes and Landsat imagery with a recoding and overlay technique.

In summer 1999, we conducted field surveys of natural and seminatural vegetation in 32 additional counties across Iowa with the majority being in the western part of the state. These data were digitized and will be used to assist in assigning map labels to classes generated during the unsupervised classifications.

The IA-GAP staff continues to meet biannually with staff from Kansas, Missouri, Nebraska, South Dakota, and North Dakota to share data and information on polygon edge-matching, legend compatibility, accuracy assessment, and other problems that are com-

mon to GAP in the Great Plains Region.

Vertebrate modeling: Species lists for mammals, birds, reptiles, and amphibians are compiled and include state, federal, and global status codes for each species. These lists, which are ready for expert review, appear on the IA-GAP Web site. Selected scientists from across the state are being invited to serve as expert reviewers of the species lists and habitat models. During 1999 we continued to assemble historical data from museum and private collections and to compile information from the literature on species occurrence, geographic ranges, and optimal habitat requirements.

Modeling of Iowa vertebrates has begun. Our goal is to complete the modeling effort by December 2000 and begin the preparation of distribution maps in January 2001, soon after the land cover map is complete.

Land stewardship: We continued to acquire data on legal boundaries of federal, state, and county lands in Iowa. Acquisition of county properties has consumed the most time; of 99 counties, 60 have been completely digitized, 20 are near completion, and data for an additional 8 counties have been acquired but not digitized. Data have been requested from the remaining 11 counties. State land boundaries were initially digitized by the Iowa Department of Natural Resources in 1991. This database has been recently updated by the Department of Natural Resources (DNR) to include new acquisitions and other changes up to mid-1999 and will be made available to IA-GAP in January 2000. Boundary information for federal lands has been obtained from the U.S. Fish and Wildlife Service and the U.S. Army Corps of Engineers. We anticipate completion of the land stewardship layer for IA-GAP in summer 2000.

Other accomplishments: Extension wildlife staff at Iowa State University, Department of Animal Ecology, with the help of an educational grant from the Iowa Resource Enhancement and Protection program, conducted eight NatureMapping training workshops across the state in 1999; 110 people were trained. The program has been enthusiastically received by a diverse group of people, including school teachers and environmental educators, landowners, nonprofit conservation groups, businesses, and agencies. A database and Iowa NatureMapping Web site are currently under development. NatureMapping data will be sent for accuracy assessment to Iowa State University via the NatureMapping Web site, then stored in a publicly accessible database at the State of Iowa GIS Office server. Additional funding is being sought to carry NatureMapping to another level during the coming year.

In spring 1999, EPA Region 7 agreed to partially fund a pilot study to develop field and analytical techniques for accuracy assessment using ground surveys and the pixel (30 x 30 m) as the basic sampling unit. The statistics laboratory at Iowa State University is developing a protocol for sampling design and data analysis to be used in a regionwide approach for accuracy assessment of land cover maps. In March 1999, coordinators from Missouri, Iowa, Kansas, and Nebraska met with EPA administrator Marla Downing and statisticians Sarah Nusser, Iowa State University, and Steve Stehman, State University of New York-Syracuse, to discuss procedures for the pilot field study conducted in 1999. We selected a four-county area in NE Iowa to conduct our portion of the pilot study and collected data from 145 sites in September and October 1999. Each randomly selected pixel was located using a real-time GPS unit. Each pixel in a nine-pixel matrix (target pixel in the center) was assessed for vegetation and land cover and assigned a class corresponding to one of the 29 map labels. The results of the pilot study are expected to be available by March 2000, when a decision will be made whether to proceed with a regionwide accuracy assessment.

Kansas

Under way

Anticipated completion date: April 2001

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Land cover: Currently, mapping of the state has been completed to the cropland/natural vegetation stage. All of the land cover has been classed to the alliance level, but we continue to refine the cover classes. The land cover layer will be completed in December 1999. During the following nine months, accuracy assessment of the land cover layer will be ongoing with a heavy investment of time occurring during summer 2000. Figure 1 demonstrates current progress (see Web version of the Bulletin at http://www.gap.uidaho.edu/Bulletins/8).

Animal modeling: Currently, species lists of terrestrial vertebrates to be mapped are finalized following expert review. Range distribution maps are being generated based on museum collections, publications, and current observations. We estimate that 85% of the literature has been collected for vertebrate models, and we are in the process of building wildlife habitat relationship models both for the state and Great Plains region. Ancillary databases also are beginning to be discussed and built for use in the predicted habitat relationship models. During the next nine months, all wildlife habitat relationship models will be completed. Drafts of predicted species distributions will be completed and sent out for expert review. Following expert review, final species distribution maps will be generated.

Land stewardship mapping: Currently, the land stewardship layer is near completion. Polygon boundaries are done for 210 managed areas throughout the state. As more land is purchased for conservation in the state, we will update the layer to keep it current. A number of attributes (e.g., owner, county of location) already is in the database that goes along with polygons. We are in the process of querying land unit managers in cooperating agencies about the level of protection in each area and will add this attribute informa-

tion as it is obtained. Our goal is to complete the stewardship layer by June 2000.

Analysis: Analysis will be conducted by the end of 2000.

Reporting and data distribution: Reporting and data distribution are expected to be initiated by fall 2000, and we anticipate asking for an extension to complete the final report.

Other accomplishments and innovations: We have created a Great Plains ACCESS database for modeling of vertebrates within the Great Plains states (North Dakota, South Dakota, Nebraska, Kansas, and Iowa). This database should allow us to produce seamless maps of the predicted distributions of Great Plains vertebrates in the future.

Kentucky

Under way

Anticipated completion date: June 2002

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Land cover: All data layers for one physiographic province, the Shawnee Hills of the Interior Low Plateaus, have been produced. Layers include interpreted air video points, classified TM data, convexity/concavity, slope, aspect, and National Wetlands Inventory (NWI). A draft of a detailed vegetation map containing natural vegetation map units for the Shawnee Hills has been produced, using a decision tree process, and is under review. Air video flight lines in other portions of the state have been ground-truthed, and air video has been recently collected over the eastern part of the state. The short-term goal for the coming year includes incorporating urban (high and low density), agriculture (pastureland/grass, cropland), and mined lands (bare ground, revegetated) into the draft map. Completing a draft map of the entire state is the major goal for the coming year.

Animal modeling: Considerable progress was made in 1999 toward modeling vertebrate distributions in Kentucky. We finalized the list of terrestrial vertebrate species to be modeled after its review by our state experts. Our final species list includes 51 reptile, 52 amphibian, 63 mammal, and 198 bird species (364 species total). Range maps of current distributions were delineated. A Web page for the review of the range maps was constructed with the aid of the Kentucky Department of Fish and Wildlife Resources (KDFWR), and the review process for the ranges has been completed. Final range maps will be completed in December 1999. We are completing our database of the habitat association for each species. We are also establishing a Web page, with the aid of KDFWR, for the review of our habitat association information. The habitat associations will be posted for review by the end of 1999.

In addition to the required tasks of Gap Analysis, we are using the species range maps to map species richness in the ecoregions and physiographic provinces of Kentucky. We have presented our analyses of species richness at the 2nd Annual Biodiversity Conference at Western Kentucky University and the 1999 Kentucky Academy of Science meeting at Eastern Kentucky University. Through meetings such as these we maintain open communication with biologists, educators, and other interested parties in the state.

The database of final habitat associations will be produced during 2000. Also, we will produce an initial wildlife/habitat relationship model for each species. We plan on making draft maps of the predicted occurrence of species depending upon the status of the vegetation mapping for Kentucky.

Land stewardship mapping: Work on the stewardship layer has focused on assessment of data available. Agencies at the federal, state, and local government levels as well as nongovernment organizations were contacted. Available information regarding data format (digital or analog), management status, contact names, etc. were obtained. Existing digital coverages will be acquired and converted to a common projection during 2000. The large amount of nondigital ownership data makes it improbable that all managed lands in Kentucky will be included in the final analysis. A method for prioritizing the conversion of analog to digital data, focusing on conservation lands, will be developed.

Louisiana

Near completion

Anticipated completion date: June 2000

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Land cover: The land cover section for the final report is 98% complete, with an anticipated completion date of December 1999. Data directory structure for final CD distribution was completed in October 1999. We are working on the metadata for ancillary data sets.

Animal modeling: Species distribution maps were reviewed and corrected. Final digital data were delivered to the project office in August 1999. Hyper-distribution maps were created for all four major vertebrate groups (mammals, birds, reptiles, and amphibians) in October 1999. Data directory structure for final CD distribution was completed in October 1999. The animal modeling section for the final report is 98% complete, with an anticipated completion date of December 1999. We are still working on the metadata.

Land stewardship mapping: The data directory structure for final CD distribution was completed in October 1999 for Louisiana's land stewardship and management. The Land Stewardship and Management section for the final report is 98% complete, with an anticipated completion date of March 2000.

Analysis: The analysis of land cover types and vertebrate species by land stewardship and management status was completed in October 1999. Data directory structure for final CD distribution was also completed in October 1999. The Analysis section for the final report is currently under way, with an anticipated completion date of December 1999.

Reporting and data distribution: Currently, the National Wetlands Research Center is in the process of writing the final report, with an anticipated completion date of April 2000.

Maine

Complete (see http://wlm13.umenfa.maine.edu/progs/unit/gap)

Maryland, Delaware, & New Jersey

Near completion

Anticipated completion date: October 2000

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Land cover: During 1999 the land cover mapping made significant progress (see map in Web version of Bulletin at http://www.gap.uidaho.edu/Bulletins/8). The Delmarva Peninsula, the piedmont, southern New Jersey, and eastern mountains of Maryland have been completed as draft maps. The remainder of Maryland and New Jersey will be completed early in 2000, and accuracy assessment will begin at that point.

Attempts to install the necessary hardware to import our video into a GIS format are under way. This will enable additional video to be used in the classification process where GPS capture was intermittent during video flights (e.g., over the mountains in western Maryland).

A project Web page has been developed and will be available soon via link to the national GAP Web page. Status of the project as well as availability of products may be determined from information found at that location.

Animal modeling: In 1999, most of the vertebrate modeling work involved finalizing habitat layers, completing development of the database, and fine-tuning the modeling software. In addition to land cover-derived habitats, the habitat layers used in the modeling include wetland/riparian buffers, elevation, forest area (measured by thickness), riparian forest width, forest isolation, edge habitats, road density, land use (e.g., pasture), aquatic habitats, special habitat features (e.g., cliffs), and other special habitats that are generally smaller than the land cover MMU (e.g., vernal pools). The feasibility of developing other potentially important habitat layers (e.g., soils) is still being evaluated.

The database includes tables for species-unique codes, species modeling status, species range, species/habitat associations by taxa, forest metrics relationships (e.g., for forest interior dwelling birds), species guilds, species taxonomy, habitat types, habitat cross-walks (e.g., to alliance), species/landform relationships, species/wetland buffer relationships, species-special habitat features relationships, and several other tables to be used in the modeling or for various queries. The database was developed in Personal Oracle8 and has been successfully imported to MSAccess. The modeling software was developed through ArcView Avenue scripting to enable as much automation of the modeling as possible and includes some nice custom query capabilities. Draft models and distribution maps will be sent out for expert review during the winter of 1999/2000, and final models will be run by April 2000.

Land stewardship mapping: During 1999 the stewardship layer for the Maryland portion of the project was completed. The Delaware portion is essentially complete; the work is under review as of November 1999. For New Jersey, private conservation lands data have been collected, but the public lands data are still outstanding. The land stewardship layer is expected to be completed for Delaware by the end of 1999 and for New Jersey in early 2000.

Analysis: GAP investigators expect to complete analysis of the protection and management status of biodiversity in Maryland and Delaware by spring 2000 and expect the New Jersey analysis to be completed by late summer 2000.

Reporting and data distribution: The final report writing for Maryland, Delaware, and New Jersey has begun and should be completed by October 2000. The GIS layers for Maryland and Dela-

ware will be distributed in ARC/INFO/ArcView format, with associated data tables in Microsoft Access format, on CD-ROM. A similar approach will probably be used in New Jersey. The status and availability of these products will be reported via the GAP Web page.

Other accomplishments and innovations: By developing our vertebrate modeling scripts in ArcView's Avenue, we have provided both a user-friendly interface for accessing data tables and custom control over the modeling process. Users can query for species/habitat relationships or maps of species distributions, or survey the base GIS layers used in the modeling; lists of species occupancy can also be generated from input of habitat information. In addition, users can query the community alliance and wildlife habitat tables, generating a list of potential alliances/habitat by input of plant species, location, or physical characteristics of the site. Efforts are under way to make this software package portable for eventual distribution of the GAP data sets.

Data sets are being used for considerable analysis even in their draft form. Examples include identifying areas with high potential for supporting forest interior neotropical migrant songbirds on the Delmarva Peninsula, priority sites for forest restoration and/or acquisition, and a multiagency federal, state, and private collaboration on the Delmarva Peninsula (the Delmarva Conservation Corridor Initiative).

Massachusetts, Connecticut, & Rhode Island

Complete; update under way

Anticipated completion date: June 2000

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Land cover: An accuracy assessment of the land cover map completed in 1997 is now under way. Preliminary results indicated that there were significant classification errors, especially in the Cape Cod region. An error model is being developed from the accuracy assessment project. A revised land cover map will be developed from this error model. Additionally, development of a new land cover map is planned within the next 18 months as part of an NSF-funded project with the Department of Computer Science at the University of Massachusetts.

Animal modeling: With completion of the expert review of mammal range maps during summer 1998, all vertebrate models are complete. Predicted habitats for all 273 vertebrates modeled in the Southern New England region were identified and coarse species richness maps developed for each taxonomic group. Additionally, habitats were identified throughout the Connecticut River watershed for priority species of neotropical migratory birds. We plan to redo the vertebrate habitat maps once the revised land cover map is available.

Land stewardship mapping: All conservation lands in the region are mapped and classified according to conservation status. The database for Connecticut was not as well developed as for Massachusetts and Rhode Island. Over 15% of Southern New England is classified as conservation lands, and about 7% of the land area was classed in the categories 1 & 2.

Analysis: Species richness analyses have been completed. The final gap analysis will be complete by June 2000.

Reporting and data distribution: All data layers are currently available on the Southern New England Gap Analysis home page (http://outsider.fnr.umass.edu/gaphome.html). We plan to distribute the vertebrate models and predicted habitat data layers as an ArcView project. Revision of the land cover map will begin in April 2000. The final vegetation map will not be distributed on CD until revisions are complete. A manual for incorporating GPS-logged aerial videography into land cover mapping efforts is under development and will be distributed on CD-ROM in May 2000. The final report and a report on accuracy assessment will be available in June 2000.

Other accomplishments and innovations: Conducted two one-day workshops for regional planners on "Gap Analysis in the Connecticut River Watershed: Landscape-based Approaches for Conserving Biodiversity." The workshops were funded in part by the Silvio O. Conte National Fish and Wildlife Refuge and the University of Massachusetts.

Michigan

Under way

Anticipated completion date: September 2002

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Land cover: Classification of the Northern Lower Peninsula is expected to be completed in the second quarter of FY 2000. Classification of the Southern Lower Peninsula will begin in the first quarter of FY 2000. Classification of the Eastern Upper Peninsula is expected in the second or third quarter of FY 2000. The Western Upper Peninsula is completed in a preliminary version that upon review may require revision.

Animal modeling: The animal modeling effort will begin in FY 2000 with an expected collaboration with Michigan State University.

Land stewardship mapping: The stewardship layer was begun in 1996 and continues. Completion is expected in summer of 2000.

Analysis: Gap analysis is scheduled to begin in FY 2001.

Reporting and data distribution: Land cover and stewardship data will begin to be served by UMESC in the second and third quarter of FY 2000.

