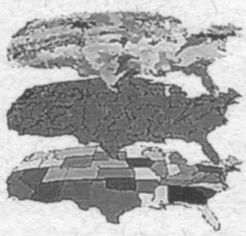

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Director's Corner

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After several years of investment, the Gap Analysis Program, which now includes approximately 500 organizations, is entering a phase of reaping significant benefits. As more and more state projects are completed, major applications of both data and results are surfacing, and the benefits from these applications are considerable. The recent EIS for the newest National Wildlife Refuge, Kankakee, in Indiana, used GAP data. GAP was identified in the Bureau of Land Management's 1999 Performance Plan as a source of essential biodiversity information. The first systematic assessment of the conservation status of vegetation communities across a huge, multistate ecoregion was completed and reported by Stoms and others (1998). That study identified twenty natural community types as vulnerable to elimination or degradation if intervention is not taken. For many of these communities, federal land agencies can avoid future conservation crises by changing current land management practices. A second multistate analysis covering an even larger region is presented in the article by Gerry Wright and others on page __.

This year GAP final reports were completed for Arkansas, California, Maine, Montana, and Washington. In 1999 we expect to see at least 10 more final reports. State projects were begun in 1998 in Ohio, Georgia, and North Dakota. Also this year the mission of providing biodiversity conservation assessment moved beyond the existing methods for mapping distributions of vegetation types and each species of amphibian, bird, mammal, and reptile. Important progress was made in developing capabilities for mapping distributions of ant, crayfish, fish, mussel, plant, and snail species.

This departure beyond vertebrate species is significant and defining. GAP has been legitimately criticized that as a biodiversity program, it has not included those phyla that make up most of the diversity of life on Earth. While this is true, there were also good reasons for the strategy that focused on vertebrates when GAP began. Now, however, GAP is beginning to explore and discover how to map distributions of species from some of the 21 phyla other than chordates. While we may set priorities for which life forms to focus on first, at the end of the day, biodiversity is still a package deal. If we are going to be a biodiversity program, achieving conservation through good science and information rather than an interest group for particular life forms, then we must commit to apply principles of gap analysis to all forms of life.

Grasping this bigger picture, however, does not come easily to everyone. The enormous success attained by GAP resulted this year in an attempt to start a separate "aquatic gap analysis program." While eagerly embraced at first, it later became clear that this attempt did not share an understanding of biodiversity writ large, nor a cooperative commitment to biodiversity conservation that might truly help break that "land-water" barrier which has plagued the way natural resources management has been traditionally carried out. Sadly, the attempt to create a separate program would perpetuate this traditional division of land and water as two separate worlds. One is almost forced to ask, "Are mammals not aquatic?" How could birds ever be separated from water bodies? And reptiles? Amphibians? Debates about where the land ends and the water begins surely go back a long, long way. Most biologists today would agree that for management purposes, it just does not make sense to try to separate life along the humidity gradient. Additionally, one central reason for the greater declines of taxa that depend more strongly on submerged environments (Master et al. 1998) is precisely this historical disjunct between land and water in resource planning, management, and research. To be effective in managing our living resources sustainably, we must use a holistic model to develop information about them. Happily, the decision by the USGS is that there will be only one Gap Analysis Program, and we are getting about the business of applying the principles of gap analysis to other phyla as, of course, the budget will allow (which is another matter).

Pragmatic advances in applying gap analysis to fish, crayfish, mussels, and snails are summarized in the article by Scott Sowa. Scott's work has begun to show a spatially explicit relationship between community diversity and species rarity that may someday prove to be as significant as principles of island biogeography. Marci Meixler and Mark Bain also provide excellent descriptions of habitat characterization, animal modeling, and analysis for fish species in New York on page __. Craig Allen and colleagues describe their approach for modeling ant species distributions in Florida in quite some depth, and Walter Fertig and colleagues at the University of Wyoming describe how they sorted plant species for gap analysis.

This year The Nature Conservancy delivered formal descriptions of approximately 1,150 vegetation alliances from the Midwest, Southeast, and Southwest. This fundamentally important work is the base line for establishing a credible taxonomy of consistent ecological communities for the U.S. and is the point of origin for the floristic levels of the National Vegetation Classification. Marion Reid of TNC gives us a bird's-eye view of this in her article on alliance descriptions of the western U.S. Leonard Pearlstine and others from the Southeastern GAP group explain a new approach for standardizing on two different groupings of vegetation alliances for mapping purposes: alliances that consistently occur in tightly interdigitated patterns ("ecological complexes"), and alliances that are similar in composition, where the dominant species that distinguish certain types are in the same genus ("compositional groups," e.g., there are two different Typha alliances distinguished only by the shift in dominance from *T. latifolia* to *T. angustifolia*). Their approach promises to solve some of the problems inherent to the "mapping vs. ecology" tension zone.

Also this year GAP completed a successful pilot project on biodiversity decision support systems for county planners and began work on a similar system for National Wildlife Refuge managers. Patrick Crist and Margo Herdendorf give readers a wonderful account of the concepts as well as the implementation of a system that is complex and sophisticated behind the scenes yet straightforward and simple for the user.

These are just some of the innovations that are covered in this year's GAP Bulletin. All of them represent the erupting science and technology now pouring out of GAP. The huge amount of species habitat modeling promulgated by GAP has resulted in a international symposium planned for next October (see page __). To top it off, the GAP web site was recognized by *Natural History* magazine as one of the top 10 biodiversity web sites in the world. The hundreds of geographers, zoologists, community ecologists, botanists, computer scientists, conservation biologists, and remote sensing experts that make up the GAP community deserve to be proud of our progress and optimistic about the future of conservation.

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Decision Support Systems: New Tools for Data Users

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Putting digital data and information in the hands of users more efficiently and easily is the "hot" topic among data-producing agencies today. In October 1998, I presented the Gap Analysis Program's (GAP) three-pronged approach to dissemination at the "Gateways to the Earth" workshop—an initiative of USGS. These three approaches are:

1. The GAP web site, which acts like a gateway of its own to the state projects which serve not just GAP data but, in many cases, a large collection of other state information and services.
2. CD-ROMs, which are currently GAP's official and preferred method of data delivery to the public. While not discounting the growing importance of Internet delivery, I believe CDs currently offer a more efficient method of transmitting our very large data sets in a way guaranteed to provide the user with all documentation, including the final project report, needed for intelligent data use.
3. Decision support systems (DSS). GAP has recognized a need for biodiversity decision support systems in general, and DSS for GAP data in particular. This is because GAP data is novel in the decision-making realm—planners and managers have never before had data like GAP or a methodology for incorporating it into their decision-making processes. How they should accomplish this, though, is neither obvious nor simple.

There are many definitions of DSS, but essentially, they are systems that package information and tools that interpret that information in a form more readily integrated into decision-making processes (Zhu et al. 1998). Typically, but not always, they are comprised of a GIS for spatial data, databases of textual or tabular data, an interface designed for the user's needs, as well as models, scripts, and programs that process the data according to the user's specific criteria and queries.

In addition to the Gateways workshop which focused on an Internet-based interface to the breadth of USGS programs and information, I also attended two other workshops on DSS. In September, the Aurora Partnership workshop was sponsored by the Department of the Interior (DOI) and Environmental Systems Research Institute (ESRI). This was a meeting of over 100 representatives from federal agencies, private consulting and software firms, nonprofit groups, and academics from around the country interested in DSS. Its purpose was to demonstrate the state of DSS and exchange ideas on how to coordinate efforts and share knowledge. The goal of the partnership is to facilitate the intellectual and technological development of DSS. In October, the USGS Biological Resources Division likewise had a meeting to survey existing BRD DSS activities and discuss ways to strategically implement and coordinate DSS.

Jankowski et al. (1997 p. 578) identify three functions for a decision support system:

> *(1) help decision-makers formulate, frame, or assess decision situations by identifying the salient features of the environment, recognizing needs, [and] identifying appropriate objectives by which to measure the successful resolution of an issue; (2) provide support in enhancing the abilities of decision-makers to obtain and analyze possible impacts of alternative courses of action; and (3) enhance the ability of decision-makers to interpret impacts in terms of objectives, leading to an evaluation of alternatives and selection of a preferred option.*

The goals of GAP's pilot systems are less ambitious than the three functions described above, but their capabilities are balanced with the basic objective of making the consideration of biodiversity by nontechnical users as simple and routine as other commonly considered elements such as stormwater management or scenic views. Stormwater management is a suitable analogy because it required many years of base data collection and analysis-tool development by the federal government prior to becoming a common element of consideration at the local level (Environmental Protection Agency 1995). Negative effects of over- or improper development in the form of increased flooding and pollution created the political will to adopt regulations and tools to implement them (Environmental Protection Agency 1995). I believe that the state of biodiversity decline has reached a similar crisis and will follow a similar pattern of solution development and implementation.

To address this need, GAP currently has two ongoing DSS development projects to serve two different user groups with very different missions. The first is BEST, the biodiversity expert systems tool designed for local government land use planners to consider impacts of proposed land uses on species and plant communities (see http://www.gap.uidaho.edu/gap/RA/View.asp?ProjectID). It is intended to operate at the front end of the development permit process and allows queries of impacts from specific land use types on individual biotic elements. BEST is an expert systems tool, rather than a full decision support system in the more robust definition (Zhu et al. 1998) in that it provides knowledge necessary for objective decision-making. It does not guide the user through the complete process to reach the final decision such as "permit or deny the development proposal" because of the many other nonbiotic factors that must be considered by land use planners. We define an expert systems tool in this context as one that incorporates knowledge of experts into a system that allows easy retrieval of that knowledge to support decisions by nonexperts. Such systems are applicable to situations where it is impractical or inefficient to provide direct interaction with the expert because it is either too costly or the need is too infrequent to retain continuous access to such expertise. The approach is also valuable when the expert knowledge would be inefficient to access on a case-by-case basis, such as when literature reviews or calculations are required. In those situations, it is more efficient to gather the information all at once and archive it in a database (Zhu et al. 1998).

The second GAP DSS under development is Refuge-GAP, intended to aid the U.S. Fish and Wildlife Service in using GAP and other data for refuge planning (see sidebar). This system has some similarity to BEST in that it allows the user to specify a parcel, in this case an existing refuge or user-defined area, and to identify those elements that may occur on the parcel. It is also hierarchical so that the user can query for elements with different levels or categories of risk. Unlike BEST, it contains a decision-making process for scoring lands for acquisition potential using an established system LAPS (Land Acquisition Priority System). The combination of functions provided in Refuge-GAP supports both an established agency process and also the ability to explore and query the information in a more flexible manner.

These two systems characterize the two basic, though not exclusive, types of biodiversity applications: short-term impact assessment and long-term planning. BEST is an example of a system designed to address short-term local retention of biodiversity. This is accomplished by predicting impacts to individual biota from specific land uses at the level of individual parcels. Refuge-GAP is a planning system that provides a broad-scale, longer-term view of elements in need of further protection by the refuge network. The former predicts risk and aids in mitigation of that risk before the impact has occurred, while the latter identifies elements that could be currently at risk (conservation gaps) and reduces their level of risk in the future through refuge planning.

When the concepts underlying these two systems are coupled, a system emerges that addresses biodiversity conservation across the gradient of scales from large-area, long-term planning to single-parcel, short-term decision-making and design. This coupling is critical to moving systematic conservation forward because too often large-area plans fail for lack of attention as to how the plan will be implemented by site-level decisions. Likewise, site-level based activities conducted without the context of a larger plan result in fragmented, ineffective, or destructive actions.

The recent workshops have called for integration of DSS tools to create more robust systems that can address, for example, biodiversity, natural hazards, and socioeconomics in project planning. Integration of tools is complicated, however, by their creation in separate institutions for different user groups. It suffers from the same difficulties of integration that GIS data itself suffered prior to standards for metadata and interoperability—problems not yet entirely resolved. The difficulty of integrating DSS modules composed of custom scripts, models, and interfaces will, I believe, be far more difficult than problems of GIS data interoperability. Institution of top-down directives and funding systems to facilitate integration similar to those of FGDC and NBII programs for GIS data may be the only way to address this need, but such approaches are not currently viewed as desirable or feasible. For these reasons, I suggested to BRD that the focus of integration be on the output of DSSs. That is, that the output from one system be readily readable and usable by another system. Outputs are already fairly standardized in the form of GIS, text, tabular, and graphic image formats. The dream of some may be a suite of "plug-and-play" DSS modules, but without substantial funding, standards, and agency directives, that dream may never be realized.

Moving Forward

Technologically, development of a DSS has become a relatively simple task with off-the-shelf tools for interface development and better integration of GIS, database, and graphics software. The real work comes in the interpretation of the user's mission or decision-making process to queries that can be answered by a DSS. In the simplest of systems, this requires converting the data and documentation to a format that is directly informative to the user's questions and making documentation accessible and friendly. In a manuscript for *Landscape Ecology* (Crist et al. in press) I explore the science needs in the development of biodiversity decision support systems. However, the discussion is far from exhaustive. The science needs fall under three categories that must be integrated in a biodiversity DSS: biological science, GIS/technological science, and decision process science. The discipline of the user group for which the DSS is designed has to be incorporated with all of these. Each of these categories is discussed briefly below.

Biological Science Needs:

Given our desire to create *biodiversity* decision support systems (or BDSS as I will refer to it from here on), the most important need in this regard is for distribution and status information for *all* biotic elements. GAP follows an element-based approach in mapping and analysis. I advocate the same for a DSS because I believe there are not yet, and may never be, surrogates appropriate for multiple phyla, umbrella species, or ecoregion approaches that can effectively conserve all biodiversity. This is because such approaches cannot incorporate all of the requirements of every species. Given the unlikelihood that all elements will be mapped and assessed before many of them are extirpated, however, I acknowledge the need for the use of surrogates where appropriate. These surrogates should be applied at the level of the guild, in sufficient detail to conserve the diversity of niches for species with the narrowest niche requirements. I also recognize the need for more comprehensive ecosystem assessment and conservation methods to deal with the nonbiotic components of biodiversity conservation, such as ecosystem processes. Some specific biological science needs are:

(a) Species information database: In constructing BEST, qualitative information on the biotic elements had to be drawn from GAP, Heritage databases, literature, and personal communications. Gathering and interpreting sufficient information to designate species sensitivities was a substantial effort that required approximately four months for 40 species.

This experience has led me to advocate a central, national database (or linked distributed databases centrally accessed) of our sum knowledge of all species. The content would include not only the taxonomy and habitat association information, but the life history, known sensitivities, and of course, known and predicted distribution. This information, collected according to uniform protocols and a stable set of data fields, could be accessed for use in the development of land use and management plans and individual project impact assessments. Standardized databases of biological elements are taking shape through The Nature Conservancy (http://www.consci.tnc.org/src/zoodata.htm), Natural Heritage Programs, Gap Analysis Program, and the Integrated Taxonomic Information System (ITIS) (http://biology.usgs.gov/cbi2/programs/itis.html), but they generally lack the data required for the kind of biotic impact prediction that many users need. Another benefit of such an approach is that it could foster archiving the vast amount of information gathered every year by academia, agencies, private consultants, naturalists, and programs such as NatureMapping (http://salmo.cqs.washington.edu/~wagap/nm/).

(b) Impact guilds: Despite the need to address biodiversity conservation at the individual species level (Noss and Cooperrider 1994), many plant and animal species may face extinction before they can be adequately studied for sensitivities to human impacts. This suggests that we must generalize existing knowledge of studied species to provide guidelines for related species in the form of "impact guilds" (Truett et al. 1994, O'Neill et al. 1986). Because some genetically related species show high degrees of variation in response to the same disturbance, impacts guilds should be based upon similar response to the same categories of human land uses, e.g. "elimination of the herbaceous layer impacts foraging" (Arcese et al. 1997). The use of this approach can allow assessments of species not previously studied by relating them to other studied species with which they share similar requirements and therefore sensitivities. Individual species assessments, therefore, will not be absolutely necessary to take actions to help conserve those species while they are still viable.

<u>GIS/Technological Science Needs</u>:
As noted above, many of the technological problems of constructing a DSS have been solved with off-the-shelf tools suited to easy system development; however, there are still some difficult challenges. Among these are:

- Interoperability among platforms. Most systems, including ours (developed for ArcView), are not easily ported to other platforms.
- Adaptability to changing and future technologies
- Data exchange—how easy will it be for a nontechnical user to upgrade or add data to the system?

<u>Decision Process Science Needs:</u>
This science is probably the least developed, but much work is being conducted (Jankowski et al. 1997, Pressey et al. 1993). The most important and obvious need is to understand the user's decision process, what data is needed for that process, and how that data must be packaged, filtered, transformed, etc., to answer user queries. I have found through our pilot projects that

simply asking users what they need is not effective; they often have no experience with DSS or GAP data and cannot envision how to incorporate it into their decision-making process. Therefore, an iterative approach to DSS development is required. This begins with a pilot system to demonstrate system ability to deal with some core queries, followed by user feedback on necessary changes and additions to the system. I provide some more thoughts on DSS implementation later; following are some categories of decision process science needs related to a BDSS.

A starting point in the development of a BDSS is a categorization scheme for human activity impacts. In the development of BEST, which "cans" biological expertise for instant access by the system user, we had to build a bridge between the languages of planners and biologists. This led us to develop a system for categorizing land uses in terms of ecological impacts rather than the standard planning descriptions such as "single family subdivision" that have no ecological meaning. This system provides a biologist with the information to assess biotic sensitivities to land uses without direct knowledge of the exact land use or specific design. The system also had to take the biological knowledge and report it back to the planner in terms meaningful to him or her. Putting aside the real need for conservation plans for every species, we should conduct specific impact assessments for each biotic element and each proposed human activity at the local level. This would require a substantial effort. Therefore, a categorization scheme that can translate human activities into categories of impacts is necessary to provide a more generalized approach.

There is discomfort with the idea that a biologist will assess potential impact to a biotic element without knowing the specific land use and design (M. Scott, pers. comm.; also Truett et al. 1994), but some authors readily acknowledge both the necessity and workability of such an approach (Duncan et al. 1986, Blair 1996). Currently, for individual land use project assessments, the biologist and land use planner must educate each other about both the nature of the land use, and nature of the habitat and biotic elements, and integrate the information into knowledge that can be used to determine biotic impacts (C. Whiteside, pers. comm.). Although such an arrangement would be beneficial, few jurisdictions can afford it. BEST uses a priori categorization of land uses to levels of impact, therefore capturing the knowledge in a single effort to be used for all future assessments (with periodic updates as needed). Emlen (1974) gives support to this approach, noting that the effects of urbanization on birds can usually be readily identified in the form of increase in perch sites that support territorial bird species, cavity and arboreal nest sites, water availability, ground predation, and food. Therefore, one should be able to examine species' habits and resource needs, compare these to categories of urbanization and land use, and predict if the species will do better or worse after development. Knight and Cole (1995) likewise identify characteristics of recreation activities that can be used to predict species reactions in combination with information on the species. They also note that the similarity of the human disturbance to natural disturbance can be used to predict species reactions.

New types of land uses appear all the time (e.g. paint ball, jet skis); therefore, it is important that the impact categories be generalizable and do not require an individual study of every new land use type before predicting possible impacts. The concept is familiar to land use planners and managers when developing land-use zones or management units where the capabilities and desired types of uses are identified with enough flexibility to accommodate unforeseen uses. The approach has also been used by conservation planners to denote zones of differing degrees of use and management activities (Foreman et al. 1997). The scheme used in BEST (Table 1) is an attempt to categorize land use impacts; it has known and unknown inadequacies. I believe, however, that it is an improvement over others (e.g., Blair 1996, Knight and Cole 1995) that categorize land use from a human-social rather than ecological perspective. To make the categorization useful for biologists to predict impacts on biodiversity, the latter perspective is critical (Clemmons and Buchholz 1997). Adoption of this approach would allow any of the hundreds of different human land uses to be satisfactorily and objectively placed into categories of habitat impact and biologists to relate the categories of impact to biotic sensitivities. While a small group of informal reviewers composed of both planners and biologists found the pilot scheme satisfactory, I sense this is only evidence of the lack of previous consideration of such a need.

Developing an ideal scheme would first require identification of the characteristics of human activities applicable to assessing species sensitivities. In an attempt to balance simplicity with sufficient detail in BEST, I divided land use impacts into two categories: land cover alteration and human presence. I believe that balance will remain critical for a functional system, but the characteristics should be established through rigorous examination. The quantitative requirements of the categories require a substantial research effort to identify meaningful levels of physical habitat disturbance and human presence for each category. These measures need to be easily obtainable by the planner or manager from the land use characteristics as well as meaningful to the biologist assessing the species' response. A national standardized scheme will be essential for consistent application and distribution of the knowledge of human activity impacts throughout the nation. Development of the scheme could be done through the FGDC similar to the way the National Vegetation Classification (FGDC 1997) was established. Experts on all taxonomic groups would have to be involved to develop one or more categorization schemes that would be suitable for all taxa; not a trivial task to say the least.

Table 1. Land use impact categorization scheme. "L" categories are for physical impacts on land cover; "H" categories are for impacts from conspicuous human presence on the landscape. Detailed definitions are provided in BEST.

L-1: The tract will not be disturbed in any way other than ecologically-based restoration activities conducted within a management plan.
L-2: The tract may have low alteration throughout, and no more than 10% of the tract may have moderate, high, or severe alteration.
L-3: The tract may have moderate alteration throughout, and no more than 30% may have high or severe alteration.
L-4: The tract may have high alteration throughout, and no more than 70% may have severe alteration.
L-5: Greater than 70% of the tract is severely altered.

H-1: Intensity is low. Frequency is low. Duration is low. Example: a natural area with hiking trails.
H-2: Intensity is low to moderate. Frequency is moderate. Duration is low to moderate. Example: a recreation area with high volume of hikers and picnickers, low density residential.
H-3: Intensity is moderate to high. Frequency is moderate to high. Duration is moderate. Example: moderate-density residential, campgrounds.
H-4: Intensity of human occupation is high. Frequency is high. Duration is high. Example: commercial areas, fairgrounds, schools, etc.

Coupled with the human activity impacts scheme is a standardized biotic sensitivity ranking scheme. The biotic rankings provide the information to the planner as to the degree of anticipated impact to the species from the proposed land use. I developed a five-level ordinal scheme for BEST, ranging from 1) beneficial to 4) severe, and a fifth level (dangerous to humans) applicable to animals (see Table 2). However, at least one other scheme (and probably more) exist, such as that of the National Marine Fisheries Service (1996). While I believe that scheme is overly complex and not sufficiently explicit, it could be modified for a standardized national scheme by including the "dangerous" ranking (level 5) and "beneficial" (level 1) from BEST. These two categories are important for avoiding hazardous conflicts and predicting creation of nuisances from land uses that benefit human-adapted species. Numerous schemes are possible (for a more extensive discussion see Westman 1985), but what is required is a scheme that is simple enough to quickly complete species assessments a priori and not require biologists to use a level of precision inappropriate to the available knowledge. At the same time the scheme must provide sufficient information to the planner to indicate what behaviors and habitat characteristics are being impacted and the degree of severity of the impact. In the end the information must be suitable for making the decision as to whether the activity should be relocated, denied, or mitigated and how. It is also very important that the scheme produce consistent results when tested by a group of biologists applying the scheme to the same group of species (M. Scott, pers. comm.).

Table 2. BEST Biotic element sensitivity ranking scheme.

Rank 1. Beneficial: the proposed land use will likely be beneficial to the biotic element, and/or the land use will cause no harm.

Rank 2. Neutral: The element is expected to be compatible and viable with the proposed land use. There may be some minor incompatibilities that may be mitigated with changes to density, design, or type of use after the project design is known.

Rank 3. Moderate sensitivity: There are incompatibilities that will likely harm the biotic element, its future population viability, or the human occupants and/or their property. The degree of land use impact should be reduced by one level either through its intensity or area, and/or the use should be changed.

Rank 4. Severe sensitivity: There is a likely total incompatibility between the land use and the biotic element. The land use impact should be substantially reduced by two levels, or the land use should be changed.

Rank 5. Dangerous: The tract has habitat for an animal that is dangerous to people or a considerable nuisance in human developments (Arcese et al. 1997). Continuous human occupation is not compatible. Temporary or seasonal human uses that do not conflict with the species of concern are appropriate.

Implementation

User groups are not homogeneous entities, and, even if we could develop one system for each user group, it simply would not suffice. For instance, county governments range from minimal service providers of fire protection and road maintenance to those as sophisticated and complex as that of a large city (Johnson 1998). The goal of DSS development in general, and GAP's initiatives specifically, should not be to try and serve all potential users, but to produce models for a breadth of application types. These can then inspire and facilitate further development and distribution of systems within those user communities. For example, our approach with USFWS is to develop an initial product and then facilitate the production model and training in its use within USFWS itself.

The commitment to DSS must be long and patient. Many institutions are only now committing resources to the creation or use of spatial data, and it will be years before institutions routinely provide resources for DSS development and implementation. GAP will continue to work with interested cooperators on pilot projects and coordinate our efforts with those of Aurora, DOI, BRD, and others.

Conclusion

The interest and enthusiasm that our pilot project BEST has generated has been gratifying but also surprising, given the small amount of funding and time devoted to its development as well as the subsequent uncertainties in its output. This indicates to me that a) there is tremendous need and desire for this type of system and b) given the fact that human impacts continue daily with little biological consideration, people are willing to live with large uncertainties in the decision process. With undeniable and staggering losses of biodiversity occurring, it will be critical for the potential user groups of these systems to provide the resources needed not only to implement them but also conduct the research necessary to develop systems that deliver scientifically sound and defensible results.

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Refuge-GAP: A GAP Decision Support System for Refuge Planning

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The Gap Analysis Program (GAP) began as a small research project in the U.S. Fish and Wildlife Service (FWS) and spread nearly nationwide by the time it became a program of the U.S. Geological Survey. The initial intent of GAP was to provide the FWS and others with information on the status of biodiversity elements so that the network of conservation lands, including the National Refuge System, could better maintain the nation's biological heritage. While the program's breadth has expanded, our original commitment to the FWS has not changed. The National Wildlife Refuge System Improvement Act (U.S. 1997) contained language that called on the FWS to "strengthen the conservation of biological diversity throughout the Refuge System." A recent workshop on implementing the new refuge act identified Gap Analysis as a primary means to "identify how the Refuge System contributes to biodiversity conservation compared to other federal lands" (Defenders of Wildlife 1998). The accompanying article "Decision Support Systems: New Tools for Data Users" identifies some impediments to easily incorporating GAP data into these types of decision-making processes. In response to this problem, GAP teamed with the University of Wyoming's Spatial Data Visualization Center and FWS to address this need. The result is a decision support system called "Refuge-GAP" (www.sdvc.uwyo.edu/wbn/refuge) that uses Wyoming GAP and other biological data in a desktop GIS environment (ArcView) to assist FWS managers in meeting requirements of the new legislation.

National Wildlife Refuges are a critical component of the nation's network of preserves for wildlife and biodiversity. In managing the refuges, the FWS is also responsible for identifying additional critical areas in need of protection under the refuge system. These can come as additions to existing refuges or new refuges. The biodiversity data sets produced by Gap Analysis, in conjunction with the powerful analytical capabilities of GIS, provide the FWS with an objective tool for identifying parcels of land which meet initial criteria for protection.

The decision support tool is designed to mirror the FWS's Land Acquisition Priority System (LAPS) for significant community biodiversity targets. This is a four-step process that ranks lands for acquisition according to: a) degree of alteration, b) significance to biodiversity protection, c) management considerations (land use), and d) species of concern. Refuge-GAP prompts the user to assign ranks to each of these variables; then the user is taken through a series of menus which display data that are available as input variables, and it prompts the user for the input of weights for each of the variables (Figure 1). Once all the variables have been weighted, they are combined in a GIS analytical process, and the result is a map depicting areas ranked for importance to the National Wildlife Refuge system.

The decision support tool is also designed to report on biodiversity elements for specific areas. This project-specific component of the tool allows a regional FWS office to more efficiently review permit applications for various development and management activities. The user inputs the location of the permit application into the decision tool, which then summarizes the number of elements (vertebrate species, land cover types) known or predicted to occur within a specified radius (Figure 2). The tool also provides users with the capability to summarize and view elements by rank, such as state species of concern or identified as conservation gaps (Figure 3). In addition to increasing the efficiency of a review process, the tool can also contribute to cumulative impact analysis at a regional level. The location of each permit review can be recorded into a spatial database along with the results of the review. This database can then be summarized to assess cumulative impacts as well contribute to the land acquisition prioritization process. This capability may someday lead to "geographic policy analysis."

Refuge GAP was developed in a few months with only $3,200 and was envisioned as a starting point to demonstrate both the utility of GAP and the technology to aid the FWS in its mission. From here, we will distribute the system to those in FWS interested in evaluating it. Our hope is to team with FWS in development of a robust system that incorporates rangewide distribution and status data on biotic elements and can be easily implemented and maintained by the FWS.

Note: Two examples of habitat maps can be viewed on the web (www.gap.uidaho.edu/gap/Bulletins/7/).

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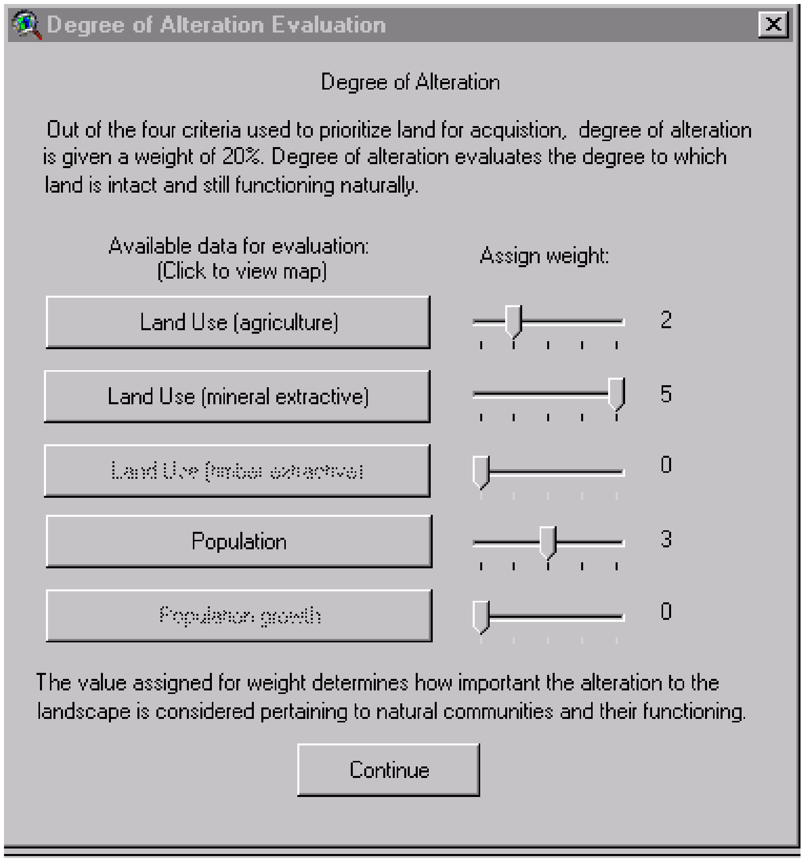

Figure 1: Interactive menu for the Land Acquisition Priority System component of Refuge-GAP

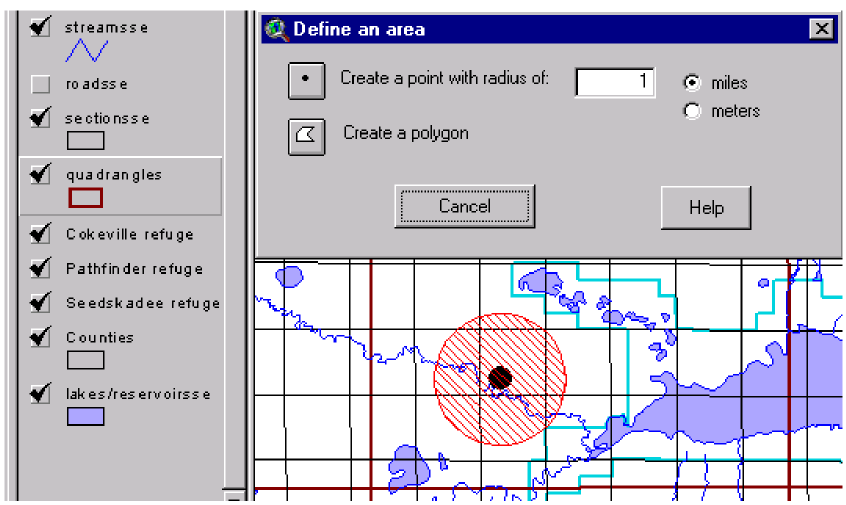

Figure 2: The system user can identify locations to be analyzed for biotic occurrence and conservation status.

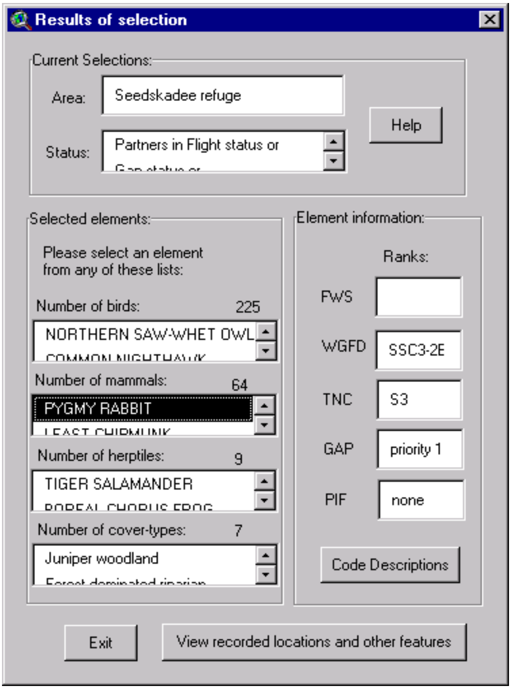

Figure 3. Results of elements coinciding
with the area of analysis are reported with the status rankings.