Minnesota

Under way

Anticipated completion date: September 2002

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Land cover: The state has been divided into 29 spectrally consistent classification units (SCCUs) based on a procedure described in the Upper Midwest GAP Image Processing Protocol. Ten classified SCCUs, complete with accuracy assessment, are scheduled for delivery to UMESC in the first quarter of FY 2000.

Animal modeling: A working group of species experts has been formed by the Wildlife Section of the Minnesota DNR. Work towards the development of the vertebrate species distribution models will begin in FY 2000.

Land stewardship mapping: Preliminary public ownership/stewardship mapping is completed. The map is based on an ARC/INFO vector coverage of the Public Land Survey. Section corners are georeferenced. From those, a polygon grid of 40-acre tracts has been generated. Each 40-acre polygon is then attributed for owner, manager, stewardship category, etc. In FY 2000 UMESC will crosswalk the MN DNR public owner categories to the official GAP categories. Independent verification and cross-referencing of the Minnesota DNR lands stewardship classification will begin in FY 2000.

Analysis: Gap analysis is scheduled to begin in FY 2001.

Reporting and data distribution: Land cover and stewardship data will begin to be served by UMESC in the second and third quarter of FY 2000.

Mississippi

Near completion

Anticipated completion date: January 2001

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Land cover: Land cover mapping has been completed. The final map product has been aggregated to 43 classes. Among them are a number of classes discerning structure or age of the overstory vegetation. Particularly, four classes have been obtained that relate to the age of Mississippi's pine ecosystems. Although this information is not required for the current mapping standards, the personnel from the Spatial Information Technologies Laboratory at Mississippi State University believed they could extract this information from the TM images. These data have proven very useful in refining vertebrate distributions for species such as Red-cockaded Woodpecker (*Picoides borealis*) and Bobwhite Quail (*Colinus virginianus*). Accuracy assessment is nearly complete and should be finalized by December 1999. Map classes have been associated with NVCS alliances for each of the five ecoregions in the state. Metadata construction is in progress.

Animal modeling: Wildlife habitat relationship models are being applied to the final vegetation layer. Finished models are under review by vertebrate committees. Amphibian and mammalian species are finished pending final review. Bird species are still under scrutiny by the review team. Ancillary data from 900 bird point counts conducted in Mississippi's national forests and a large collection of museum records have aided in the refinement of habitat relationships and distributions. Models are expected to be finalized and reviewed by early spring 2000.

Land stewardship mapping: The land stewardship layer for the state is complete. The Mississippi Department of Wildlife, Fisheries, and Parks provided MS-GAP with GPS-located boundaries for all state and federal lands. Additional properties, such as TNC and tribal lands, have also been incorporated. Metadata construction is near completion for these data.

Analysis: Macros have been written to perform the final analyses for the project. Testing of the macros on preliminary distributions has proven effective. All analyses should be complete by late spring 2000.

Reporting and data distribution: The final report is being written as phases of the project near completion. The land cover section is nearly complete and will be finalized with the accuracy assessment. Sections on stewardship and vertebrate distributions are currently in progress with completion expected in late spring 2000.

Other accomplishments and innovations: Through the process of data acquisition and sharing and development of strong working relationships with MS-GAP cooperators, a movement has started in the state to provide "life after GAP." Cooperative research efforts to apply knowledge and expertise in the field of spatial technology to natural resource management (such as applying spatial technologies to conservation law enforcement, aiding Partners-in-Flight with establishing priority lands, and optimizing locations for

aquaculture facilities) have prompted an initiative to be placed before the Mississippi legislature. The initiative, called the "Natural Resource Decision Support System," would provide recurring funds to support three new employees at Mississippi State University. These persons would provide biannual updates and refinements to the MS-GAP land cover and provide support to agencies in terms of applying spatial technologies and existing spatial data to help solve current natural resource problems. This initiative would provide needed information to policy makers and resource managers to make scientifically based and ecologically sound management decisions.

Missouri

Complete. Publication products under development.

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Land cover: Complete. Phase I land cover was completed by the Missouri Resource Assessment Partnership. This was then generalized from the original 30 m cell size to the 2 ha minimum mapping unit used for vertebrate modeling. Also, 5, 10, 20, 40, and 100 ha land cover bases were created using an in-house generalization AML to try to maintain some of the linear features and connectivity present in Missouri's file. Phase II land cover contains 46 classes and will be provided in summer 2000 as an update on the National GAP home page.

Animal modeling: Complete. Among the 348 vertebrates modeled were 66 mammals, 164 birds, 74 reptiles, and 44 amphibians. These models were created using the base land cover map of 2 ha and derivative products such as ecotones, core interiors, regionalized areas, and riparian measures. Other data layers were developed to aid in the modeling, such as wetland components, prairies, soils, precipitation, temperature, population density, road density, as well as many other feature types such as caves, springs, etc. An additive weighting model was developed for each species, which calculated an index to occurrence. It is somewhat similar to a Bayes Theorem approach in that it uses subjective weights in an additive fashion. These weights represent what the literature, biologists, and the modeler believe to be the likelihood of a species occurring, given that a specific habitat or landscape component exists.

Land stewardship mapping: Complete. The stewardship layer was created by the Missouri Resource Assessment Partnership. Public lands comprise only 6.7% of Missouri with 4.7% under federal and 2% under state jurisdiction. The average size of these holdings is very small. Less than 1% of Missouri falls within areas designated as management status 1 or 2. All areas greater than 16 ha were analyzed for biodiversity components.

Analysis: Complete. Species biodiversity as measured by species richness was calculated on five spatial extents. These included county, EMAP hexagons, 7.5-minute quadrangle, quadlet (1/6 of quadrangle), and public land survey section. These results were comprehensively reviewed against the Missouri Fish and Wildlife Information Systems county lists for all terrestrial species to provide a measure of reliability and consistency. A more refined review was conducted against the results of the Breeding Bird Atlas project at the quadlet level for all bird species. This was followed by the analysis of these richness indices and individual species predicted occurrences within the context of stewardship. Species tied to grassland complexes are the most at risk, followed by those species that require larger contiguous areas. Wetlands have high richness, but there are few areas outside preserves where these habitats exist in Missouri. Focus for Missouri's future biodiversity efforts must be on private land holders as they control over 90% of the state.

Reporting and data distribution: Completed. The draft final report was submitted in January 2000. Data distribution from these 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.

Other accomplishments and innovations: The methods used in the generalization of the land cover are fairly unique as they were developed to try to capture the linear "travelways" present across many of Missouri's landscapes. The program was developed in AML and utilizes ARC/INFO processing in both grid and vector environments. Programs were developed to take advantage of the matrix (i.e., agricultural, grassland, or forested) within which the process was being run. In addition, regional variables were created to allow for the maintenance of polygons within which only diagonal connectivity exists.

The methods developed for vertebrate modeling expand the usability of the data sets by acknowledging and incorporating the fact that these data are fuzzy and that "habitat" is not always associated with a single cover type but rather a suite of cover types in juxtaposition that can provide for all the species' needs. The modeling approach of mapping this as a continuum of response (occurrence) and then not clipping these results to a range map but rather calibrating these measures to a range greatly expands the users' flexibility with these data as well as not perpetuating sampling errors or biases that can permeate the range information.

Montana

Complete (see http://www.wru.umt.edu/reports/gap/)

Nebraska

Under way (http://www.calmit.unl.edu/gap/)

Anticipated completion date: October 2001

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Land cover: We have completed a preliminary statewide classification and are in the process of refining the product. We have been working with Iowa, South Dakota, and Kansas on accuracy assessment strategies. We conducted a pilot study of accuracy assessment during summer 1999 and are currently planning for the summer 2000 accuracy assessment field campaign. In addition, we are working with the USDA/NRCS to get county-level land cover draft maps out to NRCS field offices across the state to solicit comments from local experts. Plans for next 12 months: finalize land cover mapping, including integration of NWI data, and conduct land cover accuracy assessment.

Animal modeling: We have completed assembly of species lists for the state. The herpetiles list has undergone expert review and has been revised. The bird and mammal lists are currently in expert review. We have initiated model development for reptiles and amphibians; based on preliminary results we are incorporating climate and soils data as complementary environmental variables. We are cooperating with the Great Plains Regional GAP modeling group to develop common models and modeling methodology. We continue to work with the Nebraska State Museum on integrating their species occurrence records into a format usable in GAP. As the land cover products from the Rainwater Basin and Cooperative Hydrology Study (COHYST) projects become available, we will apply the animal models to these data, which are based on more recent TM images (1997-98), to assess the effects of multi-date thematic data on predicted species occurrences. Plans for next 12 months: Finalize bird and mammal species lists, ingest relevant museum data, complete herpetile and mammal models, initiate bird models, select and apply accuracy assessment methods to each animal model, Web-publish animal models as they are completed to solicit comments and review.

Land stewardship mapping: A preliminary product is currently undergoing review and refinement. We continue to work closely with the Nebraska Games and Parks Commission in this aspect of the project. Plans for next 12 months: finalize stewardship database.

Analysis: Analysis is pending completion of animal models. Plans for next 12 months: Initiate analyses as animal models are completed.

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

Other accomplishments and innovations:

1. Ongoing assessment of elk habitat in northwest Nebraska in cooperation with the NE Game and Parks Commission and the School of Natural Resource Sciences.

2. Cooperating with Rainwater Basin Joint Venture (U.S. Bureau of Reclamation – $180,000; NE Game and Parks Commission) in land cover mapping using 1997-98 TM data.

3. Cooperating with the COHYST of the Central Platte, which is sponsored by five natural resource districts, two public power districts, NE Game and Parks Commission, NE Natural Resources Commission, and the NE Department of Water Resources ($87,000). The project will produce improved land cover mapping including crop-level discrimination across a region covering one-third of Nebraska using 1997-1998 TM data and digital orthophotos.

Nevada

First-generation GAP data will be provided through the National GAP Web site by summer 2000; this preliminary project will not have a standard report.

Version 2 update under way

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Land cover: Nevada is participating in the regional GAP update for the Southwest. During the year 2000, organizational tasks include listing potential cooperators and their contributions, compiling relevant literature, collecting masking data, interacting with regional plant ecologist on alliance descriptions, and interacting with the regional office (Utah State University Remote Sensing/GIS Laboratories, Logan) on initial mapping procedure and concurrent field season.

Animal modeling, land stewardship mapping, and analysis: Organizing during the year 2000.

Reporting and data distribution: Anticipated for spring 2004.

New Hampshire

(see Vermont and New Hampshire)

New Jersey

(see Maryland, Delaware, and New Jersey)

New Mexico

Version 1 complete (see http://rgis.unm.edu/price.htm). Version 2 update under way

New Mexico is included in a five-state (AZ, CO, NV, NM, UT) regional effort to update and expand information from GAP projects conducted for the individual states in the 1990s. Mapping of biotic elements and land stewardship will follow established GAP methods but will be conducted cooperatively for the region, without regard to state boundaries. The current New Mexico project is in the start-up phase for this multiyear Southwestern Regional Gap Analysis Project (SW-ReGAP). Project responsibilities in New Mexico focus on reinitiating the cooperative network, assisting a regional lab with imagery analysis, and acquiring selected vegetation and animal occurrence data. Specifically we will 1) develop the partnership infrastructure for land cover mapping and other data set preparation, 2) identify training site data for land cover mapping, 3) assist a regional lab with selecting ancillary data for the full project, 4) prepare a rule base for making land cover mapping decisions, 5) consolidate existing animal distribution models for ecoregional task assignment, 6) evaluate recent changes to land stewardship data, and 7) create and maintain regionwide Web pages, FTP site, and list server to facilitate regional cooperation and data exchange.

Results of this project will be used to develop New Mexico's contribution to the full multiyear SW-ReGAP. This step is critical to ensure that appropriate research staff and facilities are brought to bear on the ecoregional conservation assessment. Further, this project will provide the starting point for the first-ever conservation evaluation of animals and plant communities throughout the Southwest that crosses state jurisdictional boundaries.

To develop the infrastructure necessary to complete the long-term project, we are incorporating personnel from several departments within New Mexico State University (animal and range sciences, biology, fishery and wildlife sciences, geography, entomology, plant pathology, and weed science) as well as the agricultural experiment station, the physical sciences laboratory, and the Army Research Laboratory at White Sands Missile Range. These experts are providing input for this portion of the project by identifying training site data, ancillary data, scene selection, and creation of the rule base. The SW-ReGAP home page (http://leopold.nmsu.edu/fwscoop/swregap) will provide information for both project personnel and cooperators and the general public.

New York

Near completion

Anticipated completion date: June 2000

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Land cover: Accuracy assessment, as described in last year's status report, continued in 1999. We evaluated map accuracy at three different levels in the nested hierarchy of the National Vegetation Classification System (NVCS). Using conventional accuracy assessment methods, our land cover map accuracy at an NVCS level approximately equivalent to Anderson Level I is 74.4%. At the NVCS subclass level, our map accuracy is 56.5%, and at the level of NVCS superalliance, our accuracy is 42.0%. Values for map accuracies using the more computationally intensive "fuzzy" accuracy methods were generally a few percentage points better than values derived by conventional accuracy assessment methods.

Animal modeling: We are continuing a successful and productive cooperation with the ongoing NY Amphibian and Reptile Atlas, sponsored by the New York State Department of Environmental Conservation (NYSDEC), with field work ending in 1999 (http://www.dec.state.ny.us/website/dfwmr/wildlife/herp/index.html). We have received updated information on current distributions of amphibians and reptiles from the herpetological atlas project through the 1998 field season. Association matrices, relating vertebrate species occurrences to each of the 45 land cover types we have identified were completed, reviewed by teams of experts, and assessed for accuracy during the third quarter of 1999. Predicted occurrences of terrestrial vertebrates were assessed for accuracy using known occurrences of species from recent museum data (mammals only), recent herpetological atlas field data, checklists of birds from state parks, breeding bird occurrence data from the NY Breeding Bird Atlas, and checklists of birds and other vertebrates from federal refuges. The NY-GAP Project also is cooperating with NYSDEC and the Federation of New York State Bird Clubs to assure that new information collected as part of the Second NY Breeding Bird Atlas Project, scheduled to begin in 2000, can be incorporated fully into the NY-GAP database for future gap analysis applications.

Land stewardship mapping: During 1999 we substantially refined, expanded, and updated our existing land stewardship coverage to reflect significant acquisitions of new public lands and increased availability of accurate statewide land stewardship information in digital form. Included in the land stewardship coverage at this time are boundaries for all state wildlife management areas, state forests, state parks, New York City reservoir watersheds with restricted access, Adirondack Park Preserve, Catskill Park Preserve, Department of Defense lands, national parks and historic sites, federal wildlife refuges, and large preserves managed by The Nature Con-

servancy, represented by approximately 8,000 polygons. Assignment of management status categories to these areas was completed during the last half of 1999, and stewardship codes were assigned in consultation with staff from NYSDEC and the New York State Office of Parks, Recreation, and Historic Preservation.

Analysis: Accuracy assessments for maps of predicted vertebrate distributions were completed during the last quarter of 1999. Overall map accuracy for predicted vertebrate distributions, at the ecoregional scale, is 84.2%, with 86.2% for amphibians, 83.6% for reptiles, 89.2% for birds, and 77.9% for mammals. Gap analysis for the statewide database will be initiated and completed during the last quarter of 1999 and the first quarter of 2000.

Reporting and data distribution: A draft final report will be submitted to the National Gap Analysis Program Office for review in March 2000. After review, a final report will be completed and submitted by late June 1999. Data distribution is expected to be primarily on CD-ROM, with limited hard copy distribution, and from Web pages. Data distribution by NYSDEC is expected to be accomplished on a regional basis using a central server linked to GIS workstations in each of the nine regional offices of NYSDEC. The creation of the Cornell University Geospatial Information Repository (CUGIR; http//cugir.mannlib.cornell.edu), a major National Spatial Data Infrastructure node, also offers opportunities for additional modes of data display and distribution not available previously. Once produced by USGS, CD-ROM products will be offered for sale through the NY Cooperative Fish and Wildlife Research Unit.

Other accomplishments and innovations: See note on page 57 of this issue.

New York Aquatic Gap Analysis

Complete

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Habitat characterization for Aquatic GAP: Habitat was characterized using the parameters stream size, habitat quality, water quality, gradient, and riparian forest cover. The first three parameters were combined to form a habitat characterization from which fish diversity was predicted. The latter three parameters were used for macroinvertebrate diversity predictions. The first round of habitat characterization involved static, manually intensive classifications from topographic and Mylar land use overlay maps. In an effort to deviate from such limiting classification, the NY Aquatic Gap Analysis group developed computerized macros to automate classification from digital elevation models, land use, and road and railroad coverages. This provided equal or better accuracy, increased flexibility, and enabled us to calibrate the model using previously collected data. The calibrated habitat characterization incorporated five additional GIS layers (surficial geology, bedrock geology, depth to bedrock, point-source pollution, priority waters) and involved optimization using discriminant analysis procedures.

Analysis: Field data were collected in the summer of 1998 on fish species diversity, macroinvertebrate family diversity, stream width and depth, substrate, general habitat assessment, water chemistry, and gradient at 39 sites. This information was used to test the five parameters in habitat characterization and overall diversity of fish and macroinvertebrates.

Reporting and data distribution: The NY Aquatic Gap Analysis group maintains a Web site for dissemination of up-to-date information on model methodology and results. This site can be found at http://www.dnr.cornell.edu/hydro2/aquagap.htm. In addition, a comprehensive report was compiled in October 1999 for the U.S. Geological Survey discussing the methods, results, products, analyses, and conclusions to date.

North Carolina

Under way

Anticipated completion date: December 2000

Contact: Alexa McKerrow
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Land cover: In 1999 we expanded the vegetation mapping efforts inland with two separate efforts: one in the southern mountains and the other in the sandhill region. In addition, field data collection and video interpretation were completed for the piedmont. We have continued to utilize the decision-rule process for mapping, with the addition of variables derived from the digital elevation models for the mountains. By spring 2000 we will be completing the statewide land cover map by following the protocols developed in each of the smaller-scale mapping efforts.

Animal modeling: Draft county and hexagon range maps are currently available for review by experts in the state. With the help of the North Carolina Natural Heritage Program and the North Carolina State Museum we will be finalizing those data layers by early 2000. In addition to soliciting one-on-one reviews and holding joint meetings for review of the range and habitat association data layers, we are developing a Web site to support that process as well as final data delivery needs. By February 2000 final ranges and habitat associations will be available for incorporation into the final analysis.

Land stewardship mapping: Several separate state efforts have been undertaken to develop the data layers required to develop the land stewardship layer. A reasonable base data layer with respect to boundaries exists for state-owned lands and wildlife refuges. Federal lands will require a considerable effort to bring them up to date. We have been in communication with the North Carolina Natural Heritage Program, North Carolina Center for Geographic Information and Analysis, and the Fish and Wildlife Ecological Services Raleigh Field Office and are hoping to develop a cooperative agreement to develop a set of data layers that will meet each of the individual programs' needs in addition to those of the North Carolina GAP Project. We are hoping to have a fulltime staff member assigned to this task by January 2000.

Analysis: Final analysis will be initiated in June 2000.

Reporting and data distribution: Reporting and data distribution will begin in March 2000, starting with the basic data layer development and concurrent with the final analysis.

North Dakota

Under way

Anticipated completion date: October 2003

Contact: Larry Strong
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Land cover: Three dates of Thematic Mapper (TM) imagery (spring, summer, and fall) for each of 14 path-row orbit combinations were acquired to provide complete coverage for North Dakota (ND). A seven-class land cover classification for ND was produced by building upon the recent efforts of Ducks Unlimited (DU) and U.S. Fish and Wildlife Service (FWS) in the Prairie Pothole Region of ND. Guided K-means clustering and maximum likelihood classification of spring and fall TM images were performed to produce a land cover classification compatible with the DU/FWS land cover map for areas south and west of the Missouri River. Vegetation surveys were conducted on thirty 28.6 x 28.6 km study areas distributed among eight ecoregions in the summer of 1999. Within ecoregions, study areas were chosen to maximize: 1) access to public lands, 2) the amount of natural and seminatural vegetation, and 3) variability of surface geology and soil types. Global Positioning Systems were used to delineate vegetation polygons on public lands. A large number of vegetation polygons on private land were delineated on 1:31,680 scale color prints of TM imagery from roadside surveys conducted after ground surveys of public lands in the study areas. Vegetation community element of occurrence records from ND Natural Heritage Program's Biological Conservation Database were obtained and converted to a georeferenced vector object. Access to the ND State Lands Range Inventory Database for school lands was granted, and efforts are under way to convert the data to a georeferenced vector object. Several digital vegetation and land cover classifications for selected areas in ND were obtained from ND-GAP cooperators. Training data sets will be constructed for a more detailed vegetation and land cover classification using the three dates of TM imagery and elevation, climate, soils, and geology data in a classification tree analysis.

Animal modeling: Checklists of all vertebrate species in North Dakota have been completed and reviewed by expert reviewers. For herpetiles and birds, locational data have been assembled into GIS coverages, and range maps have been completed and subjected to expert review. Literature reviews have started, and wildlife-habitat relationship (WHR) models have been completed and reviewed for two species, respectively. For mammals, most locational data have been assembled into GIS coverages, and large mammal range maps have been completed and reviewed. Small mammal range maps have been sent to expert reviewers. Literature reviews have started, and WHR models have been completed and reviewed for three species. Efforts in the next 12 months will include the creation of mammal range maps, literature reviews for most of the vertebrate species, generation of WHR models and requests for expert review, and the development of environmental data sets for modeling species distributions.

Land stewardship mapping: Land stewardship data were obtained from the Army Corps of Engineers, Bureau of Land Management, Bureau of Reclamation, and National Park Service. Land stewardship data have been requested from the FWS, the Forest Service, and the ND Game and Fish Department. The FWS has an aggressive effort to construct land stewardship data for North Dakota and will make the data available for GAP. We obtained a CD-ROM of the ND Department of Transportation base map data, which includes coverages for federal and state public lands in ND. During 2000 we will continue to acquire existing digital data from appropriate agencies.

Ohio

Under way

Anticipated completion date: May 2003

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Thomas Waite
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Land cover: The Ohio GAP project has undergone a change in personnel. Completion of the land cover map is being negotiated with The Ohio State University's Center for Mapping. The goal for the 12 months from January 2000 will be to begin production of the land cover map using 1999 MRLC data obtained from the OhioLink program.

Animal modeling: A new PI for animal modeling, Dr. Thomas Waite, of The Ohio State University, Department of Evolutionary Ecology and Organismal Biology, has been selected. Graduate student Troy Wilson has compiled a species list of terrestrial vertebrate taxa in Ohio from existing information sources. The goal for the next 12 months will be to develop a database of information on species distributions, location information, references, and habitat affinities. Data sources on species occurrence and distribution have been identified for the Ohio Aquatic GAP project. Ohio Aquatic GAP will use the valley segment classification system to identify stream valley segment types in Ohio. The classification is planned to be completed by January 2000.

Land stewardship mapping: The Ohio Department of Natural Resources (DNR) is compiling a land ownership map for Ohio. OH-GAP will coordinate efforts with the Ohio DNR to produce a land stewardship map by December 2000.

Reporting and data distribution: A fact sheet will be completed by March 2000.

Oklahoma

Near completion

Anticipated completion date: June 2000

Contact: William L. Fisher, Assistant Unit Leader
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wfisher@okstate.edu, (405) 744-6342

Land cover: The final land cover map is complete and under review.

Animal modeling: Modeling of the distribution of the 427 terrestrial vertebrate species is under way.

Land stewardship mapping: The final land stewardship map is complete.

Analysis: Overlay analysis to identify potential gaps in biodiversity conservation will begin following completion of animal distribution modeling.

Reporting and data distribution: Planning is under way.

Oregon

Near completion

Anticipated completion date: June 2000

Contact: Jimmy Kagan, Director/Ecologist and GAP PI
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Current (1993) land cover: An original land cover map (Version 1) was completed for Oregon in 1992. A second-generation land cover map (Version 2) has been recently completed (August 1998, using 1993 imagery) and is currently available. Metadata are available for this second-generation cover, but the accuracy assessment is incomplete, and the classification is not tied to the NVCS. An associated vegetation manual has been completed for the new map. A description of the mapping process is included in chapter 2 of the OR-GAP final report.

Historic (~ 1850) land cover: A statewide historic land coverage was created by OR-GAP, modified from a coverage developed by the Oregon Biodiversity Project. The coverage approximates a 1:100,000 scale, and metadata are complete. The historic land cover categories are tied to the NVCS and have been cross-walked to the wildlife habitats developed for the current land coverage (Version 2). Descriptions of the mapping process and classification are included in chapter 3 of the OR-GAP final report.

Animal modeling: Animal modeling has been completed for Oregon three times, the first time using the Version 1 GAP vegetation map. The result of this project is the book *Atlas of Oregon Wildlife* by Csuti et al. The initial models relied on hexagon distributions prepared for all native wildlife species. Since these were completed over eight years ago, we updated the hexagon distribution covers for all wildlife species in March 1999. Version 2 models (ARC/INFO programs - AMLs) were developed for all vertebrate species using the updated hexagon distributions and the Version 2 land cover, with an updated wildlife habitat relationship matrix to reflect the differences between the first- and second-generation land coverages. The updated modeled distributions received limited peer review through local experts. As the Version 2 maps are fairly similar to the thoroughly reviewed Version 1, OR-GAP feels the review has been sufficient. OR-GAP also developed historic models using similar techniques with modified hexagon distributions (based on historic distribution, including extirpated species) and the historic land coverage. The details of the current and historic modeling process are included in chapter 4 of the final state report.

Land stewardship mapping: The land stewardship cover is complete and was used to develop the gap analysis. The coverage and metadata for 1999 (used in the analysis) are posted at the OR State GIS Service Center. An updated version of the cover will be produced in 2000. A summary of the stewardship mapping and categorization effort was included as chapter 5 in the draft final Oregon report.

Analysis: Analysis using the Version 2 data is completed. A summary of the analysis is included in chapter 6 of the OR-GAP draft state report.

Reporting and data distribution: The draft final state report is being peer-reviewed by the national GAP staff and by Oregon peer reviewers. A limited number of hard copies of the final report will be produced. The final report and the basic coverages will be posted at or linked to the Oregon GAP home page, which will be maintained at either the Oregon Natural Heritage Program or the Or-

egon Department of Fish and Wildlife office in Portland. We intend to develop links to allow downloading these coverages from many sources. The basic coverages that are currently posted include the stewardship cover, the first- and second-generation GAP vegetation covers, and a presettlement vegetation coverage. All final GAP products, databases, and coverages will also be included on the CD-ROM, with an ArcView application we developed that creates historic and existing species distributions.

During the next 10 months of the project, using funds from the U.S. Fish and Wildlife Service and the state of Oregon, we will distribute GAP data to watershed councils, local governments, and other decision makers in Oregon. We will also train others in the use of the data and in assessment methods and tools. We intend to provide GAP data, Oregon Natural Heritage Program threatened and endangered species data, and analysis to assist in watershed, basin, or ecoregional planning efforts. We are working with the Northwest Office of the Defenders of Wildlife to distribute GAP data and also to assure the updated GAP coverages are included on their CD-ROM product, *Oregon's Living Landscape, an Interactive Introduction to Oregon's Biodiversity*. This CD-ROM was produced as part of the Oregon Biodiversity Project, in which both the Oregon Natural Heritage Program and the Oregon Gap Analysis Program were partners.

Other accomplishments and innovations: As part of our association with the Oregon Biodiversity Project, an application was developed that allows both GAP and Natural Heritage data to be summarized on a watershed basis. This application was developed by the Defenders of Wildlife staff and is included on their CD-ROM. We are working on developing a similar, Web-based application. We are hoping to adapt the Colorado State University Internet site for distributing OR-GAP and Oregon Natural Heritage Program data.

Pennsylvania

Near completion

Anticipated completion date: June 2000

Contact: Wayne L. Myers
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Land cover: Land cover maps have been completed with generalized categories. Accuracy assessment is pending.

Animal modeling: Models are completed and have been reviewed. Fish, bird, and mammal models were run for mapping; herp models are running.

Land stewardship mapping: Stewardship mapping has been completed.

Analysis: is in progress for reporting.

Reporting and data distribution: Expect draft ready for review by national GAP by February 29, 2000. Web service will be provided by Pennsylvania Spatial Data Access (PASDA) at Penn State University.

Rhode Island

(see Massachusetts, Connecticut, and Rhode Island)

South Carolina

Under way

Anticipated completion date: March 2001

Contact: Elise V. Schmidt
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Land cover: We have completed the initial land cover map for the state and are now in the process of incorporating ancillary data. We are using data from the National Wetlands Inventory and NRCS soil surveys to further refine our initial classification of 28 land cover types. There are other digital databases available that will be used to add additional land cover types. The land cover is expected to be complete by August 2000.

Animal modeling: The database for animal distribution and habitat affinities is complete and has been reviewed by state experts. We are now compiling the expert reviewer comments to determine where more research needs to be conducted. SC-GAP has data from state and university museums as well, which are ready to be incorporated. A user interface is being developed for limited access to the database through the Internet, so that the experts can review the final maps and database. We will complete sampling for ant diversity in all physiographic regions and most land cover types in the state within the year 2000. Ant diversity will be a part of our animal modeling. The animal database is expected to be complete by August 2000.

Land stewardship mapping: The land stewardship database is complete except for a small portion of properties. We are working with involved parties to ensure correct classification of GAP status on public lands in South Carolina.

Analysis: The gap analysis is expected to begin in August 2000 and be completed by December 2000.

South Dakota

Under way

Anticipated completion date: May 2001

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Vickie J. Smith, GAP Coordinator
South Dakota State University, Brookings
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Land cover: Land cover classification was completed for eastern South Dakota in June 1999. Twelve categories were separated, including two alliance classifications, which were delineated using on-screen digitizing, and four wetland categories from the National Wetland Inventory (NWI). An image of land cover for eastern South Dakota can be viewed at http://wfs.sdstate.edu/sdgap/eastland.htm. Currently, two of nine western South Dakota scenes have been classified using alliance training data from the USGS/TNC Vegetation Mapping Program for Wind Cave National Park. Within the two scenes, 19 categories are present, including 13 association-level categories. Assessment is under way to determine the accuracy of this method of classification. Completion of the South Dakota land cover map is expected by May 2000. Accuracy assessment using a stratified random sample for the state will begin during the summer of 2000.

Animal modeling: Distribution maps are completed, reviewed, and revised for 88 mammal species. They can be viewed at http://wfs.sdstate.edu/sdgap/mammals.html. Small mammal/vegetation associations are being determined at Wind Cave National Park. These data will be used in accuracy assessments of small-mammal distributions. Maps are nearly completed for 43 herp species, and the avian species list is under review. South Dakota is working cooperatively with four surrounding states (North Dakota, Kansas, Iowa, and Nebraska) to create regional models for all vertebrate species. Currently, 16 species have been modeled for the region. Literature review has been conducted for nearly 80% of the species to be modeled by South Dakota.

Land stewardship mapping: We have added state parks and recreation areas, The Nature Conservancy holdings, and state wildlife refuges to our stewardship map in the past year. We are attempting to acquire information for a three-mile-wide section along the borders of Montana and Wyoming. Permission has been granted to include only two of the seven Indian reservation boundaries in our stewardship map. Our current stewardship map can be viewed at http://wfs.sdstate.edu/sdgap/stewardmap.htm.