Gap Analysis for Ant Species

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Introduction

Clearly, when we speak of biodiversity, it is appropriate to consider plant and invertebrate diversity as well as vertebrate diversity. Vertebrates account for less than 2% of presently described animal species (Gaston 1991). Almost all undescribed species are invertebrates. Few of the estimated 27,000 species going extinct each year are vertebrates (Wilson 1992). Vertebrates utilize relatively large home ranges likely to span several vegetation and habitat types. Most vertebrates, even habitat specialists, are habitat generalists when compared to invertebrates. The scale of perception and environmental exploitation of invertebrates is orders of magnitude smaller than that of vertebrates. Furthermore, the ability of technicians to classify vegetation types exceeds the resolution of habitat utilization by vertebrate species (Maser et al. 1984). For example, the Florida Biological Diversity Project is using a habitat classification scheme that recognizes >100 plant associations. At this level, few, if any, vertebrates are specific to any one association (C.R. Allen, unpublished data), and most species span numerous associations.

Nodes of high biological diversity determined from vertebrate species richness are likely to be in the range of 100s to 1000s of hectares (e.g., Cox et al. 1994). Decisions concerning land use, habitat protection, and conservation are likely to be an order of magnitude smaller. Additionally, small areas unable to support a large variety of terrestrial vertebrates may nonetheless be species-rich (containing a high richness of plant and invertebrate species). Land-use and conservation decisions made using vertebrates as indicators of biodiversity will realistically assess impacts on or protect vertebrates but may have little usefulness in conserving overall biodiversity.

The case for using arthropods for the inventory of biodiversity has been convincingly made (Kremen et al. 1993). Prendergast et al. (1993), in an examination of species richness in Great Britain, compared the diversity hot spots of birds, mammals, butterflies, and liverworts and found that the species-rich areas within each taxon rarely overlapped. Landres et al. (1988) cautioned against the use of vertebrates as an index of biodiversity; a range of well-chosen organisms that will explicitly better represent overall biological diversity is needed in an index of biological diversity. Due to the vast number of described invertebrates, it would be impossible to include them all in initial efforts. Therefore, invertebrate groups should be carefully chosen to maximize their contribution to determining overall patterns of biodiversity.

Butterflies have been suggested as an invertebrate taxonomic group to utilize for biodiversity monitoring (Kremen 1992). However, data from Florida indicate that despite the host-plant specificity of some larval forms, adult butterflies are mostly edge-type species with little overall habitat specificity. Indeed, birds may be more habitat specific than butterflies (Debinski and Brussard 1994). Among the invertebrates, the Formicidae exhibit many traits that make them an excellent choice for inclusion in an index of biodiversity. Ants are relatively easy to identify, and a relatively short period of training and adeptness with a dichotomous key will enable most persons to identify the ants of temperate regions. In Florida there are approximately 190 ant species, similar to the number of herpetofauna and avian species. Ant species are easy and inexpensive to sample, and a variety of established sampling methodologies exist. Additionally, the range and habitat affinities of ants are well known when compared to families such as Scaraebidae (an estimated 250 species in Florida; Woodruff 1973), or Staphylinidae (an estimated 450 species in Florida; Frank 1986).

Ants act as keystone species in many instances (Risch and Carroll 1982). They provide key and irreplaceable ecosystem services such as pollination, nutrient turnover, energy flow, and seed dispersal (Handel et al. 1981). The Formicidae exhibit a wide range of habitat specificities and diversity of lifestyles. Some species utilize very specialized microhabitats (see below), and feeding niches are likely to be saturated (Holldobler and Wilson 1990). Because of niche saturation, the Formicidae are excellent indicators of fine-scale habitat heterogeneity, which in turn is an excellent indicator of biological diversity. Additionally, niche specialization means that general ant sampling may be used to bioassay ecological trends by monitoring trends of species with specific life-history traits of interest. Ants, indicative of terrestrial habitat heterogeneity, and birds, indicative of structural heterogeneity across habitats (e.g., Cyr and Cyr 1979), may make an excellent pair of organisms for indexing biological diversity. Short generation time in ant species translates to rapid response to environmental change. These positive characteristics are good for inventory and monitoring and allow for a finer-scale resolution in biodiversity mapping. The inclusion of the Formicidae in an index of biodiversity yields a broader base and more precise information for cross-scale decision making.

Several species present in Florida illustrate the potential of the Formicidae as indicators of biodiversity. The tropical fire ant, *Solenopsis geminata*, acts as a keystone species (Risch and Carroll 1982) affecting invertebrate community composition where it is not displaced by the exotic *S. invicta*, which itself acts as a keystone (Wojcik 1994). Several species of ants are endemic to Florida, and others are nearly so. *Paratrechina wocjiki* is endemic to central Florida where it may be found in a variety of habitats (Deyrup and Trager 1986). *Conomyrma flavopectus* is restricted to sugar sands in central Florida with early successional stages of sand pine (Trager 1988). *Paratrechina phantasma* is endemic to Florida scrub and dune habitats (Trager 1984). Four species of ants are endemic to the unique Florida scrub and sandhills habitats; this exceeds the number of endemic scrub species for any of the vertebrate taxa or for butterflies.

Many species are habitat-specific. *Xenomyrmex floridanus* is restricted to mangrove (Deyrup et al. 1989). *Leptothorax allardycei* is limited to sawgrass and *Crematogaster vermiculata* to cypress (Deyrup et al. 1989); no vertebrates are sawgrass or cypress specialists. *Leptogenys*

habitat specificity. Indeed, birds may be more habitat specific than butterflies (Debinski and

manni is endemic to Florida and feeds only on isopods (Trager and Johnson 1988); such niche specialization is not unusual, given the general niche saturation found in the Formicidae, and may be useful in ecological monitoring.

The predaceous species *Odontomachus clarus* illustrates interesting biogeographical patterns (mirrored by some much studied and heralded vertebrates, such as the Florida Scrub Jay). *Odontomachus clarus* is known only from xeric upland areas of Mexico, the southwestern United States, and subtropical Florida (Deyrup et al. 1985). Florida Formicidae are largely a mix of temperate continental species and species of West Indian origin, a pattern also seen in Florida's birds and butterflies.

Because vertebrates and invertebrates interact with their environment at different scales, there is a critical need to include some invertebrate taxa in an index of biodiversity, and ants are a desirable and defensible taxa to use. Recently the USGS-BRD has considered mapping the Formicidae at a national level. Here we present two different methodologies for spatial mapping of ant diversity and a comparison of patterns of species richness between ants and mammals in southern Florida.

Methods

Literature-based (Florida): Geographic distribution of species (i.e., ants and mammals) was determined at the county level. For ants, distribution was determined primarily from published sources (Buren and Whitcomb 1977, Carroll 1975, Cole 1982, Creighton 1950, Deyrup 1991, Deyrup and Trager 1986, Deyrup et al. 1988, 1989, Johnson 1986, Klotz et al. 1995, MacKay 1993, Samways 1983, Schneirla 1944, Smith 1930, 1933, 1944, 1979, Thompson 1989, Thompson and Johnson 1989, Van Pelt 1947, 1950, 1956, 1958, 1966, Watkins 1985, Wheeler 1932, Wilson 1964) and from the unpublished data of D. P. Wojcik and C. R. Allen. The availability of data varied by county. For several counties largely in private ownership with limited access, little data was available, and for some other species distribution is poorly known. We interpolated distributions in counties lacking data based on the presence or absence of species in adjacent counties or known biogeographic affinities of species. These data were then used to produce a county x ant species matrix. All resulting county-level distribution maps were reviewed by recognized experts.

Habitat affinities for ants also were determined primarily from literature review. The Florida bibliography of species habitat use and ecology includes >1300 sources (too many to cite, but the bibliography may be accessed at http://coop.wec.ufl.edu/gap) which have been used to create descriptors of habitat use by species, including ant species. These data were then used to produce an ant species x land cover type matrix. In conjunction the two matrices were then used to produce habitat-specific spatial distributions of all ant species present in Florida, as well as a map of overall ant species richness.

Sample-based (South Carolina): In South Carolina the most recent (and only) comprehensive documentation of ant distribution appeared in 1916 (Smith 1916, Smith and Morrison 1916). This general lack of data in South Carolina necessitated that South Carolina take a sample-based approach to mapping ant diversity, which is currently under way. Ants are sampled throughout the state of South Carolina. Sampling is stratified by physiographic region (sandhills, coastal plain, piedmont, mountains) and by generalized South Carolina Gap Analysis land cover types (n = 28). Ten replicates (randomized within the constraints of access to some properties) in each land cover type in each region will be sampled for a total of approximately 1120 sampled habitat patches across the state (not all land cover types are represented in each strata and some may be of minor importance). Each habitat patch will be sampled by establishing a linear transect consisting of multiple sample points. Sample points will consist of bait samples and pitfall traps. Together, these two sampling methods will capture a majority of ant species present in the state. Pitfall sampling is the better method of sampling overall ant diversity, as aggressive species (e.g., red imported fire ants) will preclude other species from baits. We will also conduct limited sampling with other methods, such as arboreal (C.R. Allen, unpublished manuscript) and subterranean sampling. At each sample point, data on habitat also will be collected. Results of these sampling efforts will be used to simultaneously determine both the county-level distribution and habitat affinity of each species.

Ant sampling is relatively easy and fast. However, identification of species can be problematic. To successfully produce a sample-based data set of ant distributions for a GAP layer, we have had to establish a highly cooperative effort. In this case, cooperators include Clemson University's Department of Aquaculture, Fisheries and Wildlife and Department of Entomology, the South Carolina Cooperative Fish and Wildlife Research Unit, the South Carolina Gap Analysis Program, the National Gap Analysis Program, the USDA Agricultural Research Service, and the South Carolina Department of Natural Resources.

Spatial correspondence between ants and mammals in south Florida

One example of how the data are used is in comparing ant distributions with distributions of mammals. Land cover for the lower peninsula of Florida was mapped at 30-m resolution from classification of 1993 and 1994 Landsat Thematic Mapper satellite imagery. Bands 2,3,4, and 5 of the imagery and a tasseled cap transformation were used in an iterative unsupervised clustering algorithm. Labeling of the spectral clusters with vegetation associations followed the National Vegetation Classification (Grossman et al. 1998, FGDC 1997) to the alliance level (Weakley 1997). Labeling was assisted by auxiliary information such as land use/land cover maps from the South Florida Water Management District, National Wetlands Inventory maps, soils maps, and vegetation surveys and photo-interpreted points from low altitude aerial videography in Everglades National Park and Big Cypress National Preserve (Figure 1). *Note: Figures can be viewed at http://coop.wec.ufl.edu/GAP/antmammal_spatial_corr.htm.*

Ants and mammals were modeled in similar ways, following Gap Analysis procedures (Scott et al. 1993) and as outlined for ants above. We produced species richness maps of both taxa (Figures 2 and 3). Richness of both taxa was normalized such that the highest richness for each taxon was equal to one and the lowest richness equal to zero, so that the two coverages were comparable. A coverage of spatial correspondence was then produced by subtracting the normalized mammal species richness map from the normalized ant richness map.

Results: In the coverage of spatial correspondence (Figure 4), values near 0 (green) reveal that richness between mammals and ants are equivalent. High positive values (red to orange) identify areas with higher mammal richness relative to ant richness, and high negative values (blue to magenta) identify higher ant species richness relative to mammal richness.

Comparisons of mammal and ant species richness reveal interesting patterns of correspondence and disharmony between the two taxa. The large areas of green on the correspondence coverage indicates that richness between mammals and ants was similar over much of the Florida Everglades (but see below). However, two interesting deviations occur. In the Big Cypress area of southwest Florida, there is a lack of correspondence between mammals and ants, primarily in cypress-dominated habitats. This is not necessarily because mammal species richness is especially high in these areas, but because ant richness is low. Further north, the opposite situation exists; normalized ant species richness is higher than normalized mammal species richness in several pine-dominated habitats. In most terrestrial habitats (excluding the saturated everglades habitats which constitute a large area of south Florida), spatial correspondence between ants and mammals is low.

Discussion

Invertebrates contribute far more to overall species richness than do vertebrates, and nodes of high richness among different taxa are likely not to correspond. This mandates the inclusion of invertebrates in an index of biodiversity. Among the Arthropoda, the Formicidae are a good family of choice for mapping because data are available or relatively easy to obtain, they utilize a wide variety and large number of niches, and some ant species are very habitat- and condition-specific. Utilizing the Formicidae in biodiversity mapping efforts offers the chance to increase the thematic resolution when representing geographic nodes of high species richness. Future land-use decisions will likely be at a scale an order of magnitude smaller than decisions made in the past. The inclusion of the Formicidae in programs investigating biodiversity assures that land-use decisions will be made utilizing species information applicable across a range of scales.

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Unprotected At-Risk Plant Communities of the Western U.S.

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Most analyses conducted to date using GAP data that cover large multistate regions have been limited to tabulating those plant communities at greatest risk within a particular geographic region (e.g., Stoms et al. 1997) or to identifying broad geographic zones where conservation efforts should be concentrated to maximize the conservation of biodiversity (e.g., Kiester et al. 1996). Few studies have identified specific lands that would be a high priority for conservation action, although we expect more as state projects are completed and data are distributed (e.g., Crist et al., in press). Thus GAP data so far have seen limited application to land-use planning because such efforts typically take place locally and at small ecological scales (Stevenson 1998). We believe that if GAP vegetation data are to be useful for land-use planning at the scales normally employed, they must be used to identify specific land parcels associated with a particular plant community where protection should be a priority. The intent of this ongoing project has been to develop a stepwise process to achieve that goal over a large geographic area. The geographic region we studied was a 2,090,000 km^2 area encompassing all or parts of the 11 U.S. states west of the Continental Divide.

We used the vegetation cover maps developed by the individual GAP state projects, aggregating the different map classifications to the alliance level where possible. We used land ownership and land management maps compiled by the respective state GAP projects and other sources. Two broad categories of land ownership were defined for each tract of land: public and private. Public lands were subdivided into two categories based on the degree to which biodiversity is protected. We focused our effort on the 42 plant communities that had less than 10% of their area on protected lands. These plant communities occupied 35% of the study area, and initially, we considered them to be inadequately protected and therefore potentially at risk. For each of these plant communities, we calculated the total land area occupied, the geographic range (number of states) the community occurred in, the number of patches (polygons) occupied, the average patch size, and identified all counties where the plant communities occurred as well as the recent population growth rate of those counties.

We calculated that to adequately protect all of the plant communities to the 10% level would often require substantial change in management on 2.2 million ha in the region. To put this figure in perspective, this would require the conversion to protected status of a land area (albeit dispersed) equivalent to three Yellowstone National Parks. We did not think this was a sociopolitically feasible starting point in a long-term conservation strategy for the West. Therefore, using the criteria of total land area occupied by a given vegetation type, its geographic range, and the number of patches occupied, we attempted to reduce the list of “at risk” plant communities and their associated land area to a more workable figure.

Through this process we identified 26 vegetation types assumed to be at great risk. We calculated their protection would require conversion of about 700,000 ha of public lands to a protected status and acquisition or protection of 111,000 ha of privately owned lands. These changes would be spread out over 43 counties in the region, so no one area would be disproportionately impacted.

We are attempting to prioritize the individual land parcels involved in this process by arbitrarily limiting our selection to land patches >2,500 ha to assure the ecological viability of those lands. In addition, we have sought to prioritize the protection of those patches that occur in counties where the population gain over the last decade exceeded 30%.

The end result of this study will be a prioritized list of specific land parcels in a given county, which we feel should receive additional protection in order to achieve the specified conservation goal for a given plant community.

Our approach is contrary to that of those who advocate the protection of very large land areas as a biodiversity conservation strategy (e.g., Noss 1996) since our experiences have shown that socioeconomic constraints often limit the success of such ambitious schemes (Wright 1996). As a result, many large reserves exist only in plans and on maps. A set of strategically placed reserves of a size which is consistent with resources available for their protection may be a more realistic option (Zuidema et al. 1996).

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Compositional Groups and Ecological Complexes: A Method for Alliance-Based Vegetation Mapping

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The National Vegetation Classification (NVC) is a hierarchical classification based on a) vegetation structure and b) floristic composition that treats all existing terrestrial vegetation types in one system. This classification was developed by The Nature Conservancy (TNC) (Anderson et al. 1998) and has been adopted as the National Vegetation Classification Standard (NVCS) by the Federal Geographic Data Committee (FGDC 1997) with the Ecological Society of America acting as a review board. The National Gap Analysis Program, recognizing a need for a consistent classification across federal programs as well as within its own program, has supported the development of the NVC for several years. Mapping land cover to the alliance level (a physiognomically uniform group of plant associations sharing one of more dominant or diagnostic species) is a stated goal of the program.

Historically, land cover mapping from remotely sensed satellite data rarely exceeded one or two dozen classes, usually confined to Anderson (1972) Level II classification. Statewide mapping from Landsat TM imagery with critically limited time and budget constraints has been a challenging task. Vegetation in the southeastern U.S. is diverse and spatially complex, and the regional portion of the NVC reflects this. There are 680 alliances listed in the September 1998 version of the alliance-level classification (Weakley et al. 1998) as either confident or probable in the 12 states of the Southeast (AL, AR, FL, GA, KY, LA, MS, NC, SC, TN, TX, VA). Concerns over how alliance-level mapping can be accomplished have led to innovative developments in vegetation community sampling with videography, new classification procedures exploring the use of decision rules, ancillary data sources, and image stratification, as well as stretching the limits of tools for data ordination and transformation. While the issue has been raised of the appropriateness of the alliance level of the NVC as a mapping goal, the availability of it as a national and federal standard outweighs any difficulties inherent in its internal complexity. In addition, the rapidly evolving nature of remote sensing technology necessitates that standards not be dictated by current technological limitations. Land cover mapping to the alliance level with a high degree of accuracy may not always be possible or practical in the first iteration, but we need a labeling system that will be compatible with future, more detailed mapping.

Here we present the Southeast Region's proposed approach for labeling map units in a way that is consistent with the NVC but accommodates the fact that all alliances cannot be mapped from TM imagery and existing ancillary data. This labeling approach also provides the framework for scaling up from state to regional products in an ecologically meaningful way. The proposed approach has received the endorsement of National GAP and maintains compatibility with the NVC at the alliance level.

At the Southeastern GAP meeting in the spring of 1998, it became apparent that each state was using some form of alliance aggregation in their land-cover mapping. In order to develop a regional or national land-cover map, it will be necessary for individual state projects to come to a consensus on common labels for their map units. The labeling structure that emerged from those discussions resulted in the definition of two types of alliance aggregations. These are defined as:

1) Compositional Groups: a grouping of alliances with similar taxonomic composition and physiognomy, and
2) Ecological Complexes: a grouping of dissimilar alliances that are spatially and ecologically related on the landscape.

Compositional groups are composed of alliances that are spatially discrete but cannot be discriminated into separate classes because of spectral similarity. For example, in south and central Florida, freshwater marsh is prevalent, and cattails (*Typha spp*.) cover large areas. From satellite imagery and other available data sources, *Typha domingensis* and *Typha latifolia* can not be separated. As a result, Florida is proposing a Cattail Marsh Community Group composed of three herbaceous cattail alliances. Similarly, Virginia, Kentucky, and Tennessee have each proposed compositional groups to accommodate mixed vegetation dominated by southern yellow pine.

Ecological complexes are distinguished from compositional groups in that it is the spatial closeness of the alliances that prevents discrimination based on satellite imagery. In North Carolina, pocosin wetlands are spatially heterogeneous with pine pond (*Pinus serotina*) woodlands being intermixed with evergreen shrublands dominated by sweet bay (*Magnolia virginiana*), gallberry (*Ilex glabra*), swamp red bay (*Persea palustris*), and titi (*Cyrilla racemiflora*), along with mixed titi-honeycup (*Cyrilla racemiflora - Zenobia pulverulenta*) shrublands in such close spatial proximity that they cannot be delineated separately at the resolution of Landsat TM. North Carolina has created a Pocosin Ecological Complex to encompass these structurally dissimilar but ecologically and spatially related alliances.

Notice that these groupings are not hierarchical levels that fit neatly between the formation and alliance. For instance, the Pocosin Ecological Complex aggregates evergreen woodland and evergreen and mixed shrub alliances which represent different formations in the National Vegetation Classification. It would be meaningless, therefore, to place the Pocosin Ecological Complex in the existing NVC structure. The Compositional Groups and Ecological Complexes stand beside the NVC, not within it. Because the groupings are aggregations of published NVC alliances, however, they can always be decomposed to the alliance level—as time and technology allow. They therefore maintain the integrity of the NVC structure.

Having the types of aggregates defined does not automatically mean that the classes will be consistent across the entire region. In the Southeast, the states have initially developed their lists of complexes and groupings independently, and it is now necessary to review and develop a logical organization that works for and across all the states in the region. At the Southeast GAP meeting it was decided to approach standardization by developing common lists for each ecoregion. While it is likely that a state will have unique compositional groups and/or ecological complexes, they should reflect distinct communities and not independently derived aggregated map labels.

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Gap Analysis in Riverine Environments

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Background

As Jennings (1997) mentioned in Bulletin No. 6, the National Gap Analysis Program is in the initial stages of developing the aquatic component of Gap Analysis. This effort, to date, has included drafting general technical documents to guide the development of pilot projects as well as establishing two pilot projects. These include a project for the upper Allegheny River basin in western New York, initiated in 1995, and a statewide project for Missouri, initiated in 1997. The purpose of this article is to outline the basic approach developed by the Missouri Resource Assessment Partnership (MoRAP).

The project addresses several objectives; however, the three primary ones are: 1) develop an objective method for identifying gaps in biodiversity conservation in riverine environments, and set priorities for filling those gaps, 2) identify problems of and methods for effectively integrating the terrestrial and aquatic components of Gap Analysis, and 3) document information needs, successes, failures, obstacles, time, and costs, which will assist other states with similar efforts.

We established some priorities for our project to make it more reasonable in scope and to help us maintain a more structured approach. First, we are strictly focusing on riverine environments. Missouri is essentially a "stream state" with the majority of our aquatic biodiversity concerns situated in riverine environments. Second, although Gap Analysis will continue to include all taxa, this project focuses on fish, mussels, crayfish, and snails. These four taxonomic groups were selected primarily because of the availability and quality of existing sampling data.

Approach

There are five major steps to the approach we developed. The first step involves delineating and mapping a 1:100,000 digital data layer of valley segment types for Missouri. These valley segment types can be viewed as the lotic counterparts of wetland or lake type classifications (Figure 1). To accomplish this step, we are using the Aquatic Community Classification System developed by The Nature Conservancy (Lammert et al. 1996). This hierarchical classification system focuses on ecological regions and hydrogeomorphic variables to delineate distinct valley segment types. Using this digital data layer, we will then generate the critical base line inventory statistics required for conducting accurate assessments and developing meaningful conservation priorities. These statistics include how many valley segment types there are within each ecological section (Bailey 1980), how many miles there are of each type, and where they are (Figure 2).

The second step incorporates digital instream and watershed management and land use information into a coarse-level analysis process (Figure 3). Essentially, the question being addressed in this step is how well are we currently conserving each of Missouri's valley segment types. Answering this question requires relativistic comparisons using percentage statistics: for example, calculating the percentage of each valley segment type currently in the public trust, the percentage of the total stream miles each valley segment type represents within each region, and the percentage of each valley segment type that can be classified as high-quality. There are numerous other calculations like these that will be incorporated into this step of the process. The key point is that this step needs to be flexible enough to meet a wide variety of user needs yet remain focused on establishing first-cut biodiversity conservation priorities for each region. As can be seen in steps one and two, we are not using biological information to develop our initial conservation priorities. Our initial reasoning is that all types of the various riverine environments must be considered as having conservation value, regardless of their biological communities. Therefore, we first focus on the rarity and the conservation status of riverine types themselves. Consequently, riverine environments inherently low in diversity are weighted equally with those inherently high in diversity at the outset. This avoids the problem of developing conservation priorities which simply focus conservation efforts on those inherently diverse environments while ignoring very unique environments that may have relatively simple communities. I believe that the number of rare species tends to be strongly associated with community diversity, at least in aquatic environments; however, this relationship is probably scale-dependent. Even conservation assessments that focus on rare, threatened, or endangered species will tend to establish conservation priorities favoring inherently diverse environments rather than unique environments. This may not be true for all regions; for instance, the very simple communities of the Arid Southwest harbor a large number of rare aquatic species. However, this association between rarity and diversity definitely holds true for the majority of the nation as well as those regions covering Missouri (Figure 2).

Once conservation gaps are identified for the valley segment types and initial priorities established, we move on to step three in which distributional data for all known species of fish, mussels, crayfish, and snails are used to predict the community potential of each individual valley segment in the state. To accomplish this difficult task, we need three different pieces of information in digital format (Figure 4). First, we need to know the statewide distribution of each species. More specifically, we need to know all of the watersheds (14-digit Hydrologic Units; USDA 1992) in the state in which a given species exists. Second, we need to know all of the general habitat requirements or affinities of each species so we can predict their distribution throughout the watersheds in which they are known to occur. (Few species are found throughout entire watersheds; most reside in specific segments of watersheds such as headwater segments or only warm water segments.) Finally, we need the valley segment data layer, which provides the habitat type template for predicting local distributions. This is analogous to the land cover layer for predicting the distribution of terrestrial species. The end product of this exercise will be a 1:100,000 digital data layer of valley segment types for Missouri, with each segment attributed with the fish, mussel, crayfish, and snail species likely to occur in that segment under pristine conditions (Figure 5).

In step four we use the distributional data developed in step three to revise our initial conservation priorities (Figure 6). Specifically, we use this information to identify specific locations of "high-priority" valley segment types which: a) are relatively high in species richness, b) serve as centers of endemism, or c) harbor species of special concern. For simplicity's sake, we label these valley segments as "segments of biological significance." Like the second step, step four must also remain flexible to meet a wide variety of user needs. This fourth step is necessary and important because the same valley segment type will be found in many different locations and, due to zoogeographic factors, these different locations will often have different biological assemblages. This fourth step thus serves an important role in further refining management options since even slight differences in species assemblages among locations may have a significant effect on decisions related to biodiversity conservation.

The final step in the overall process involves further refining our conservation priorities by identifying specific valley segments which are both biologically significant and high-quality examples of a particular valley segment type (Figure 7). The resulting final maps will then show the locations at which our biodiversity conservation efforts should be focused and where we can assume we will most likely succeed. To assess the relative quality of each valley segment, we will develop "quality-ranking" models. To accomplish this we are working with resource professionals from around the state to identify the major "stressors" and management activities within each ecological section that either positively or negatively influence our riverine environments. Once identified, we will compile digital data for those major stressors and management activities. We will then develop a protocol, to account for these major stressors and management activities, which examines both the local conditions surrounding a given segment (e.g., is it channelized or lacking a natural riparian corridor?) as well as the condition of its surrounding watershed (e.g., percent forested, road density, potential pollution sources, acres of CRP, etc.).

When this five-step process is completed, thousands of miles of stream will have been examined, resulting in a workable number of high-priority stream segments on which to focus conservation efforts. The three most important aspects of the aquatic component of Gap Analysis are: 1) it provides an objective (i.e., data-driven) approach for assessing biodiversity conservation needs, 2) it provides the common framework necessary to make truly relative conservation assessments across states, regions, watersheds, etc., and 3) it has built-in flexibility to account for a wide variety of user needs. Information from the Missouri project will assist state and federal resource agencies in making decisions pertaining to new land acquisitions, new management plans, or for identifying focus areas for land owner incentive programs and research.

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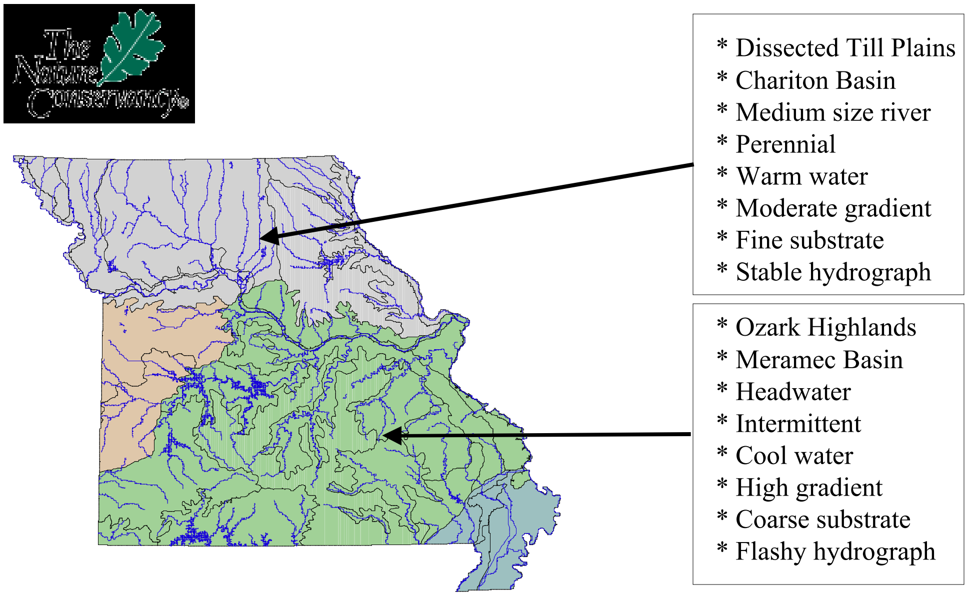
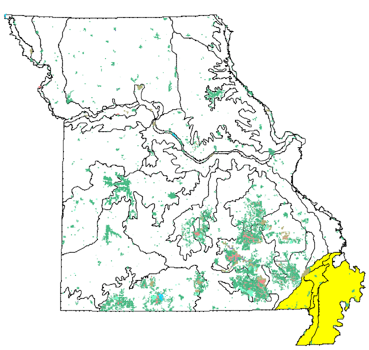


Figure 1. Hypothetical example of two very different valley segment types delineated by following The Nature Conservancy's Aquatic Community Classification System.

Region: Mississippi Alluvial Plain



Valley Segment Type	Total Number of Miles	Percent in Public Land	Percent High Quality	Initial Conservation Rank
H	46	0	0	1
O	123	0	0	2
M	227	0	3	3
A	40	0	15	4
S	89	0.005	5	5
I	245	0.006	8	6
C	314	0.4	5	7
T	187	0.5	12	8

Figure 2. An example of how baseline (i.e., total number of miles) and assessment (e.g., percent in public land) statistics for each valley segment type will be generated for each Ecological Section in the state. These statistics represent the first step toward setting meaningful conservation priorities.

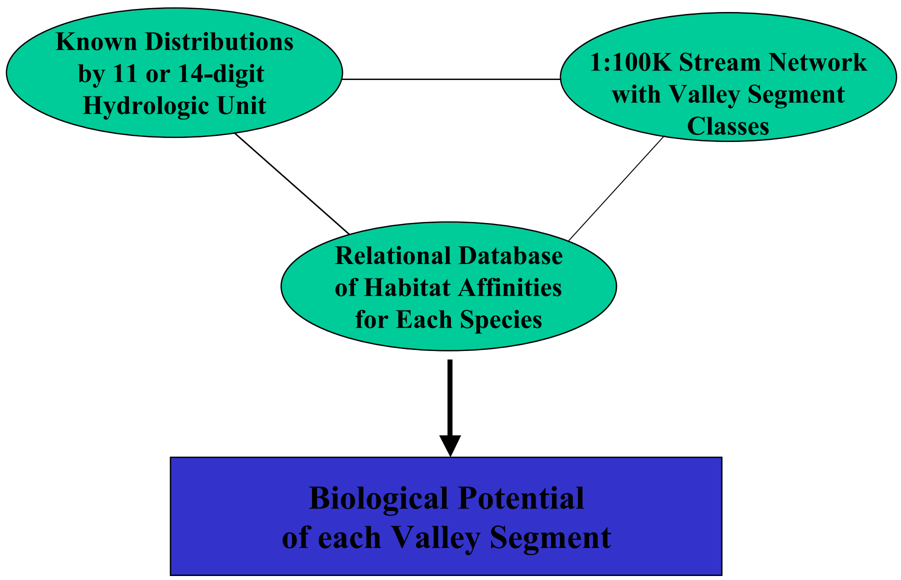
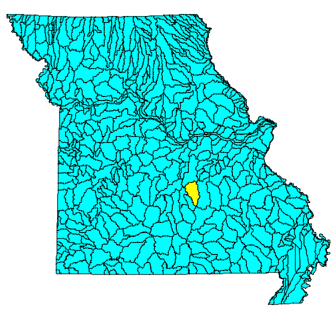
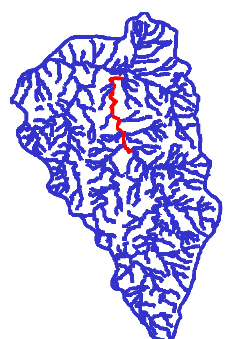


Figure 3. Diagram showing the three digital information sources required to predict the biological potential of a given valley segment. Since existing land uses are not factored into this modeling effort, the resulting predicted distributions represent the potential aquatic community of a given segment under pristine conditions.



ITIS codes for species known to occur in the Little Piney Creek Watershed

Fish	Mussels	Crayfish	Snails
161737	80193	97474	70312
161738	80239	97456	70611
161989	80015	97377	76700
163368	80279	97467	76682
163376	80072		81406
163593	80208		81408
163395	80293		
163841	80151		
163456	80364		
163949			
*			
*			
Etc…			



ITIS codes for species predicted to occur in a selected valley segment of the Little Piney Creek Watershed

Fish	Mussels	Crayfish	Snails
161737	80193	97474	70312
161738	80239	97456	70611
161989	80015		81406
163368	80072		
163376	80364		
163593			
163395			
163841			
163456			
163949			
*			
*			
Etc…			

Figure 4. An example for the Little Piney Creek watershed showing the difference between the species known to occur in a given Hydrologic Unit and the subset of species predicted to occur within a selected valley segment.

Valley Segment Type	Number of Unique Species	Number of Federal Species of Concern	Number of State Species of Concern	Initial Conservation Rank	Revised Conservation Rank
H	0	1	2	1	4
O	0	0	0	2	7
M	1	1	3	3	3
A	0	0	1	4	5
S	0	0	0	5	8
I	1	2	4	6	2
C	0	0	1	7	6
T	2	2	4	8	1

Figure 5. Example of how biological statistics are used to revise initial conservation ranks for high-priority valley segment types.

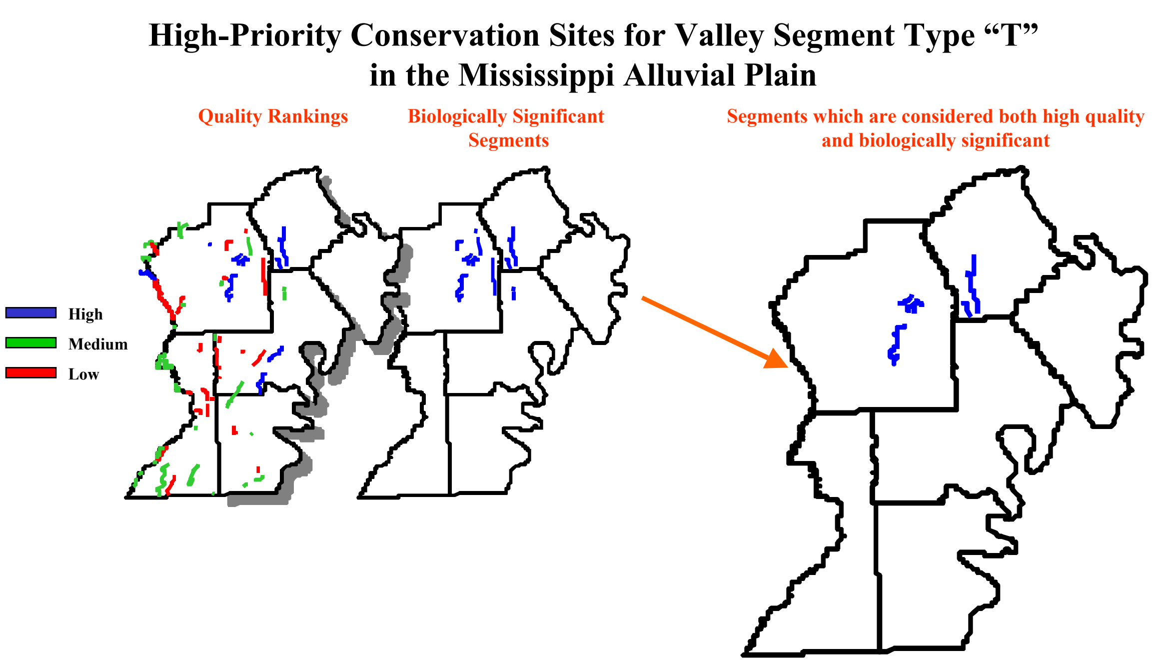


Figure 6. Example of how specific locations are identified for selected valley segment types at which conservation efforts should be focused and are most likely to succeed.

Final Report Summary: New York Aquatic GAP Pilot Project

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A pilot GAP project for aquatic systems 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. Our pilot project has been a low-level effort (e.g., a one-person project) for two years. We established methods for database development and GIS analyses using one river basin in western New York.

The original purposes of gap analysis (Scott et al. 1993) remained unchanged when applied to aquatic environments. However, the connected nature of aquatic habitats and the mobility of aquatic species complicate traditional gap analysis methods. Emphasis was placed on streams and rivers, as these waterbodies harbor a large majority of the freshwater biodiversity in the United States and are the focus of water quality assessments by management agencies. Methods were developed to reflect habitat status over a network of streams because aquatic species respond to cumulative effects due to the flowing nature of water in streams. A key habitat attribute influencing aquatic species is water quality, thus we developed a nonpoint-source pollution model that relies on land cover. This component of our aquatic GAP model integrates the terrestrial and aquatic parts of gap analysis. Finally, aquatic biodiversity conservation will likely focus on land management, not land acquisitions, since aquatic biodiversity is generally highest in large streams and rivers, making land acquisitions impractical. Again, the linking of terrestrial and aquatic GAP coverages is essential to address conservation issues.

The basic aquatic GAP model predicts relative levels of fish and macroinvertebrate diversity and identifies stream reaches having high biodiversity that are 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 classified into one of eighteen habitat types for fish diversity predictions and one of eight habitat types for macroinvertebrate diversity predictions. Fish species and macroinvertebrate taxa were linked to habitat types using life history data. Maps and information on management and conservation areas were included in the GIS to locate unprotected stream segments with high diversity. As in other GAP projects, these are the "gaps" or areas where future conservation efforts should be focused or management practices altered.

Our aquatic GAP pilot was developed for the Allegheny River watershed of western New York. This region has a mix of forests (67%), agriculture (crop and dairy 28%), water and wetlands (3.4%), residential and urban areas (1.5%), and barren land (.1%). Aquatic habitats are largely comprised of small headwater streams (86% of the stream kilometers), with only 11% of the stream kilometers in large streams and small rivers and even fewer kilometers in large rivers. From our GAP model, 92% of the stream kilometers were modified or highly altered habitats leaving just 8% of the stream kilometers as potentially supporting the highest species diversity. The classification of stream segments into modified and highly altered categories was largely due to agricultural land use predominantly occurring in stream valleys and roads adjacent to streams. Approximately 79% of the stream kilometers were predicted to have good water quality using the nonpoint-source pollution model. When habitat status and water quality were combined, 913 (94%) of 980 stream segments were considered altered in some way. Thus, although degraded water quality was an important factor in the anticipated reduction of biodiversity for all sizes of streams, it was not nearly as dispersed or prevalent as physical habitat degradation. Overall high-quality stream segments were few and were well distributed across watersheds. These high-diversity habitats were the stream segments with high-quality water, intact channel habitat, a closed streamside canopy, and a high gradient. Good-quality streams were primarily headwaters (91%), with the remaining 9% comprised of large streams and small rivers.

The most diverse fish habitats were predicted to occur in large stream and small river segments with intact habitat quality and water quality suitable for life support. Only eight stream segments were identified in this class. Due to the large degree of human land use immediately adjacent to streams, there was an abundance of stream segments classified as modified and highly altered in habitat quality. This, in addition to the stream segments classified as degraded in water quality, greatly reduced the number of stream segments available for classification as highest in fish diversity. The most diverse macroinvertebrate habitats were predicted to occur in high-gradient, closed-canopy streams with good water quality (262 stream segments). Unlike in predictions for fish, the limiting factor in anticipated macroinvertebrate diversity was water quality degradation. Good water quality was predicted to be prevalent, especially in typically high-gradient headwaters, therefore there were many sites expected to have high macroinvertebrate diversity.

The goal of our pilot project was to demonstrate the feasibility and utility of the gap analysis methodology for predicting biodiversity distribution at the watershed scale. We illustrated this through the creation of a geographic information system model that classified stream habitats and related fish species and macroinvertebrate taxa to these habitats. The use of a land cover map in the prediction of water quality served as a link to gap analysis efforts in terrestrial systems. One major finding in this pilot project was the scarcity of stream segments with high predicted fish diversity, defined as large streams or small rivers with intact habitat and good water quality. GIS analyses showed that agricultural land use and roads were concentrated in midsized stream valleys where flat land along rivers was not vulnerable to destructive flooding. Although intuitive as an afterthought, the GAP model identified this pattern and clearly explained why so few quality midsized streams remain in what is largely a forested setting.

Another finding suggests that the existing conservation status may not actually afford significant protection. Of all stream segments, about half (48%) were under some form of protection by state parks, wildlife management areas, state-regulated wetlands, and water quality management classes A or AA. Despite the large percentage of streams in protected areas, the conservation-oriented management classes do not appear effective for aquatic biodiversity conservation. Many stream segments in protected areas were classified as poor quality. The protection of small land units did not substantially reduce the effects of runoff from agricultural lands or of alteration of streams along roads and farms. The utility of our GAP model in conservation planning was demonstrated by being practical to implement and capable of making predictions of the distribution of biodiversity and of management gaps.

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Making Gap Analysis Work for New York Waters: A State Perspective on Aquatic GAP

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A review of the New York Aquatic GAP pilot project ("Making GAP Analysis Work for New York Waters" workshop) was held in December 1997 with natural resource agencies in New York. The workshop was attended by representatives of many bureaus and offices of the New York Department of Environmental Conservation (NYDEC): Hudson Valley region, marine resources, habitat protection, fisheries, bioassessment and monitoring, and water resources. Representatives of the New York offices of the U.S. Fish and Wildlife Service, The Nature Conservancy, and the U.S. Geological Survey also participated. Our aim was to present the methods developed in the pilot project for the aquatic component of GAP in New York to a select group of agency representatives, to recommend actions, and to obtain their thoughts and ideas for applying gap analysis to all New York waters. The event worked well because the attendees were interested in and enthusiastic about the application of GAP methods to aquatic environments. They readily contributed ideas on how to enhance the GIS models, enhance the pilot project to better meet their agency's needs, and apply GAP to real management issues in New York. The workshop discussions also posed some challenges to making "aquatic" GAP a highly state-relevant technology.

An encompassing notion that emerged was that national programs and within-state perspectives often contrast. The National GAP Program seeks to develop standardized methods to be applied broadly and consistently across the nation for the purpose of identifying biodiversity conservation priorities—this purpose requires methods that are general, broad-scale, and oriented to diversity of species. NYDEC and other state agencies see the greatest gain in GIS efforts aimed at specific kinds of problems (e.g., streamside buffers, bank erosion, vegetation beds), fish species and life stages, and assessing threats of a site-specific nature. Further, it was noted that the GAP Program counts geographic coverage as a measure of accomplishment, and the workshop attendees recommended that the geographic scope of future work be either halted or reduced. The top priority of workshop attendees was to see the GAP models tested and perfected in a limited area using data that is already assembled and detailed, targeted field surveys. Consequently, some hard thinking by workshop attendees was needed to see a way to closely mesh state and federal interests in this program.

In the interest of integrating GAP technology with state needs and priorities, three general themes were raised in the many comments offered during the review. First, the GAP Program's focus on high species diversity as a measure of management priority was not seen as central in the issues or approach of New York agencies. Agency representatives were largely interested in fish species and often just one life stage (e.g., spawning) of some species. This species-oriented perspective would call for model development aimed at very specific habitats, which differs from the GAP approach of mapping habitats associated with species and communities. Some means of addressing diversity and communities while retaining predictive power for species and life stages of economically important species will be needed to blend national and state-level needs.

A second issue was the scale of GAP technology development and application. The GAP Program aims at developing broad-scale habitat coverages for states or regions, but this does not match the scale of management issues on the agendas of state agencies. Some way is needed to use a GIS system to simultaneously provide broad spatial coverage and do fine-scale applications. Finally, the GAP Program's development approach is to complete statewide habitat coverages and learn how to best use those for identifying conservation "gaps." The workshop attendees strongly favored model development, testing, and refinement in a limited area before moving to statewide coverages. Some sort of dual development approach is needed to balance model refinement and validation with expanding spatial coverage.

Despite the differences in perspectives, almost everyone at the workshop realized the utility and potential applications of predicting biota from remotely sensed data and mapped habitats. This is the basic philosophy of GAP, and no suggestions were made to abandon it. Also, there was no sentiment for the apparent alternative GIS development mode of consolidating aquatic biosurvey data to map known species distributions. New York agencies have extensive biological survey data, there are established programs maintaining this information, and most of it is in computer databases. The inconsistencies identified in the workshop dealt only with the level of biological predictions (diversity vs. species), the scale of development (statewide vs. limited area), and the initial development approach (statewide coverage construction vs. validated protocol refinement).
The leadership of the NYDEC is committed to seeing aquatic GAP continue in the state, and it has made a commitment to shared support of GAP. With the workshop results in mind, a joint USGS (NY Coop Unit) and NYDEC proposal was formed for the continued development of aquatic GAP in New York. Some changes in the methods of our pilot project were identified to make aquatic GAP serve a diversity of needs while retaining the basic attributes of the National GAP Program. Building greater prediction flexibility into the GAP protocol would bridge the need to address species diversity and species-specific mapping. Unlike terrestrial GAP that largely relies on satellite data, aquatic GAP used a variety of data that we mapped in categorical form, such as shaded or open canopy cover, high or low gradient, and stressful or suitable water quality. The use of continuous data (e.g., gradient in m/km rather than high and low slope) on a variety of parameters (canopy cover, water quality, channel structure, etc.) would greatly enhance the capability of GAP models to deal with varied prediction needs. We already developed GIS tools to automate the acquisition of continuous form data for GIS modeling. Prediction algorithms would differ for species and diversity, and a subset of variables with optimized weighting could be developed for each use. The workshop promoted a staged approach to developing GAP coverages in New York; that is, expand state-level coverage by developing coverages basin by basin across the state. This approach allows both expanded GAP coverage while working in watersheds with extensive data useful in model testing and refinement.

The proposed USGS/NYDEC Aquatic GAP Project would develop the GIS software and protocols for implementing an automated system and developing prediction equations. The national aquatic GAP methods, developed over time with experiences in several states, would include a set of GIS data layers to develop and how (the GIS structure), a set of classification equations for national-scale syntheses (National GAP classification rules), and a protocol for developing study and species-specific predictions (habitat classification optimization). If the mathematical formats were standardized, a wide variety of uses could be accommodated depending on user interests without separate development efforts. The "Making GAP Work for New York Waters" workshop raised tough questions about the basic aquatic GAP approach. The new ideas presented in the joint USGS/NYDEC proposal could not have been developed without the input of the New York agencies.

Gap Analysis for Plant Species

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GAP projects have made an important contribution towards modeling distributions of terrestrial vertebrates but rarely have addressed other organisms. Vascular plants, in particular, have been treated primarily as components of vegetation rather than as individual species. As with vertebrates, there are also significant conservation gaps between distributions of plant species and protected areas. A GAP approach to plant species (Hartman and Reiners 1997) may be overdue in light of recent studies suggesting that 12.5% of the world's flora is in danger of extinction (Walter and Gillett 1997).

Performing gap analyses for plants presents different challenges than for vertebrates. Theoretically, sedentary organisms like plants should be easier to map and model than motile organisms. In practice, plant distributions may be more sensitive to vagaries of local climate, topography, and substrate than vertebrates and require finer-grained environmental data for predictive modeling. State vascular plant floras also typically consist of thousands of species, compared with hundreds of species in similar terrestrial vertebrate faunas. Due to their high species richness, it is far less practical and more laborious to model distributions for entire floras than vertebrate faunas.

An alternative to attempting a gap analysis of an entire state flora is to randomly select a subsample of representative plant taxa. But on what basis does one select representative species? In Wyoming we have developed a computerized database (using Microsoft Access) to stratify the state's 2,752 native and introduced vascular plant species and varieties (Dorn 1992; Fertig unpublished data) in order to randomly select subsets of taxa for predictive modeling purposes. To create this database, each taxon was ranked according to four criteria: geographic distribution pattern, in-state abundance, growth form, and major biome affinity.

Geographic distribution patterns reflect Wyoming's context within the global range of each taxon. Geographic pattern classes included exotic (non-native to Wyoming), widespread (found commonly throughout the state and North America), sparse (numerically uncommon and restricted to widely scattered, specialized habitats in the state, but wide-ranging outside Wyoming), peripheral (at the edge of its range in Wyoming), disjunct (geographically isolated in Wyoming from its main continuous range), or endemic (restricted to a small geographic area only in Wyoming or 1-2 adjacent states). These distribution patterns were determined from state range maps produced by the University of Wyoming's Rocky Mountain Herbarium and the literature.

In-state abundance was derived from Nature Conservancy Heritage ranks using a modified 5-point scale ranging from critically rare (1) to widespread and abundant (5) (Fertig 1997). State ranks take into account population size, trend, and number of occurrences. Each plant was also categorized by its typical mature growth form (tree, shrub, perennial forb, annual forb, perennial graminoid, annual graminoid, or fern-like). Lastly, biome affinity was based on the chief biogeographic region occupied by each taxon in North America as determined by the literature. Major biomes in the Wyoming flora include the Great Plains, eastern deciduous forest, Rocky Mountain forest, intermountain desert steppe, arctic/alpine, and wetlands (Barbour and Billings 1998).

The value of the database comes in its ability to readily sort groups of taxa with similar abundance, growth form, and distribution patterns. A total of 1260 such groups are theoretically possible, although only 262 are actually represented in the Wyoming flora (for example, there are no widespread, alpine/arctic tree species ranked S1 in the state). This stratification process has allowed us to randomly and proportionally sample species from selected groups for GAP modeling. It has also facilitated the study of interesting ecological and biogeographic patterns in the state flora (Figure 1).

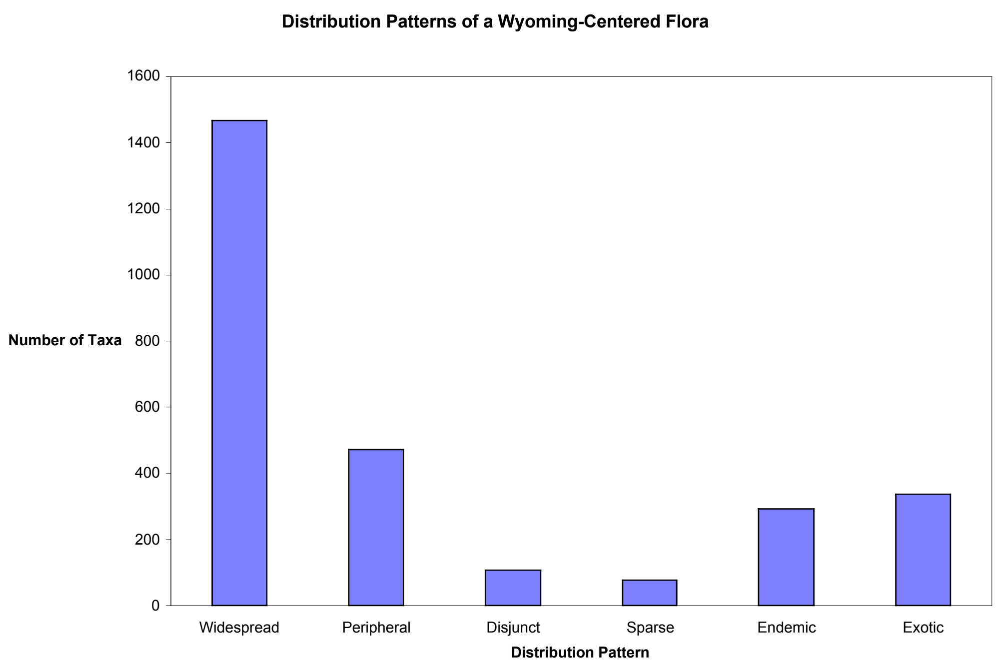

Figure 1. Geographic distribution patterns of the Wyoming flora. See text for description of distribution pattern types.

For the purpose of GAP modeling in Wyoming, we have randomly selected 200 plant taxa from our stratified database to represent the state flora. Exotics and ubiquitous species (those ranked S4S5 or S5) were purposefully excluded from the modeling pool because they are not of preservation concern or because their ranges are too large to benefit from predictive modeling. Species were also eliminated if they were too uncommon within Wyoming and adjacent states to meet a minimum sample size of 25 locations required for our distributional modeling needs. With the removal of these species, the selection pool consisted of 2016 taxa in 212 groups. Small groups of similar composition were then combined and the relative proportion of each group to the total flora was calculated to completely stratify the selection pool. Two hundred taxa, with at least one species representing each combined group, were then randomly chosen.
Development of this database has facilitated gap analysis by stratifying the flora into manageable, yet representative, subsamples. Customized sortings are possible depending on the criteria, classes, and weightings one might wish to impose on the stratification process. We have also been able to quantify the flora of Wyoming and identify patterns in plant distributions related to growth form, state abundance, geographical distribution, and biome affinity. Similar databases can be developed in other states provided that adequate information is available on the status and distribution of the flora.

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Vegetation Alliance Descriptions of the Western U.S.

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Background

The Nature Conservancy (TNC) and the network of state Natural Heritage Programs have developed a national, hierarchical, vegetation classification to further their shared mission of conserving biological diversity (Grossman et al. 1994, 1998). This classification can serve many purposes, including inventory, mapping, resource and ecosystem management, and scientific research. It has received widespread support from state, federal, academic, and international partners (Jennings 1993, Greenall 1996, Loucks 1996, FGDC 1997). Jennings (1997) discussed the progress being made toward further development of this system through the cooperative efforts of TNC, the Ecological Society of America, the Gap Analysis Program (GAP), the Federal Geographic Data Committee (FGDC), and many others. In this classification, vegetation of all types, whether dwarf-shrub bogs, mixedgrass prairies, or pinyon-juniper woodlands, are treated together in one system.

Ecologists in each of the Conservancy's four regions and the national office have worked closely together to coordinate the development of this classification across the United States. Since 1985 TNC's Western Conservation Science Department has worked with state Heritage Programs to develop a regional vegetation classification. A 1994 draft included vegetation types for all the coterminous western states except California, and was distributed for review and testing (Bourgeron and Engelking 1994). Since then the western regional vegetation classification (WRVC) has undergone several revisions. The WRVC has now been integrated with other regional classifications into a single national list of vegetation types (Anderson et al. 1998).

The National Vegetation Classification System

Details of the background, structure, and development of the classification are presented in a series of documents (Grossman et al. 1998, Anderson et al. 1998). The system is a physiognomic-floristic classification of existing vegetation, structured hierarchically, with physiognomic criteria at the highest (coarsest) levels of the hierarchy and floristic criteria at the lower (finer) levels. The formation concept, with units modified from UNESCO (1973), guides the definition of the physiognomic units, and the association and alliance concepts define the floristic units (Figure 1).

TNC SYSTEM (TERRESTRIAL)

PHYSIOGNOMIC CLASS (WOODLAND)
PHYSIOGNOMIC SUBCLASS (DECIDUOUS WOODLAND)
PHYSIOGNOMIC GROUP (COLD-DECIDUOUS WOODLAND)
SUBGROUP (NATURAL/SEMI-NATURAL)
FORMATION (TEMPORARILY FLOODED COLD-DEC. WOODLAND)

physiognomic levels

ALLIANCE (*Populus deltoides* Temp. Flooded Woodland)
ASSOCIATION (*Pop. deltoides*/ *Distichlis spicata* Woodland

floristic levels

Figure 1. TNC's NATIONAL VEGETATION CLASSIFICATION SYSTEM (Example)

The basic unit of the physiognomic portion of the classification is the "formation," a "community type defined by dominance of a given growth form in the uppermost stratum (or the uppermost closed stratum) of the community, or by a combination of dominant growth forms" (Whittaker 1962, see also Schrader-Frechette and McCoy 1993). In practice, formations are defined by varied, conventionally accepted combinations of growth-form dominance and characteristics of the environment (e.g., cold-deciduous alluvial forests, evergreen desert shrublands, alpine meadows).

The alliance is a physiognomically uniform group of plant associations sharing one or more dominant or diagnostic species which, as a rule, are found in the uppermost strata of the vegetation (see Mueller-Dombois and Ellenberg 1974). Dominant species are often emphasized in the absence of detailed floristic information (such as quantitative plot data), whereas diagnostic species (including characteristic species, dominant, differential, and other species groupings based on constancy) are used where detailed floristic data are available (Moravec 1993).

Using a combined physiognomic/floristic system allows the identification of vegetation types from both a "top-down" (divisive) and "bottom-up" (agglomerative) approach. The top-down approach allows the use of physiognomic distinctions to help map vegetation, stratify sampling, and where floristic information is lacking, delimit vegetation units. A bottom-up approach employs plot sampling and floristic analysis as the primary means for defining associations. Where physiognomy is variable, the bottom-up approach can also be used to help determine the important physiognomic distinctions. The relationships between physiognomy and floristics are not always simple; when they do not correspond, precedent may be given to the floristic relationships over the physiognomic structure.

Describing Alliances in the Western United States

GAP develops vegetation maps with mapping units comparable to the level of the national classification's alliance, or aggregations of these into cover types (e.g., Driese et al. 1997). A series of cooperative agreements between the four TNC regions and GAP has provided support to Conservancy ecologists to develop descriptions of each alliance (see Sneddon et al. 1994, Drake and Faber-Langendoen 1997, Weakley et al. 1997). The Western Conservation Science Department began this work in late summer of 1997 and continues to develop these descriptions for all alliances in the WRVC. This work is being accomplished by gathering information over the range of distribution of each alliance, primarily through the review of literature and other data sources available for the plant associations that make up an alliance. This information on the associations is then synthesized into a rangewide description for each alliance. At this time, 733 natural and semi-natural alliances are included in the WRVC (for AZ, CA, CO, ID, MT, NM, NV, OR, UT, WA, and WY). The region covers roughly 1/3 of the contiguous U.S. For comparison, 219 alliances are described from TNC's Midwest Region, and over 670 are described for the southeastern United States.

The descriptions are being completed by TNC's Western Conservation Science ecology staff and are projected to be complete in late March 1999. Information being developed for each alliance includes:
- Placement in the classification hierarchy;
- Relationship to other classification systems;
- Range of distribution;
- Vegetation structure and composition;
- Dominant and diagnostic species;
- Environmental features with which it is associated;
- Ecological dynamics and successional status; and
- Literature references.

Additional data being developed include attributing alliances to section-level ecoregions (Bailey 1995) and recording the specific environmental variables (elevation range, aspect and slope, geologic parent material, geomorphic processes, landscape type, soil drainage, pH, and depth) with which the alliance is associated.

Applications

An alliance level classification helps to guide vegetation mapping programs as vegetation maps are a special application of a vegetation classification (Küchler 1988). For mapping applications supported by GAP it is important that the vegetation classification be based on the similarity of structural, floristic, and ecological characteristics of vegetation. The vegetation units are used to label relatively homogeneous polygons or signatures of vegetation to make a map that portrays spatial relationships of vegetation across the landscape.

Alliances, primarily based on dominant species in the top or dominant strata of the vegetation, are particularly amenable to mapping. However, because a map is at a fixed scale and the scale and pattern of alliances are variable, the mapping units may not have a one-to-one relationship to the alliance units. Depending on the map scale desired, vegetation often will form a number of mosaic patterns. A mapping convention can be adopted to attribute a map polygon with multiple alliances and, because the classification system is hierarchical, it is possible to produce map units at different levels of the classification hierarchy.

Current techniques do not permit all alliances to be delineated using remotely sensed data, therefore documenting distributions of alliances by Bailey's *Provinces* and *Sections* will be valuable to GAP projects. Documenting which alliances occur in each section should increase the accuracy of image interpretations and speed the development of more accurate image processing techniques.

As is being done in this project, the development of specific environmental data fields within the alliance description eases the application of the data for predictive modeling of vegetation patterns by linking alliance descriptions to other databases and spatial data sets. This information would be invaluable for analysis, mapping, and modeling of abiotic characteristics of plant associations within each alliance. This creates additional opportunities to improve methods to validate and enhance the utility of GAP vegetation maps. GAP vegetation mapping efforts should feed back to make further improvements to the vegetation classification.

Using the classification by GAP projects also supports the development of new partnerships to make these improvements. Natural Heritage Program ecologists have the expertise and field experience needed for field validation of vegetation maps (at all scales of mapping), and the data being developed for vegetation alliances should prove useful in efforts to create predictive models and maps at the scale of the plant association. Natural Heritage Programs are currently working with various state and federal agencies (e.g., NPS, BLM, USFS, NRCS, EPA) on vegetation mapping and classification projects that could be linked directly to GAP for map validation and establishing sites for long-term environmental monitoring.

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Rule-Based Image Interpretation

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The North Carolina GAP Project is using a decision rule process for mapping vegetation in the coastal plain. Building on the methodology developed by Slaymaker et al. (1996), we have advanced its application incorporating a rule image. As opposed to directly "deciding" pixels into a given land cover class, the output image is created using the rule numbers themselves. This results in a "rule image" that provides a useful intermediate step, allowing the analyst to check for logic errors by determining the amount and spatial distribution of the pixels classified by a suite of individual rules. This process of writing, applying, and verifying the rules can be repeated until the majority of pixels are coded. Once the quality control check is complete, the rule image is simply recoded to create the land cover map. Neighborhood majority functions are then used to code any remaining unclassified pixels.

The rule image makes it possible to return to an intermediate stage for cover classes requiring refinement. By isolating pixels selected by a single rule, the information used in that rule is maintained, and additional information can be added to refine the classification. For example, we can return to a specific rule that decides longleaf pine woodland and build on the unique spectral, soil, and wetland information that was used to isolate that subset of pixels. If we output the land cover class directly, the range-unique attribute combinations used to label that class are lost.

Methods

Ground Truth Data Acquisition: Four primary sources of ground truth information were collected for the decision rule mapping process. These sources include aerial videography transect data, ground samples obtained during videography training field work, the North Carolina Natural Heritage Program's plant community occurrence database, and ground samples collected by the North Carolina Division of Coastal Management. Aerial videography transects were flown in the spring and fall of 1996 and again in the spring of 1998. The video equipment is designed to collect both wide-angle and zoom video. A time-code stamp on each frame ties it to a simultaneously collected GPS location (Slaymaker et al. 1996).

In the lab, video transects are used in the selection of sites to be visited on the ground. During the interpretation phase, if we see vegetation that is difficult to interpret, new sites are selected for field visits to verify the interpretation. Using the sources listed above, approximately 20,000 points were gathered for the coastal plain of North Carolina. The majority of these (86%) came from aerial videography interpretation. Point labels were assigned based on National Vegetation Classification alliances where possible (Weakley et al. 1998). Certain labels (small stream swamp, low pocosin) contain several alliances that could not be distinguished at the resolution of the aerial video. As new labels are added to the list, a crosswalk to alliance list is updated. One fourth of the interpreted points for each vegetation class have been reserved for a final assessment over the entire ecoregion. The assessment will be conducted after refinements are made, based on review, and after merging across Landsat TM scene boundaries has been completed.

Data Sets Used in the Vegetation Classification: Four data sources were used for mapping the coastal plain: a) U.S. Fish and Wildlife Service's National Wetland Inventory (NWI), b) Natural Resources Conservation Service's county soil surveys, c) Landsat Thematic Mapper imagery from the Multi-Resolution Land Characterization Consortium's (MRLC) nationwide purchase, and d) the southeast regional land cover developed by EROS Data Center (EDC; Version 98-03, Hughes STX Corporation under contract to USGS). The EDC regional land cover is used as a masking tool. All pixels classed as urban, water, agriculture, pasture, other grasses, or barren are currently left unchanged by our work. The pixels corresponding to those that had been mapped as natural vegetation are used in an unsupervised clustering of the raw data to get 80 clusters.

Decision Rules Process: The decision rule process involves developing a database from the interpreted points which includes the values of each of the different data layers for each location. Specifically, in ERDAS Imagine, we use the "pixel to ASCII" function to obtain a file with the values from the soil surveys, NWI, and clustered image that occurs at each of the X,Y locations in the interpreted points. This database is then used to develop a series of IF…THEN statements for each of the 80 clusters. In Imagine, the rules are applied sequentially, and once a pixel has been classified using a conditional statement, it is not considered in subsequent rules. To mimic this while writing the rules, we analyze the data cluster by cluster and iteratively subset the points based on the combination of the ancillary information used to develop each rule. For example, in cluster 25, the majority of the points that occurred on Croatan soil and had a NWI code of saturated palustrine needle-leafed evergreen forest were labeled pond pine woodland. A rule would be written based on that combination of ancillary information. The points decided by that rule are then removed from the data set, and the process is repeated for the remaining points in the cluster.

Once the rules are written, a crosswalk between rule number and land cover is developed, and the rules are incorporated into an Imagine model. As mentioned above, we send the rule number to the output image which can then be queried using our interpreted points. If the pixels are decided as we expect, then the rule numbers can be recoded to create the vegetation map. If, however, we find mismatches between the land cover associated with the rule at that location and the interpreted points, we can readily trace the errors back to their origin. We can determine if the errors are due to true confusion between classes that cannot be overcome given the data we have or caused by typographical mistakes or errors in the logic of a rule. Once recoded to create the vegetation image, the regional land cover classes that were masked out are merged back with the vegetation classes. Class-specific majority filters are used to code previously unclassified pixels.

Review and Final Evaluation

The draft vegetation map for the southeast coastal plain is now available for review. In general, the comments we have received to date have confirmed limitations we had previously recognized.

We know, for example, that we have not separated mesic from xeric longleaf pine woodlands. In this case, we will return to the rule image and look more closely at the spectral and soil data associated with the longleaf rules. We are retaining 25% of the interpreted points for a final assessment after the entire ecoregion is merged. In the meantime, we are working with a comparison of the interpreted vs. decided points in order to determine the level of confusion between the mapped classes. While we have reserved points for an assessment of the vegetation cover within the state, we would like to incorporate a systematic assessment of all land cover classes in both the final map and the original regional land cover.

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Applying Gap Analysis to County Land Use Planning in Washington State

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Introduction

The Washington Gap Analysis Project (WA-GAP) recently published the fifth and final volume of its final report and is now looking forward to continuing its efforts with the application of WA-GAP data to a variety of land and resource management problems. Last year I had the privilege of being involved in one of the first attempts at applying this information to land use planning in Spokane County, Washington.