Aquatic GAP: Plans are under way to hire a graduate student in early 2000. River reach files have been acquired, and watershed boundaries have been formulated for three major river systems in eastern South Dakota, through a project researching presence of Topeka shiners in eastern South Dakota streams (see article on page 35 of this issue). Habitat information has been collected on historic locations of the Topeka shiner. These data will be used as a pilot project for Aquatic GAP to formulate predictions of the current Topeka shiner distribution in these stream systems.

Tennessee

Completion date unknown, please contact coordinator below.

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Sue Marden, Vertebrate Ecologist
Tennessee Wildlife Resources Agency
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Land cover: The detailed vegetation map is completed. The vegetation map was produced using classification techniques applied to Landsat TM imagery and aerial videography. Accuracy assessment was performed using a subset of points set aside from the aerial videography interpretation. Final figures for accuracy assessment are being tabulated. Completion of metadata and preparation of data for final delivery to National GAP remain to be done.

Animal modeling: Predicted species distributions and species richness data have been produced for Tennessee's 364 terrestrial vertebrate species. The species distribution data are in the process of being written onto CDs to send to National GAP.

Land stewardship mapping: The land stewardship layer is completed. Lands mapped are current through December 1997. The public lands coverage has been updated, while land management status needs to be assigned before any further analysis.

Analysis: Gap analysis has been completed.

Reporting and data distribution: The final report is near completion. Data are being written to CD-ROMs for delivery to National GAP. Plans are to present TN-GAP data as part of the Tennessee Wildlife Resources Agency (TWRA) Web page.

Other accomplishments and innovations: The Tennessee Biodiversity Program (established by the Tennessee Conservation League [TCL]) 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 ArcView 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 in 1999 by TWRA, TCL, Tennessee Valley Authority, and National GAP as a planning guide for developing and carrying out natural resource conservation and management programs.

Texas

Under way

Anticipated completion date: December 2000

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Land cover: The land cover map for Texas has been completed; all scenes have been stitched together. Data from field work, completed in all 254 counties in Texas, were used to classify the scenes. Data from videography were used for accuracy assessment. Overall accuracy of the classified product was above 80%. 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.

Vertebrate modeling: We have identified 637 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 637 species being modeled, and statewide GIS layers have been created from the following profile variables: precipitation, temperature, soils, hydrology, ecoregions, and elevation. Preliminary distribution models for herpetofauna and mammals have been completed. Fifty percent of the preliminary distribution models for birds have been completed.

Analysis: 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 cooperators in Texas and Mexico.

Other accomplishments: Data prepared for West Texas are being used to prepare selected species-specific maps (e.g., prairie dog towns and Scaled Quail distribution).

Utah

Update under way

Anticipated completion date: June 2004

Contact: Doug R. Ramsey
Remote Sensing/GIS Laboratories
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The first-generation Utah Gap Analysis project has been completed. An update is under way. We are part of Southwest Regional GAP, which includes Nevada, Colorado, New Mexico, and Arizona. To date we have been updating the ancillary data layers and researching the feasibility of adding a soil component to our ancillary data set. We have also been reviewing the vegetation reference data collected in our first gap analysis for use in the update. As part of a regional effort we have been helping each state define mapping zones. The purpose of the mapping zones is to divide the landscape into similar units of landform features, soils, and biotic elements.

Older Utah GAP products are still readily available for both UNIX and PC computer systems. We also have a CD-ROM on Intermountain Region Land Cover Characterization that incorporates GAP data from Nevada, Southern Idaho, Western Wyoming, and Utah.

Land cover: Modeling land cover characteristics will not begin until all vegetation reference data are collected for a mapping zone. The collection of data is scheduled to begin in spring 2000.

Animal modeling: Dr. Thomas C. Edwards of the Utah Cooperative Fish and Wildlife Research Unit will undertake the wildlife habitat modeling for Utah. Dr. Edwards can be reached by phone at (435) 707-2529, by fax at (435) 797-4025, and by e-mail at tce@nr.usu.edu.

Land stewardship mapping: Individual management units for the state of Utah will be updated for public and private lands.

Analysis: All data layers are scheduled for analysis completion by 2004.

Reporting and data distribution: All products derived from Utah's Gap Analysis as well as Southwest GAP are scheduled for completion by 2004.

Vermont and New Hampshire

Near completion

Anticipated completion date: June 2000

Contact: David Capen
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Land cover: Land cover mapping for both Vermont and New Hampshire is complete. Edge-matching between New Hampshire and Maine gave acceptable results.

Animal modeling: Refining models and processing additional ancillary data for about 25% of vertebrate species; modeling is complete for other species.

Land stewardship mapping: Complete for both states, including private conservation parcels and hundreds of ownerships protected by easements.

Analysis: In progress; macros for most steps have been developed and tested. Final analysis awaits refinement of selected habitat models.

Reporting and data distribution: Reports will be submitted for review in early 2000; data distribution should follow later in the year.

Other accomplishments and innovations: Both Vermont and New Hampshire have undertaken statewide reserve selection projects that have complemented the Gap Analysis effort. Each of these projects has incorporated physical factors of the landscape into their analyses. We believe that this approach, coupled with the land cover maps of GAP, offers a more sensitive and more comprehensive means of identifying hotspots of diversity than does the modeling of vertebrate distributions.

Virginia

Near completion

Anticipated completion date: June 2000

Contact: Scott D. Klopfer
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Fish and Wildlife Information Exchange, Blacksburg
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Land cover: The final VA-GAP land cover map was completed in spring 1999. This map is currently available through anonymous FTP from the Fish and Wildlife Information Exchange (FWIE) server at ftp.fwie.fw.vt.edu. The final map contains 26 land cover classes and two forest complex classes. For more information on VA-GAP's land cover mapping efforts, please contact Scott Klopfer (sklopfer@vt.edu).

Animal modeling: Vertebrate modeling is near completion.

Land stewardship mapping: The stewardship map for VA-GAP is complete and available for download at ftp.fwie.fw.vt.edu. This coverage contains all federal, state, and some privately owned lands in Virginia. For more information regarding these efforts, please contact Scott Klopfer (sklopfer@vt.edu).

Analysis: The quantitative accuracy assessment of the vegetation map is completed. The accuracy of the final land cover map was found to be between 67% (conservative estimate) and 87%. Analysis of species distributions and protection gaps is near completion.

Reporting and data distribution: Many of the basic data sets used by VA-GAP are available to the public via FTP. Our Web-based data distribution node is expected to be complete by spring 2000. The final VA-GAP report is in progress, and plans for a statewide VA-GAP data use workshop are under way.

Other accomplishments and innovations: VA-GAP continues to serve as a means of communication for federal and state agencies in Virginia. The results of our accuracy assessment indicate that our abiotic factor (a.k.a. "enduring feature") modeling/remote sensing hybrid classification method was able to provide us with accurate land cover classifications.

Washington

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

West Virginia

Near completion

Anticipated completion date: September 2000

Contact: Charles Yuill
West Virginia University
Natural Resource Analysis Center, Morgantown
cyuill@wvu.edu, (304) 293-4832 x4492

Land cover: Complete; additional verification continuing.

Animal modeling: Near completion. Models and range maps are complete. Modeling under way using revised final land cover. Herpetiles are complete. Range maps are on project map server.

Land stewardship mapping: Complete; updated to 9/1/99.

Analysis: Near completion.

Reporting and data distribution: Near completion. Final report for project is under way. A report for wide distribution has been initiated and will be published from state funding sources. All mapping will be placed on map server, and CDs will be produced. Data distribution is under way for available products; EPA, USGS, and TNC have obtained products to date.

Other accomplishments and innovations: A grant was obtained to fund the West Virginia Land Status and Trends Project, a five-year project that will update WV-GAP and conduct detailed assessments of forests, agricultural/open lands, landscapes of special concern, and land use conversions in West Virginia. The project will also refine and apply data using landscape ecology metrics within the Watershed Characterization and Modeling System (WCMS) in a landscape atlas project for The Canaan Valley Institute (a multistate NGO focusing on watersheds).

Wisconsin

Under way

Anticipated completion date: September 2002

Contact: Tim Weiss
Wisconsin Department of Natural Resources
Bureau of Wildlife Management, Madison
weissn@dnr.state.wi.us, (608) 267-9428

Land cover: Classification of the state followed the Upper Midwest Gap Image Processing Protocol and is now completed. Crosswalking the remote sensing land cover classes to the National Vegetation Classification System will begin in FY 2000.

Animal modeling: Vertebrate modeling will be undertaken by the Upper Midwest Environmental Sciences Center (UMESC) in cooperation with the state DNR beginning in FY 2000.

Land stewardship mapping: Public land ownership/stewardship mapping is being undertaken by the Wisconsin DNR and is partially completed. Federal lands and state lands are mapped to date; county lands remain to be mapped.

Analysis: Gap analysis will be undertaken by UMESC and is scheduled to begin in FY 2001.

Reporting and data distribution: Land cover data will begin to be served by UMESC in the second and third quarter of FY 2000.

Wyoming

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

NOTES AND ANNOUNCEMENTS

GAP Named Winner of Major National Award

The national environmental nonprofit Renew America recently announced that the USGS Gap Analysis Program has been selected for a National Award for Environmental Sustainability in the category of Wildlife/Biodiversity. The prestigious awards are being given by Renew America to 16 programs throughout the nation.

The National Awards for Environmental Sustainability honor companies, communities, and individuals that are leading the change to sustainability through their programs. Award winners were selected from a pool of nearly 200 programs that have been recognized by Renew America and the National Awards Council for Environmental Sustainability, a coalition of 60 leading businesses and environmental and community groups. "These award winners represent some of the 'best of the best' of this country's environmental programs. They are shining examples of how citizens across America can support our nation's environmental and economic goals every day," said Anna Slafer, Executive Director of Renew America.

On April 17, 2000, Gap Analysis was honored at the Renew America Awards Ceremony that helped kick off "Earth Week" in the nation's capital. Dana Reeve, actress and author of *Care Packages: Letters to Christopher Reeve from Strangers and Other Friends*, hosted this year's Awards Ceremony.

John Mosesso, GAP Program Manager, commented that, "GAP is providing resource managers and planners across the nation with basic scientific information regarding the status of biodiversity within their states. … Good information allows good decisions that help keep common species common."

The winners were selected by representatives of the National Awards Council for Environmental Sustainability (NACES). Coordinated by Renew America, NACES comprises 60 national environmental, nonprofit, government, and business organizations, including the National Audubon Society, The Nature Conservancy, The Humane Society of the United States, AT&T, U.S. EPA, the National Geographic Society, and the Smithsonian Institution.

The Gap Analysis Program will be listed and described along with this year's finalists in Renew America's Environmental Success Index, a comprehensive database of more than 1,400 successful environmental programs throughout the United States. It is available free on the World Wide Web (www.crest.org/renew_america).

New Staff at National GAP Office

Ree Brannon is our new GIS Analyst in the National GAP office. She comes to us with a background in natural resources, GIS, and remote sensing. Ree's undergraduate background is in biology and range management. She received a master's degree in Forestry from West Virginia University, while she worked on the initial land cover mapping efforts for WV-GAP. Her 15 years in the Forest Service gave her experience in natural resource management, planning, and research. Now, for GAP, her responsibilities include doing quality assurance for the GIS data during project closeout, preparing the GIS data for CD publication and Web serving, and eventually (once we catch up on the backlog of state projects) merging the data for regional assessments and pursuing more applications for GAP data. If you have questions on GIS data standards or would like to share your experiences in any of these areas, contact her at (208) 885-3720 or by e-mail (abrannon@uidaho.edu).

GIS Data Delivery

To facilitate the quality assurance process for delivery of GAP GIS data, Ree Brannon developed a directory structure and an example checklist for the layers, which are posted in the Standards section of the Handbook (http://www.gap.uidaho.edu/handbook/Standards). As she reviews state projects, this structure may be modified. The Standards section will undergo a major review for consistency.

We still require data delivery on CDs, and the directory structure allows you to organize your CDs. Some general comments from experience working with states that have submitted final projects:

- Try to keep all of one theme together on one CD (for example, all land cover layers). Your vertebrate grids will be the largest bundle of data, if they don't all fit on one CD, divide by major taxonomic groups (e.g., birds on one CD, mammals and herps on another).
- The organization for metadata may seem redundant. Each data layer must be accompanied by its metadata (the *.html file) in the same directory. Plus, you must include copies of all metadata in the directory called meta_master. The Standards will be edited to require three forms of metadata (*.txt, *.html, and *.sgml). These are readily created in MetaMaker. For BRD units, this is business as usual (as Executive Order 12906 has been on the books since 1994). For others, it is important to understand that any generation of spatial data done with federal dollars requires metadata. The redundancy in format is to provide one file for error checking (*.txt), one for presentation on the Internet (*.html), and one for indexing elements for the spatial data clearinghouse (*.sgml). Remember, metadata describe the evolution of the spatial data set being documented. If there are companion files to the GIS data (reports, spreadsheet, another GIS layer), use metadata to reference them.

- We are publishing reports and data for two kinds of users, those who just want to browse and view results and those who may want to use data for analysis. Hence the requirement for graphics that can be viewed without GIS capability.
- The standards and directory structure were created to expedite product review and to simplify future regionalization activities. If you do not follow these guidelines (by changing names or merging data files), this may result in delays or requests to resubmit the data. Whereas metadata describe the legacy and development of a spatial data set, use READMEs to describe the files in one directory. This helps if a user needs to know what codes mean in a grid or coverage, or a crosswalk for species grids names and common/scientific names of the species.
- Here are some commonly overlooked files that need to be included: crosswalks from codes to text names, documentation of source data (species literature, source of conservation status calls in stewardship layer), digital form of Table of Contents, the extended land cover map (10 km beyond state boundary), and descriptive READMEs.

Ultimately, the best advice is to put yourself in the shoes of the user to determine if you have done the best job making the data usable and understandable. If you have comments, suggestions, or questions, contact Ree Brannon at (208) 885-3720 or abrannon @uidaho.edu.

Ree Brannon
National Gap Analysis Program, Moscow, Idaho

Announcing National GAP Annual Meeting in Texas

The 10th Annual National Gap Analysis Program Meeting will be held August 13-17, 2000, in San Antonio, Texas. It will be hosted by the Texas Cooperative Fish and Wildlife Research Unit and the Natural Science Research Laboratory at Texas Tech University. The focus of this year's meeting is looking back on the first 10 years of GAP and forward to the next 10 years. Special emphasis at this meeting is also placed on biological informatics and the Mexican component of GAP. Concurrent sessions and workshops will cover vegetation mapping, predicting species distributions, mapping conservation lands, accuracy assessments, conducting gap analyses, building partnerships, interactive social science, and outreach.

The meeting is open to GAP investigators, their staff, project collaborators, and others interested in GAP methods and results. Additional information on the conference can be found on the GAP home page at http://www.gap.uidaho.edu/Meetings/2000 or by contacting Becky Sorbel at (208) 885-3555 or gap@uidaho.edu.

Elisabeth Brackney
National Gap Analysis Program, Moscow, Idaho

Recent Publications by GAP Researchers

Bain, M.B., A.L. Harig, D.P. Loucks, R.R. Goforth, and K.E. Mills. 1999. Criteria for aquatic ecosystem protection and restoration: Approaches using biological and physicochemical structure. Proceedings of the Conference on Power Generation Impacts on Aquatic Resources, U.S. Department of Energy and the Electric Power Research Institute, Palo Alto, California, 10 pp.

Bain, M.B. Spatial and temporal attributes of streams and fish limiting the prediction accuracy of species-habitat models. For Predicting Plant and Animal Occurrences: Issues of Scale and Accuracy. Island Press, Washington, DC. Submitted July 1999.