When this work began in September 1997, Spokane County was updating its comprehensive plan as required by the Washington Growth Management Act (RCW 36.70A). The new county plan calls for the identification, improvement, and protection of fish and wildlife habitat. Additionally, the plan calls for the minimization of habitat fragmentation by protecting important fish and wildlife areas and open space and by interconnecting corridors to form a continuous network of fish and wildlife habitat and ecosystems. Furthermore, the county's Critical Areas Ordinance (CAO) requires the protection of a variety of priority habitats, including wildlife corridors and landscape linkages. The county was interested in developing a method for locating and identifying these priority habitats and chose to enter into a pilot WA-GAP implementation

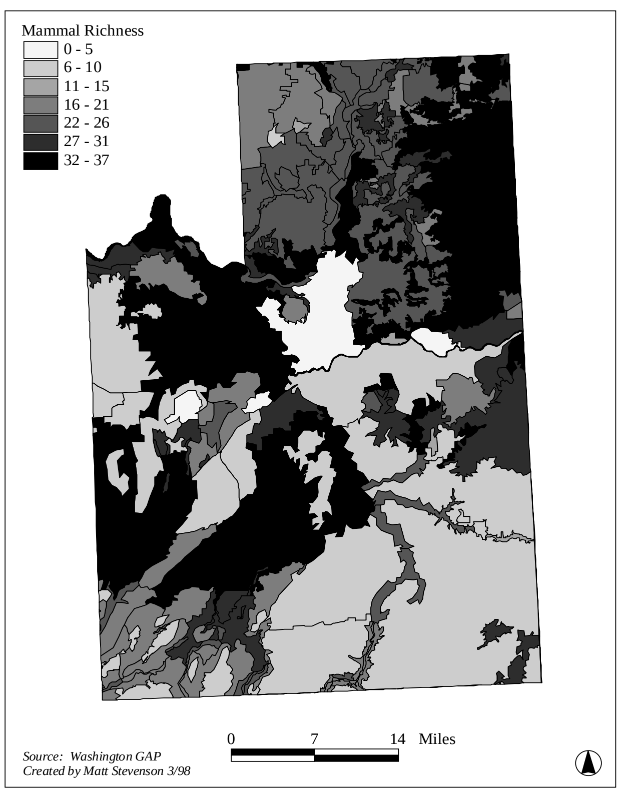

Figure 1: Mammal Species Richness.

project involving the Washington Department of Fish and Wildlife, the Inland Northwest Land Trust, and the Department of Urban Design and Planning and the Washington Cooperative Fish and Wildlife Research Unit, both at the University of Washington.

Methods

The protection of biodiversity was chosen as the design strategy for locating and delineating wildlife corridors and landscape linkages in Spokane County because we felt it would be the most effective way to achieve the CAO fish and wildlife goals. Furthermore, planning for biodiversity before species become endangered may help prevent imposition of governmental regulations as human activity continues to expand into previously undeveloped areas. The dual criteria of species representation and richness were chosen to capture biodiversity at the scale of the entire county. Species richness for Spokane County is depicted in Figure 1.

Representation

The purpose of achieving species representation was to ensure that every species predicted to occur in the county is included at least once within any network of corridors and reserves created using WA-GAP data. Because we determined representation for mammals, birds, and reptiles and amphibians as individual taxonomic groups and then combined the results, we did not generate a minimum representative set. As a consequence, some species which were represented only once within the representative set for their respective group are represented more than once by the combination of the sets for mammals, birds, and reptiles and amphibians. This approach resulted in the map shown in Figure 2, the combination of the representative sets for all terrestrial vertebrates modeled by WA-GAP.

Richness

Establishing increments of species richness by taxonomic group was necessary before areas of high species richness could be identified as potential locations for reserves. This process entailed the creation of a decision rule for which WA-GAP polygons should be selected, based upon the number of species predicted to be present in each. For this analysis, we arbitrarily set threshold levels at 75% of highest possible richness for mammals and birds and 50% of possible richness for reptiles and amphibians.

All polygons with high species richness as indicated by the use of this rule were initially considered for habitat reserves. The ideal polygons for potential habitat reserves were large, with high species richness, natural land cover, low internal and adjacent human development, and high levels of agreement with other wildlife distribution databases. Potential habitat reserves for all three groups are reflected in Figure 3.

Connections between potential habitat reserves and the suite of areas where all species are represented were made by identifying and selecting polygons with high species richness and natural land cover between the potential reserves and representative areas. Maps of species richness, representation, and potential connections between these areas were combined to produce Figure 4, the "raw material" from which a potential wildlife corridor and landscape

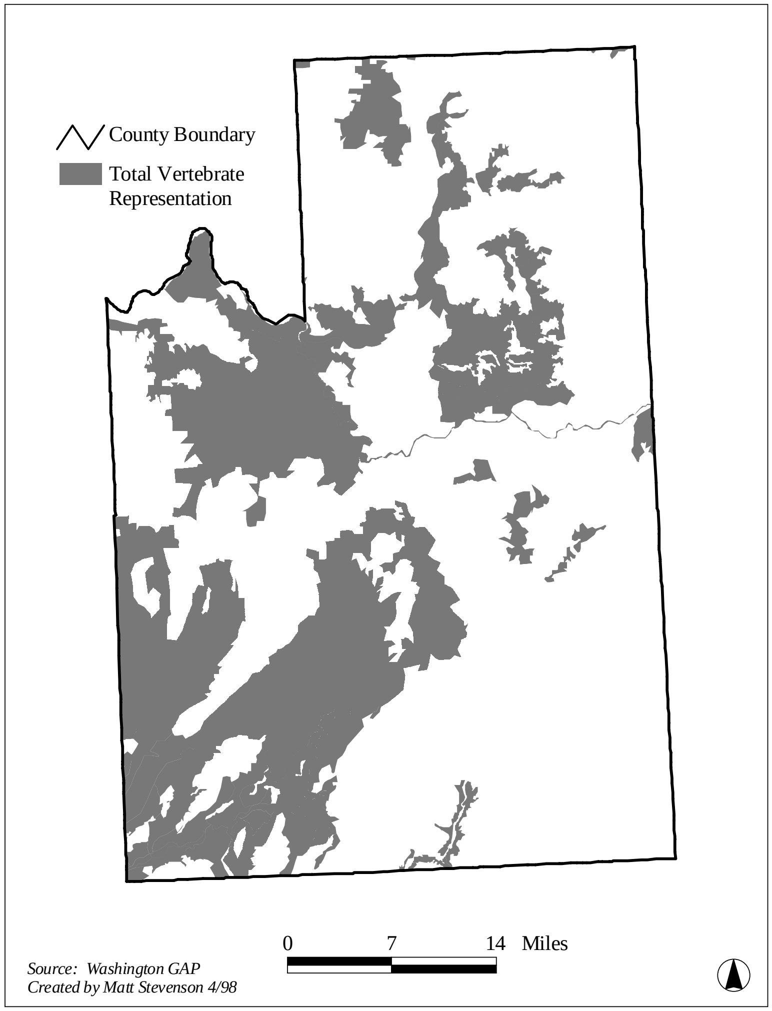

Figure 2: Total Vertebrate Representation.

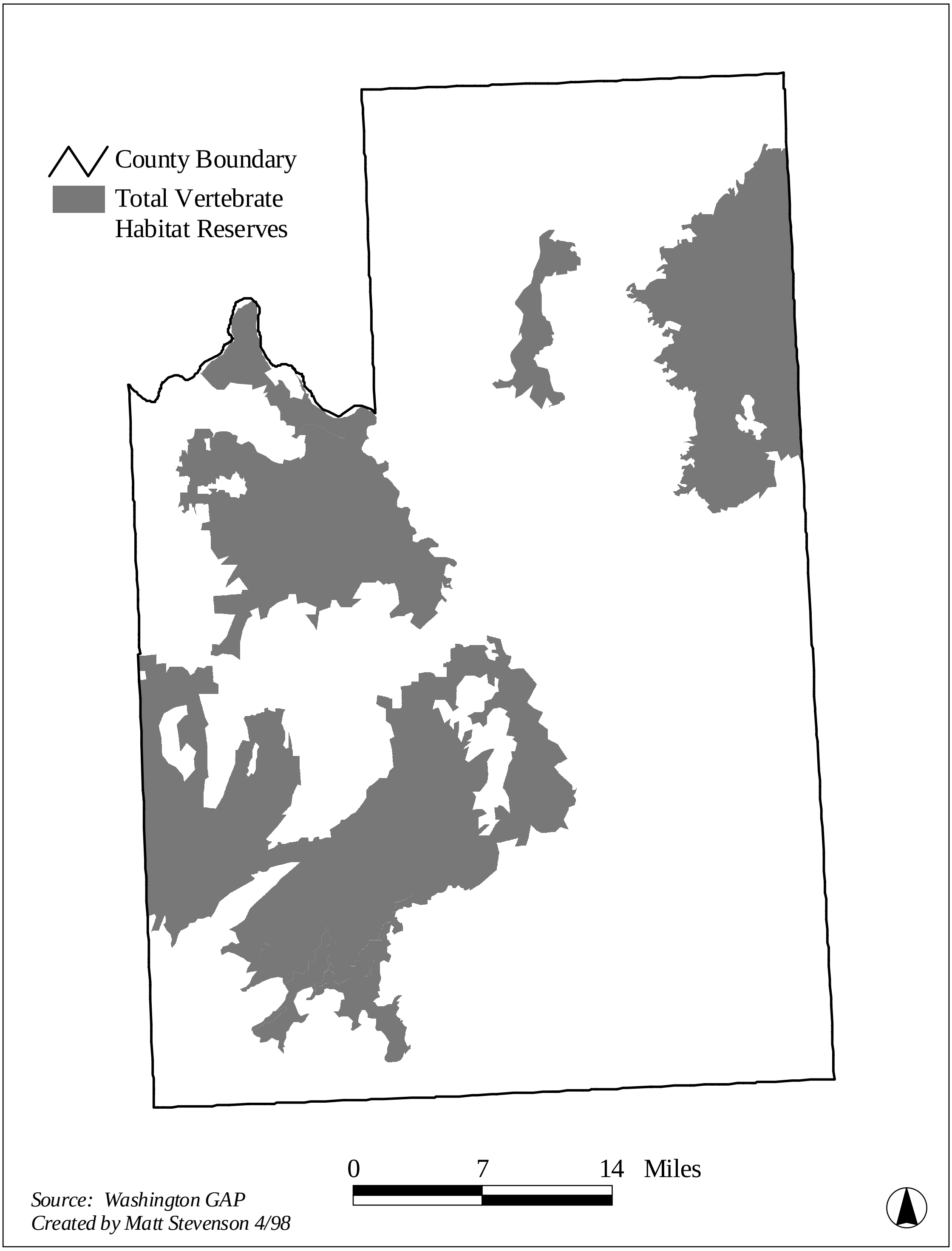

Figure 3: Total Vertebrate Habitat Reserves.

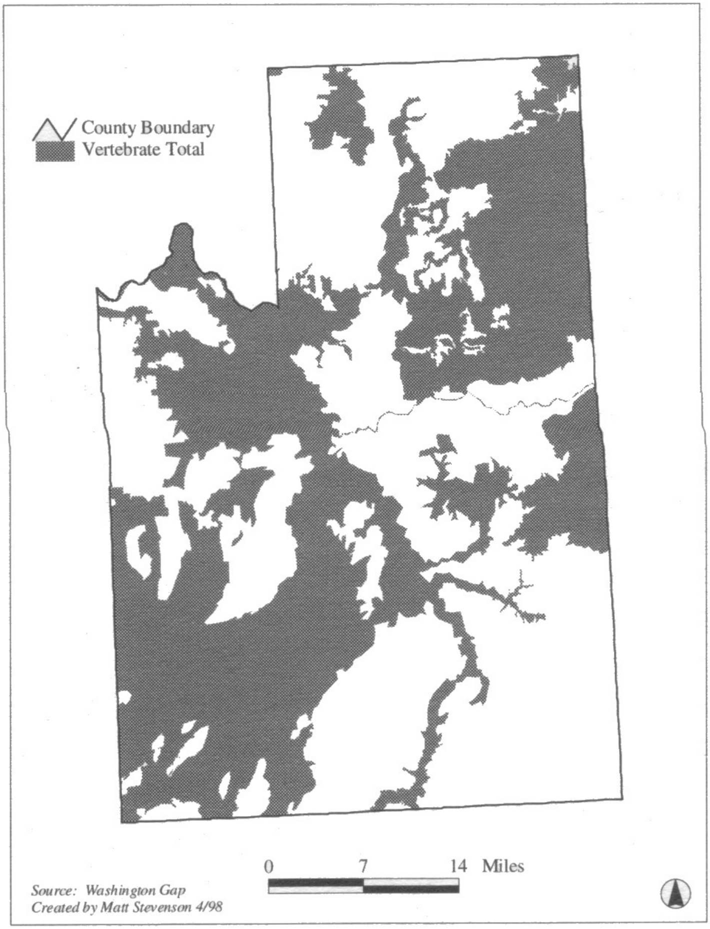

Figure 4. Combined richness, representation, and connections.

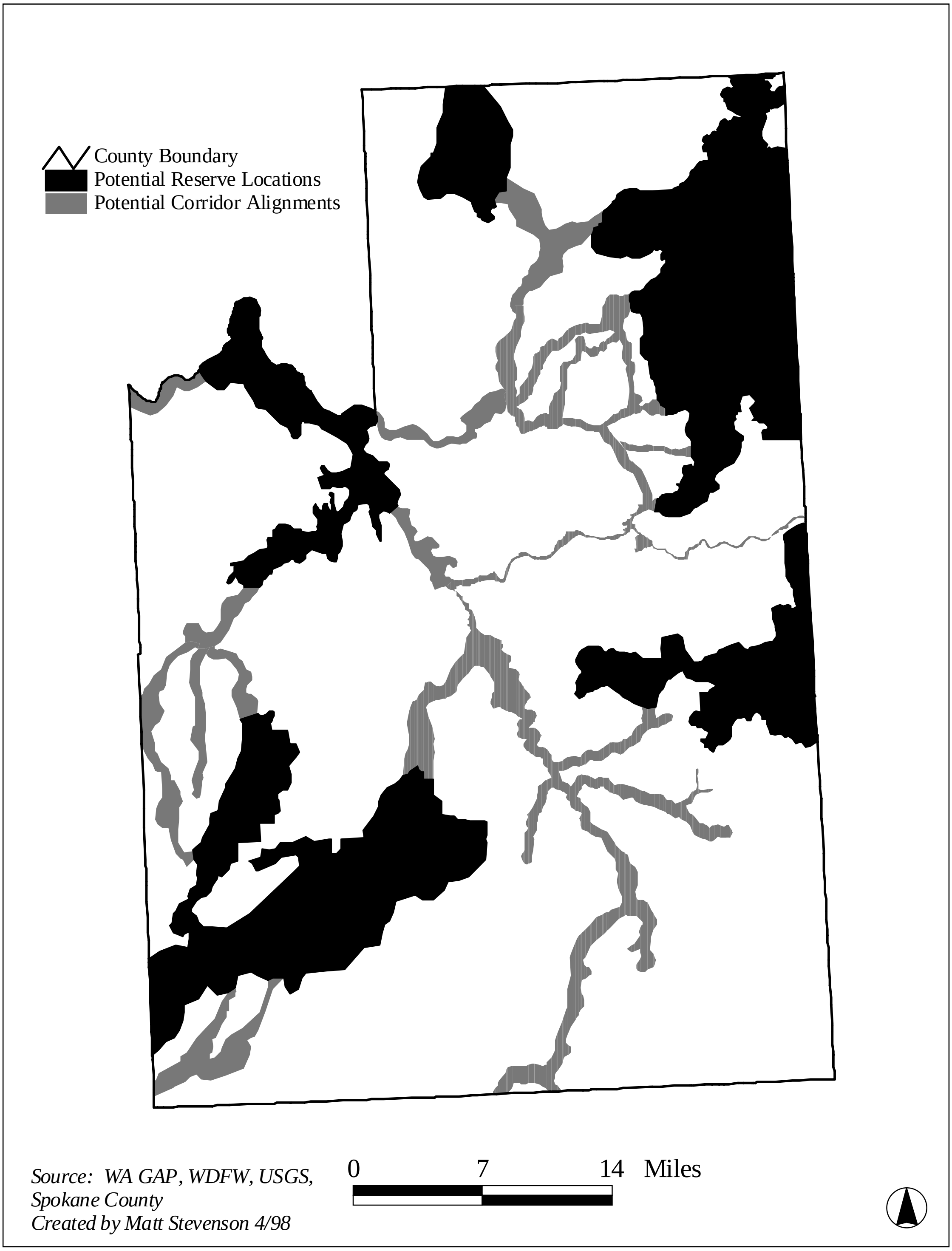

Figure 5: Proposed System of Wildlife Corridors and Habitat Reserves.

linkage system might be created. Just over half of Spokane County is indicated in Figure 4 as being important for protecting biodiversity. This is a tremendous amount of land! In order to refine the areas indicated through the additive process described above, it was necessary to utilize additional sources of information providing a greater level of detail.

The additional information included a fine-grained (5-acre MMU) land cover map I created for the Interim Urban Growth Area (IUGA) surrounding the City of Spokane and its suburbs. A parcels coverage containing property boundaries was provided by the county and served as a proxy for the level of development outside of the IUGA. However, due to the sensitive nature of the information related to ownership and assessed valuation in the parcels coverage, the county provided only the boundaries and none of the attribute data. Additional county data sets used include roads, topography, wetlands and hydrology, land use and zoning, growth area boundaries for other cities, critical areas already recognized, governmental land holdings, and utility and railroad rights of way.

The final result of the additive process (determining representation, richness, and creating connections), plus the reductive process (refining the result from the additive process with additional higher-resolution information), is shown in Figure 5. This proposed system comprises approximately 30% of the county, a substantial reduction from the initial area indicated at the end of the additive process.

Results

If the system of wildlife corridors and habitat reserves shown in Figure 5 were implemented with no substantial modifications, all vegetation zones within the county would see a minimum 10% increase in protected area in addition to already protected land. Protection for the largest vegetation zone in the county, Ponderosa Pine, would increase by 26.5%. For vertebrate species, birds, mammals, and reptiles and amphibians would see median increases in protected areas of 38, 39, and 43%, respectively. (Once again, this is in addition to land already designated for the protection of biodiversity). These increases result in a combined median increase of 39% for all terrestrial vertebrates. It should be noted that this 39% increase occurs on only 30% of the county's total land area.

Discussion

To implement the results, Spokane County (and any other municipalities interested in conducting similar analyses) will have to use a wide variety of land-use planning tools. There is no single mechanism by which the biologically important lands in Spokane County can be instantly protected. Rather, a combination of incentives, regulations, and acquisitions is the approach most likely to achieve the goals established in the CAO.

Presently, Spokane County is using the results to update their Comprehensive Plan and Critical Areas Ordinance. The Washington Department of Fish and Wildlife is using the information to analyze and evaluate properties proposed for acquisition under the state's Conservation Futures program. The Inland Northwest Land Trust (INLT) is using the results as the centerpiece of their land protection work this year and intends to do so for the foreseeable future. According to Chris DeForest, Executive Director for the INLT, "Without this information, we would be operating by hunch and expert guess."

For more information about WA-GAP and land use planning, please contact Dr. Frank Westerlund in the Department of Urban Design and Planning at the University of Washington (206) 543-4190, or Dr. Christian Grue, WA-GAP Principal Investigator, at the Washington Cooperative Fish and Wildlife Research Unit, (206) 543-6475. Matt Stevenson can be contacted at Utah State University, Department of Fisheries and Wildlife, (435) 797-3892, mrs@nr.usu.edu.

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The *NatureMapping* Program's First Five Years

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Since its inception in 1992, The *NatureMapping* Program has been identified as the outreach program for the Washington Gap Analysis Project (WA-GAP) and the Washington Department of Fish and Wildlife (WDFW). The program has become the outreach program for the National Gap Analysis Program and continues to pull in more partners in other states, including businesses. REI, for example, provides a *NatureMapping* field kit and other equipment at substantial discounts. ESRI, Inc. donated 100 copies of ArcView to Washington State teachers, and Maptech, Inc., the makers of Terrain Navigator, offer their CD-ROMs containing 7.5 minute and 1:100,000 topographic maps at half-price. Terrain Navigator has a very easy-to-use software interface allowing users to mark their locations and save them as a file which will record latitude and longitude (or UTM) and elevation. Geomantics, Inc. is another company helping us plan and design ways to distribute our printed materials nationally, via the program's web site.

The popularity of the program in Washington State and nationally is growing exponentially. There are three audiences the program reaches: individuals, schools, and communities. The Washington State database, however, has become a repository for a fourth audience: researchers. Personal field notes and research projects where data are generated but not stored anywhere except on an individual's computer, are being converted and submitted to the program for use by others. All data are tagged with an observer identification code if further information is needed by a user. Only the "GAP 1040" attributes are being stored in the *NatureMapping* database at the University of Washington. The GAP 1040 is designed after the IRS 1040, where we handle our finances differently, but we have to report them consistently. We want everyone to include these attributes, at a minimum, in their projects. Most data sets are linked on the web. Procedures to edit and update the database and maps on the web site (http://www.fish.washington.edu/naturemapping) have been developed during the analysis of the first five years' data. The September 1998 cutoff consisted of 30,750 records. Additional data sets from organizations such as Adopt-a-Beach and the Washington Department of Fish and Wildlife's backyard wildlife sanctuary winter bird count will be added for the next analysis. Figure 1 shows the breakdown of the categories of observers. It should be noted that although forty-eight teachers or schools submitted data, each of those may have involved 30 to 270 students and just as many parents in the data collection process.

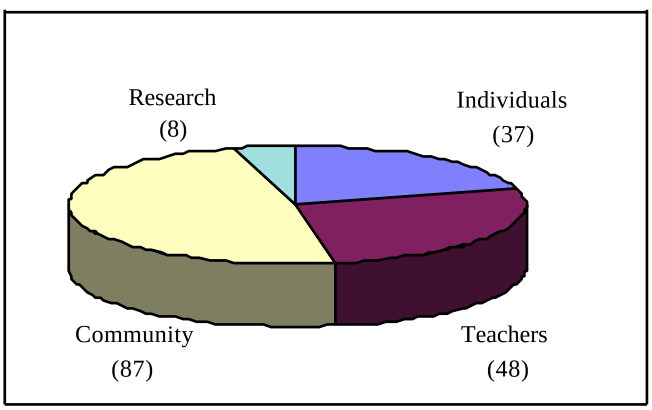

Figure 1. Categories of observers.

The community category is comprised of Seattle Audubon weekly field trips and local government sponsored projects where personnel work with community volunteers to collect wildlife and habitat data. Seattle Audubon's field trip leaders have contributed 41% of the 30,750 records over the past three years.

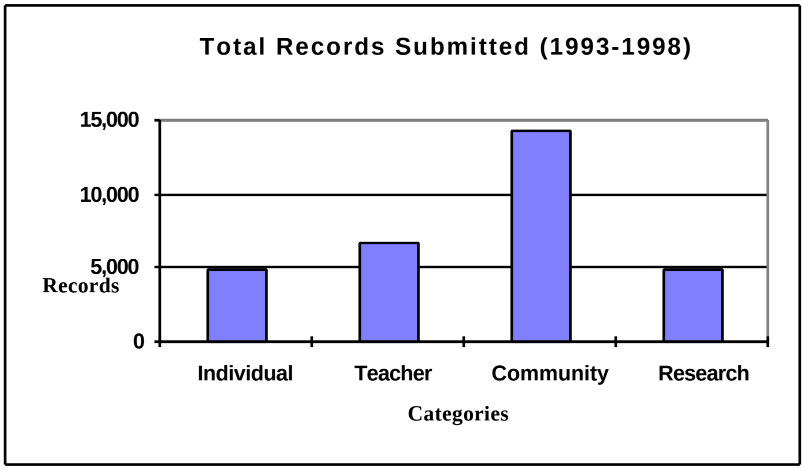

Figure 2. Total number of records submitted by observer category.

The program began receiving data in 1993, but some of the records go back to the early 1900s. These data are, for example, from a project that conducted an extensive literature review of Puget Sound water birds, or from personal field notes of an 85-year old naturalist that go back to 1964.

Approximately 415 species, including 23 herpetile species, 57 mammals, 3 marine mammals, and 1 salmonid have been reported and are currently undergoing further review. WA-GAP's vertebrate distribution maps are the base maps on which the *NatureMapping* observations are overlaid for coarse-scale evaluation. Fine-scale evaluation is conducted on a species-by-species basis. Experts and other data sets are being used to edit aquatic species and winter bird observations.

Although the American crow was the most recorded species in the first three years of analysis, the American robin has moved ahead (Table 1).
The web site is the primary tool to disseminate wildlife and habitat data and provide educational materials, data collection protocols, and other forms of information. The site receives approximately 11,000 hits per month. Other education and outreach activities include

Table 1. The top 20 species reported in the first five years.

Species ID	Common Name	Total Records
TUMI	American robin	1,201
LAGL	Glaucous-winged gull	1,182
COBR	American crow	1,095
CECO	Pigeon guillemot	668
ANPL	Mallard	651
PAAT	Black-capped chickadee	650
MELME	Song sparrow	610
CYST	Steller's jay	582
ARHE	Great blue heron	555
PIER	Rufous-sided towhee	490
AGPH	Red-winged blackbird	454
BRCA	Canada goose	447
STVU	European starling	437
HALE	Bald eagle	426
BUJA	Red-tailed hawk	399
HABA	Black oystercatcher	391
COAU	Northern flicker	378
JUHY	Dark-eyed (Oregon) junco	370
PHAU	Double-crested cormorant	355
HIRU	Barn swallow	338

workshops. There are three workshops now offered. The Level 1 WILD *NatureMapping* Workshop focuses on terminology, species identification, and geography. Field work is conducted after an overview of data collection protocols and species identification tips. The ability to record the correct location of the observation is strongly emphasized. Each participant is provided with a 1:100,000 topographic map of their area and learns how to locate their Township/Range/Section, the common way of reporting wildlife in Washington. Washington state workshop participants receive their Township (36-square-mile) printout of the WA-GAP classified satellite imagery, with GAP land cover polygons, roads, rivers, and Township/Range/Section coverages. There are, however, instructions and resources provided to the participants for latitude and longitude identification. In states east of the Mississippi, which do not use Township and Range, participants are trained to find their latitude and longitude.

The Project Design Workshop is Level 2. Participants learn how to design monitoring projects for their backyards, schools, and communities. Wildlife ecology and management issues, animal behavior, and special projects directed by researchers and state and county agencies are highlighted, providing an opportunity for participants to work with local experts. Participants learn more about classifying and using their satellite imagery maps for their projects.

The Level 3 Workshop focuses on technology. Participants learn how to use The *NatureMapping* Program's data entry software, export their data into a spreadsheet for additional analysis, and then import their data into ArcView. These workshops are held at the University of Washington's School of Fisheries computer lab and at Washington State University's (WSU) Spokane branch GIS lab. WSU is a recent partner offering training for participants in eastern Washington and northwestern Idaho.

In an effort to meet the demand for *NatureMapping* by other states, the program held its first annual meeting May 1998 in Silverdale, Washington. Representatives from Washington, Idaho, California, Virginia, Washington D.C., Iowa, Canada, and Norway attended. Presentations included Virginia's 20-month-old *NatureMapping* equivalent, *WildlifeMapping*; Iowa's plans to begin with a focus on freshwater mussels; and Norway's national student/scientist water quality monitoring program. The Orchard Prairie School is the second smallest school district in Washington. Their second-through-seventh graders have been *NatureMapping* for two years and traveled across the state to present their biodiversity skit to the meeting participants. Orchard Prairie's *NatureMapping* work is highlighted on a kiosk at Seattle's Woodland Park Zoo, which receives almost a million visitors a year.

The next annual meeting will be held again in Silverdale, with more time devoted to non-native species, freshwater fish, and marine animals. Status reports will be presented by states in various stages of the program. A full-day field trip to the Theler Wetlands will be repeated to collect data and work with the community on the major issues facing their watershed, such as the salmon listings, water quality, development and restoration, and wildlife use within the estuary and surrounding town.

The *NatureMapping* Program focuses on

- education,
- dissemination of Gap Analysis and other biodiversity data sets to a local level,
- research using data submitted by the participants, and
- feedback in the form of data, information, maps, and personal conversations.

This focus has allowed it to become an integral part of the WA-GAP, WDFW, and the University of Washington's Department of Urban Planning activities with county planners. County analysis is conducted in an ecological context using WA-GAP data and further refined by county and WDFW data. The first county, Spokane, has used the corridor and reserve recommendations to address their critical-areas ordinances and state-legislated growth management act requirements. A second county, Pierce, will begin in 1999 and will add an aquatic component since salmon have been listed as threatened with extinction under the Endangered Species Act. In both cases The *NatureMapping* Program acts as a conduit for educating the public. It includes its participants in ground-truthing and verification of the proposed corridors and open spaces. It involves the public, including schools, in their county's decision-making process. Also, the *NatureMapping* Program receives and distributes data for its public database. If all counties become involved, the end result will be a state map of corridors and reserves developed using landscape ecology as the guiding principle, then refined and monitored by land planners and citizens within their own political boundaries. This process not only fulfills the Gap Analysis Program's mission to promote conservation of biodiversity through information and to facilitate the application of this information to land management, but guarantees the implementation of a statewide strategy to conserve Washington's natural biological diversity.

Illinois GAP Partners with Conservation 2000

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The National Gap Analysis Program (GAP) was initiated to address biodiversity conservation at the state and national levels, while Illinois' Conservation 2000 (C-2000) was established to address the natural resource needs of Illinois into the year 2000. C-2000 is a six-year, $100-million legislative initiative designed to take a broad-based, long-term ecosystem approach to conserving, restoring, and managing Illinois' natural lands, soils, and water resources while providing additional high quality opportunities for outdoor recreation. The Illinois Gap Analysis Project and C-2000 are cooperating to gather and maintain ecological data to monitor trends in Illinois ecosystems. One of the aims of Gap Analysis is to provide data and analyses to conduct proactive rather than reactive natural resource management. Illinois is fortunate to have a program such as C-2000 that shares these goals implemented at the state level.

C-2000 supports a variety of specific programs including the Critical Trends Assessment Program (CTAP), EcoWatch, and the Ecosystem Partnership Program. The data generated by these innovative programs, each of which is briefly discussed below, will supplement the Illinois GAP project.

Critical Trends Assessment Program

CTAP is a long-term program aimed at monitoring and preserving Illinois' biological resources. CTAP, to date, has produced a Land Cover Database of Illinois (Luman et al. 1996), conducted statewide scientific monitoring, defined the state's resource-rich areas (Suloway et al. 1996, http://www.inhs.uiuc.edu/cwe/rra/rra.html), and assisted Ecosystem Partnership Areas. The Illinois Land Cover Database, generated in conjunction with CTAP and GAP, has been instrumental in promoting this and other research programs, including evaluating potential elk reintroduction sites (Van Deelen et al. 1997) and identifying large and/or aggregated grasslands statewide (McKinney et al. 1998). The Land Cover Database was made possible by the joint funding and efforts of CTAP and GAP.

The long-term monitoring being conducted by CTAP biologists involves intensive field sampling. Thirty sites for each of four primary habitats throughout Illinois will be visited each year over a five-year period before being revisited. The Land Cover Database was used to identify potential monitoring sites in the four primary habitat types of forest, stream, grassland, and wetland. Each monitoring site was chosen based on criteria specific to each habitat. Maps depicting relevant habitats and potentially suitable sampling locations were produced for use in the field by scientists. Data collected at each long-term monitoring site include soil characteristics as well as identification of plant, bird, and mammal species. Illinois GAP will compile and complement this information and could use it for identifying vertebrate distributions. The collaboration between CTAP and GAP has had a significant impact on environmental programs in Illinois. Information generated by CTAP and Illinois GAP will continue to promote the objectives of ecological assessment, monitoring, planning, and management.

A component of C-2000 and CTAP is to maintain and enhance ecological and economic conditions in Illinois. A first step towards this goal was identification of areas in the state which are relatively rich in natural resources. A resource-rich area is large enough for its ecosystems to operate properly, has the potential for protecting or restoring habitat on a large scale, contains examples of natural communities with significant habitat and species diversity, and has habitat types that are rapidly declining in the state (Suloway et al. 1996, Jeffords 1998). Within Illinois, 30 resource-rich areas were defined (Figure 1). The GAP project aims to identify areas with high biodiversity or areas rich in natural resources. This type of analysis conducted for CTAP will greatly benefit and inform Illinois GAP.

EcoWatch

Another major component of C-2000 is EcoWatch, which seeks to train "citizen scientists" and students to monitor various ecosystems in Illinois. Volunteers are given a well-defined set of activities developed by the Illinois Department of Natural Resources (IDNR). They are allowed to choose one or more sites and entrusted with yearly monitoring activities (Jeffords 1998). The data from these "citizen scientists" is collected in a systematic and timely manner and then submitted to IDNR for use in assessing long-term trends. Currently, RiverWatch and ForestWatch are components of EcoWatch, with PrairieWatch, WetlandsWatch, SoilWatch, and UrbanWatch in various stages of development. The concept of EcoWatch is simple, but implementation is more challenging. The challenge comes in ensuring the data the volunteers collect are scientifically rigorous enough to be valid, but the collection procedures are simple enough to be done by volunteers (Jeffords 1998). Extensive curriculum materials, identification keys, and potential sampling locations have been developed in support of this program. Since 1994, over 800 citizens, including school teachers, have been trained in EcoWatch procedures.

Gap Analysis attempts to identify habitat types and species not well represented on federal-, state-, or county-owned lands in Illinois. Volunteers collecting data throughout the state will assist in better defining the underrepresented species and communities. Currently the Illinois GAP Project is mapping distributions of species occurring in collections at the Illinois Natural History Survey. Specimen locality records from these collections are being used in modeling species distributions across the state. The data collected by "citizen scientists" will enhance and update the current data on species distributions. Collaboration between GAP and EcoWatch includes shared goals, a strong environmental education component, and support of EcoWatch using data and GIS capabilities developed by Illinois GAP.

Ecosystem Partnership Program

The Ecosystem Partnership Program is a further component of C-2000. These public/private partnerships attempt to combine natural resource stewardship with compatible economic and recreation development by bringing local stakeholders together. The partnerships seek to make resources (e.g., technical and popular reports on local recreation, natural resources, and economics of their area) of the IDNR—and, by extension, GAP—available to people at the grassroots level who are interested in problem solving. The information can be used, for example, to design individual projects such as habitat restoration. Currently there are 22 Ecosystem Partnerships throughout Illinois (Figure 2). This innovative approach is particularly appropriate for Illinois, where over 95% of the land is privately owned.

Building and maintaining these types of partnerships is one of the goals of implementing GAP. All the data collected, assembled, and mapped for the GAP project will be quite valuable when they become available to the citizens of Illinois. The Ecosystem Partnerships in Illinois will facilitate the distribution of these data as well as make hardware, software, and expertise available to citizens. In this way, Ecosystem Partnerships will help assure that GAP will have tangible and long-term benefits to the state.

Illinois GAP and C-2000

It is hoped the data collected and mapped for GAP will not be restricted by political boundaries but rather a step towards comprehensive land conservation planning (Gap Analysis Program 1996). The well-established C-2000 program with its EcoWatch volunteers, ecosystem partnerships (Figure 2), resource-rich areas (Figure 1), and land cover database has already crossed political boundaries and is of great value to Illinois GAP. The existence of C-2000 in Illinois provides the GAP project with valuable data and avenues in which to promote the goals and implementation of proactive biodiversity conservation at the community and landscape levels.

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A Partnership Providing Field Data for Gap Analysis: Texas Tech Museum and Texas GAP

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Between 30,000 and 300,000 species of plants and animals (many not yet described by scientists) are thought to become extinct each year, and much greater numbers of individual populations and genetic varieties are also being lost (Lugo 1986, Wilson 1986). Erwin (1986, p. 127) concluded "Our generation will participate in an extinction process involving perhaps 20 to 30 million species." Each loss is significant and each species irreplaceable.

A partnership between the Museum of Texas Tech University, and the Texas Cooperative Research Unit (TCRU) was developed to: 1) acquire and preserve examples of genetic biodiversity of fish and wildlife species from widespread geographic regions, 2) develop DNA libraries and DNA probes to be used to document biodiversity, 3) establish a computer database, accessible worldwide, of DNA fingerprints, DNA profiles, and all museum collections, including skins and skeletons, to be used by natural resource managers, researchers, and law enforcement personnel, and 4) prepare computerized databases compatible with geographic information systems (GIS) such as the National Gap Analysis Program.

Cryopreservation, the method of preserving tissue samples under ultra-cold conditions, provides the means to preserve in a relatively small space and at minimum expense, the genetic information of a large number of species, populations, and individuals. DNA probes using RFLP (restriction fragment length polymorphisms), microsatellites, and sequencing techniques provide powerful tools to accurately discriminate genetic differences within and among species, subspecies, and populations. The probes allow detection and quantification of genetic diversity and can help maintain biodiversity by identifying genetic traits. Advances in image analysis and computer technology now allow, for the first time, a holistic approach to data storage, retrieval, analysis, and electronic exchange of museum collections, including natural history specimens, artifacts, cultural data, and maps of species distributions.

Landsat imagery and ancillary data are being used by the TCRU in support of the National GAP Program to map natural resources in Texas. This GIS capability, combined with specimens and cryopreserved tissue samples now in the museum, provide a spatially-based reference for genetic data and DNA for future biotechnology projects to facilitate fish and wildlife management. The voucher material (skins and bone) now in the museum is a resource of value to researchers throughout Texas, the U.S., and other countries.

Access to specimen collections, such as those at the Museum of Texas Tech University, are vital for their base line data from which trends in biological resources can be determined, trends that can impact all aspects of society, for example, human health (Baker et al. 1997). With expanding human population and increased industrialization along the Mexico-U.S. border, base line data should be established now so that future environmental changes can be compared.

The Need

The three goals of the existing project at Texas Tech University (TTU) are: 1) to preserve samples of diverse genetic material for future generations, 2) to develop TTU as the national leader in image storage and analysis of museum collections, and 3) to provide training for technical assistants, students, faculty, visiting scientists, law enforcement, and resource management personnel. Tools developed will be used to provide genetic information necessary to properly manage fish and wildlife populations of national and international importance. Computerized data banks, including video images and numerical data of these and other collections in the museum, will become widely available through the Internet.

The Museum

In the past, one of the major hindrances to the use of museum data in conservation studies and projects such as GAP was the relative difficulty in accessing the data. Over the past several decades, advances in computer technology have made it feasible to make extensive use of computer databases. Only in the past eight to ten years has the computing power become available to manage very large data sets on a desktop computer. Prior to that, access to a mainframe was required. In addition, database technology itself has matured to allow efficient, simple, and rapid access to data. Finally, the development of the Internet allows a simple and efficient means for data dissemination.

At TTU a relational database management system (named "WildCat") has been developed in response to increased demand for access to data and to the large influx of specimens from the faunal survey of Texas. WildCat provides for efficient storage and retrieval of specimen data and cross-referencing of basic specimen data to ancillary data such as published records, DNA fingerprints, etc., and at the same time introduces several features new to the management of collection data. Among these are bar codes used to identify specimens and increased dependence on the database for producing specimen documentation.

Currently, a unique bar code is assigned to each part (skin, skull, heart, kidney, etc.) of all specimens being added to the collection. Bar codes allow immediate access to the records in the electronic database and simplify collection management tasks. In addition to assigning bar codes to incoming specimens, a retroactive euration project is planned during which all specimens currently in the collection will be assigned bar codes.

In order to facilitate rapid specimen and data processing, specimen data are entered into the computer database when the specimens are collected. The data are verified for accuracy and completeness before being imported into the main database. Specimen documentation is generated from the database, thus consistency between specimen labels, catalogs, and the database is insured. In addition, the time required for electronic processing of data is much shorter than that required to process the same data by hand. Thus, more accurate and complete data are available in a much more timely manner than was previously possible.

In addition to WildCat, the Museum of Texas Tech is also developing an on-line database to serve as a resource in decision-making activities. Access to the database will be controlled at various levels. The general public will have access to very general information while scientists and public agencies will have access to more complete and specific information. This database will include not only data regarding the specimens but also information about habitat, climate, etc.

Field Work

There are 52 Landsat scenes covering the state of Texas. At least 50, and up to 200, ground points are selected from each scene for on-site verification of the dominant plant communities. Sites are selected based upon the homogeneity of the spectral images and accessibility of the site for observation. With this level of field work, TX-GAP will include approximately 2600 geographic points identified by UTM coordinates and classified on the ground to alliance.

Typically, models of vertebrate distribution for GAP have been based on known association with alliances, habitat type, and records from the literature. The partnership among the museum, Texas Parks and Wildlife Department (TPWD), and TX-GAP provides site-specific inventories of species to develop and verify maps and models of vertebrate distribution. For example, scientists at TTU have been compiling an electronic database of specimens and tissue to document and archive wildlife diversity on state-owned property in Texas. Although in the early stages, these studies have identified 118 species new either to the state-owned properties or to Texas counties. We find these results exciting and surprising, as the state of Texas is extraordinarily rich in mammalogical surveys. No fewer than five major works have been conducted on the mammalian fauna of Texas (Bailey 1905, Davis and Schmidly 1994, Schmidly 1977, 1983, Dalquest and Horner 1984). Countless research articles documenting the distribution and occurrence of Texas mammals have been written as well. In addition to this research, the biologists at TPWD have been conducting surveys as part of their own database and inventory programs. Clearly there remains much to learn about the mammalian fauna of the state of Texas.

Specific research projects under way or in the development stage, as joint efforts of TPWD and TCRU, include studies of scaled quail (*Callipepla squamata*), mountain lion (*Felis concolor*), and influence of habitat alterations such as grazing, burning, and agricultural practices on distribution of small mammals, amphibians, and reptiles. Data collected from these studies will be combined with remote sensing techniques and historical data to assess habitat characteristics, develop and refine distribution models, provide base line inventories, and improve the value of TX-GAP products and GIS tools in development of management plans for Texas wildlife.

Summary

Results of the partnership between TPWD, the museum, and TCRU will benefit the Texas GAP project in several ways. Jointly collected data will provide current point data and records for evaluation. These data have been collected from 14 sites statewide over the last five years. They are among the most current and intensive data available for much of Texas. Fortuitously, these data and the respective sites represent all of the geographic regions of Texas and include a majority of the biological diversity present in this state. These data will be of enormous value in testing the utility of GAP models. As these data include a variety of mammalian species and represent several geographic areas, they can be used to verify the distribution predictions of the models or to identify key variables in the equations. Lastly, these data will provide a permanent record for evaluating or fine-tuning future gap analyses.

Acknowledgements

We would like to thank Jeff Lee, Jeff Johnson, and Kelly Allen for reviewing this manuscript. The Texas Cooperative Fish and Wildlife Research Unit is jointly sponsored by Texas Parks and Wildlife Department, Texas Tech University, USGS-Biological Resources Division, and the Wildlife Management Institute.

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Gap Analysis for Mexico: An Emerging Program

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Efforts to extend GAP within North America have been ongoing since 1995, but fiscal realities and difficulties in designating personnel to oversee the effort delayed concentrated efforts until late in 1996. Since 1996 a number of sources have contributed to the establishment of a "Mexican GAP." Cash and in-kind contributions for field and laboratory work were provided through the following combination of sources: The Mexican Agency CONABIO (Comision Nacional para el Conocimiento y Uso de la Biodiversidad en Mexico - Commission for the Knowledge and Use of Biodiversity in Mexico); the Director's Contingency Fund of the National Biological Service (funded in 1996); the Inventory and Monitoring Program of NBS (funded in 1996); USGS-BRD Gap Analysis Program, University of Missouri Cooperative Fish and Wildlife Research Unit, Texas Cooperative Fish and Wildlife Research Unit, the Institute of Ecology at UNAM (Universidad Nacional Autónoma de México) and the Autonomous Mexican State Universities of Chihuahua and Coahuila.

After field visits by personnel from Texas Tech University, field work for the U.S.-Mexico International Gap Project began during fall of 1998. The project is concentrated in regions adjacent to Texas in the Mexican states of Coahuila and Chihuahua. A schedule of progress for the first phase of Mexican GAP was set during a recent meeting in Chihuahua as follows:
Some of the difficulties facing a GAP project in Mexico include the lack of a database on plant assemblages, the sparsity of vertebrate distribution records for some areas, and the different types of land-management categories (e.g., "ejidos" or communal lands). Mexico also presents a variety of opportunities related to gap analysis, such as the presence of strong field-oriented botanists at state universities, the existence of a national biodiversity database administered by CONABIO, lower costs of labor, and opportunities for funding from international development agencies (e.g., World Bank, IADB, CEC, AID).

Mexico, however, presents a unique opportunity for partnership with GAP efforts in the U.S. It possesses extremely high biodiversity and, as in the U.S., there are many pressures on its native species. Forming a partnership with Mexico will not only help address regional biodiversity issues that affect the states of California, Arizona, New Mexico, and Texas but will also allow GAP to begin addressing problems that require international cooperation.

Over time, we anticipate that the fundamentals of the GAP approach are so strong it cannot help but spread to neighboring countries and beyond. Indeed, efforts are currently under way to establish a GAP-type effort in Canada as well as Mexico. Given the vast resource of experiences in the U.S. and the impending edge-matching of the states, we are confident that the next decade will see the production of biodiversity maps that are continental in scale.

Deliverable (Completion) Dates

Product	Date	Responsible for
1. Vegetation field work	12/31/98	AUCh/AUCo
2a. Preliminary vegetation maps, edited in the GIS by scene (hard copy and digital format) - 100% of scenes	01/31/99	TCFWRU
2b. Identification of all abiotic coverages	11/30/98	(Done in Mexico, TTU pays expenses via grants)
2c. All abiotic coverages in digital format	06/30/99	(Done in Mexico, TTU pays expenses via grants)
2d. Final vegetation maps, validated and edge-matched at regional level (hard copy and digital format)	05/31/99	TCFWRU
3. Lower Rio Grande vertebrates list (Mexico and the U. S.)	12/31/98	TCFWRU
4. Lower Rio Grande vertebrate-habitat associations database (Mexico and the U. S.)	05/31/99	TCFWRU, but exchange of personnel and cross-training between TTU & IE and possibly AUCh will take place.
5. Thematic coverages representing the variables used to model species distributions (e.g., soils, temperature, altitude, and hydrography)	08/31/98	TCFWRU
6a. Preliminary distribution maps by species (hard copy), ready for expert review	10/31/99	TCFWRU
6b. Final distribution maps by species, validated (hard and digital copy)	12/31/99	TCFWRU
Land stewardship map (hard and digital copy)	05/31/99	IE
Gap analysis (representativeness of species richness and vegetation communities in the current conservation system)	05/31/00	TCFWRU and IE

AUCh = Autonomous University of Chihuahua
AUCo = Autonomous University of Coahuila
IE = Instituto de Ecologia, UNAM
TCFWRU = Texas Cooperative Fish and Wildlife Research Unit

A Technique for Representing Diminishing Habitat Occupation: Feathering Predicted Species Distributions Near Range Limits in Maine

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Introduction

Species ranges are typically portrayed in Gap Analysis as binary maps, showing areas occupied and not occupied by species. If occupied habitats are predicted by simply identifying suitable habitat within a species' range, a sharp boundary can occur along that predicted distribution. There are times when a species' potential habitat has a sharp boundary (e.g., riparian species occupying wetlands in arid landscapes, or habitats abutting ocean). In Maine, inland boundaries are more often a synthetic representation of unknown accuracy. Range boundaries represent an arbitrary small-scale line within a declining probability gradient where the animal is judged sufficiently rare to disregard its occurrence (Krohn 1996). Ranges also can change rapidly and frequently (Hengeveld 1989; Krohn 1996; Brown and Lomolino 1998), suggesting that fixed sharp boundaries between potentially occupied and unoccupied habitats are inappropriate.

Modelers using habitat maps with 100-ha minimum mapping units (MMUs) avoided these artificial boundaries by including in their predictions habitat polygons that overlapped any portion of the species' range (Scott et al. 1993). Habitat polygons extended varying distances beyond the range limit, essentially blurring the sharp boundary. If polygons were very large (e.g., matrix habitat), they would cause predicted distributions to extend too far into areas outside the species' range. Modelers therefore subdivided habitat polygons using some convenient tessellation such as counties (Scott et al. 1993) or watersheds (e.g., B. Thompson, pers. comm.), reducing the size of habitat polygons.

These methods worked well when habitat maps had large MMUs, but MMUs of 2 ha are now suggested. For example, the 1994 vegetation map of Colorado has 16,618 polygons, whereas the map for Maine has 1.45 million polygons and covers one third the area (84,113 ha) of Colorado. Equally important is the contrast in habitats throughout a state. In Colorado, differences in factors such as elevation, precipitation, and snowfall lead to strong patterns in vegetation patches. In Maine, small patches of given habitats are relatively evenly distributed throughout the state. Whereas predicted distributions of species in Colorado tend to be more naturally segmented by contrasting landscape types, predicted distributions of Maine species are often fairly uniform across their range limits. For example, the habitats of Three-toed Woodpeckers (*Picoides tridactylus*) in Colorado are naturally segmented, having no sharp range boundary, whereas the range limit of the species in Maine is distinct (Figure 1).

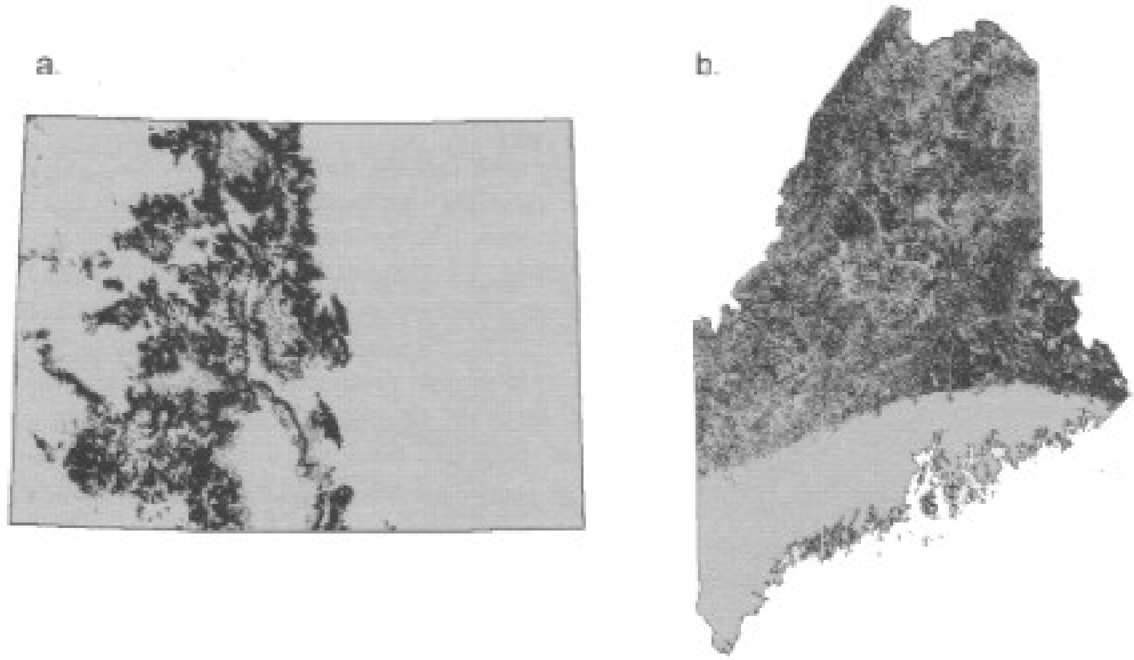

Figure 1. The predicted habitat for Three-toed Woodpeckers in Colorado (a) and Maine (b). Fragmented habitats in Colorado mask range limit boundaries, whereas in Maine the range limit boundary is distinct.

Given that range limits represent gradients in the probability of species occurrences and that maps of a species' predicted distribution seemed to unnecessarily show sharp range boundaries, we sought to feather Maine's habitat maps along their boundaries. To do so required the assumption that randomly selected patches along a species' range limit could be considered valid nonhabitat. We made this assumption because: 1) vertebrates tend to be rare along their range limits (Brown 1995); 2) doing so would portray predicted habitat at 1:100,000 scale more fairly than nonfeathered maps; and 3) conservation decisions should be made only after on-the-ground surveys have been conducted (Scott et al. 1993) so these fine-scale changes in habitat suitability would not affect management decisions.

First we attempted to turn habitat patches to nonhabitat based upon a stratified-random selection. Selection was stratified by the distance to the range limit. Within a given buffer distance (e.g., 50 km), habitat patches distant from the range limit were very likely to remain habitat. Patches nearer the range limit were progressively more likely to be changed to nonhabitat. Steps involved in processing a given raster-based habitat map where to: 1) calculate the Euclidean distance to the species' range limit; 2) identify habitat patches within the feathering distance; 3) identify patches to be retained; 4) discard the patches within the feathering distance that were not selected; and 5) merge the resulting feathered habitats with the remaining habitats within the state. Despite several attempts, we could not generate acceptable feathered habitat maps using this process, and all attempts required too much processing time to be practical. Even modest-sized feathering buffers included tens of thousands of habitat patches. Lists of patch identifiers (i.e., nonspatial scalers) could be generated and a subset of identifiers selected quickly, but using the resulting list of identifiers to select the spatial patches to retain was computationally intensive. A similar technique we tested identified patch centroid cells (yielding one cell per patch, which simplified logic), and randomly selected habitats to conserve. Patches with centroids selected were retained. A final technique assigned a random number to each cell, then inspected the maximum value assigned to each patch to determine if it should be retained. Each of these methods generated fairly reasonable, but not ideal, maps. Regardless of the method, the resulting feathering effect also varied spatially based upon the size of habitat patches, which we judged inappropriate.

In our second attempt, we used a cell-based rather than patch-based method to feather habitat maps along range boundaries for Maine Gap Analysis. Whether to retain a habitat cell or not is a simply binary decision without the complexities of patch selection. We used four levels of habitat quality in our modeling before converting maps to presence/absence. We used these levels of quality while feathering habitats; cells ranked high quality were less likely to be converted to nonhabitat than sites of low quality. As a species' range limit was approached, probabilities across quality scores converged until at the range limit all patches were converted to nonhabitat. Many functions were assessed that controlled the relationship between the distance from range limits and the probability of cells being selected [e.g., log(distance), sqrt(distance), sqrt(sqrt(distance))]. A simple linear relationship was judged most effective (Figure 2). The steps in analysis were similar to those described above: 1) a Euclidean distance to the range limit was calculated for each cell and standardized to 0-1; 2) a random-value grid was generated, multiplying each random value by a score based upon the habitat quality for the cell [i.e., quality 4 = x * 1.8; 3 = * 1.4; 2 = * 1.0; 1 = * 0.7]; 3) cells were selected to be retained or discarded based upon the random-value grid being greater than another random value, and the distance to the range limit; and 4) results within the feathering distance were merged with the remainder of the state.

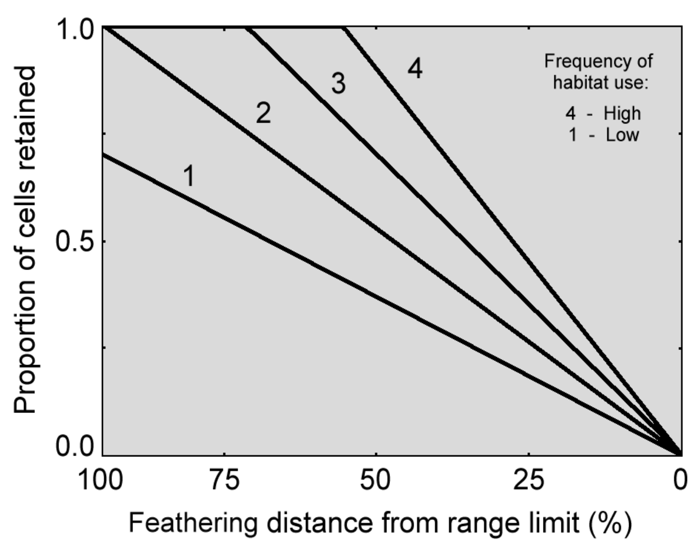

Figure 2. The probability of cells remaining used habitat, across the feathering distance, which is species-specific. Most cells remain suitable habitat at the maximum feathering distance, whereas most cells are judged nonsuitable habitat nearest the range limit.

Results

An example of maps for Three-toed Woodpecker (Figure 3) demonstrates that range limits were less obtrusive and maps seemed more reasonable after habitat maps were feathered. The distance over which we feathered ranges varied by species, from no feathering for Bald Eagle (*Haliaeetus leucocephalus*), whose map was based upon essential habitats defined by legislation (Maine Department of Inland Fisheries and Wildlife 1998), to 3 km for rare species with patchy occurrences such as Blanding's Turtle (*Emydoidea blandingi*), to 50 km for wide-ranging species such as Three-toed Woodpeckers.

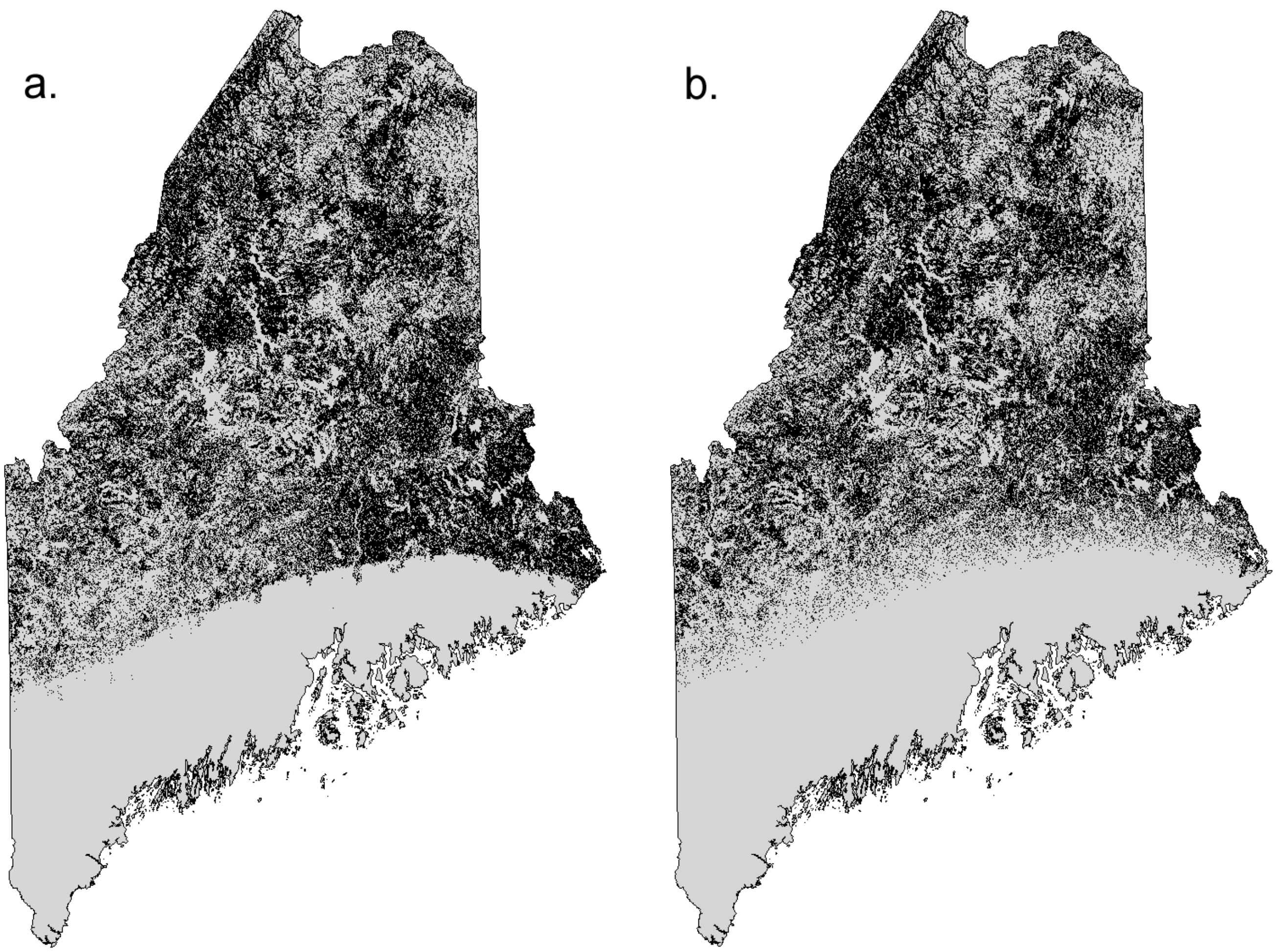

Figure 3. Predicted habitat for Three-toed Woodpecker. Map 'a' is the predicted habitat prior to feathering the range limit boundary. Map 'b' is the feathered final map of predicted habitat for Maine.

Many research questions remain regarding portraying habitats along range limits. For example, while we assumed that the abundance of species decline near range edges, there is evidence that in some cases this is not so. For example, an ungulate population erupting in New Zealand after introduction was described as a "rolling wave of density" moving across space, with relatively high density occurring temporarily at the edge, and the highest density further back in the range (Riney quoted by Caughley [1970]). However, three of the four range edge models outlined by Caughley et al. (1988) assume that population density is lowest near the range edge and highest in the core of the range (also see Caughley and Sinclair 1994:60-64). Thus we believe that our general assumption of low densities near the range edge is a reasonable first approximation, although additional field data are needed.

Our general methods would be most appropriate based upon patch removal versus cell removal. Also the weighted probability for habitats being selected should be sensitive to the habitat types themselves. Finally, ideal models would dispense with range limits entirely, using verified relations with environmental variables instead (as reviewed in Brown and Lomolino 1998). More research is needed to characterize spatial and temporal patterns of distributions along range limits, but the method we used to feather Maine vertebrate potential habitat maps along their ranges was effective, yielding maps that portrayed potential habitats better than unfeathered maps.

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STATE REPORTS
(Status as of fall 1998)

Project Status Summary

In 1998 five GAP state projects were completed, including Arkansas, California, Maine, Montana, and Washington. Together with Utah, New Mexico, and Wyoming, who submitted their final products previously, this brings the total number of completed projects to eight. In 1999, we expect to receive at least 10 additional final reports. Projects that are close to completion include Arizona, Colorado, Indiana, Louisiana, Massachusetts/Connecticut/Rhode Island, Missouri, New York, Oklahoma, Pennsylvania, Tennessee, Vermont/New Hampshire, Virginia, and West Virginia.

State projects were begun in Ohio, Georgia, and North Dakota this past year. Five states in the Southwestern region—Arizona, Colorado, Nevada, New Mexico, and Utah—are presently initiating a regional update. Idaho and Oregon will also be completing updates in 1999.

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Alabama - organizing

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Alaska - not started

Arizona - near completion
Anticipated completion date: February 1999

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Land cover: The Arizona GAP land cover map, having 54 classes, is finished. It is available at http://srnr.arizona.edu/nbs/gap. The accuracy assessment of this map is being completed through a partnership of University of Arizona and Northern Arizona University. The final figures for the assessment are now being tabulated and will be available early in 1999 at the above address.

Animal modeling: Animal distribution models are being refined. These should be ready for the final GAP report by the end of December 1998.

Land stewardship mapping: The land stewardship map is completed and ready to be incorporated into the final GAP report.

Analysis: Gap analysis has been completed for Arizona; the tables and graphs are now being finalized for the final report.

Reporting and data distribution: The final AZ-GAP report is in the process of completion, with a few pieces yet to be finished. Our anticipated date of delivery is the end of February 1999. Some of the data are currently available on our web site (listed above). We will be adding data as they become available and anticipate that all data will be on the web site by the end of March 1999.

Arkansas - complete

Contact: Fred Limp
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Arkansas-GAP was completed in summer 1998 and delivered to National GAP as a 5-CD volume funded as a data distribution research project. Data are available from the AR-GAP home page (http://www.cast.uark.edu/gap/). National GAP is currently working with AR-GAP on finalizing the CD product for distribution, expected in early spring 1999.

California - complete

Contact: David Stoms, Project Manager
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Land cover: Mapping is complete, and maps are available for the entire state or for any of the 10 regions of the state through the CA-GAP web site (see below).

Animal modeling: The California Department of Fish and Game helped us improve the crosswalk from plant community types to wildlife habitat types. Predictive modeling has been completed for 455 native terrestrial vertebrates, using a rating rather than a yes/no suitability mapping. We are collaborating with Dr. Jim Quinn from the University of California-Davis and his staff on a validation of the modeling by comparing predicted species lists with lists of observed species for a large sample of managed areas throughout the state.

Land stewardship mapping: Mapping has been completed. Because of redistribution restrictions on the 1:100,000-scale stewardship used for the analysis, we also compiled a 1:2,000,000-scale version being distributed with the final CA-GAP database.

Analysis: All analyses have been completed. In addition to the standard analyses for GAP, we developed a "threat index" based on roadedness and projected population growth to further prioritize plant communities appearing to be most vulnerable based on management status.

Reporting and data distribution: The CA-GAP report has been completed and is posted on our web site (see below). We are currently arranging to print a large number of copies of the executive summary for wide distribution. The GIS database is also available on-line. A CD-ROM will be published by the end of 1998 that will contain the report in Windows Help format, the database as ARC/INFO export files or image and text formats, and an interactive atlas. The interactive atlas is designed to make the CA-GAP data useful to persons without access to or experience with GIS software. It incorporates the ArcView Data Publisher software, along with a customized user interface we created, to assist users in querying and displaying GAP data in meaningful ways. The database and the CD-ROMs will be transferred to the California Department of Fish and Game for long-term maintenance and user support. Check the CA-GAP home page (see below) for links to their web site.

Other accomplishments and innovations: Besides the completion of the CA-GAP report and publication of the database, most of the progress in the past year has been in the area of applications of GAP data for other purposes. We highlight three of these applications here.

One of the problems in analyzing the potential effects of development at the county- or finer scale is determining the biological importance of the ecosystems and habitats being impacted. There may be very detailed data for the local area, but how should the regional context be measured? Is a 20% loss of a habitat in any given county significant? It depends on the county's share of the overall extent of the habitat type. Chris Cogan, a Ph.D. student from the University of California, Santa Cruz, has linked several models and spatial analyses to evaluate the loss and fragmentation of the biota in a county. GAP status and land cover data are used in determining regional importance. Local scale data are then used to report on potential loss of locally important features.

In a second application, emissions of volatile organic compounds from vegetation can exceed those from human-caused sources, such as cars. Thus they need to be accurately estimated before we can develop realistic and effective strategies for controlling human-caused sources. Models exist to calculate spatially explicit, short time-step emissions. The data required include weather, species-specific emission rates, and the total mass of leaves that are emitting. Knowing the composition of the land cover is critical because emission rates can vary by three orders of magnitude among species. For the Southern California Ozone Study, Arthur Winer from UCLA and colleagues are testing how well the CA-GAP database predicts both the composition and structure of various cover types in modeling emissions. The CA-GAP land cover database includes data on dominant canopy species and, in southern California, on cover density classes. Dr. Winer's group randomly sampled a small number of GAP polygons in San Diego with transects to measure composition and cover/volume and compared both the estimated composition, classification, and predicted emissions. Although far from perfect agreement in any of these parameters, the preliminary results appear promising, especially given the assumptions about cover that must be made in interpreting the GAP data. Much of the disagreement about species was between taxonomically related species with similar emissions rates.