Bain, M.B., A.L. Harig, D.P. Loucks, R.R. Goforth, and K.E. Mills. In review. Criteria for aquatic ecosystem protection and restoration: Approaches using biological and physicochemical structure. *Journal of Environmental Science and Policy*.

Boone, R.B., and W.B. Krohn. 1999. Modeling the occurrence of bird species: Are the errors predictable? *Ecological Applications* 9:835-848.

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Crist, P.J., T.W. Kohley, and J. Oakleaf. 2000. Assessing land-use impacts on biodiversity using an expert systems tool. *Landscape Ecology* 15:47-62.

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Groves, C.R., L.S. Kutner, D.M. Stoms, M.P. Murray, J.M. Scott, M. Schafale, A.S. Weakley, and R.L. Pressey. 2000. Owning up to our responsibilities: Who owns lands important for biodiversity? Pages 275-297 in B.A. Stein, L.S. Kutner, and J.S. Adams, editors. Precious heritage: The status of biodiversity in the United States. Oxford University Press, New York.

Hepinstall, J.A., S.A. Sader, W.B. Krohn, R.B. Boone, and R.I. Bartlett. 1999. Development and testing of a vegetation and land cover map of Maine. Technical Bulletin 173. Maine Agricultural and Forest Experiment Station, University of Maine, Orono, Maine. 104 pp.

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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.

Krohn, W.B., R.B. Boone, and S L. Painton. 1999. Quantitative delineation and characterization of hierarchical biophysical regions of Maine. *Northeastern Naturalist* 6:139-164.

Loucks, D.P, M.B. Bain, and R.J. Pendall. Socioeconomic, physical, and ecological processes in watersheds characterized by sprawl development, limited water, and quality impairment: Research needs, approaches, and opportunities. Natural Resources Forum. Submitted June 1999.

Meixler, M.S., and M.B. Bain. 1999. Application of Gap Analysis to New York State waters. Final project report by the New York Cooperative Fish and Wildlife Research Unit, Cornell University, Ithaca, New York, to the U.S. Geological Survey, Gap Analysis Program.

Meixler, M.S., and M.B. Bain. Accuracy of a GIS model that integrates fish species and stream habitat at the river basin scale. For Predicting Plant and Animal Occurrences: Issues of Scale and Accuracy. Island Press, Washington, DC. Submitted July 1999.

Scott, J.M. 1999. A representative biological reserve system for the United States? *Society for Conservation Biology Newsletter* 6(2):1, 9.

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.

Scott, J.M., B. Csuti, R.G. Wright, P.J. Crist, and M.D. Jennings. 1999. Regional approaches to managing and conserving biodiversity. Pages 55-70 in R.K. Baydack, H. Campa III, and J. B. Haufler, editors. Practical approaches to the conservation of biological diversity. Island Press, Washington, D.C. 313 pp.

Scott, J.M., F.W. Davis, G. McGhie, R.G. Wright, C. Groves, and J. Estes. Nature reserves: Do they capture the full range of America's biological diversity? *Ecological Applications*. Accepted.

Scott, J.M., E.A. Norse, H. Arita, A. Dobson, J.A. Estes, M. Foster, B. Gilbert, D.B. Jensen, R.L. Knight, D. Mattson, and M.E. Soule. 1999. The issue of scale in selecting and designing biological reserves. Pages 19-35 in M.E. Soulé and J. Terborgh, editors. Continental conservation: Scientific foundations of regional reserve networks. Island Press, Washington, D.C. 227 pages.

Stevenson, M. 1999. A different look at the land. *Planning*. July:8.

Recent Publications Mentioning GAP

Maybury, K.P., editor. 1999. Seeing the forest and the trees: Ecological classification for conservation. The Nature Conservancy, Arlington, Virginia. 37 pp.

Peterson, D.J., S. Resetar, J. Brower, and R. Diver. 1999. Forest monitoring and remote sensing: A survey of accomplishments and opportunities for the future. RAND Science and Technology Policy Institute, MR-1111.0-OSTP. 92 pp.

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Ricketts, T.H., E. Dinerstein, D.M. Olson, and C. Loucks. Who's where in North America? Patterns of species richness and the utility of indicator taxa for conservation. *BioScience* 49:369-381.

Wilson, E.O. 2000. On the future of conservation biology. *Conservation Biology* 14:1-3.

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The 1999 issue of the Gap Analysis Bulletin is the eighth of a series of annual publications produced by the National Gap Analysis Program. The theme of this year's issue is a look back on the first ten years of GAP as well as forward to the next decade. The bulletin features 24 articles on various aspects of gap analysis methods and results. Topics addressed include land cover mapping, animal distribution modeling, reserve design, aquatic GAP, land use planning, and other applications of GAP data. As always, the bulletin also includes updates on the status of each GAP state project as well as notes and announcements.

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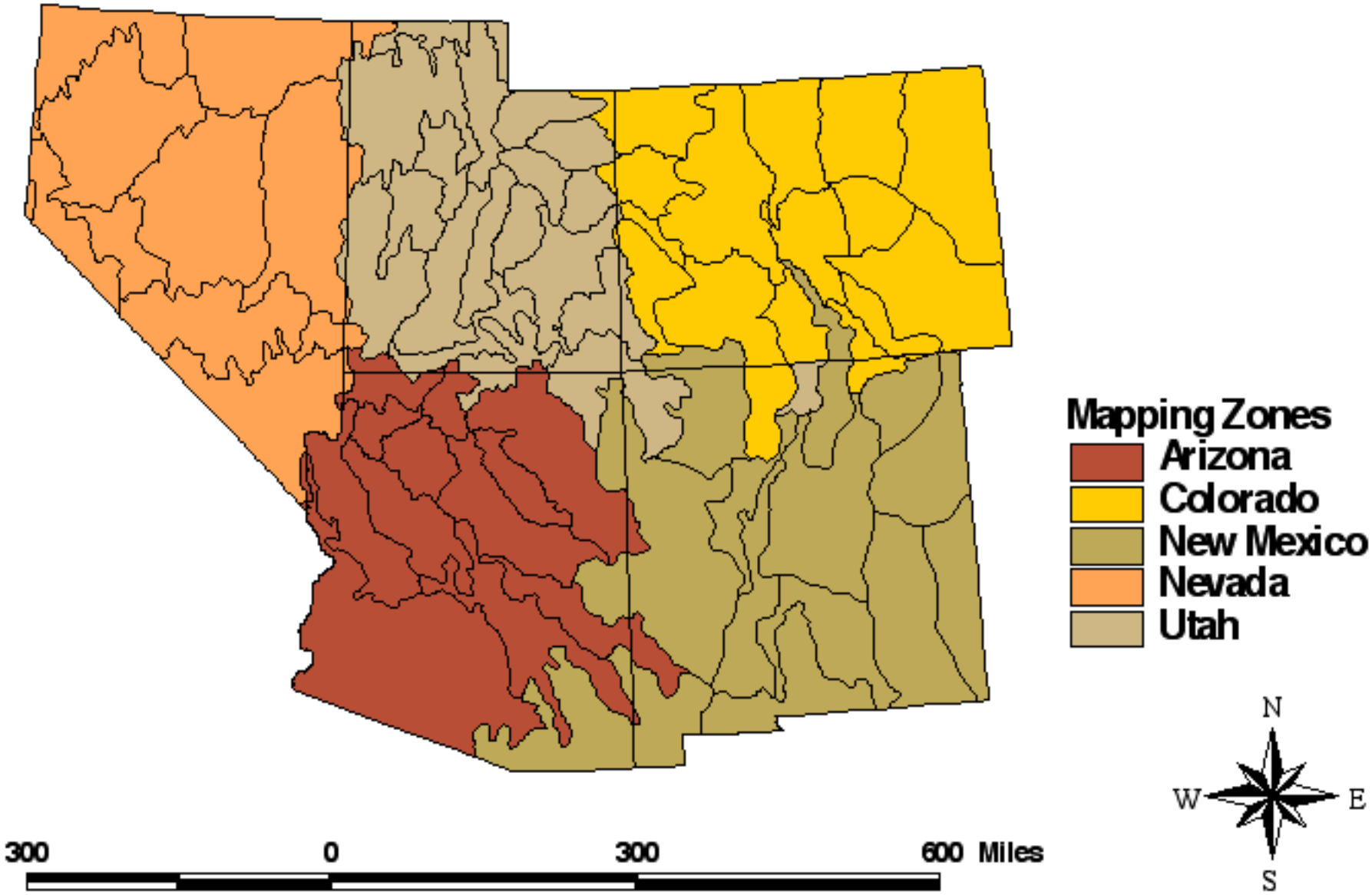
Southwest Regional Gap Analysis Project



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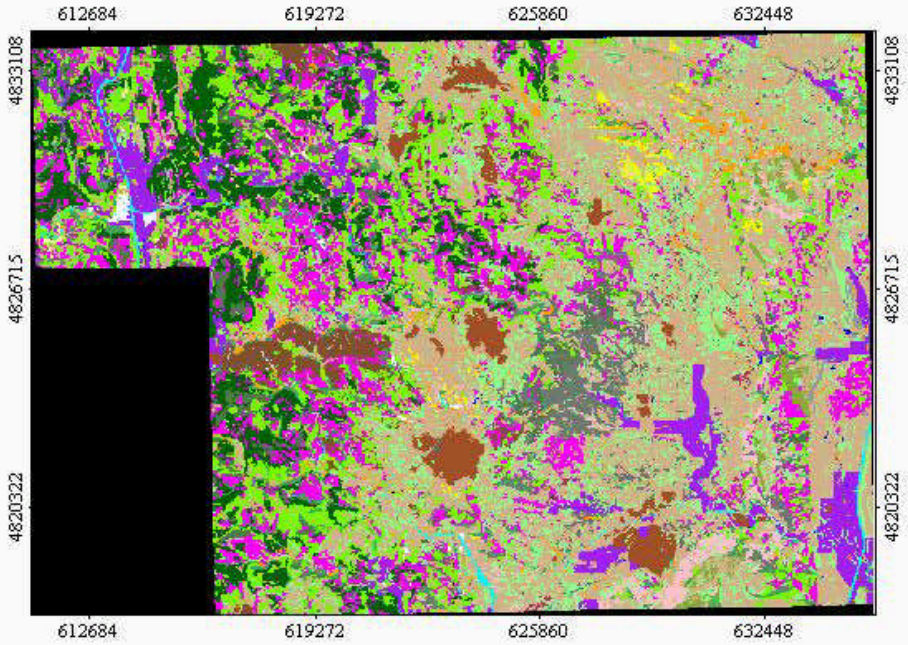

Legend

- Purple-3-Awn Fetid Marigold
- Pine Limestone Cliff Sparse Vege
- Redbeds Sparse Veg.
- Black Hills Rock Outcrop Sparse
- Shale Barren Slope Sparse Veg.
- White Sed. Rock Outcrop
- Same as #15 with Burned Pine
- Emmergent Wetland Her. Complex
- L Bluestem: G Grass
- W Wheatgrass / K Bluegrass Compl
- Introduced Weedy Graminoid
- Needle-&-Thread
- Mt. Mahogony I
- Lead Plant Shrubland
- Chokecherry
- Western Snowberry
- Plains Cottonwood/ Western Snowb
- Boxelder / Chokecherry
- Bur Oak
- Green Ash
- Birch- Aspen
- Ponderosa Pine Complex I
- PP - L Bluestem
- PP - Chokecherry
- PP complex II
- Young Ponderosa Pine Dense Cover
- Transportation, Communication, U
- Mixed Urban or built up land
- Cropland and pastures
- Open Water
- Strip Mine & Gravel Pits

N

Scale 1:190371

Meters: 0 3000 6000 9000

Kilometers: 0 4 8

Miles: 0 4

Feet: 0 10000 20000 30000

Figure 1

Figure 1. USGS-NPS classifications for Wind Cave National Park (WCNP). South Dakota.

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Table 3. Error matrix for 13 categories derived from Cluster Selection method of interpretation.

	Purple-3-awn – Fetid Marigold	Redbeds Sparse Veg	Burned Pine	Little Bluestem – Grama Grass	Western Wheatgrass – Kentucky Bluegrass	Needle-and-Thread	Mountain Mahogany	Lead Plant	Chokecherry Shrubland	Western Snowberry Shrubland	Ponderosa Pine Complex I	Ponderosa Pine – Little Bluestem	Ponderosa Pine Complex II	Total
Purple-3-awn – Fetid Marigold	8		3		12									23
Redbeds Sparse Veg				3	1									4
Burned Pine	6		14		1						4	6	8	39
Little Bluestem – Grama Grass	4		9	28	57	1		1				2	1	103
Western Wheatgrass – Kentucky Bluegrass	6		9	41	223	6	3	2		5	2	7	6	310
Needle-and-Thread				3	5									8
Mountain Mahogany	1		3	3	3							4	3	17
Lead Plant				1	4									5
Chokecherry				1	10	1		1			1	1	2	17
Western Snowberry				1	15				1				6	23
Ponderosa Pine Complex I											81	2	13	96
Ponderosa Pine / Little Bluestem			6	5	8	2				5	16	21	61	124
Ponderosa Pine Complex II	3		6	1	14				1	5	41	14	54	139
Total	28	0	50	87	353	10	3	4	2	15	145	57	154	908

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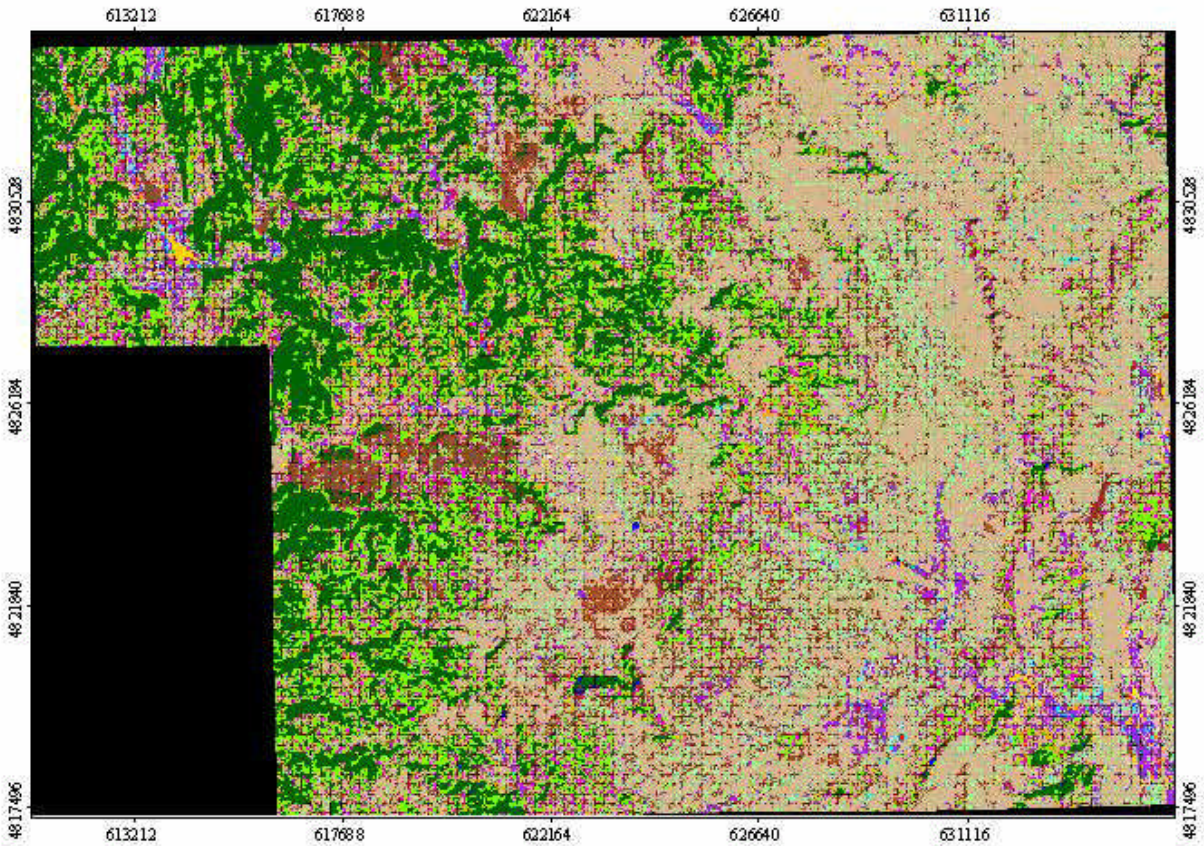