The third application developed a systematic protocol to identify potential sites for research natural areas (RNAs) for the U.S. Forest Service. The current methodology typically uses a screening approach to delete areas that do not meet the selection criteria and look at what is left. We felt this approach was too subjective and did not help choose among sites when there were many that passed the screening step. We developed a procedure that relied on GAP land cover and land ownership data. The first step is to identify the cover types that should be represented in RNAs. GAP data provides a regional context that determines which types are most dependent on national forest lands. For the types identified as target types on this basis, the second step is to measure the variability of the environments in which they occur. The third step calculates a site suitability for each target type to identify which sites are most typical for that type. Then a site selection model is used to select alternative sets of sites based on different weighting of the importance of the suitability rankings. This model is designed to find efficient solutions to represent the most cover types in a given number of sites while considering the suitability of the sites as well. This "weighted-benefits maximal covering location problem" model has also been applied using the CA-GAP wildlife data by 7.5' quadrangle for the entire state of California.

The URL for the CA-GAP home page is http://www.biogeog.ucsb.edu/projects/gap/gap_home.html. The web site contains links to the final report, the GIS database for downloading, and information about the CD-ROM.

New publications:

Stoms, D.M., M.I. Borchert, M.A. Moritz, F.W. Davis, and R.L. Church. 1998. A systematic process for selecting representative research natural areas. Natural Areas Journal 18:338-349.

Stoms, D.M., M.J. Bueno, F.W. Davis, K.M. Cassidy, K.L. Driese, and J.S. Kagan. 1998. Map-guided classification of regional land-cover with multi-temporal AVHRR data. *Photogrammetric Engineering and Remote Sensing* 64: 831-838.
Stoms, D.M., F.W. Davis, K.L. Driese, K.M. Cassidy, and M.P. Murray. 1998. Gap analysis of the vegetation of the Intermountain Semi-Desert Ecoregion. *Great Basin Naturalist* 58: 199-216.

Colorado - near completion

Anticipated completion date: March 1999

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Land cover: The land cover map is undergoing accuracy assessment under direction of Co-Principal Investigator Dr. William Reiners through work of Ken Driese of the botany department, University of Wyoming. Sixty percent of the initial air videography sample frames for Colorado have been interpreted by Tom Owens. Work on Wyoming frames is anticipated to begin in early 1999. Copies of the land cover base line with draft metadata have been provided to CO-GAP and National GAP cooperators for use, review, and comments. *Note: A graphic of Colorado land cover can be viewed in the web version of the Bulletin.*

Animal modeling: Vertebrate modeling outputs were distributed to CO-GAP cooperators for review from July through November 1998. Vertebrate models were finalized in November 1998, and final stewardship/species cross-tabulations were generated for use in completion of the CO-GAP chapter on "Analysis Based on Management Status." Data models (Habitat Affinities Modules) and model map outputs will be moved to the web in early 1999. *Note: A graphic of species richness can be viewed in the web version of the Bulletin.*

Land stewardship mapping: Land stewardship mapping was finalized in September 1998 by CO-GAP team member Larry Satcowitz by incorporating stewardship/status information on proposed Bureau of Land Management (BLM) Wilderness Study Areas. Status categories were reviewed with BLM personnel. Draft metadata were prepared for the land stewardship coverage and distributed for review by cooperators. *Note: A graphic of land stewardship can be viewed in the web version of the Bulletin.*

Analysis: Gap analysis was conducted on ArcView Spatial Analyst by Lee O'Brien of the CO-GAP team. Vertebrate models for 597 species were generated and cross-tabulated against the land stewardship coverage. Tables reformatted through Excel spreadsheet macros were generated for the final report.

Reporting and data distribution: The final report for CO-GAP has been developed through fall 1998, with draft chapters being routed to CO-GAP team members for review. Final chapters were sent to cooperators for review in December 1998. CO-GAP land cover and land status information has already been integrated into the Natural Diversity Information Source (NDIS), being developed by the Colorado Division of Wildlife (CDOW) in collaboration with the Natural Resource Ecology Laboratory at Colorado State University, Colorado Natural Heritage Program (CNHP), and others. The development of NDIS (http://blueberry.nrel.colostate.edu/ndis) is jointly funded by CDOW and Great Outdoors Colorado with matching contributions from the Denver Museum of Natural History, Rocky Mountain Elk Foundation, CNHP, and others. Internet access to CO-GAP coverages and analysis outputs will also be made available in winter and spring 1998/99.

Other accomplishments and innovations: The vertebrate modeling parameters for CO-GAP were developed into Habitat Affinities Modules in a Visual dBase environment for distribution to cooperators for their review and comments. These modules will be moved to a CO-GAP home page for access and download to encourage ongoing review and refinement of the modeling efforts. CO-GAP models will be provided to NDIS for consideration in continuing development of web site content. Colorado is looking forward to National GAP-inspired efforts to "regionalize" GAP modeling.

Connecticut

(see Massachusetts, Connecticut, and Rhode Island)

Delaware

(see Maryland, Delaware, and New Jersey)

Florida – under way

Anticipated completion date: December 1999

Contact: Leonard Pearlstine
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Land cover: Land cover classification from 1993/94 Landsat Thematic Mapper imagery is complete for peninsula Florida from the keys up to and overlaying Georgia. There are currently 102 thematic classes, although some of these classes will be aggregated in the final product. The two Landsat scenes of the Florida panhandle will be completed in winter/early spring 1999. These scenes will complete the state.

Animal modeling: Habitat affinity matrices have been completed, and all the taxonomic groups except birds, reptiles, and amphibians have been reviewed. Review of the latter will be completed in the early spring of 1999. During the next 12 months the habitat matrices will be updated with the current standard taxonomic codes and matched to the final land cover classification. Previously completed and tested models are awaiting the final animal matrices and land cover for the production of a spatial habitat database and biodiversity models.

Land stewardship mapping: The Florida Natural Areas Inventory (The Nature Conservancy Heritage Program) and the Geoplan Center at the University of Florida have independently compiled GIS coverages of conservation land for the state of Florida. Our analysis of the two coverages has shown very good overall agreement. In the next 12 months we will combine the two coverages to include areas missing in one or the other and coding each of the conservation areas to GAP standard rankings based on the level of conservation protection.

Analysis: Data production will be completed in spring 1999, and final analysis will follow GAP standards. Final analysis will be completed in the next 12 months.

Reporting and data distribution: Reporting and data distribution will follow GAP standards. A final report will be prepared within the next 12 months.

Other accomplishments and innovations: Aerial land cover sampling with a digital color infrared camera has been used to assist the labeling of unsupervised classifications. Noncontinuous transects have been flown for all of north Florida at a spatial resolution of between 3 and 5 cm. A navigation system directs the pilot and triggers the camera while collecting a real-time corrected GPS position and pitch, roll, and heading information. Positional error of the images is typically less than 30 m; however, recent improvements in the camera setup have resulted in errors of less than 20 m. Doctoral research is under way to examine the potential for automated computer recognition of invasive plant species using the digital camera imagery.

Georgia - under way

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Karen Payne, Program Coordinator
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Land cover: We are beginning our mapping this year. We have recently received statewide TM coverage of Georgia for the years 1996-1998. Our goal is to create a general land cover map of the state, similar to an Anderson level II classification, before generating an alliance-level map during the next year. We are in the process of gathering existing vegetation point data from cooperating governmental agencies and private organizations.

Animal modeling: We will be starting to collect data and literature this winter. We anticipate hiring a graduate student in the fall of 1999 to begin working on these models.

Land stewardship mapping: We anticipate completing our land stewardship map this winter. We have included Army Corps of Engineers lands, wetland mitigation sites, and conservation easements held by land trust organizations. This work was partially funded by EPA Region 4.

Hawaii - organizing

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The Hawaii Ecosystem Data Group (EDG) will be conducting HI-GAP. The group includes the Fish and Wildlife Service, The Nature Conservancy, the Biological Resources Division of the USGS, the University of Hawaii's Center for Conservation Research and Training, Hawaii's Department of Land and Natural Resources, and the Hawaii Ecosystem at Risk program. A workshop is planned for March 1999.

Idaho - update under way

Anticipated completion date: May 1999

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Land cover: The latest Idaho land cover classification was completed in December 1998. It was created through the joint efforts of the Wildlife Spatial Analysis Lab at the University of Montana, the remote sensing/GIS labs at Utah State University, and the Idaho Gap Analysis Lab. Vital statistics: 80 land cover types, 30-m resolution, 2-ha minimum mapping unit. Estimated accuracy ranges from 53.4% to 93.39% in North Idaho and 63.6% to 79.3% in southern Idaho. The vegetation raster grid, the accuracy data, and a draft of the vegetation section of the Idaho GAP final report can be downloaded from www.wildlife.uidaho.edu/idgap.htm.

Animal modeling: Wildlife habitat relationship (WHR) models have been created for breeding birds and mammals of Idaho and sent out for expert review. We are currently incorporating reviewer comments and revising the models. Dr. Charles Peterson of Idaho State University is creating WHR models for Idaho's amphibians and reptiles. The estimated date of model completion for all species is March 1, 1999. The accuracy assessment of our models should be completed by April 1, 1999.

Land stewardship mapping: The updated Idaho land stewardship coverage is nearing completion. Although it is based on the original Idaho GAP stewardship map, this coverage shows substantial improvement in detail for land with protection status 1 and 2. The expected date of completion is February 1, 1999.

Analysis: The ARC/INFO AML programs to conduct the gap analysis of Idaho have been written. We are awaiting completion of the Idaho land stewardship coverage to begin analysis of the land cover types. Analysis of the WHR models will be conducted as the models are completed. Expected date of completion for the analysis phase is April 1, 1999.

Reporting and data distribution: Section 1 of the final report, the land cover of Idaho, has been completed. It is available from the Idaho GAP web site at www.wildlife.uidaho.edu/idgap.htm. Other chapters are in progress. As products are completed, they will be available on the Idaho GAP web site.

Illinois - under way

Anticipated completion date: September 2000

Contact: Jocelyn L. Aycrigg, GAP Coordinator
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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 GAP vegetation classification is being performed for separate natural cover elements of the original imagery using a Boolean mask for specific classes (forests, forested wetland, and rural grassland). Classification protocols are similar to protocols for UM-GAP (see GAP Bulletin 5:35). Classification to the community/alliance level has been completed for southern Illinois.

Our efforts will next concentrate on the western side of the state along the Mississippi River and then move on to the remainder of the state.

Animal modeling: We have created a list of amphibian, reptile, and mammal species 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. There are approximately 27,000 specimens in the amphibian and reptile collection for Illinois of which we have mapped about 20,000. The mammal collection contains about 12,000 specimens of which we have mapped 95%. Once we finish mapping, we will delineate ranges for each species and conduct an expert review of the range maps. Furthermore, we will start building habitat association information for each 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 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 needs to be determined and assigned for each property.

Analysis: We have completed some preliminary analyses using locational data for amphibians, reptiles, and mammals to create species richness maps using the EMAP hexagons. We will continue to do more analyses as our species and vegetation mapping progresses.

Reporting and data distribution: We hope to start writing segments of the report at the end of 1999. The INHS has a substantial amount of information on plants and animals in Illinois available on its web pages. Efforts are under way to develop an IL-GAP web site and link it to related information already on the web. In particular, web pages identifying the vegetation alliances in Illinois and associated distribution maps for southern Illinois have been developed.

Other accomplishments and innovations: Referenced below are three projects that have been completed by GAP participants using the land cover database of Illinois in the analysis.

McKinney, L.B., M.G. Joselyn, J.L. Aycrigg, and P.W. Brown. 1998. Identification of large grassland ecosystems in Illinois. Final report. Illinois Natural History Survey, Champaign, Illinois. 169 pp.

Suloway, L., M. Joselyn, P.W Brown. 1996. Inventory of resource-rich areas in Illinois: An evaluation of ecological resources. Illinois Department of Natural Resources/EAA-96/08. 167 pp.

Van Deelen, T.R., L.B. McKinney, M.G. Joselyn, and J.E. Buhnerkempe. 1997. Can we restore elk to southern Illinois? The use of existing digital land-cover data to evaluate potential habitat. *Wildlife Society Bulletin* 25(4):886-894.

Indiana - under way

Anticipated completion date: February 1999

Contact: Forest Clark, Principal Investigator
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Land cover: Land cover mapping and accuracy assessment for the Indiana project are complete. We are finalizing metadata. Draft data are available by contacting the Principal Investigator. Goals for the next 12 months are to work with partners to improve the thematic detail and accuracy of the Indiana land cover product.

Animal modeling: The vertebrate models are complete, including detailed models for some edge-associated, riparian-associated, and wetland-associated species. Vertebrate models are running as of November 1998. Goals for the next 12 months include making the models widely available for evaluation by interested users in Indiana.

Land stewardship mapping: Land stewardship mapping is complete. Goals for the next 12 months include working with the Indiana Department of Natural Resources and other agencies to update and add additional categories (e.g., Wetland Reserve Program lands) to the coverage.

Analysis: Analysis is under way as of November 1998. Goals for the next 12 months include using the results of the analysis and conducting additional analyses to facilitate biodiversity conservation in Indiana. The primary mechanism for this will be the Indiana Biodiversity Initiative.

Reporting and data distribution: These are under discussion by the Steering Committee in Indiana. The standard report will be issued, and data will likely be available on CD-ROM and on the web. Preliminary data are already being made available.

The Indiana GAP project continues to conduct metaprojects using the GAP methodologies and infrastructure. Three projects in progress are: development of the environmental assessment for the proposed Grand Kankakee Marsh National Wildlife Refuge; support for the U.S. Fish and Wildlife Service Ecosystem Management Initiative through development of a GIS to support the Migratory Bird Resource Priority of the Ohio River Valley Ecosystem Team; and support for the Indiana Biodiversity Initiative, a multi-organization effort to protect biodiversity in the context of an economically productive Indiana landscape.

Iowa - under way

Anticipated completion date: December 1999

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

Land cover: The Iowa Geological Bureau completed the first phase of mapping the land cover of Iowa into six basic classes: trees, grassland, cropland, water, urban, and barren. Mapping was facilitated by ancillary data from the Natural Resources Inventory provided by USDA-NRCS. (Contact: Jim Giglierano, Iowa DNR, Geological Survey Bureau, 109 Trowbridge Hall, Iowa City, IA 52242, Phone: 319-335-1594, jgiglierano@igsb.uiowa.edu).

Following the FGDC's standard vegetation classification system, a list of 75 natural and seminatural vegetation alliances were identified as existing in Iowa. This list was reduced to about 35 map classes, including agricultural categories, that potentially can be mapped in phase 2 of the land cover classification. Extensive field data were collected in summer 1998 for use in cluster identification and labeling. Tom Rosburg, Drake University, submitted more than 500 sites with rapid vegetation assessments. Additional assessments were received from county and state biologists. We continue to seek and acquire ancillary data sets that will assist in image processing and land cover mapping.

A program developed by the U.S. Fish and Wildlife Service for aggregating National Wetland Inventory codes into five major classes (temporary, seasonal, semipermanent, permanent, and open water) was modified and used to prepare a GIS layer for Iowa wetlands. The aggregation process was completed in December 1998 for all 99 Iowa counties, and the resulting layer will be used as the primary ancillary data set for wetland mapping. Currently all data are being merged, and protocols are developed and tested for the satellite scene that covers the northeastern corner of the state.

The IA-GAP staff continues to meet biannually with 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 common to GAP in the Great Plains Region. GIS coordinators from Iowa, Kansas, Missouri, and Nebraska met with Iowa State University statisticians in July 1998 to discuss a uniform plan for accuracy assessment of the final land cover maps in the four-state region. General consensus was reached on protocols and data analysis.

In October 1998 IA-GAP held a one-day workshop for approximately 80 participants to inform cooperators of the status of the project and receive feedback.

Vertebrate modeling: Lists of vertebrate species for which distribution models will be developed have been completed and are available on the IA-GAP web site. The lists include 178 species of birds, 65 mammals, 48 reptiles, and 21 amphibians. A digital copy of the recently completed Iowa Breeding Bird Atlas was obtained. Museum records and other ancillary data for mammals, reptiles, and amphibians are currently being compiled and consolidated into a single database. Geographic ranges, habitat associations, and modeling criteria are in early draft stages.

Land stewardship: Federal land coverages have been acquired but not checked. Data for state lands in Iowa are mostly complete and digitized. Boundaries for about one-half of county lands have been obtained. Stewardship status codes have been assigned for approximately 20% of the areas.

NatureMapping: Iowa State University has received an educational grant from the Iowa Resource Enhancement and Protection program to start a statewide NatureMapping project. A steering committee was formed, and workshops are being planned for winter 1998 and spring 1999.

Kansas - under way

Anticipated completion date: September 2000

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Land cover: Currently, 85% of the state has been mapped to the cropland/natural vegetation stage, and 12% has been classed to the alliance level. During the next 12 months, three tasks will be undertaken by the land cover mapping group. First, field data collected during the summer of 1998 will be entered into a relational database to serve as input to the alliance vegetation mapping effort. Second, the 15% of the state remaining to be classed to the cropland/natural vegetation stage will be completed by January 1999. Lastly, a substantial portion of the remaining 88% of the state needing to be classed to the alliance level will be completed. A graphic demonstrating current progress is available on the web version of the Bulletin.

Animal modeling: Currently, species lists of terrestrial vertebrates to be mapped are being finalized following expert review. Range distribution maps for EMAP hexagons are being generated, based on museum collections, publications, and current observations. We are beginning to build wildlife habitat relationship (WHR) models. Ancillary databases also are being located to help in building these predicted habitat relationship models. During the next 12 months, all WHR models will be completed. Drafts of predicted species distributions will be completed and sent out for expert review as portions of the land cover map become available. Following expert review, final species distribution maps will be generated.

Land stewardship mapping: Currently, 90% of the land stewardship layer has been updated using 1-m digital orthophotographs; editing and correcting protected areas coverages will continue over the next 12 months.

Analysis: We do not expect to start analysis within the next 12 months.

Reporting and data distribution: Reporting and data distribution will not be initiated within the next 12 months.

Kentucky - under way

Anticipated completion date: September 2002

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Tom Kind (land cover)
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Terry Derting (vertebrate modeling)
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Land cover: To map the land cover of Kentucky we are using an iterated unsupervised classification procedure to produce a base layer for use in land cover modeling. Satellite scenes have been mosaicked into pathwise coverages that are the fundamental classification and mapping elements. A spectral classification has been completed on one of the four paths covering the state, with work well under way on the second path. In keeping with a consensus reached by the Southeast GAP working group, scenes were stratified according to Bailey's ecoregions, and a separate spectral classification was produced for the deciduous vegetation in each region. A complete set of 1:24,000 DEM coverages have been acquired from the USGS and mosaicked to match our pathwise classifications.

A literature review was done to establish vegetation/landform relationships with ancillary data sets, including DEMs and derivatives, a concavity/convexity model, ecoregional analysis using Bailey's ecoregions, National Wetlands Inventory (NWI) digital data, and NAPP color infrared photography. In addition, new aerial videography was flown in fall 1998 to supplement the existing flightlines acquired in 1996. A draft of potential alliances and aggregations for the first satellite path has been completed and is available for inspection on our web site.

Major goals for the land cover mapping in year two include: developing a consistent land cover modeling procedure based on the available ancillary data and the results of the spectral classification, completion of a vegetation cover-type layer for our first two satellite paths, and continuation of the path-by-path classifications.

Animal modeling: The vertebrate component of KY-GAP is officially under way. A wildlife biologist was hired in September 1998 to assist with this component of the project. Initial work on the vertebrate layer has focused on the development of species lists for mammals, birds, reptiles, and amphibians that include species element codes, scientific names, common names, state and federal ranks and status, and references. Data sets made available from the Kentucky Department of Fish and Wildlife Resources (KDFWR) and the Kentucky Nature Preserves Commission (KYNPC) will be major sources of information for the vertebrate layer. Experts at the KDFWR, the KYNPC, and other state and regional institutions have made commitments to serve as reviewers for the vertebrate mapping. We anticipate completion of the species lists, a database of locational records, and delineation of geographic ranges for mappable species during the first 12 months of the vertebrate mapping component of the project. During 1999 we will also begin work on development of habitat relationships for species in each vertebrate group with the assistance of undergraduate research students. We are working closely with the staff of Tennessee and other GAP projects in the southeastern region to ensure compatibility of products for use in regional maps.

Other accomplishments and innovations: Major accomplishments during the first year of the program include: acquisition and processing of three TM data sets to be used in the land cover mapping; development of a methodology for organizing and classifying the satellite data and related ancillary data sets; and establishing cooperative partnerships with private, state, and federal organizations within Kentucky to help with the acquisition of reliable ground truth.

To continue to promote GAP to a wider audience, a presentation on Gap Analysis was given at the Kentucky GIS conference in May 1998. Yearly participation in this conference is anticipated as a way of keeping the Kentucky GIS community informed of our mission and our progress. Also, a web site has been developed to provide a general educational resource relating to Gap Analysis in Kentucky. In addition to providing a way of keeping abreast with our progress, the web site will provide an on-line method for expert reviewers to give their feedback. Development of this web site has been accomplished with the cooperation of the KDFWR.

Louisiana - near completion

Anticipated completion date: April 1999

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Mark Swan (land stewardship mapping)
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Land cover: LA-GAP has completed the final vegetation map layer. The original 25-m vegetation layer has been resampled to a 30-m resolution to meet the National GAP standards. The layer was then aggregated to a minimum mapping unit of eight continuous pixels, using the GigaMerge software (see Ford et al. 1997, also see www.cs.umt.edu/MERGE/). The vegetation layer has been clipped to the 43 USGS 30 x 60-minute map series that makes up the state. The compilation of the ground-truth data into a database for accuracy assessment validation is complete. Accuracy assessment has been delayed due to errors found in the Imagine software for calculating accuracy assessments (for more on this problem see "Accuracy Problems in Imagine Software" on the GAP Bulletin Board/Notices). An ArcView Avenue program is being written to produce an accuracy statement. Ancillary data sets (STATSGO soil data, geology 1:500,000 scale, USGS [7.5-minute quadrangles, 30 x 60-minute tiles, roads, railroads, pipelines, hydrology], TM coverage, parish boundaries, state boundary, Wetland Reserve Program parcels, and National Wetlands Inventory data) are complete. The goal for winter 1998/99 is to complete the metadata for all ancillary data sets, complete the accuracy assessment for the land cover/land use layer, and complete the land cover section for the final report.

Animal modeling: Species distribution maps were resolved to EPA hexagons from faunal guides (mammals and herps) and survey data (birds). Location data for museum specimens collected in Louisiana were not compiled expressly for GAP. Wildlife habitat relationships (WHR) were extracted from literature, natural history guides, and expert advice. Vegetation classes used in WHR tables were cross-walked to LA-GAP cover classes, and first generation predicted distribution maps were developed. Due to low appeal of predicted distributions of herps and water birds, second-generation maps are currently being developed by incorporating a more extensive hydrology-related data layer into the modeling process.

Land stewardship mapping: In 1998 we added recently acquired properties, completed the attribution of all polygons to GAP standards, and merged several coverages into one coverage, as required by GAP. The latter presented difficulties in that many state wildlife management areas (WMAs), national wildlife refuges (NWRs), and national forests share boundaries, requiring the elimination of sliver polygons. By mid-1999 we will have:
1) updated our current polygons consisting of state parks, military bases, WMAs, NWRs, national forests, natural areas, and one national park;
2) added a large set of state lands (not parks or WMAs), Army Corps of Engineers properties, and some additional private lands widely advertised as preserves or wildlife areas, and scenic streams (either as lines or very narrow polygons);
3) completed metadata for the stewardship coverage;
4) completed the written chapter on Louisiana's land stewardship and management.

Analysis: The analysis began in December 1998 and should be finished in late February 1999.

Reporting and data distribution: The land cover chapter is in progress and waiting for the accuracy assessment statement. Currently the National Wetlands Research Center is in the process of building a web site for the LA-GAP data.

Other accomplishments and innovations: see "Using GAP for nonpoint water pollution management" on page

Literature cited:
Ford, R., R. Redmond, and S. Barsness. 1997. "Merge": Breakthrough software for user-defined MMUs. *Gap Analysis Bulletin* 6:22-23.

Maine - complete

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Land cover: Completed. A document detailing the methods used, "Development and testing of a vegetation and land cover map of Maine," has been drafted and will soon be sent out for review.

Animal modeling: Completed. An M.S. student is conducting more detailed research on testing the predicted vertebrate occurrences, going beyond the review presented in the final ME-GAP contract report.

Land stewardship mapping: Completed. Another M.S. student is working with this and other GIS data layers to test whether or not Maine's conservation lands have captured a fair representation of the state's natural variability in selected abiotic and biotic factors.

Analysis: Completed.

Reporting and data distribution: A final report documenting the Maine Gap Analysis was sent out for review. All reviews were completed, and the final contract report was written. The first gap analysis of Maine was completed at the end of 1998.

Maryland, Delaware, & New Jersey - under way

Anticipated completion date: December 1999

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Land cover: During 1998, significant progress was made on land cover mapping. All of the TM scenes for Maryland and Delaware have been re-registered; all ancillary data have been collected (land cover, STATSGO soils, National Wetlands Inventory, slope, elevation, and aspect), rasterized, and registered to the TM scenes. The decision rules have been written for two scenes, and interpretation is under way for the remainder of Maryland and Delaware.

This project is using MicroImages' TNTmips for image processing. In the fall of 1998, MicroImages was contracted to write a script in their native programming language to facilitate the image classification following the methods of Slaymaker and others (1996). The script is completed, and classification is under way. The Delmarva Peninsula will be completed shortly after the first of the year. The remainder of the Maryland-Delaware portion will be completed in spring of 1999, and accuracy assessment will begin at that point.

Late in 1998 an agreement with New Jersey's Department of Environmental Protection, Natural and Historic Resources Group, and The Nature Conservancy was finalized to facilitate the GAP land cover and stewardship efforts in New Jersey. Work is expected to begin following completion of the draft work from Maryland and Delaware in late spring and be completed late in 1999.

Contact**:** Ann Rasberry (see above)

Animal modeling: Considerable progress was made in 1998 in modeling vertebrate distributions for the mid-Atlantic GAP Project. A previously completed database of species' distributional limits has been incorporated into the modeling process for Maryland and Delaware, and significant progress has been made toward the completion of a similar database for New Jersey. Investigators are nearly finished compiling literature reviews and summary documents of species-habitat relationships for approximately 200 species of breeding birds, 70 species of mammals, and 110 species of reptiles and amphibians. A relational database has been developed to store range information and species-habitat relationships. This database also has query and modeling tools to extract this information and apply it to spatial GIS layers in generating distribution models. A currently available general land cover data set is being used in preliminary modeling efforts and will be replaced with the final GAP land cover data set once it is completed. The modeling process has been effectively automated, with the database containing adjustable parameters for controlling habitat suitabilities and weighting of habitat layers. It is anticipated that all the bird and mammal models will be completed by the end of 1998, and the reptile and amphibian models completed by February 1999.

One significant challenge in the modeling process was to effectively model forest-interior bird species. This subclass of species has a strong negative response to forest fragmentation; distribution models based on habitat alone, irrespective of landscape-level parameters measuring forest fragmentation, considerably overestimate species distribution. This subclass includes many species in decline in this region, including a number of neotropical migratory songbirds (see Robbins et al. 1989). GAP investigators developed a number of GIS layers to measure landscape-level metrics of forest fragmentation and, in consultation with research personnel at the Patuxent Wildlife Research Center, applied these layers to the modeling process. The accuracy of models has been greatly improved. In addition, further analysis has enabled investigators to identify important forest stands for forest-interior birds, priority restoration sites, and potential additional factors limiting populations (see below).

Additional data tables have been developed with information on wildlife habitats and plant community alliances for the mid-Atlantic region. GAP investigators updated the list of alliances for the three-state region from documents developed by The Nature Conservancy and state Natural Heritage Program ecologists; these are all in an ongoing improvement mode. A list of wildlife habitats, which includes closely related alliances or aggregations thereof (and may better represent habitats perceived by wildlife species), has also been developed from the wildlife literature. These classifications, in addition to the FGDC classification standard, have been fully cross-linked in the database. Species distribution models can be applied at any classification level based on these cross-links.

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Land stewardship mapping: GAP investigators conducted a land stewardship data development meeting during the summer of 1998 at which a process was outlined for completing this data layer. Management plans were obtained for several of Delaware's Wildlife Management Areas, and contacts were identified for future interviews regarding management. An updated GIS layer of boundaries was obtained for all federal, state, and NGO lands as well as conservation easements in Delaware.

Most of the conservation area boundaries in Maryland have been collected. A letter has been sent to all managers of federal and county properties in the state requesting a copy of the area management plan. Maryland Department of Natural Resources (DNR) is responsible for developing area plans for all state lands, which are being obtained. Staff are developing a check list for reviewing the area plans, which will also be used to interview area managers where no management plan exists. Once completed, this process will expand to Delaware. The land stewardship layer is expected to be completed by spring 1999 for Maryland and Delaware and by late fall 1999 for New Jersey.

Analysis: Considerable analysis is under way for identifying areas with high potential for supporting forest-interior neotropical migrant songbirds on the Delmarva Peninsula, as well as priority sites for forest restoration and/or acquisition. Preliminary analyses indicate that few remnant forest stands exist which meet area and habitat requirements to support an intact forest avifauna. These stands have been identified and are currently being evaluated for ownership and land management status. In addition, analysis has been performed to identify clearings, which, if reforested, would substantially increase suitability for forest-interior birds. Maps and presentations of this material are currently being compiled for various audiences, including the Delaware Department of Natural Resources and Environmental Control, the Delaware Open Space Council, the Delmarva Conservation Corridor Initiative, and various land conservation groups.

GAP investigators expect to complete analysis of the protection and management status of biodiversity in Maryland and Delaware by fall 1999 and expect the New Jersey analysis to be completed by December 1999.

Reporting and data distribution: The final report writing for Maryland, Delaware, and New Jersey has begun and should be completed by December 1999. The GIS layers for Maryland and Delaware 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.

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 a 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.

Literature cited:

Robbins, C.S., D.K. Dawson and B.A. Dowell. 1989. Habitat area requirements of breeding forest birds of the middle Atlantic States. *Wildlife Monographs* 103:1-34.

Slaymaker, D.M., K.M.L. Jones, C.R. Griffin and J.T. Finn. 1996. Mapping deciduous forests in southern New England using aerial videography and hyperclustered multi-temporal Landsat TM imagery. Pages 87-100 in J.M. Scott, T.H. Tear, and F.W. Davis, editors.

Gap Analysis: a landscape approach to biodiversity planning. American Society for Photogrammetry and Remote Sensing, Bethesda, Maryland.

Massachusetts, Connecticut, & Rhode Island - complete; update under way

Anticipated completion date: February 1999

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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, and 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 of the Department of Computer Science at the University of Massachusetts (UMass).

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 vertebrate species modeled in the Southern New England region (MA, CT, RI) were identified and coarse species richness maps developed for each taxa 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 categories 1 & 2.

Analysis: Species richness analyses from the general maps have been completed. The final gap analysis should be complete by January 1999.

Reporting and data distribution: All data layers are currently available on the Southern New England Gap Analysis home page (http://tove.fnr.umass.edu/gaphome.html). We plan to distribute the vertebrate models and predicted habitat data layers as an ArcView project. 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.

Other accomplishments and innovations: The National Science Foundation funded a $1.6 million collaborative project with the UMass Computer Science Department to develop an automated process for producing 3-D terrain maps. The project utilizes context-sensitive processing and machine learning via incremental real-time classification. This is a three-year project that will develop new approaches for using a variety of digital data platforms to produce high-resolution land cover maps.

Michigan, Minnesota, & Wisconsin (Upper Midwest Gap Analysis Project) - under way

Anticipated completion date: October 2000

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Land cover: The Michigan Department of Natural Resources' Wildlife Division is responsible for the land cover classification of the Lower Peninsula (LP) and is currently working with a contractor to classify the northern half of the LP. Completion is expected in early 1999; work on the remainder of the LP will continue in 1999. The vegetation map for the Upper Peninsula (UP) is currently being developed at the U.S. Geological Survey's Upper Midwest Environmental Sciences Center (UMESC); completion of the eastern UP is expected in 1999; work in the western UP will continue in 1999. The lack of ground-truth information in the form of georeferenced digital data, including NWI, hinders more rapid progress in Michigan.

The Minnesota Department of Natural Resources (DNR), Division of Forestry, Resources Assessment Unit, is developing the land cover map for Minnesota. The DNR has contributed in-kind services, including the facilities, hardware and software, and field work. Most of the state classification is now completed—all but the accuracy assessment. With increased department support, the land cover mapping effort is expected to be completed by late 1999.

Wisconsin has been very successful in developing support for the current land cover mapping from various local, state, and federal agencies and organizations under the Wisconsin Initiative for

Statewide Cooperation on Landscape Analysis and Data (WISCLAND), of which the Gap Analysis project has been a part. The image processing protocol was developed specifically for Wisconsin, though it has undergone modifications after piloting and input from Minnesota and Michigan. The Wisconsin land cover data layer is now completed. The remote sensing derived classification scheme will be cross-walked to the NCVS in early 1999 with assistance from TNC.

Animal modeling: Vertebrate modeling for MN, WI, and MI will begin in 1999 with UMESC coordinating the effort among the state partners. Dr. Nancy Mathews at the University of Wisconsin-Madison has developed a research protocol to investigate the effects of scale on species distribution modeling in the Upper Midwest. The three-year effort is to be funded through a cooperative multiagency agreement with the NRCS and the USFS. This study is scheduled to be completed in 1999.

Land stewardship mapping: The Minnesota DNR has completed and delivered a stewardship map for the state. Based on the Public Land Survey, every 40-acre polygon has been attributed for public owner, manager, unit name, and stewardship status. Tribal, private conservancy, and private land parcels in excess of 1,000 acres are also identified. Wisconsin and Michigan are in the planning stages of developing similar databases with work beginning in 1999.

Analysis: Gap analysis planning is scheduled to begin in late 1999.

Reporting and data distribution: UMESC will begin distributing Wisconsin land cover data and Minnesota stewardship data via the WWW in early 1999.

Other accomplishments and innovations: The Upper Midwest Image Processing Protocol is published and available on-line at: ftp://ftp.emtc.usgs.gov/pub/misc/umgap/98-g001.pdf. The Upper Midwest Gap Analysis Project will host the 1999 National GAP Meeting in Duluth, Minnesota, on August 2-6.

Mississippi – under way

Anticipated completion date: December 1999

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Land cover: Much of the computationally intensive part of the vegetation mapping process was concluded during 1998. A large amount of time was spent creating and organizing image databases, transferring bitmaps, reprojecting imagery, preclustering analysis of imagery, and clustering image data. To handle and keep track of multiple image data sets, a GIS database was created using PCI for each Landsat scene. Within each database, image channels were created to store not only the spectral imagery but several working channels as well.

Several processes were used on each Landsat scene prior to statistical clustering procedures. In order to reduce spectral variability found among similar vegetation types across large areas (as found in Landsat imagery), we subset each scene into its representative physiographic provinces. The next step involved manually delineating recent timber harvest locations on the imagery. Sample classifications of the imagery revealed that these areas are spectrally similar to agricultural areas, and simple clustering algorithms could not separate the two classes. All imagery was then reprojected to align with our ancillary data sets.

As is common with Landsat imagery, there were clouds present in a few scenes. For one coastal scene it was decided to manually mask out the cloud cover prior to clustering. These areas were then patched using the data from the cloud-free date. Heavy cloud cover and haze were present in a second scene that covered the northwest corner of the state. For this scene we decided to only use the cloud-free date.

Once the data sets were organized and subset, K-means clustering was performed. Clustering was applied to bitmaps that met the following criteria: classified as pine, hardwood, mixed, agriculture, barren/grassland, or other in the land use/land cover map created by the Space Remote Sensing Center (SRSC) and not a recent harvest. This clustering was repeated for each physiographic province within each scene.

We recently received color infrared stereo aerial photography that will be used in the identification and labeling of the clusters. Having stereo triplets of photography will allow us to make the distinction among differing age and density classes of vegetation. Once the clusters are labeled, we will "burn in" a road/transportation network that was created. By burning in this layer and a marginal buffer, we hope to reduce the error of classification that is common along road edges. The road layer was created by buffering existing primary and city/county road vectors by a distance determined from measurements taken from aerial photography.

Approximately 25% of the stereo triplets are being scanned for registration to the Landsat classifications. These will be used for final verification of the cluster classifications of each scene. The remaining photography will be used prior to verification to aid in identification of cluster labels. These procedures have been documented in a master's thesis by Susan Batten, "A Procedure for Creation of a Land Use/Land Cover Map of Mississippi."

Animal modeling: Range maps have been developed and reviewed by the guidance committees. Models have been developed for nearly all of the terrestrial species. The models have been tested on an Anderson level II land classification map for accuracy and reliability. Models are under review from the guidance committees for better application of ancillary data to achieve greater refinement and accuracy. Procedures have been developed to apply the current models to the final land cover product. All models will be finalized and run on the final land cover product within the next 12 months.

Land stewardship mapping: The Mississippi Department of Wildlife, Fisheries, and Parks (DWFP) has been instrumental in developing this layer. All public land holdings have been compiled from existing digital data or digitized by the DWFP using a GPS receiver. Pertinent information regarding land holdings are entered and checked for accuracy. Management status will be added after accuracy assessments are complete. This data set will be finished within the next 12 months. Private timberlands are available but will not be included because of the frequent shifts in owners.

Analysis: Analysis has not been started. All analyses will be conducted in the next 12 months.

Reporting and data distribution: Relevant parts of the final report have been continually updated since the project got under way. Currently, the methodology sections are being updated to correspond to the final work conducted on both the land cover and vertebrate modeling. The report will be updated for all sections, including analysis, within the next 12 months.

Missouri - near completion

Anticipated completion date: December 1998

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Land cover: Phase I land cover mapping was completed by the Missouri Resource Assessment Partnership (MoRAP) and is currently being used for vertebrate modeling. Accuracy assessment was completed by MoRAP for the Phase I product based on 15,000+ verification sites distributed statewide. MoRAP, through separate state funding, is pursuing a Phase II product utilizing the information gained from this assessment to build a better land cover base. This land cover database has been integral to the regional planning efforts of the Missouri Department of Conservation as well as activities of the U.S. Forest Service and other cooperators.

Animal modeling: Modeling has been completed by the Geographic Resources Center (GRC) for 321 terrestrial vertebrate species (148 birds, 64 mammals, 44 amphibians, and 65 reptiles). Modeling was conducted for each species using base land cover classes as well as derivative and ancillary databases. These included such databases as ecotones, interiors, contiguity, distance relations, special natural features, watershed breaks, soils, geology, temperature, rainfall, population density, road density, elevation, and wetlands. These were arithmetically combined to form a continuum of suitability across the state for each species, based on modeled inputs.

Land stewardship mapping: Stewardship mapping and coding was completed by MoRAP. Some maintenance of the database has been ongoing at GRC to provide a temporally more accurate picture upon final analysis.

Analysis: Actual gap analysis is being completed for the assessment of statewide biodiversity, stewardship base assessment, and other final product creation. Analysis was performed using a variety of grids, such as for linkage to the Public Land Survey Net, 1/6 quad (as used in the Breeding Bird Atlas for Missouri), 7 5-minute quadrangle, county, and EMAP hexagon spatial units. A risk analysis is slated to be performed to assess biodiversity issues in light of population growth trends, road development, agricultural trends, and demographic factors.

Reporting and data distribution: A first draft of the final Missouri GAP report will be delivered January 1999. Data distribution will occur through the Missouri Spatial Data Information Service (MSDIS) (http://msdis.missouri.edu). Techniques, AMLs, models, and other ancillary data and source information will be provided through the Mid-America Vertebrate Resources Information Consortium (MAVRIC)(http://msdis.missouri.edu/mavric). This information will be mirrored at the Missouri GAP home page (http://msdis.missouri.edu/mogap). This will be completed within one month of final acceptance of the report by National GAP.

Other accomplishments and innovations: The first statewide effort to include crayfish, fish, mussels, and snails in gap analysis is now under way in Missouri. For more information see page of this bulletin.

Montana - complete

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Land cover: complete

Animal modeling: complete

Land stewardship mapping: complete

Analysis: complete

Reporting and data distribution: complete (available for distribution by January 1999)

Other accomplishments and innovations:
1. We were one of the first states to develop a digital process for mapping existing vegetation from Landsat TM imagery. In contrast to traditional pixel classifications, which cannot be

applied in a GIS over large geographic areas because of file size limits, our approach involves an unsupervised classification of pixels, followed by pixel aggregation to a user-defined map unit, assembly of a GIS database, and then a supervised classification of the raster polygons. Several manuscripts describing this process are in review:

Ma, Z., M.M. Hart, and R.L. Redmond. Using a color palette to drive unsupervised classifications of remotely sensed images: What you see is what you get.
Ma, Z., M.M. Hart, R.L. Redmond, J.C. Winne, and T.P. Tady. Mapping vegetation across large geographic areas: Integration of remote sensing and GIS to classify multisource data.
Winne, J.C., R.L. Redmond, M.E. Jensen, M.M. Hart, J.P. DiBenedetto, and I.A. Goodman. Integrating satellite imagery and potential vegetation to delineate pattern and map existing vegetation in a mixed-grass prairie ecosystem.
Steele, B.M., and R.L. Redmond. A method of exploiting spatial information for improving classification rules: Application to the construction of polygon-based land cover maps.

2. We developed methods to predict and then to map the magnitude and distribution of classification errors. This work was published in:

Steele, B.M., J.C. Winne, and R.L. Redmond. 1998. Estimation and mapping of misclassification probabilities for thematic land cover maps. *Remote Sensing of Environment* 66: 192-202.

3. Using the land cover database, we reanalyzed U.S. Department of Commerce data from the 1990 census for western Montana and northern Idaho. Actual counts of people from both census blocks and block groups were partitioned to new spatial units based on land cover, land ownership (public and corporate timberlands vs. other private holdings), and topography. The result is a GIS database containing human population density at a finer scale than is normally available. Other census variables can also be mapped using similar dasymetric techniques. The initial work was published in:

Holloway, S.R., J.V. Schumacher, and R.L. Redmond. 1998. People and place: Dasymetric mapping using ARC/INFO. Pages 283-291 in S. Morain, editor. GIS solutions in natural resources management: Balancing the technical-political equation. High Mountain Press, Santa Fe, New Mexico.

4. Statewide atlases of land cover and terrestrial vertebrates were prepared in digital form (Adobe Acrobat format) for ready electronic distribution.

Nebraska - under way (see 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 by major watershed to reach the vegetation alliance level. We have initiated planning for accuracy assessment. Plans for next 12 months: complete initial alliance-level land cover mapping, continue field work for land cover mapping, and conduct pilot study for regional accuracy assessment protocol (see below).

Animal modeling: We have initiated work on assembling species lists and are conducting an extensive literature review including acquisition of range maps. We continue to work with the Nebraska State Museum to determine how we can best use their collection records. Plans for next 12 months: complete species lists, assemble and digitize range maps, automate bibliographies, and identify preliminary models for vertebrate models.

Land stewardship mapping: This product is nearing completion. We continue to work extensively with the Nebraska Game and Parks Commission in this endeavor. Plans for next 12 months: complete stewardship database.

Analysis: Plans for next 12 months: preliminary/pilot testing of methodology.

Reporting and data distribution: Metadata assemblage and documentation ongoing.

Other accomplishments and innovations:
1. Completed assessment of bighorn sheep habitat in northwest Nebraska under contract to the Nebraska Game and Parks Commission;
2. completed inventory of national GAP land cover mapping procedures for USGS/BRD/GAP (see www.calmit.unl.edu/gapmap);
3. continued to work with regional partners in Great Plains GAP consortium (see http://www.calmit.unl.edu/midam/ and http://msdis.missouri.edu/mavric/);
4. worked with regional partners to develop regional land cover accuracy assessment protocols (to be partly funded by EPA Region 7).

Nevada - update under way

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Data sets are complete. Analyses are under way. Update has been initiated as a regional project (see Southwest Regional Breakout Session on p. 64 of GAP Bulletin No. 6)

New Hampshire

(see Vermont and New Hampshire)

New Jersey

(see Maryland, Delaware, and New Jersey)

New Mexico - complete

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NM-GAP data will be available on CD soon. Update has been initiated as a regional project (see Southwest Regional Breakout Session on p. 64 of GAP Bulletin No. 6)

New York - near completion

Anticipated completion date: September 1999 (May 1999 for NY Aquatic GAP)

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Land cover: The statewide land cover map was completed in February 1998. The map is based on 240 spectral clusters derived from six spectral bands of single-date, Landsat-5 Thematic Mapper data acquired between 1991 and 1993. The clusters were labeled into one of 45 land cover types using field knowledge and observations, edaphic factor data, aerial photo interpretation, and expert consultations. The classification was based on the National Vegetation Classification System and correlated with ecological community classification systems of The Nature Conservancy and the New York Natural Heritage Program.

Accuracy assessment and refinement of cluster label assignments were conducted between March and December 1998. Accuracy assessment was conducted using a stratified random sample of

109 circular, 1600-ha plots centered on the coordinate position of the start of a Breeding Bird Survey route. Each plot contained between 40 and 200 unlabeled polygons representing predicted land cover types. These polygons were labeled by field crews, based on field observations or interpretation of NAPP 1:40,000 color infrared aerial photos. A total of 10,154 data points was used for traditional accuracy assessment. A subsample of 934 polygons from 37 plots was used to measure the "fuzzy" accuracy of the land cover map, using a linguistic scale to determine how well each land cover type was predicted from satellite-based spectral information. In addition, 12 on-site, structured interviews with more than 75 wildlife biologists, land managers, and administrators from the New York State Department of Environmental Conservation (NYSDEC, our principal state cooperator), Adirondack Park Agency, and U.S. Fish and Wildlife Service allowed us to identify and correct major cluster labeling errors throughout various regions of the state.

Habitat characterization for Aquatic GAP: Habitat has been 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 (see Figure 1 in the Bulletin's web version). The latter three parameters were used for invertebrate diversity predictions (Figure 2 in the Bulletin's web version). Additional GIS layers of surficial geology, bedrock geology, depth to bedrock and point-source pollution will be included. 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 is developing computer programs to automate classification from digital elevation models, land use, road, and railroad coverages. This will provide substantially more flexibility and enable us to calibrate the model, using previously collected data.

Animal modeling: Spatially referenced coverages for breeding birds and mammals were completed and checked for accuracy during 1998. We continue to cooperate with the ongoing NY Amphibian and Reptile Atlas, sponsored by NYSDEC. We receive updated information on current distributions of amphibians and reptiles annually from the herpetological atlas project, which is scheduled to be completed by late fall 1999. Association matrices, relating vertebrate species occurrences to each of the 45 land cover types we have identified will be completed and assessed for accuracy during the first quarter of 1999. Predicted occurrences of terrestrial vertebrates will be assessed for accuracy using known occurrences of species from recent museum data, herpetological atlas field data, check lists of birds from state parks, breeding bird occurrence data from the NY Breeding Bird Atlas, and check lists of birds and other vertebrates from federal refuges.

Biological databases were developed for fish and invertebrates linking them to specific habitat type. These databases are posted on the web at:
http://www.dnr.cornell.edu/hydro2/fishcode.htm and
http://www.dnr.cornell.edu/hydro2/invcode.htm.

Land stewardship mapping: During 1998 we completed our land stewardship coverage which includes 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, and federal wildlife refuges. Assignments of management status categories to these areas is under way and will be completed during the first quarter of 1999. In addition, information was obtained and mapped for state-regulated wetlands, water quality management classification, regulated fishing areas, fish-stocked waters, and public fishing rights.

Analysis: Accuracy assessments for land cover and vertebrate distributions will be completed during the first quarter of 1999. Gap analysis for the entire database will be initiated and completed during the first half of 1999.

Field data was collected in the summer of 1998 on fish species diversity, invertebrate species diversity, stream width and depth, substrate, general habitat assessment, water chemistry, and gradient at 39 sites. This information will be used to test fish and invertebrate diversity predictions from the aquatic model and the accuracy of the factors predicting habitat characterization on which the diversity predictions were based. The analysis phase of the Aquatic GAP project is expected to be completed by May 1999.

Reporting and data distribution: A draft final report will be submitted to the National GAP office for review by late May 1999. A final report is expected to be completed by late September 1999. Data distribution is expected to be in printed text form, digitally on CD-ROM, 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 recent creation of the Cornell University Geospatial Information Repository (CUGIR, http://cugir.mannlib.cornell.edu), a major National Spatial Data Infrastructure node at Cornell's Mann Library in the College of Agricultural and Life Sciences, makes additional modes of data display and distribution available.

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 May 1998 for the U.S. Geological Survey discussing the methods, results, products, and conclusions to date.

Other accomplishments and innovations: A collaboration with the Cornell Watershed Modeling Team was developed for the final leg of the application of Gap Analysis to New York waters. A product of the collaboration is an enhanced model used to predict water quality, adapted from one developed by Adamus and Bergman.

Three innovative accomplishments of NY-GAP during 1998 have been 1) the development of new image and geographic data analysis techniques to identify urban lands; 2) the implementation of new procedures for "fuzzy" accuracy assessment of our land cover map for comparison with traditional accuracy assessment methods; and 3) incorporating socioeconomic information into our GAP database to develop a habitat vulnerability assessment for parts of the Hudson River Valley. Each of these accomplishments is described briefly below.

To help identify urban lands, a map of housing density was developed from national census data to refine the cluster labeling process by using an inverse distance weighting algorithm to predict the number of households per unit area. Centroids of census block groups were assigned a household density value based on the number of households and area of the block group. The resulting continuous grid at 30-meter resolution was classified into five categories using equal intervals. Spectral cluster assignments within each category of urban land where evaluated using a threshold cluster value. If the cluster value was above the threshold, the land remained urban. If the cluster value was below the threshold, a land cover type was assigned based on previous experience in nonurban areas.

For our exploration of fuzzy accuracy assessment methods, field crews collected a subsample of accuracy assessment data from the 109 circular 1600-hectare plots during summer and fall 1998. A fuzzy accuracy assessment protocol described by Gopal and Woodcock (*Photogrammetric Engineering and Remote Sensing* 60:181-188) was implemented by the field crews for approximately 1000 polygons from over 10,000 polygons used in our accuracy assessment process. A numeric value from one to five representing a linguistic scale of map accuracy was assigned to each polygon for each land cover type. Map accuracy is being assessed using both methods at three levels of taxonomic detail. During fall 1998 we concluded map refinements and data analysis for both traditional and fuzzy accuracy assessment activities.

In addition to our research related to urban area delineation and map accuracy assessment, we have continued our participation in the Hudson River Estuary Biodiversity Conservation Initiative under contract with NYSDEC. This project began in 1997 for the purpose of furnishing data and analytical support to facilitate conservation planning in the Hudson River Valley (HRV). It provides funding for more detailed vegetation mapping of the HRV from Albany to New York City. In cooperation with the NY Natural Heritage Program, a gap analysis is under way for the HRV, and a separate interim report will be produced by April 1999, including more detailed land cover maps at a greater resolution than for the statewide vegetation map. Additional funding has been approved for several complementary projects anticipated to begin in April 1999. We will continue 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 the implementation of biodiversity conservation strategies, and providing information to communities in the region to aid in local conservation efforts.

A more extensive habitat vulnerability assessment of the HRV will be performed during 1999/2000 by incorporating socioeconomic information into our GAP database in the form of population growth models that will predict areas of biodiversity most vulnerable to urban and suburban expansion using "build-out" scenarios (Sayeweh 1998). With designation of the Hudson River as a National Heritage River in 1998, our work takes on added significance to planning efforts along the river corridor.

Papers and posters presented at professional meetings:

DeGloria, S.D., M. Laba, S.K. Gregory, J. Fiore, E. Hill, J. Braden, J. Beecher, D. Ogurcak, R. Elliott, A. Stalter, and J. Weber. Accuracy assessment of the New York GAP land cover and ecological communities map. 8th Annual National Gap Analysis Meeting, Santa Barbara, California. 20-24 July 1998.

Fiore, J.J., M. Laba, S. Gregory, S.D. DeGloria, E. Hill, and J.T. Weber. Creating New York state's land cover map – The Adirondack Park as an example. 8th Annual National Gap Analysis Meeting, Santa Barbara, California. 20-24 July 1998.

Laba, M., S.D. DeGloria, S.K. Gregory, J. Fiore, E. Hill, J. Braden, J. Beecher, D. Ogurcak, R. Elliott, A. Stalter, and J. Weber. Accuracy assessment of the New York GAP land cover and ecological communities map. 14th NYS Geographic Information Systems Conference, Rochester, New York. 23-24 September 1998.

Smith, C.R., J.T. Weber, and M.E. Richmond. Using Gap Analysis information to guide planning for conservation of birds in New York state: A comparison of science-based and expert-opinion approaches. 8th Annual National Gap Analysis Meeting, Santa Barbara, California. 20-24 July 1998.

Publications:

Sayeweh, P.W. 1998. Combining a growth allocation model and GIS results to assess suitable biodiversity management areas: A prototype for Hudson Valley Biodiversity Program in New York state. M.S. thesis. Cornell University, Ithaca, New York.

Smith, C.R., and S.K. Gregory. 1998. Bird habitats in New York state. Pages 29-41 in E. Levine, editor. Bull's birds of New York state. Cornell University Press, Ithaca, New York.

North Carolina - under way

Anticipated completion date: June 2000

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Land cover: In 1998, we developed detailed land cover classifications for the majority of the coastal plain of North Carolina. Using decision rule methodology we have delineated 54 different map units in the southern flatwoods study area (see page). This total includes 10 nonvegetated and agricultural classes from the regional land cover. By querying the classified image with our set of interpreted points we have been able to identify which classes contain confusion. Until higher resolution imagery or additional ancillary data sources are added to the analysis, these classes will be combined and attributed appropriately as mixtures. With this information in hand, we have started discussions with the other GAP projects of the southeastern region to identify a consistent regional set of map units that could be used to produce detailed land cover map products across state lines (see page). In 1999 we will mosaic the coastal plain scenes together, incorporating comments from reviewers and assessing the region as a whole. We will be using the same approach with a few additional ancillary data sets in the piedmont and mountains.

Animal modeling: At the Southeast Regional GAP Workshop, it was decided that the habitat relationships would be built to alliances. Since then, each of the classification systems used in the primary references have been crossed-walked to the National Vegetation Classification. A database for storage and retrieval of the vertebrate species information has been developed and the core data added. A list of reviewers has been identified for both range and habitat associations. Methods for review by hard copy and via the Internet are being developed. By February 1999 we will have the preliminary range maps posted for review. Throughout the year we will be working on refining the habitat associations based on the recent literature and reviewers' comments.

Land stewardship mapping: At the request of the North Carolina Center for Geographic Information and Analysis (NCCGIA), we participated in the Framework Data Survey in which the current status and plans for developing framework data were assessed for North Carolina. In follow-up discussions with NCCGIA it became apparent that the development of a new land ownership layer would not be required for North Carolina. In 1999 we will start with the land ownership data layer that has been developed and spend our efforts on assigning the land management status codes.

Analysis: The North Carolina Natural Heritage Program in cooperation with the North Carolina State Museum of Natural Sciences is currently summarizing the results of the analyses done in the study "A Model Biodiversity Analysis for Southeastern North Carolina." In this analysis, species guilds were identified and conservation status of each assessed. The draft vegetation map for the southeast coastal plain was used to identify areas of contiguous suitable habitat for several of the species guilds. Specimen records from the museum and location data from the Heritage database were used to define the range of each of the species in the guilds.

Reporting and data distribution: Distribution of the vegetation classification is currently limited to cooperating agencies willing to provide review on the draft maps.

Other accomplishments and innovations: In April 1998 we hosted the Southeast Regional GAP Workshop. For most of the two days there were two sessions run in parallel—vegetation mapping and vertebrate modeling. During the workshop some important decisions were made to help facilitate consistency across the region. We started the process of developing regional map unit labels from groups of alliances that are consistently mapped together, either because of spatial or spectral proximity. Given the experiences in the region, the need to work on defining compositional groupings and ecological complexes for the region was recognized. This meeting was the start of a flurry of activity around transferring technical expertise in the Southeast.

North Dakota - under way

Anticipated completion date: September 2003

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ND-GAP began organizing in 1998. Northern Prairie Wildlife Research Center hosted the first organizational meeting for ND-GAP in November 1998. Representatives from ten federal government agencies, five state government agencies, three universities, and one nonprofit organization attended the meeting.

Land Cover: The first draft of a hierarchical vegetation and land cover classification scheme for ND-GAP was developed. The vegetation and land cover classification scheme will be revised to include natural and seminatural vegetation communities at a scale appropriate to classification using TM imagery and environmental data in a Geographic Information System. Existing vegetation maps from U.S. Fish and Wildlife Service, Environmental Protection Agency, Ducks Unlimited, Forest Service, and the National Agricultural Statistical Service have been acquired and imported into the ND-GAP GIS. These maps do not describe vegetation to the detail that is desired for GAP but are useful for stratification for a more detailed analysis and classification. Vegetation inventory data were identified and plans developed to convert the data into a spatial format compatible with the ND-GAP GIS. These data sets include the ND Natural Heritage Program's Conservation Data System, ND State School Lands Range Inventory Database, and data collected by biologists from Northern Prairie Wildlife Research Center, U.S. Forest Service, and Natural Resources Conservation Service, and graduate students at ND universities. Three dates of TM imagery (spring, summer, and fall) and environmental data including 3-arc second digital elevation models, climate surfaces, STATSGO soils data, a surface geology map, and National Wetlands Inventory data will be used to map natural and seminatural vegetation at a level between the formation and alliance levels of the FGDC Vegetation Classification Standard.

Animal modeling: A search and review of species check lists for ND identified 422 species of terrestrial vertebrates for probable inclusion in ND-GAP. A breakdown of this list includes 223 species of breeding birds, 95 species of avian migrants, 78 mammals, 11 amphibians, and 15 reptiles. Location records for most species are recorded by township, range, and section of the Public Land Survey System (PLSS). Because this system records the location of species observations at much greater spatial detail than the 650-km^2 hexagons used in GAP projects, we will develop the species observation database using the PLSS. We will begin building the database with breeding birds, as observation records for birds are more abundant and better organized than those for mammals, reptiles, and amphibians. Tom Skelbar joined the ND-GAP staff in October 1998 and will take the lead for the terrestrial vertebrate distribution mapping.

Land stewardship mapping: Organizations with stewardship responsibilities for public lands in North Dakota have been contacted and queried about the status of maps, digital boundary and management unit data, and realty records for their lands. Few organizations had digital boundary and management status data for all their lands. Boundary and management unit data was requested from those organizations which had digital data for all their lands. The scale of the source data is variable among the agencies ranging from larger than 1:24,000 to 1:100,000. The ND Department of Transportation (NDDOT) is converting their databases and county mapping process to a GIS. They have created a state layer to complement county databases. The state layer contains the boundaries for all public lands in the state, but the parcels are not attributed.

NDDOT anticipates completing the vector in January 1999 and will make it available to ND-GAP. In 1999 we will continue to acquire existing digital data from the appropriate agencies and the state vector prepared by the NDDOT.

Ohio - organizing

Anticipated completion date: December 2002

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Land cover: Mapping will begin in January 1999. The land cover mapping effort for Ohio will be led by Dr. Joan Nichols of the Ohio State University's School of Natural Resources. Goals for the next 12 months include team-building and training of all individuals involved in mapping. Other efforts within the state of Ohio have produced a Anderson level 1 land use map—these data will be examined for their potential use in the GAP program. It is anticipated that at least a portion of the land cover map will be complete by the end of 1999. An additional component of this work will be to evaluate different means of mapping riparian areas using remote sensing or other techniques.

Animal modeling: Compilation of animal data sets will begin in January 1999. Preliminary efforts have focused on examination of methodology of other states. Goals for the next 12 months include compilation of data regarding habitat affinities and documented occurrence of species within Ohio. Additionally, the Ohio GAP effort includes work on selected aquatic species. Several aquatic data sets have already been identified, and we are working towards the exchange and reformatting of these data for use in aquatic GAP.

Land stewardship mapping: Land stewardship mapping is to begin in January 1999. Plans for the next 12 months include examination of adjoining states' methodologies and determination of data sources.

Analysis: Analysis will only begin as we compile the animal data. Efforts are focused on examining methods of other states.

Reporting and data distribution: A fact sheet for OH-GAP is planned for late 1999. We hope to use this fact sheet to develop a cooperator base and for general project information.

Other accomplishments and innovations: OH-GAP is unique in that it represents the first integrated terrestrial and aquatic analysis in the United States. As such, it will bring together researchers from the Water Resources Division and Biological Resources Division of the USGS, the Ohio State University, and several other state and local government agencies. We anticipate that this effort will encourage research to be focused on large-scale ecosystems whose terrestrial and aquatic components are related and codependent.

Oklahoma - near completion

Anticipated completion date: June 1999

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Land cover: A draft land cover map has been completed. We are currently gathering ground-truth data for conducting an accuracy assessment of the draft map. Our goal is to complete the accuracy assessment by late winter 1999.

Animal modeling: Range maps and habitat association models for 427 vertebrates have been developed. A pilot study of the vertebrate modeling process has been completed. Modeling with the draft land cover map is ongoing. Our goal is to complete all animal modeling by late spring 1999.

Land stewardship mapping: The land stewardship map is complete, and final review of stewardship status is ongoing. Our goal is to finalize the map by late winter 1999.

Analysis: Our goal is to conduct the final analysis of GAP data layers by late spring 1999.

Reporting and data distribution: The final report and data distribution will be completed by June 1999.

Other accomplishments and innovations: The Gap Analysis methodology was used to develop a GIS-based inventory of the habitat and biological resources of Tishomingo National Wildlife Refuge in Oklahoma.

Oregon - near completion

Anticipated completion date: April 1999

Contact: Jimmy Kagan, Director/Ecologist and GAP PI
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Land cover: An original land cover map was completed for Oregon in 1992—the second GAP prototype after the original Idaho map. A second-generation land cover map was completed in August 1998 and is currently available. Metadata is available for this second-generation cover, but the accuracy assessment is incomplete, and there is no vegetation manual associated with the new map. Over the next seven months, we plan on completing the chapter on land cover mapping for the Oregon Final Report and producing a vegetation manual for the updated map as well. See Figure 1 in the Bulletin's web version for the second-generation map.

Animal modeling: Animal modeling was completed for Oregon using the first generation GAP vegetation map. The result of this project is the book *Atlas of Oregon Wildlife* (Csuti et al. 1997). The initial models relied on hexagon distributions prepared for all native wildlife species. Since these were completed over eight years ago, we have recently (October 1998) updated the hexagon distribution covers for all wildlife species. Our goal is to update the model distributions for all vertebrate species using the updated hexagon distributions and the second-generation land cover, with all of the draft models to be completed by December 1998. We have updated the wildlife habitat relationship matrix to reflect the differences between the first- and second-generation land coverages and have created ARC/INFO programs (AMLs) to generate the coverages. While the existing coverages have all been peer-reviewed, it is hoped the updated modeled distributions can also receive some peer reviews, although given the limited time frame these will probably be limited to local experts.

Land stewardship mapping: The land stewardship cover is complete after extensive work over the last six months. A graphic showing the cover, with GAP status 1 and 2 lands in red, is shown in Figure 2 in the Bulletin's web version (www.gap.uidaho.edu/gap/Bulletins/7/index.htm). We intend to update the cover with newly designated or newly acquired public lands until sometime in December 1998, when all of the species distributions have been completed. The cover will then be archived and used to generate the tables and maps in the analysis. After that, the cover will be continually updated and maintained on the OR-GAP web page.

Analysis: Analysis will begin as soon as the species distribution covers have been generated from the updated habitat models, the updated vegetation cover, and the updated hexagon distribution database. Analysis to complete the basic gap analysis chapters will be complete by February 1999. All analyses will be completed on a statewide and an ecoregional basis. Additional analysis may include an analysis of habitat losses based on a presettlement vegetation coverage for Oregon and a comparison of different methods of generating land coverages.

Reporting and data distribution: A final state report will be prepared during the next six months. The final report and the basic coverages will be posted at the OR-GAP home page. The basic coverages that will be posted include stewardship, species distribution, first- and second-generation GAP vegetation coverages, and a presettlement vegetation coverage. All of the final GAP products and coverages will also be available on the standard GAP CD-ROM.

During the next 10 months of the project, using GAP funds as well as funds from the U.S. Fish and Wildlife Service, we also will distribute GAP data to watershed councils, local governments, and other decision makers in Oregon. We intend to provide GAP data, Oregon Natural Heritage Program threatened and endangered species data, and analyses 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 the Oregon Natural Heritage Program and OR-GAP were partners.

Other accomplishments and innovations: As part of our association with the Oregon Biodiversity Project, an application was developed which 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.

Literature cited:

Csuti, B., A.J. Kimerling, T.A. O'Neil, M.M. Shaughnessy, E.P. Gaines, and M.M.P. Huso. 1997. Atlas of Oregon wildlife: Distribution, habitat, and natural history. Oregon State University Press, Corvallis, Oregon. 492 pp.

Pennsylvania - under way

Anticipated completion date: September 1999

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Land cover: A multi-scale land cover product has been completed. The forest landscape matrix was mapped at a 100-ha resolution by on-screen photointerpretive delineation from TM. High-intensity and low-intensity development was mapped to the perceptual limit by photointerpretive delineation from TM display with PennDOT road coverage superimposed. General land cover was mapped at 30-meter TM pixel level using eight classes by semisupervised labeling of 255 hyperclusters per scene, with a different approach to spectral clustering than the Spectrum method of EROS Data Center. The clustered image product is directly usable in image mode with ArcView and/or ArcExplorer, and the land cover rendition just requires a different color or legend file. Checking the confirmatory cluster assignments remains to be done. On-line DOQs will be used as reference material. Pixels are being aggregated to a 2-ha level with some combination of classes for vectorization. A mix of leaf-on and leaf-off video will also be used for accuracy assessment. Some preliminary superalliance classification may be conducted but will not be used in habitat models or formally validated in these first-generation products.

Animal modeling: Avian models are completed and ready for review. Amphibian and herp models are in progress. Models use generalized land cover and terrain feature criteria. Modeling of fishes is under consideration and will be of a preliminary nature.

Land stewardship mapping: A first version is complete and was presented at a November 1998 conference in Harrisburg, PA. It was well received, but some suggestions for additions were forthcoming.

Analysis: Analysis will be conducted in terms of species diversity by groupings of habitat affiliates (generalized guilds) to locate major habitat complexes. Echelon analysis is a complementary methodology (see PA-GAP web page at http://www.erri.psu.edu/web/projects/gappage.htm).

Reporting and data distribution: PA-GAP geographic data will be distributed through Pennsylvania Spatial Data Access (PASDA) as introduced in the PA-GAP web page. There will, of course, be a conventional GAP report as well. Project completion was slated for December 1998 but rescheduled to September 1999 because of W. Myers' fall sabbatical to lead the Pennsylvania ECOMAP effort at landscape levels. GAP in Pennsylvania is seen as a progression rather than a singular end in itself.