Legend

- Alfalfa
- Chokecherry Shrubland
- Cropland and Pasture
- Lead Plant
- Green Ash - A Elm / W Snowberry Forest
- Needle-&-Thread - B Grama / TL Sedge HV
- Other Agricultural Lands
- Plains Cottonwood / W Snowberry Forest
- Ponderoas Pine L Bluestem Woodland
- Ponderosa Pine Woodland Complex I
- Ponderosa Pine Woodland Complex II
- Redbeds Sparse Vegetation
- Mt. Mahogony / S Grama I
- SPARSE VEGETATION
- Shale Barren Slope Sparse Vegetation
- L Bluestem -G Grass / TL Sedge HV
- W Wheatgrass - K Bluegrass Complex
- Water
- Western Snowberry Shrubland
- Burned Pine
- Purple 3-awn and fetid Marigold HV

N

Scale 1:129341

Meters: 0, 2000, 4000, 6000
Kilometers: 0, 4
Miles: 0, 2, 4
Feet: 0, 8000, 16000

Figure 2

Figure 2. Classification of WCNP using a GIS Summary on entire Black Hills

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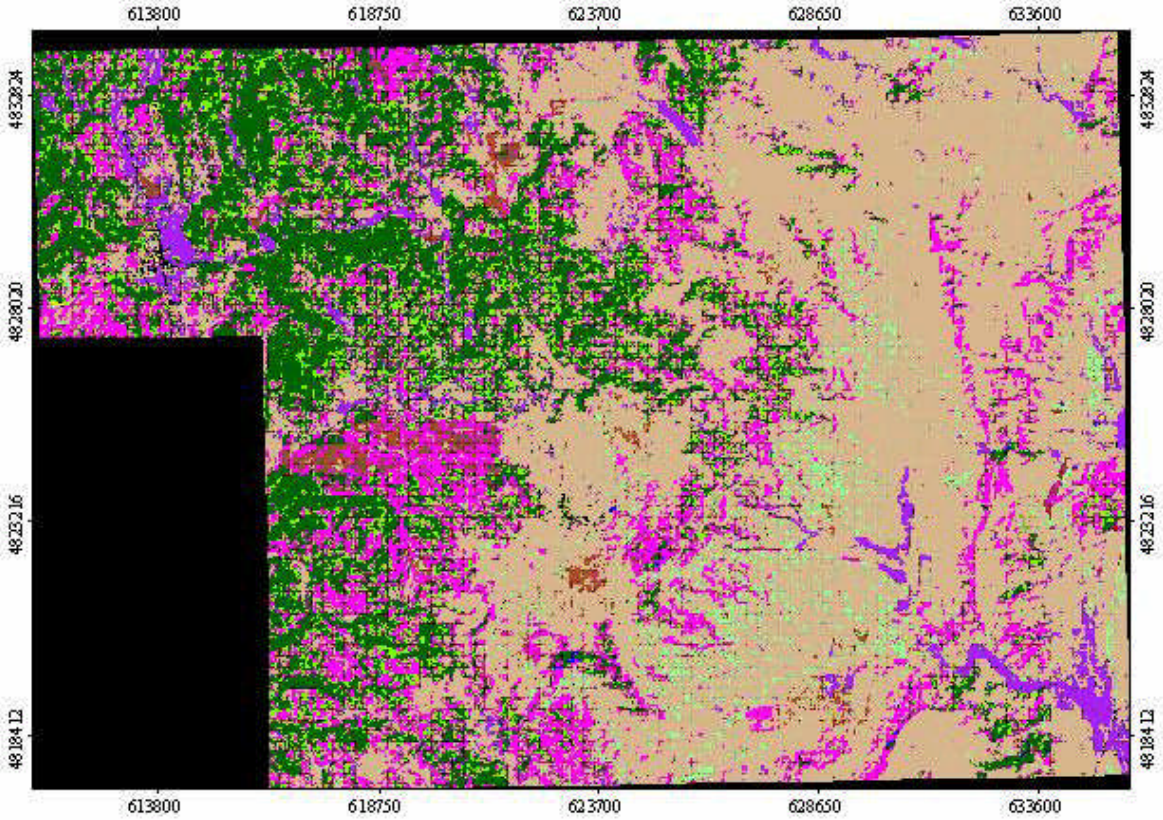

Legend

- Burned Pine
- Croplands and Pasturelands
- L. Bluestem - G Grass / TL Sedge HV
- Mt. Mahogony / Sideoats Grama I
- Other Agricultural lands
- Ponderosa Pine - Chokecherry Forest
- Ponderosa Pine Little Bluestem Woodland
- Ponderosa Pine Woodland Complex I
- Ponderosa Pine Woodland Complex II
- Purple-3-Awn Fetid Marigold HV
- Redbeds Sparse Vegetation
- Shale Barren Slope Sparse Vegetation
- Stripe Mines & Gravel Pits
- TCU, Mixed urban and Built up
- W Wheatgrass - K Bluegrass Complex
- White Sedimentary Rock Outcrop
- Water

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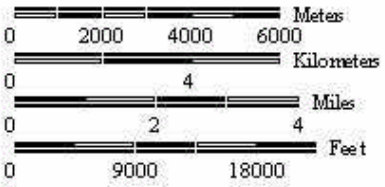

Figure 3

Figure 3. Classification of WCnp using a GIS summary on entire Black Ills efore clipping on WCNP boundary.

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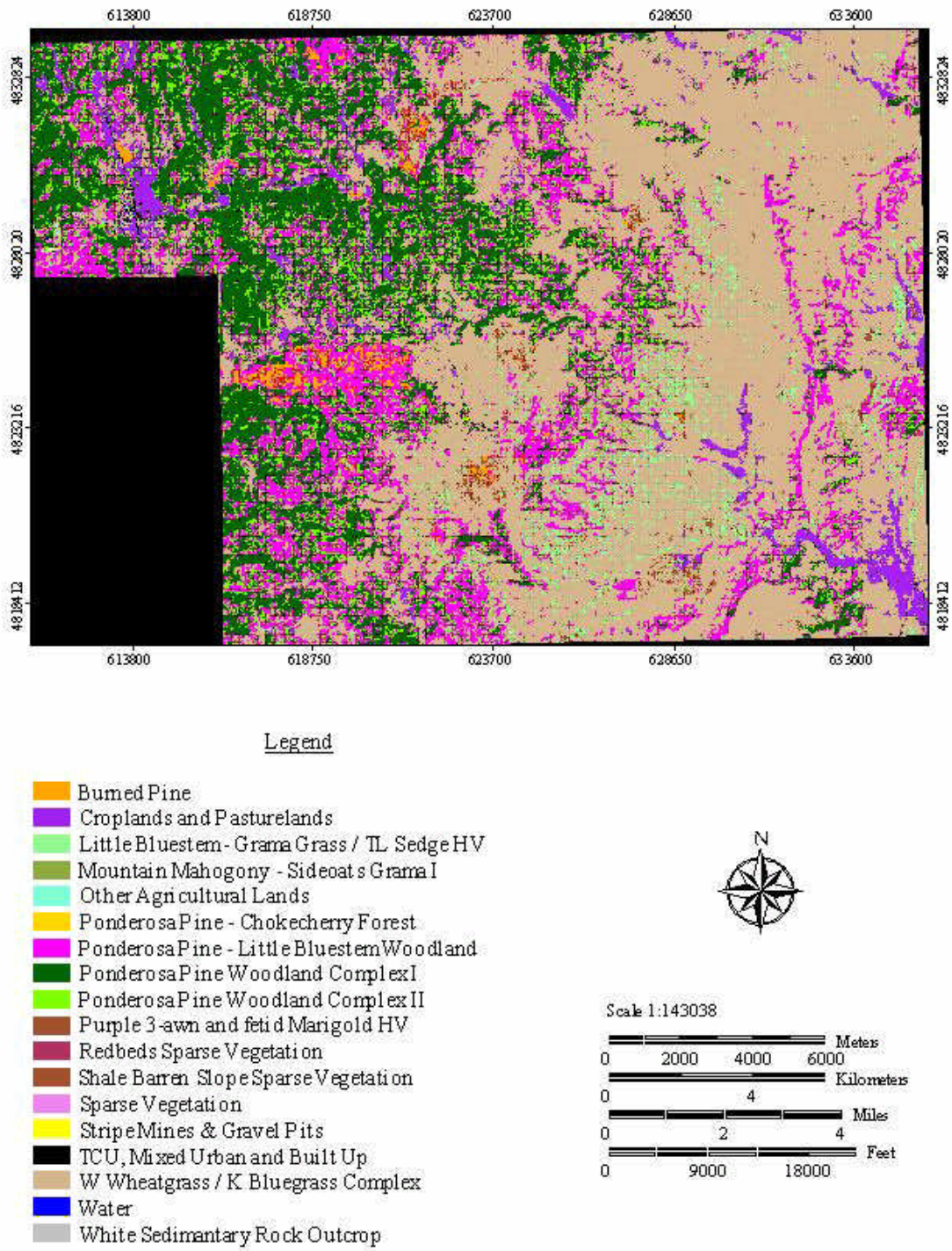

Figure 4

Figure 4. Classification of WCNP{ using the Cluster Selection Interpretation.

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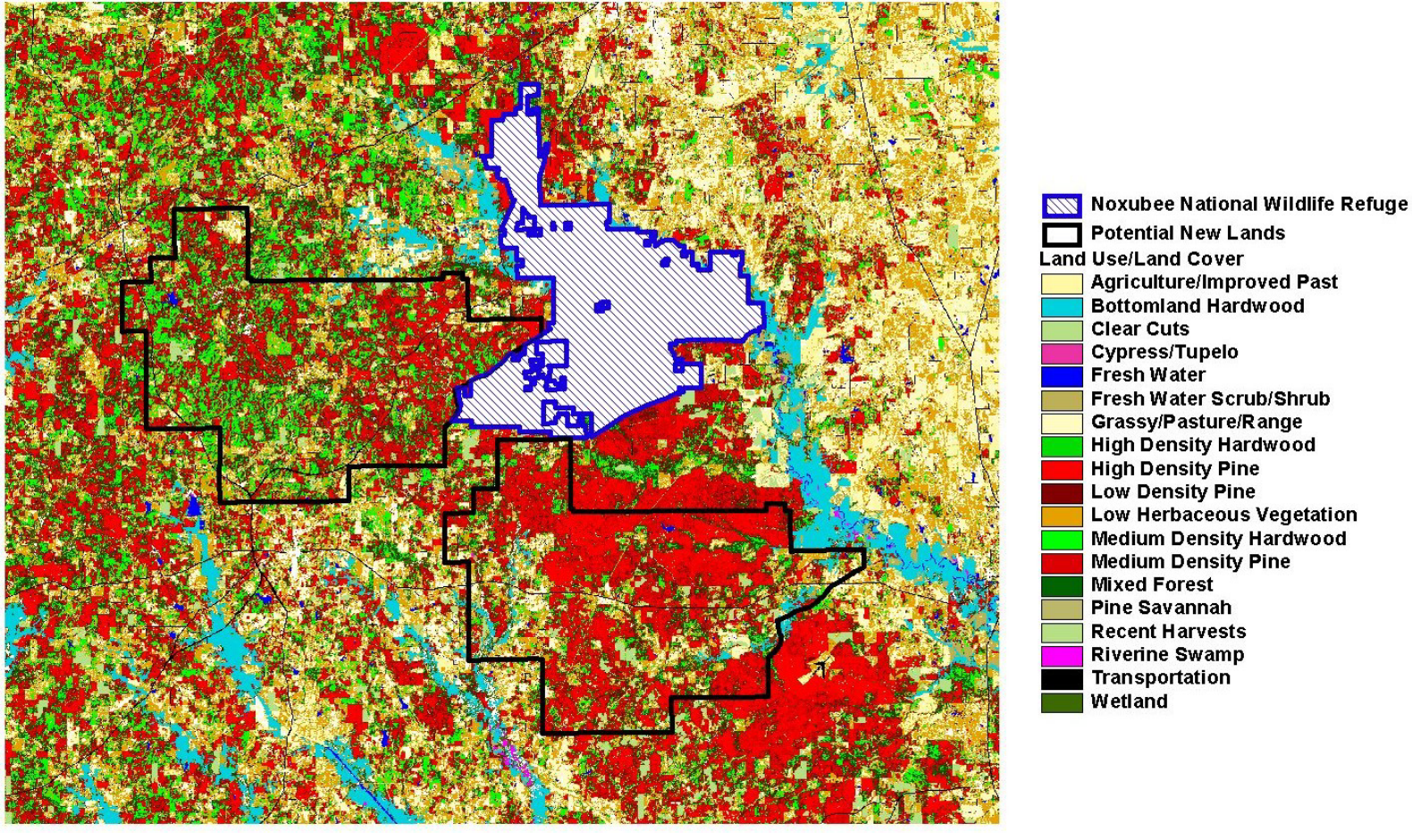

Figure 2 Theoretical contribution of adding 30,000 ha of p d-growth pine toNoxumee Wildlife Reguge for conservation of Red-cockaded Woodpecker habitat is illustrated with a moving graphic. Different locations examined resulted in varying amounts of mature pine 1,656 ha western location, 3,162 ha southern location). Land cover is generalized for illustration.