Other accomplishments and innovations: PHASE analysis of remotely sensed data and echelon analysis of (virtual) surface information are outgrowths of Gap Analysis work through a companion project sponsored by an NSF/EPA watershed research partnership. Please consult the PA-GAP web page for an introduction and links to software.

Rhode Island

(see Massachusetts, Connecticut, and Rhode Island)

South Carolina - under way

Anticipated completion date: June 2000

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Land cover: The South Carolina Gap Analysis Project (SC-GAP) has completed an initial land cover map with 28 map units comprised of general vegetation, urban, agriculture, and water classes. The purpose of this map is two-fold: to provide a background for incorporation of ancillary data and modeling of vegetation classes at the alliance level, and to provide land cover classes to be used in the animal habitat modeling. During the next year, SC-GAP will be incorporating ancillary data, developing decision trees, and conducting a pilot project for alliance-level mapping along the coast with the U.S. Fish and Wildlife Service and the South Carolina Department of Natural Resources. We hope to have much of the coastal plain mapped in the next twelve months. As part of a project to develop an ant layer in cooperation with Clemson University, South Carolina Cooperative Extension Service, and the South Carolina Cooperative Research Unit, a technician and graduate student will be collecting information for accuracy assessment of the completed general vegetation map in a stratified random sample of public lands.

Animal modeling: SC-GAP has compiled a list of 488 vertebrate species for inclusion in the animal layer. Data on distribution by county have been gathered and compiled from museum records and state and regional accounts. We have completed the database for all vertebrate species (this includes information on distribution and habitat affinities) and created maps of species distribution by county. These are now out for review to experts within the state. We have also formed a cooperative arrangement with Clemson University, the Cooperative Extension Service, and the Cooperative Research Unit at Clemson to collect ants throughout the state, describe their habitat affinities and develop a distribution layer of ant species in South Carolina (see page   for more on the SC-GAP ant project). Other invertebrates to be included in the animal layer include butterflies and tiger beetles.

Land stewardship mapping: The database of public lands is approximately 80% complete. We will continue compiling data on those lands not currently inventoried and will finish digitizing those maps not currently completed. Additionally, we will be refining our classification scheme for protected lands within the state.

Analysis: The analysis portion of SC-GAP is just beginning. Development of ancillary data to be used in the modeling of vegetation is currently under way. We are developing decision trees that will allow us to use ancillary data such as soil moisture content, elevation, and physiographic province in refining our map units from 28 general classes to the TNC alliance level of vegetation classification. Upon return of the animal distribution maps and habitat matrices from our experts, animal modeling will also commence.

Reporting and data distribution: We have reported the status of SC-GAP at the National Gap Analysis Meeting in Santa Barbara in July 1998. There was also a meeting of state cooperators in September to discuss progress and future directions. No data or maps have been distributed yet.

South Dakota – under way

Anticipated completion date: June 2001

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Land cover: We are completing general land cover maps for eastern South Dakota and the Black Hills region. Six of the eight satellite scenes east of the Missouri River have been processed using an Imagine model to isolate spectral signatures of perennial vegetation from agricultural and wetland habitats (previously classified). Human population data (CIESIN) for all of South Dakota has been obtained and processed to identify developed areas. Two satellite scenes with just the perennial vegetation have been run through a clustering algorithm in Land Analysis System (LAS) software to allow more detailed discrimination between deciduous and coniferous trees and grasslands. Satellite images covering the Black Hills region have been classified; however, many of the vegetation classes have the same spectral characteristics. Currently we are incorporating ancillary data into the Black Hills vegetation classification process and will be running and interpreting regression tree analyses. Goals for the next twelve months include processing satellite images covering the remainder of the western half of the state and creating vegetation models to distinguish vegetation alliances throughout the state to complete the land cover map.

Animal modeling: Distributions for South Dakota's 88 mammalian species were constructed based on EPA's hexagonal grid using museum records, agency records, and trapping data obtained during the summer of 1998. Completed distributions are being reviewed by a panel of experts throughout the state. Wildlife habitat relationships are being researched for construction of models to predict mammalian distributions. Habitat relation models of two species of carnivores occurring in the Black Hills are currently being constructed. Additional mammalian models will be formulated within the next year. A literature search has begun to collect habitat information for 350 avian, 37 reptilian, and 15 amphibian species.

Land stewardship mapping: A draft of the SD-GAP stewardship layer is published on our web site. We are in the process of digitizing TNC preserves, 27 state parks and recreation areas, state wildlife refuges, and Indian reservations. U.S. Army Corps of Engineers lands are in digital format but need to be combined with the web-published stewardship map. To date, approval to use the Indian reservation digital coverages has not been received from tribal counsels. Our stewardship map will be completed this year.

Analyses: Accuracy assessment of eastern South Dakota and Black Hills general land cover maps will be completed this year.

Tennessee - near completion

Anticipated completion date: June 1999

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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. Goals to accomplish in spring 1999 include finalizing the results of the accuracy assessment, implementing the aggregation algorithm, and tiling the vegetation map.

Animal modeling: Predicted species distributions and species richness data have been produced for Tennessee's 364 terrestrial vertebrates. Expert review and accuracy assessment of the species distributions need to be completed. Goals include formatting the animal distribution data into National GAP's standards for CD-ROM production.

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 prior to any further analysis.

Analysis: A preliminary predicted species distribution analysis has been completed. Species richness for each animal group was intersected with Tennessee's land stewardship coverage. Species diversity by land status was based on the species richness totals. Individual species have not been separated by land status categories. Minimum and maximum species numbers per land status category were calculated for each animal group. TN-GAP will divide each species by land status type and reevaluate the predicted species and land stewardship analysis in the next 12 months.

Reporting and data distribution: The first draft of the final report will be completed December 1998. Goals to accomplish by June 1999 include refining the data to meet National GAP standards. Plans are to present TN-GAP data as part of the TWRA web page.

Other accomplishments and innovations: The Tennessee Biodiversity Program (established by the Tennessee Conservation League) and TWRA's GIS division have been working 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.

Texas - under way

Anticipated completion date: December 2000

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Land cover: The land cover map for West Texas has been completed in draft form, and scenes have been stitched together. Field work has been completed for 229 of the 254 counties in Texas. Classification is under way and progressing at the rate of about four scenes per month. We expect to complete the field work in the remaining 25 counties before January 1999 and to classify the remaining scenes. However, massive flooding in the San Antonio and Houston areas in October 1998 has made this area inaccessible.

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 has been developed. Habitat profiles have also been prepared for 487 of the 637 species being modeled, and state-wide GIS layers have been created from the following profile variables: precipitation, temperature, soils, hydrology, ecoregions, and elevation.

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Analysis: Data prepared for West Texas is being analyzed for accuracy and to prepare selected species-specific maps (e.g., prairie dog towns and scaled quail distribution).

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 and innovations: We have established a bioinformatics program at Texas Tech University that involves the museum and draws from multidisciplinary fields and programs such as the Texas GAP Project, the Natural Science Research Laboratory, and the Department of Biology. One goal of this program is to build a relational database, as a linkage of distributed databases, which can be accessed through the Internet. We are using Oracle as the primary relational database with specific existing applications running in FoxPro, MS Access, etc. Examples of the data now available include vertebrate collections from the museum; field notes, photos, and records of the 1895-1906 biological survey of Texas; routes of the Breeding Bird Survey of Texas conducted annually by the U.S. Fish and Wildlife Service; daily weather data from 3860 sites in Texas with some records extending back over 100 years; current landscape photographs of habitats in Texas; soil maps for Texas; vegetation in Texas; aerial videography; digital elevation maps; and Landsat TM scenes for all of Texas and the North American Trade Zone established by the North American Free Trade Agreement along the border with Mexico.

Several products have been developed and placed on the Internet. Applications include soil maps by agricultural crop type, design and placement of constructed wetlands for extraction of nutrients from the effluent of cattle feedlots, integration of aquaculture with traditional agriculture, distribution models for vertebrate species in Texas, and identification of areas with high levels of biodiversity. These and other projects will allow researchers, resource managers, landowners, school children, and the general public to use the best available data in their projects, research, and decisions.

Utah - complete

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Update has been initiated as a regional project (see Southwest Regional Breakout Session on p. 64 of GAP Bulletin No. 6).

Vermont and New Hampshire - near completion

Anticipated completion date: September 1999

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Land cover: The land cover map for New Hampshire is complete, and accuracy assessment is finished. Edge-matching along the border with Maine is acceptable. Vermont's land cover map also is complete, and we are arranging to edge-match with New York.

Animal modeling: Models are complete pending occasional revisions.

Land stewardship mapping: Mapping is complete except for numerous updates on federal and state lands. Land stewardship categories have not been assigned.

Analysis: Predictive habitat models are being run in late 1998, with other aspects of analysis to follow in early 1999.

Reporting and data distribution: The goal is to have draft reports written by July 1999 and final reports submitted by the end of September.

Other accomplishments and innovations: Preliminary products from the Vermont and New Hampshire GAP Project have been used in ecological reserve selection projects for the two states. In New Hampshire, priority areas for ecological reserves were selected after a watershed-based analysis of landscape diversity, an identification of core forest sites from GAP land cover maps, and an analysis of data from the Natural Heritage database were made. In Vermont a similar project is under way, but the analyses are more sophisticated and rely heavily on landscape features that are linked to biological diversity.

Virginia - near completion

Anticipated completion date: July 1999

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Fish and Wildlife Information Exchange
Virginia Polytechnic Institute and State University
fwiexchg@vt.edu, (540) 231-7348

Land cover: The primary land cover map for Virginia was completed in spring 1998 (Morton 1998). This map is currently available through anonymous ftp from the Fish and Wildlife Information Exchange (FWIE) server at ftp.fwie.fw.vt.edu:80. Presently, VA-GAP is completing a second iteration to a super-type classification of the entire Commonwealth. The Coastal Plain and Piedmont physiographic provinces are expected to be completed by the end of 1998. The Ridge-and-Valley and Mountain regions of the state are expected to be completed by spring

1999. Accuracy assessment for the detailed land cover map will be conducted throughout the winter and spring of 1999. A substantial database comprised of ground locations, aerial videography, and maplets from cooperators will be used to refine and assess the level II land cover map. A phase II sampling effort will be undertaken for cover types with low representation in the existing database and for types which require more data to obtain acceptable accuracy. For more information on VA-GAP's land cover mapping efforts, please contact Scott Klopfer (sklopfer@vt.edu).

Animal modeling: The vertebrate model database has been researched and updated by the Virginia Department of Game and Inland Fisheries. This database (VAFWIS) will provide the basic information needed to estimate species distributions in Virginia. Animal species distributions will be examined using data from ongoing cooperative projects at Ft. A.P. Hill and Ft. Pickett military installations and the University of Virginia's Mountain Lake Biological Research Station. Testing on small, selected areas of the state has already begun. The first species distribution models will be produced for the Coastal Plain and Piedmont regions in spring 1999.

Land stewardship mapping: VA-GAP has collected property boundaries from federal and state government agencies managing land in Virginia. Other stewardship properties are being sought and obtained. These data will be combined to create the land stewardship information layer by the end of 1998. This simple map will be improved by compiling information on the management status of these properties and their potential for future management for biodiversity. For more information regarding these efforts please contact Scott Klopfer (sklopfer@vt.edu).

Analysis: VA-GAP is planning on beginning the analysis phase in early spring 1999. The products of this effort will include both standard GAP products and a series of maps, data, and statistics requested by our many state cooperators.

Reporting of data and distribution: Many of the basic data sets used by VA-GAP are available to the public via ftp. Simple land cover as well as roads, rivers, and wetland vector layers are currently served. VA-GAP is pursuing other, more user-friendly distribution options. We hope to develop a web-based site where those interested in GAP products may choose a specific area, data set, or format to download information. This site would employ scaleable maps, metadata, and other information to make GAP data more useful to a wider audience.

Other accomplishments and innovations: VA-GAP has been successful in forging strong relationships with both federal and state government agencies and nongovernmental organizations in Virginia. We continue to develop and improve a hybrid classification technique incorporating remote sensing and ecological models which we hope will improve land cover classification for areas in complex terrain. In addition, we have established ourselves as a front-runner in landscape-scale data analysis and research in Virginia.

Washington - complete

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CD products are in progress. Data can be accessed on the Internet at http://salmo.cqs.washington.edu/~wagap/.

West Virginia – under way/near completion

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Land cover: Preliminary land cover and alliance/ecological complex mapping are complete. We are refining the classifications with specialized ancillary data (e.g., a methodology for improved mapping of cove hardwoods) and additional videography classification.

Animal modeling: Models have been developed and will be implemented once final land cover tiles are available. We have developed specialized techniques for herpetile modeling that we hope to publish in 1999.

Land stewardship: Completed.

Analysis: Most analyses have not yet been undertaken. We have developed land cover data sets for the years 1925, 1932, 1950, and 1976 and are involved in change detection experiments with the land cover data from those periods and the GAP data sets.

Reporting and data distribution: We have distributed preliminary products to over a dozen federal and state agencies. We have prepared an animal modeling background document (that details the habitat abstracts and models) and have been circulating that for over six months.

Other accomplishments: GAP is being institutionalized in a West Virginia Agricultural and Forest Experiment Station project titled "The West Virginia Land Status and Trends Project." In this project we will be obtaining new imagery every three years and completing forest cover, open land, and land use/land cover status and trends assessments on a three-year cycle. GAP data will be permanently housed in the WVDNR nongame program and in the GIS research program of the West Virginia Cooperative Fish and Wildlife Research Unit.

Wyoming - complete

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Other accomplishments and innovations: Though WY-GAP was officially completed in January 1997 with the publication of the final report, there is still plenty of GAP-related activity going on in the state of Wyoming.

Wyoming Bioinformation Node: A partnership with National GAP and the University of Wyoming's Spatial Data and Visualization Center has resulted in the development and continued expansion of the Wyoming Bioinformation Node, providing Wyoming with data and services as part of the National Biological Information Infrastructure (NBII). Please see our web site, www.sdvc.uwyo.edu/wbn, for information about the following projects:

- Wyoming Species Atlas: Provides on-line access to information and GAP data for Wyoming's vertebrate species.
- Biodiversity Expert Systems Tool: incorporates GAP data and expert rules within an ArcView interface to assist county planners in reviewing development propositions.
- NBII data and metadata for many biological data sets available from various Wyoming sources.

Refuge GAP: This is an ArcView Spatial Analyst-based decision support system, utilizing GAP data, to assist the U.S. Fish and Wildlife Service in project reviews and land acquisition prioritization in Wyoming.

Wyoming Internet Map Server: The WY-GAP data has been incorporated into this interactive map and query system, which provides access to hundreds of Wyoming data sets and simplified GIS functions over the web. Web site: wims.sdvc.uwyo.edu

Contact: Margo Herdendorf
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Selecting Plant Species for Gap Analysis in Wyoming: GAP projects have made an important contribution towards modeling distributions of terrestrial vertebrates but rarely have addressed other organisms. Vascular plants in particular have been treated primarily as components of vegetation rather than as individual species. Like vertebrates, plant species also show "gaps" between their known ranges and protected areas. This project is addressing the unique issues involved in selecting and modeling plant species for gap analysis.

NOTES AND ANNOUNCEMENTS

A Survey of GAP Land Cover Mapping Protocols

Land cover mapping for the National Gap Analysis Program (GAP) is carried out on a state-by-state basis. Prior to the first-generation phase of the program, no defensible standards existed for mapping floristically defined dominant vegetation types over state-sized areas with TM as a base. Standards established by GAP did not mandate, for example, a certain spectral clustering algorithm. Those standards did, however, cover basic issues, for example, positional accuracy, MMU, thematic classification, and nominal scale (see Stoms 1996, Jennings 1994).

During the past decade an enormous amount of experimentation and development for large-area, relatively high-resolution land cover mapping has taken place within and among the GAP state projects, and the basis for many of the early standards has evolved significantly. As a result of its flexible approach, GAP has generated a large amount of new experience, methods, and a much larger "leading-edge" skill pool. In an effort to learn from all that experience and find standards that improve efficiency, consistency, and effectiveness, the Center for Advanced Land Management Information Technologies (University of Nebraska-Lincoln) carried out a national inventory of the ways in which land cover has been mapped for GAP. Results are now available on the web at http://www.calmit.unl.edu/gapmap.

Much creativity has been displayed in the varied approaches states have used to map their project areas. This study attempted to synthesize and analyze all the various land cover mapping protocols being used in the GAP community. It is hoped that this accumulation of land cover mapping information will assist in the development of improved future mapping efforts.

The land cover mapping information that was reported by each project has been analyzed and brought together in the form of a brochure and a comprehensive report on the Internet. The GAPMAP home page provides conclusions, recommendations, and information about surrounding projects that can be utilized for current and future land cover mapping strategies. The home page allows the user to query for information by individual state or by category. It also allows users to view the data through graphical representation. Those working on state projects are encouraged to correct or add any data that are inaccurately reported via the e-mail address provided on the page. Please visit the home page at http://www.calmit.unl.edu/gapmap. To obtain a brochure, contact Jill Wolf or James Merchant, CALMIT/Conservation and Survey Division, 113 Nebraska Hall, University of Nebraska-Lincoln, Lincoln, Nebraska 68588-0517. Tel: (402) 472-7531, e-mail: jwolf@tan.unl.edu or jm1000@tan.unl.edu

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Jennings, M.D. 1994. National Gap Analysis project standards. In: A handbook for conducting Gap Analysis, National Gap Analysis Program, Moscow, Idaho. http://www.gap.uidaho.edu/gap/AboutGAP/Handbook/Misc/Standards.htm.

Stoms, D.M. 1996. Actual vegetation layer. In: A handbook for conducting Gap Analysis, National Gap Analysis Program, Moscow, Idaho. http://www.gap.uidaho.edu/gap/AboutGAP/Handbook/LCM.htm.

Marlen Eve, Jill Wolf, and James Merchant
University of Nebraska-Lincoln

AMLs for Air Video Interpretation

Realizing that we would be interpreting aerial videography and other data sources across twelve separate TM scenes, we decided to create a user interface that would maximize consistency in labeling and minimize the setup time for each new study area. This interface evolved into a suite of Arc Macro Language scripts (AMLs) designed to assist in interpretation of video data using ESRI's ARC/INFO 7.x software by presenting a consistent and efficient working interface to the operator. Initial development was on a Unix workstation running Solaris 2.5; however, it has been successfully run on NT systems, with the exception of two supporting routines that utilize AWK programming language to rearrange text files for quick conversion into ARC coverages (LABEL2COVER.AML and ASC2FLTLN.AML).

The user starts with INTERP.AML, which displays a map composition in ArcPlot including the video flightline with the Landsat TM imagery as a background along with county boundaries, roads, streams, and any other data layer useful to orient the user (see Figure 1). Menues with common commands used in interpretation are presented, including query of the timecode from a flightline point, query of the covertype from a previously interpreted point, and individual covertype labeling buttons (Figures 2 and 3). Each interpreted video frame is written as a record in a text file with the following information:

- position (x,y)
- covercode
- covertype
- source (interpreting source, e.g., video, field, other data)
- region (area of interpretation, e.g., piedmont, 1436coast)
- org_id (id# from initial interpreted coverage, useful when joining multiple regions)

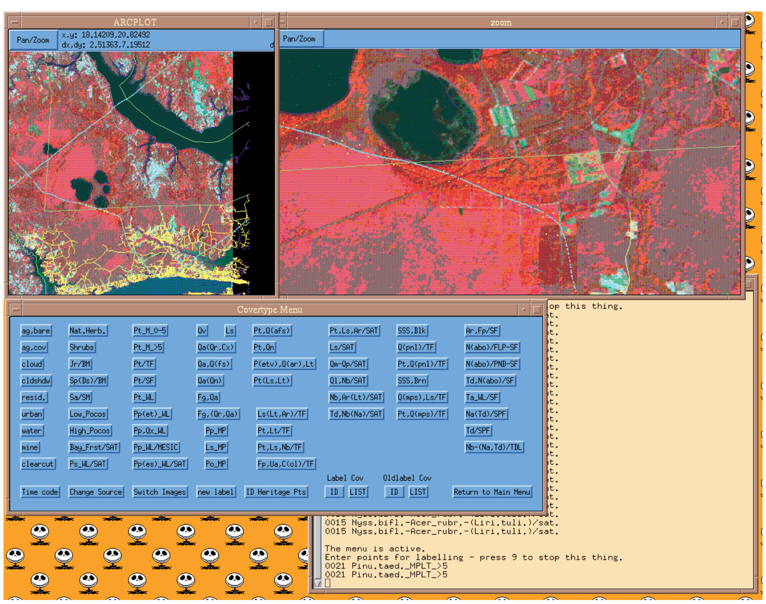

Figure 1

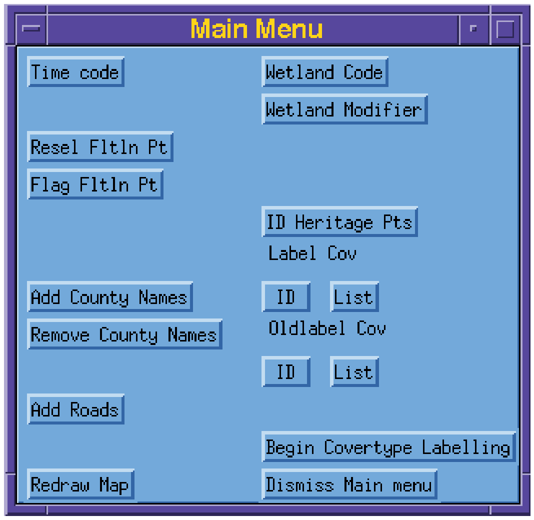

Figure 2. Menu presenting tools to query items in map, add county roads, and select flightline points for groundtruth visits.

Figure 3. Menu presenting an array of commonly labeled covertypes along with several map query tools.

After an interpreting session, the interpreted point text file can be built into a coverage with another AML called LABEL2COVER.AML. This point coverage, with all the attribute information, can be drawn up in the next interpreting session. We have also developed an AML (ASC2FLTLN.AML) to convert the ASCII output from TRIMBLE's PFINDER into a flightline coverage complete with the necessary attribute structure.

These AMLs have proven to be useful for the handling of video data and interpretation because they allow us to apply consistent labels rapidly through the use of menus without having to memorize and use excessive command line instructions. You can download these files from our anonymous FTP server at:

host: ftp.ncgap.ncsu.edu
login: anonymous
password: <your_email_address>
directory: /out/interp_files/

Steve Williams
North Carolina State University, Raleigh

Using GAP for Nonpoint Water Pollution Management

The Louisiana Department of Environmental Quality (LDEQ) uses land use data routinely to fulfill federally mandated tasks under the Clean Water Act. Among these tasks are assessing watershed impairment from nonpoint pollution sources and targeting watersheds for best management practices. LDEQ currently relies upon land use data that is outdated, generalized, and/or does not specify crop type. To remedy this, the LDEQ GIS Center is developing a current, digital, agricultural land use data set for the entire state.

A key part of this project is the Louisiana Gap Analysis Project's (LA-GAP) land cover data, which will serve for initial delineation of cropland areas, that will be further categorized into distinct classes of cropping systems. Louisiana Department of Agriculture and Forestry (LDAF) staff is assisting with delineation of cropland areas, and supplemental field information is being sought from other agencies. The final product will include a polygon coverage of agricultural fields, associated attribute data (crop type, etc.), and metadata. Rapides, Madison, and Cameron parishes have been selected as areas for method development. The GAP agriculture/cropland/grassland class was overlaid on the SPOT-TM merged imagery, and printed maps were distributed to LDAF field personnel for attribution. These maps have been attributed and returned to LDEQ and are now being examined for necessary corrections. An initial classification scheme is being developed based on the level of detail and type of information that LDAF will be able to provide. Of all the available base data sets for agriculture areas, the LA-GAP vegetation layer was chosen because it is the most recent and appears to be the most accurate. Some smoothing and generalizing of the LA-GAP polygons will be advantageous to provide a more workable base data set. The contact person for LDEQ is Aimee Preau; the LA-GAP project contact is Steve Hartley.

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Steve Hartley
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Enhancing TM with 10-Meter SPOT in Louisiana

For land cover mapping of Louisiana, data from the Landsat Thematic Mapper (TM) satellite was merged with satellite data from Le Système Pour l'Observation de la Terre (SPOT) to create a composite image of the entire state (Braud 1997). The merged image acquires the advantageous features of both spectral and spatial resolution. TM imagery is multispectral—detecting energy intensities (brightness) of seven discrete bands in the visible and infrared wavelengths of the electromagnetic spectrum. The SPOT imagery utilized for this merger is panchromatic—a black and white single band spanning the full visible range of the spectrum. TM imagery has a spatial resolution of 30 meters, while SPOT panchromatic imagery has a spatial resolution of 10 meters. When the two data sets are combined, the resulting image appears as a color 10-meter image, acquiring the multispectral feature of TM and the higher spatial resolution of SPOT. The new enhanced imagery allows data users to discriminate linear features such as fence rows, roads, pipelines, canals, and bayous smaller than the original 30-meter TM data. Another advantage of the merged data set is the increased accuracy in locating shoreline boundaries.

The process uses a red, green, and blue (RGB) composite of band 4 (near-infrared), band 5 (mid-infrared), and band 3 (red visible) from the TM and the SPOT panchromatic data. Global and local histogram functions were applied to the data prior to merging. After merging, the images were reduced from three-band, 24-bit files to a single 8-bit file that retains the true color fidelity of the composite color image. The 4, 5, 3 TM band combination provides the greatest degree of vegetation discrimination. The merged images are paneled in 30x30-minute tiles equivalent to 16 USGS 7.5-minute quadrangles, 100k USGS quadrangles, and parishes. The TM data were acquired during the winter of 1992-93, and the SPOT data were acquired during the time period of 1990-95. The data are projected to UTM Zone 15, Clarke 1866 ellipsoid, NAD 27 datum. The SPOT-TM files are stored as GEO-TIFFs and can be viewed with most graphics software programs.

For more information on data distribution, visit the Louisiana Department of Environmental Quality's web site (http://gis.deq.state.la.us). The U.S. Geological Survey's National Wetlands Research Center is currently developing a 3-volume CD of the SPOT-TM merged imagery that will include a mapping software package for viewing the data. This image-merging technique can be used with the next generation of Landsat imagery since Landsat 7 will include a 10-m panchromatic channel in addition to the 30-m multispectral bands.

Literature Cited

Braud, DeWitt H., Jr. 1997. Satellite view of Louisiana from the merge of Landsat Thematic Mapper and SPOT imagery. Louisiana Department of Environmental Quality and Department of Natural Resources, Baton Rouge, LA, and the U.S. Geological Survey's National Wetlands Research Center, Lafayette, LA.

Steve Hartley
USGS National Wetlands Research Center, Lafayette, Louisiana

Posters at 1998 Annual GAP Meeting

Close to 30 posters were on display at the 1998 GAP conference in Santa Barbara. The posters covered a wide array of GAP-related topics and generated considerable discussion. Following is a listing of the poster titles and authors. Those posters marked with an asterisk can be seen on the GAP home page at http://www.gap.uidaho.edu/gap/AnnualMeetings/1998/Posters/index.htm

Indiana GAP land cover map (S.M. Berta, C.M. Cowell, J. Wilson, and D. Wiseman)

A supervised approach to mapping the natural vegetation of Kansas (C.F. Blodgett, C.L. Lauver, S. Egbert, E. Martinko, K.P. Price, E. Ellis, and J. Riffer)

Applications and limitations of species distribution models for conservation in the Sierra Madre Occidental, Mexico (L.A. Bojorquez)

Habitat suitability of the national forests of Mississippi for the black bear (J.L. Bowman, F.J. Vilella, B.D. Leopold, and H.A. Jacobson)*

Patterns of terrestrial vertebrate richness and fire in the arid and semi-arid Western United States (J. D'Elia and G. Wright)*

Vegetation of the Texas Panhandle (A. Ernst, T.S. Schrader, S. Haskell, C. Gonzalez-Rebeles, N.C. Parker, and Y. Lan)

The 1999 National GAP Meeting: Duluth, Minnesota/Superior, Wisconsin (D. Fitzpatrick)

Creating New York's land cover map: The Adirondack Park as an example (J. Fiore)

Accuracy assessment of forest change detection methods: Problems encountered in accepting forest industry GIS data as reference in the error matrix (D.J. Hayes, S.C. Vermillion, and S.A. Sader)

An example of conservation analysis integrating vegetation cover data and site-specific information on species associated with declining habitats (S. Hall and M. Schafale)

Mississippi avian and herpetological atlases: An integral part of mapping Mississippi vertebrates (C. Reynolds, M.G. Williams, R.B. Minnis, and F.J. Vilella)*

A spatial assessment of the Northern Arizona GAP land cover map (S.R. Jacobs and K. Thomas)

An accuracy assessment of Maine's land cover/land use map (J.A. Hepinstall and S.A. Sader)

Improving ground-truth data collection efforts using ArcView (G. Schairer)*

Interpretation of aerial videography in Western Virginia using ArcView (S. McNulty)*

Comparison of predicted vertebrate species richness and known aquatic insect richness at 36 vernal pools in Virginia (K. Stein)

Is vertebrate richness an adequate umbrella for protecting biodiversity: Spatial correspondence between ants and mammals (C.R. Allen, L. Pearlstine, and D.P. Wojcik)*

Using Gap Analysis information to guide planning for conservation of birds in New York State: A comparison of science-based and expert-opinion approaches (C.R. Smith)

Wildlife habitat and vegetation modeling using general vegetation classes (S.O. West, E.V. Schmidt, F. Smith, and C. Aulbach Smith)*

If you build it, they will come: Making NBII a reality with GAP on the web (M. Herdendorf, T. Kohley, and J. Hamerlinck)*

Increased spatial resolution in primary data: The scale and aggregation problem revisited (O. Ahlqvist)*

Library of digital aerial photography (R.J. Simpson and L. Pearlstine)*

Louisiana Gap Analysis Project (S. Hartley)*

Oregon Biodiversity Project (S. Vickerman)

Elisabeth Brackney
National Gap Analysis Program, Moscow, Idaho

Next Annual National GAP Meeting

The 1999 annual GAP meeting will take place in Duluth, Minnesota, on August 2-6. It will be hosted by the Upper Midwest GAP Project (Michigan, Minnesota, and Wisconsin) and coordinated by Daniel Fitzpatrick. The meeting sessions will be held at the Duluth Entertainment and Convention Center (DECC); accommodations will be available at the Radisson Hotel Duluth-Harborview. Duluth is the gateway to Lake Superior's North Shore and many recreation opportunities.

The meeting is open to GAP investigators, their staff, project collaborators, and others interested in GAP methods and results. Because of the meeting location's close proximity to Canada, we expect a good turnout by our Canadian colleagues. Additional information about the conference and the Duluth area can be found on the GAP home page at http://www.gap.uidaho.edu/gap/AnnualMeetings/Index.htm. A call for papers will be going out soon.

Elisabeth Brackney
National Gap Analysis Program, Moscow, Idaho

Annual Southeast Regional GAP Meeting

Southeast regional GAP participants will be meeting in Athens, Georgia, on February 9 and 10, 1999. The event will be hosted by Georgia-GAP, and most activities will be held at Flinchum's Phoenix, a local retreat and conference center. Information about accommodation, travel, maps of the area, and conference activities can be found at the following GA-GAP home page link: http://greer.ecology.uga.edu/gap/conference.html.

Karen Payne
University of Georgia, Athens

Symposium on Predicting Plant and Animal Occurrences

An international conference on modeling for the twenty-first century, "Predicting Plant and Animal Occurrences: Issues of Scale and Accuracy," is to be held on October 19-22, 1999, in Snowbird, Utah. Fifteen years have passed since Wildlife 2000, new editions of texts have been written on the subject, new technologies and techniques have evolved, and there have been several theoretical advances. The goal is to bring together scientists and managers currently involved with habitat modeling to discuss the state of our knowledge about predicting and mapping species occurrences, examine the theoretical basis for model development, display current applications of modeling techniques, and focus on the future of modeling for wildlife conservation and management on public and private lands. We plan to examine the theoretical basis for model development and discuss current applications of modeling techniques. Our focus will be on the future of modeling to support multiscale landscape planning efforts for wildlife conservation and management. We will address accuracy and scale issues including an examination of the effects of temporal and spatial scale on model effectiveness and on the quality and availability of specific habitat attributes to help broaden our perspective and sharpen our creative thinking. Conference participants will include scientists and managers from around the world.

If you have any comments or questions, please feel free to contact Mike Scott (mscott@uidaho.edu, 208-885-6960), Patricia Heglund (pheglund@uidaho.edu, 208-885-2665), or Kathy Merk (kmerk@uidaho.edu, 208-885-2750). You can also obtain registration information from our web site: http://www.ets.uidaho.edu/coop/1999_symposium.htm.

J. Michael Scott
Idaho Cooperative Fish and Wildlife Research Unit, Moscow, Idaho

Team Award Goes to New Mexico-GAP

In January 1998, the New Mexico Gap Analysis Project received "The Team Award" for 1997 from the College of Agriculture and Home Economics at New Mexico State University. That award acknowledged the overall team accomplishment of the project and specifically recognized the 11 members of the core team while the project was under way.

Bruce Thompson
New Mexico State University, Las Cruces

The Gap Analysis Bulletin is published annually by the USGS Biological Resources Division's Gap Analysis Program. The editors are Elisabeth S. Brackney and Michael D. Jennings. To receive the bulletin, write to: Gap Analysis Bulletin, USGS/BRD/Gap Analysis Program, 530 S. Asbury Street, Suite 1, Moscow, ID 83843, fax: (208) 885-3618, e-mail: brackney@uidaho.edu. A digital version of the Bulletin, containing additional graphics, is available on the Internet at http://www.gap.uidaho.edu/gap/Bulletins/7/index.htm

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