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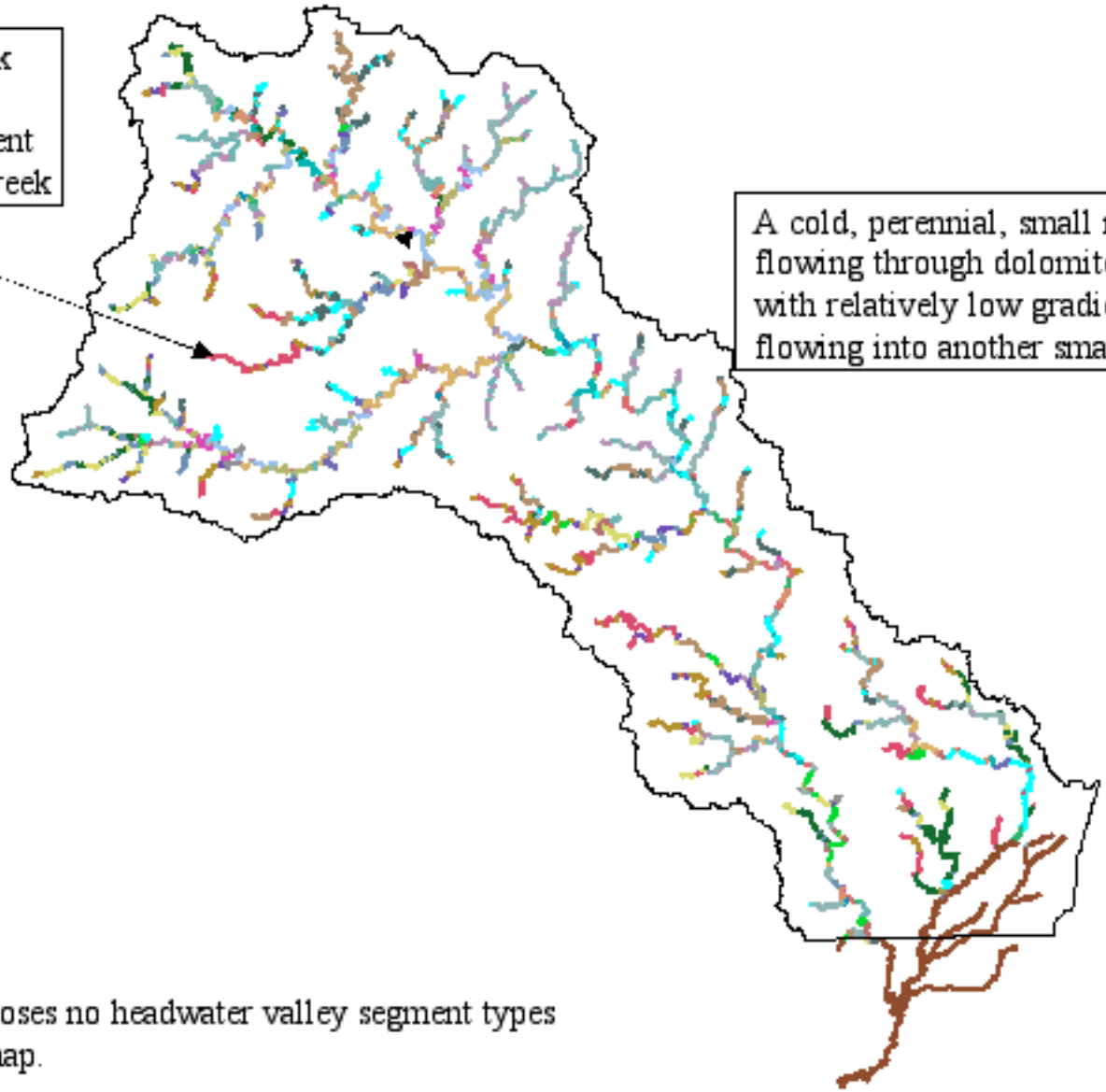
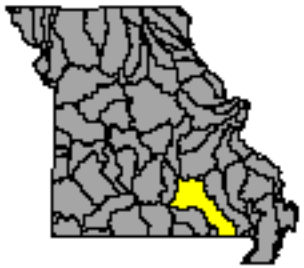
A warm, intermittent, creek flowing through sandstone with a relatively low gradient and flowing into another creek

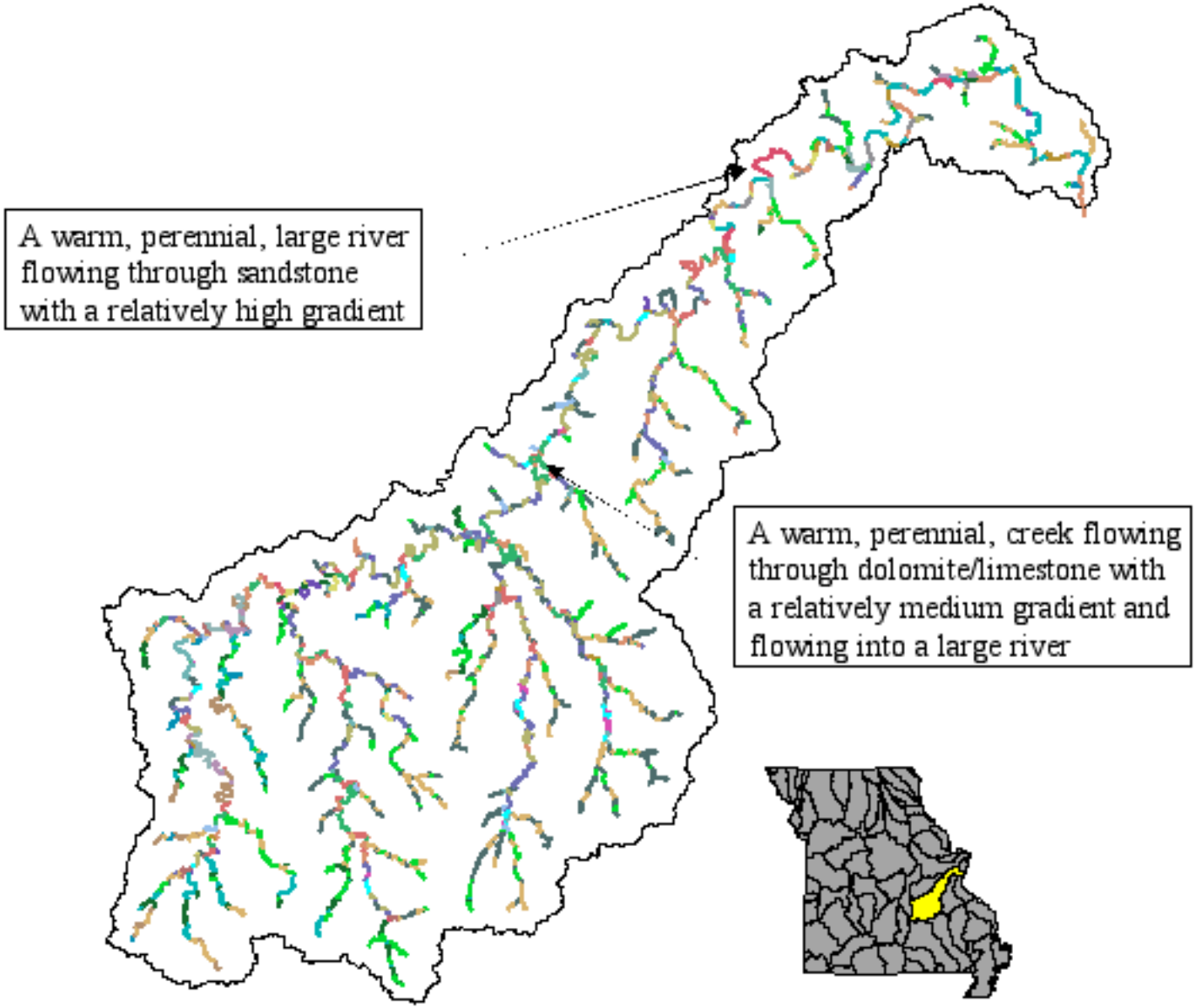


A cold, perennial, small river flowing through dolomite/limestone with relatively low gradient and flowing into another small river



Note: For display purposes no headwater valley segment types are displayed on this map.

Next Slide



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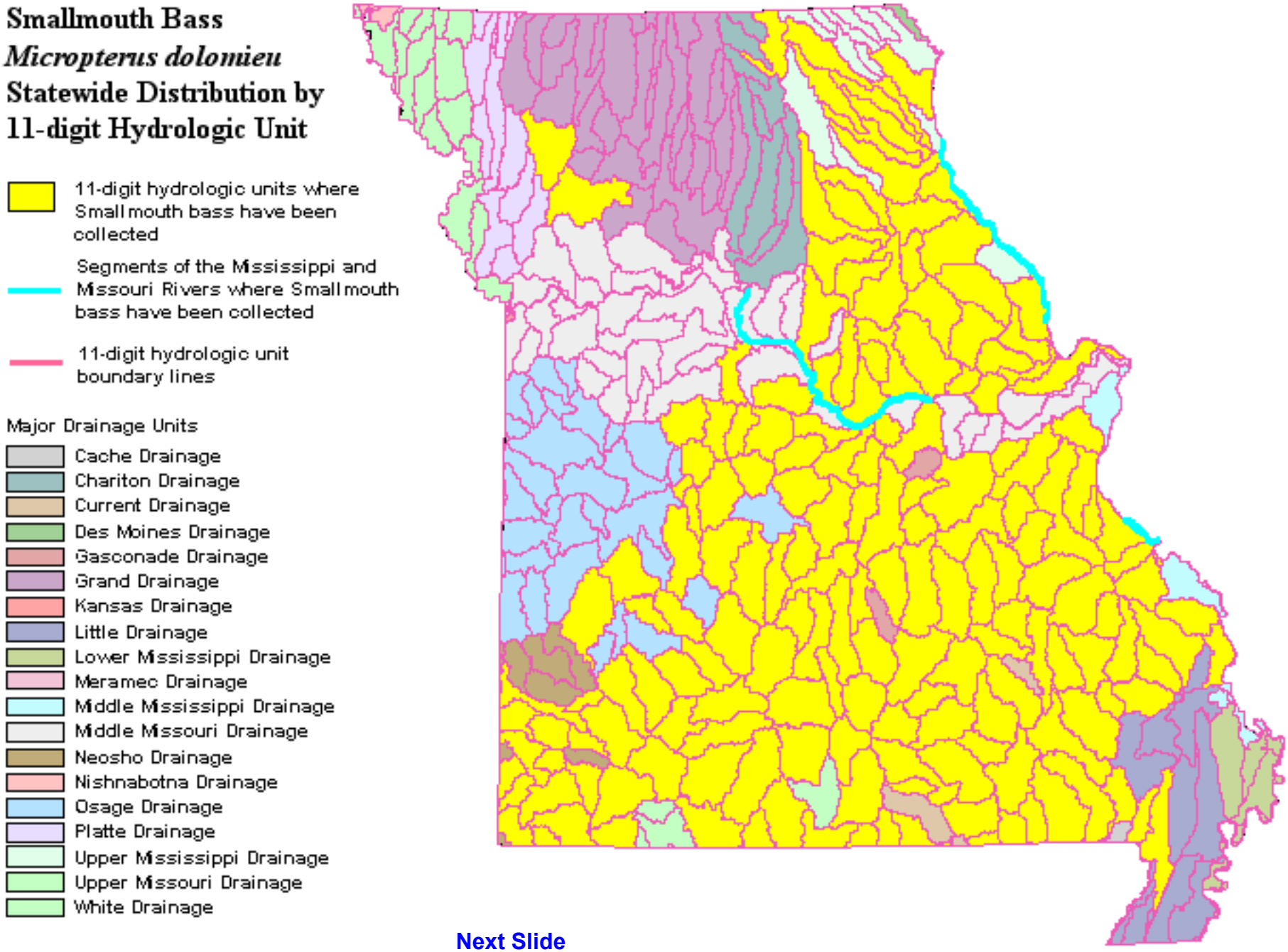
Smallmouth Bass
Micropterus dolomieu
Statewide Distribution by 11-digit Hydrologic Unit



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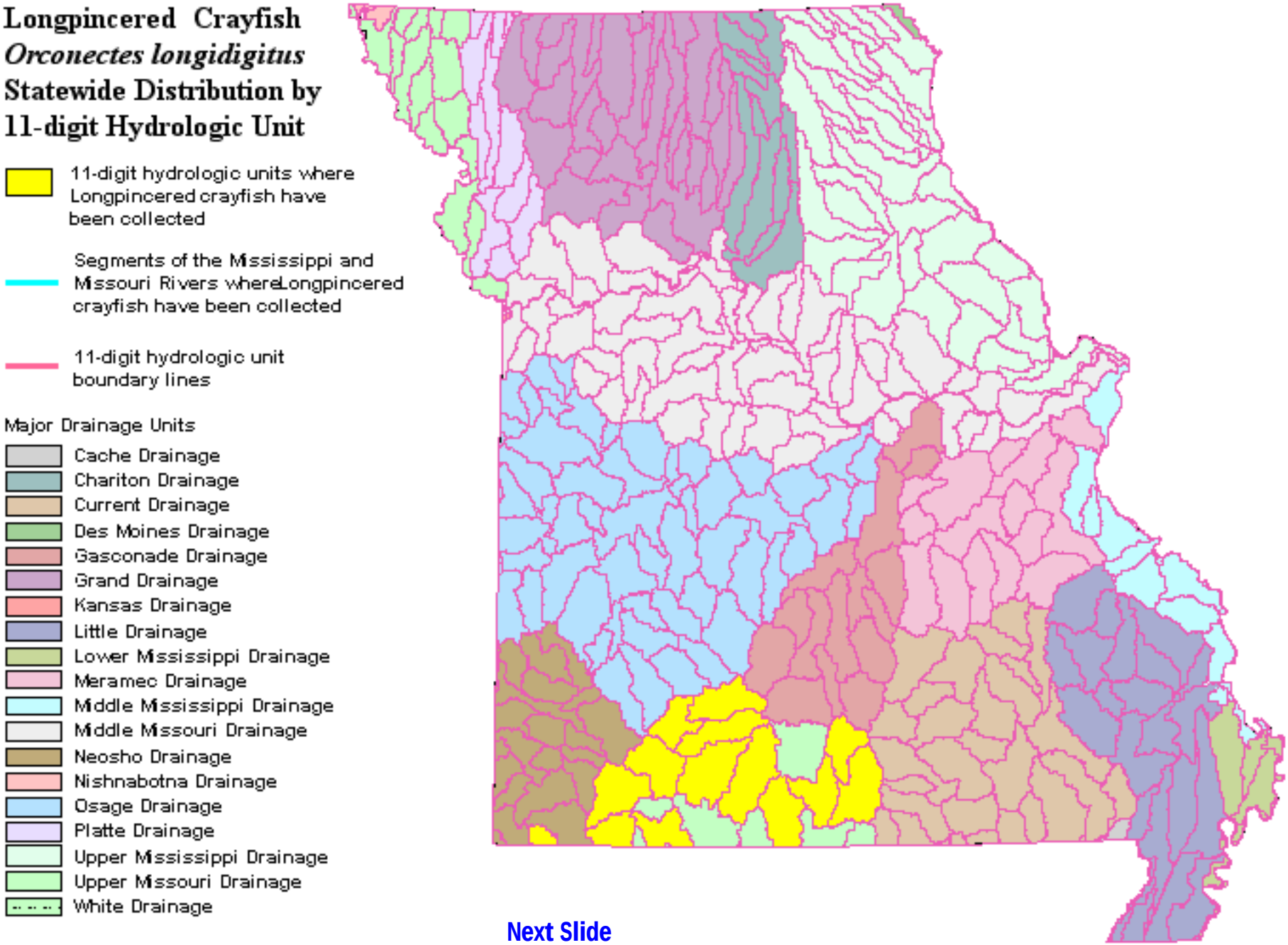
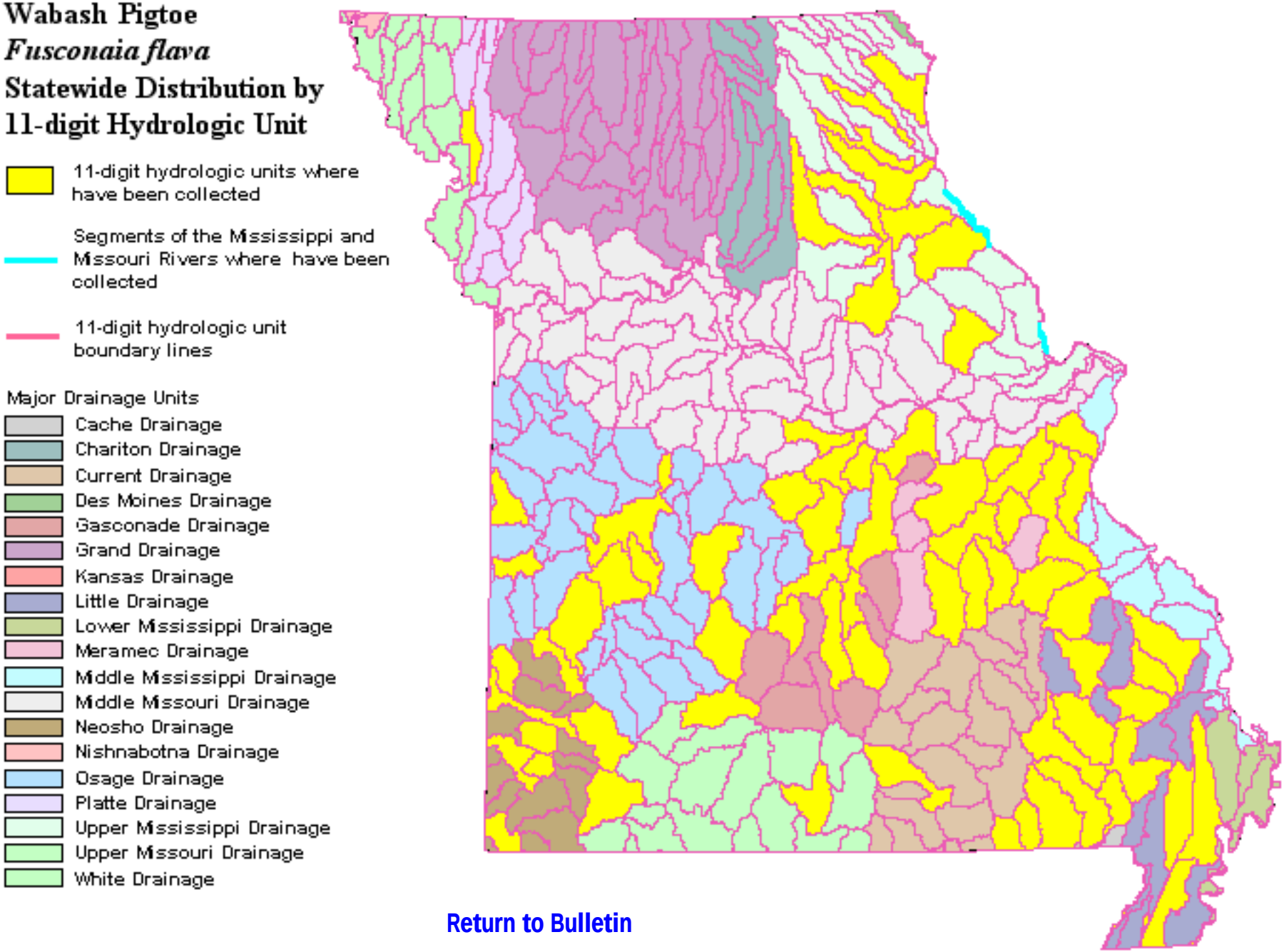
Longpincered Crayfish
Orconectes longidigitus
Statewide Distribution by 11-digit Hydrologic Unit



Next Slide

Wabash Pigtoe
Fusconaia flava
Statewide Distribution by 11-digit Hydrologic Unit



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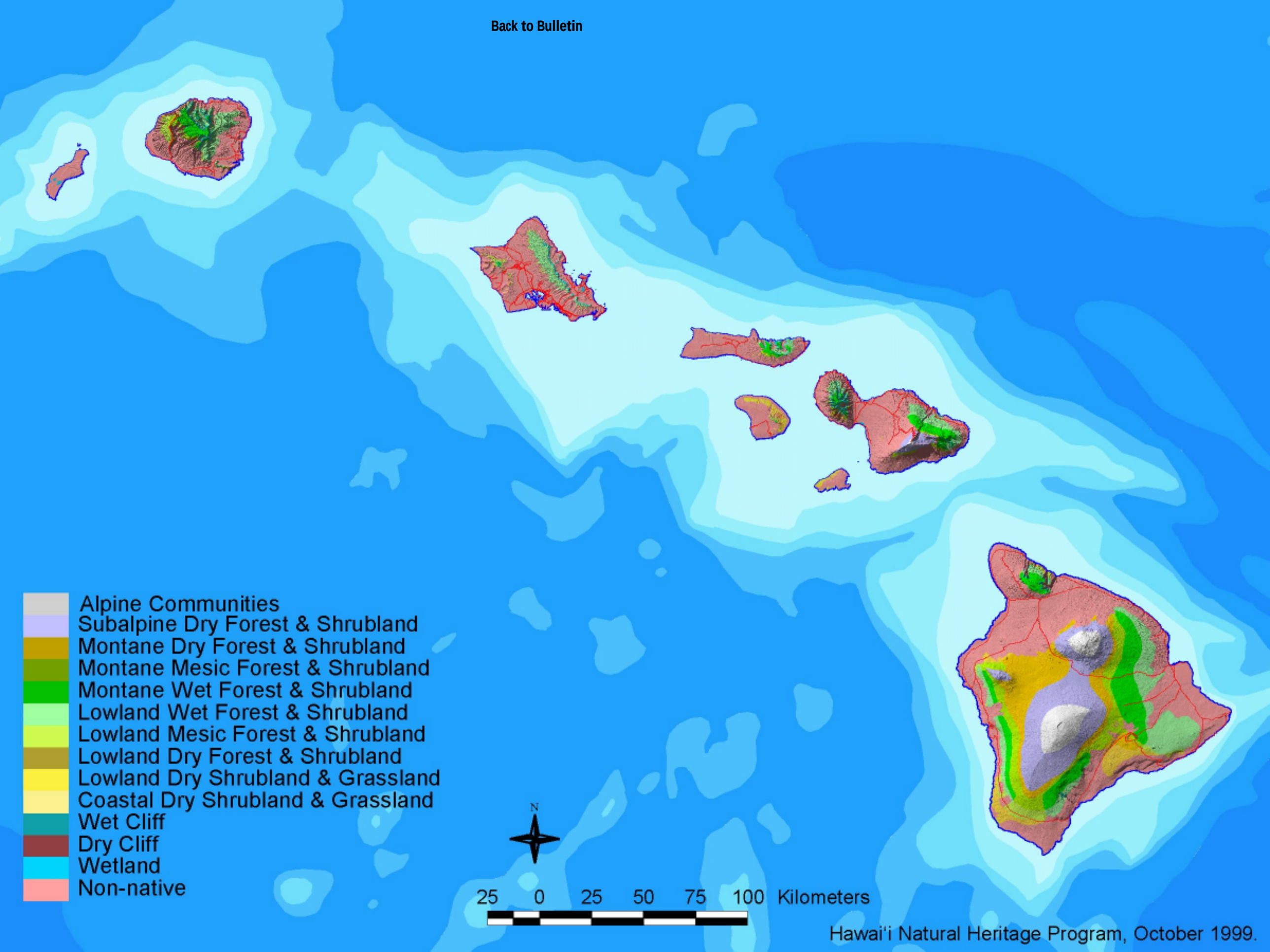
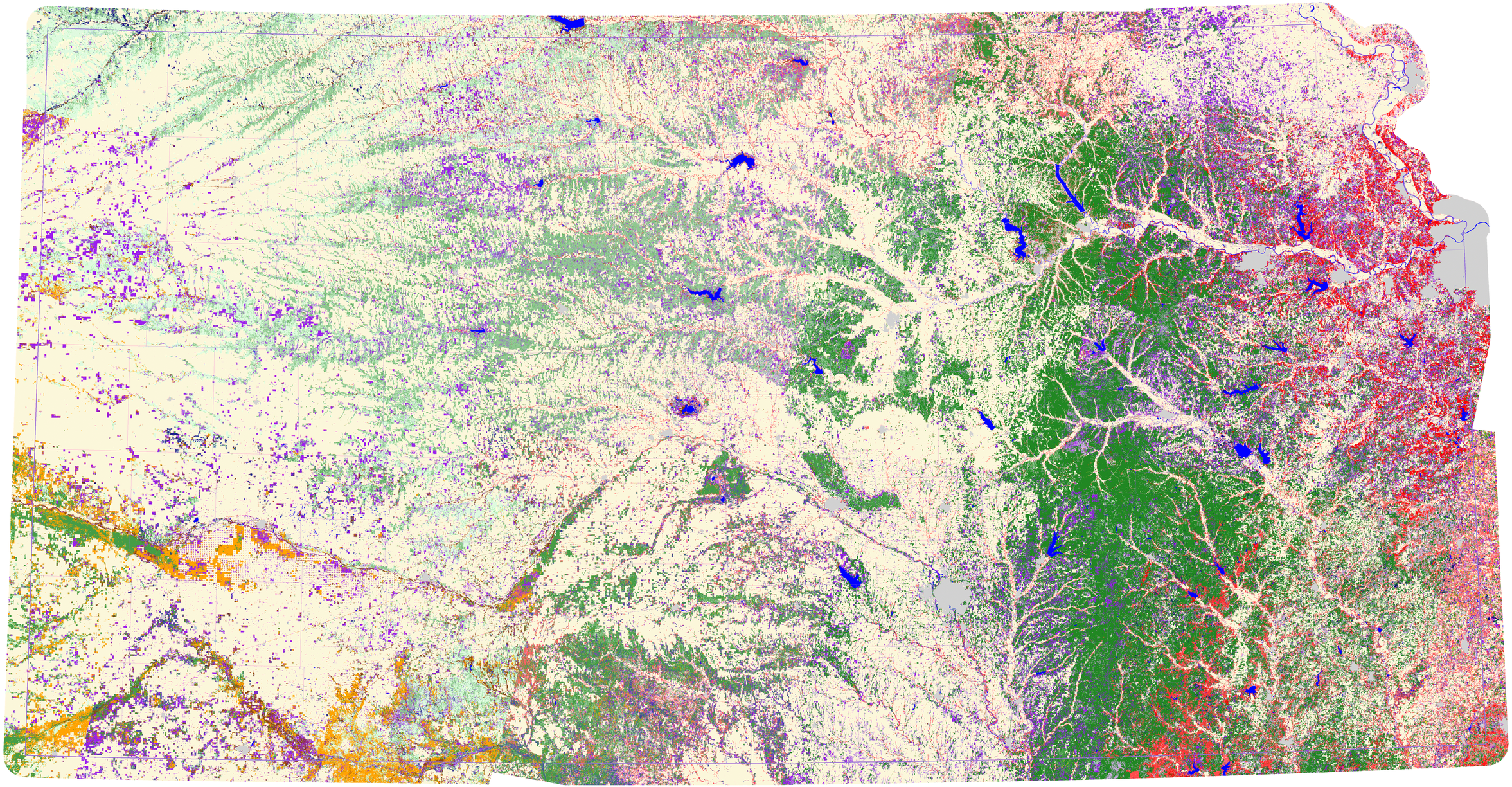


DRAFT KANSAS GAP VEGETATION MAP *DRAFT*



Scale 1:800,000 Universal Transverse Mercator, Zone 14

Land Cover and Vegetation Alliances Classes

- *Cultivated Land*
- *Urban*
- *Water*
- *Maple-Basswood Forest*
- *Oak-Hickory Forest*
- *Post Oak-Blackjack Oak Forest*
- *Pecan Floodplain Forest*
- *Ash-Elm-Hackberry Floodplain Forest*
- *Mixed Oak Floodplain Forest*
- *Deciduous Forest-Mined Land*
- *Maple Floodplain Forest*
- *Evergreen Forest-Disturbed Land*
- *Cottonwood Floodplain Forest*
- *Cottonwood Floodplain Woodland*
- *Bur Oak Floodplain Woodland*
- *Mixed Oak Ravine Woodland*
- *Post Oak-Blackjack Oak Woodland*
- *Deciduous Woodland*
- *Cottonwood Savanna*
- *Sandsage Shrubland*
- *Willow Shrubland*
- *Buttonbush (Swamp) Shrubland*
- *Weedy Upland*
- *Tallgrass Prairie*
- *Dakota (Sandstone) Hills Tallgrass Prairie*
- *Sand Prairie*
- *Western Wheatgrass Prairie*
- *Sandstone Glade/Prairie*
- *Mixed Prairie*
- *Alkali Sacaton Prairie*
- *Mixed Prairie-Disturbed Land*
- *Shortgrass Prairie*
- *Low or Wet Prairie*
- *Grass Playa Lake*
- *Salt Marsh/Prairie*
- *Spikerush Playa Lake*
- *Playa Lake*
- *Alkaline Marsh*
- *Freshwater Marsh*
- *Weedy Marsh*
- *Cattail Marsh*
- *Forb Playa Lake*
- *Pondweed Aquatic Wetland*
- *Non-native Grassland*
- *Salt Cedar or Tamarisk Shrubland*
- *Rock Outcrop/Bluff/Cliff*
- *CRP*

WARNING
DRAFT map
For Display Purposes Only
This map has not been assessed for accuracy
November 1, 1999

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Kansas Biological Survey
University of Kansas
Kansas State University

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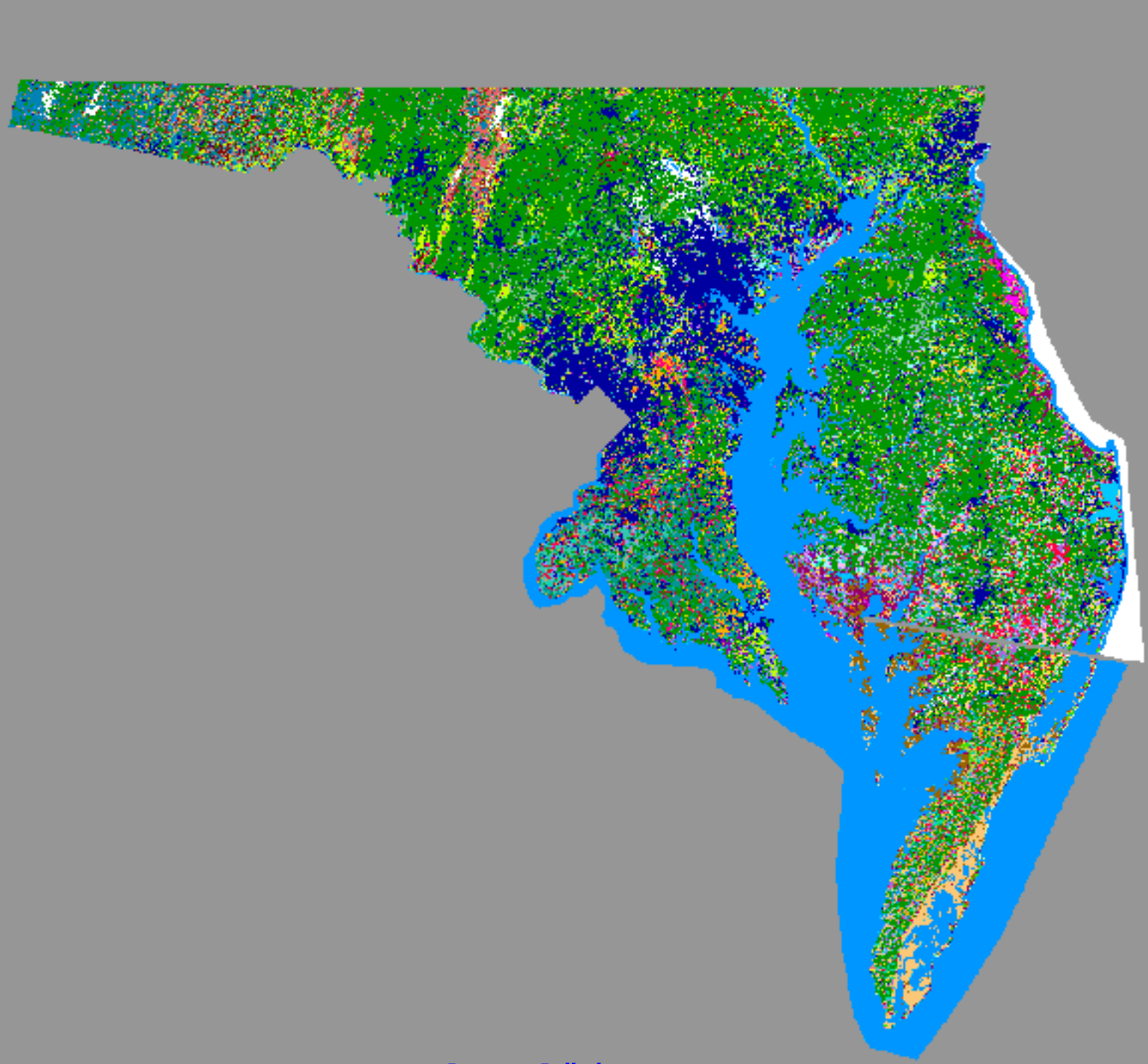

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