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The Gap Analysis Bulletin is published by the National Biological Service's Gap Analysis Program. The editors are Elisabeth Brackney and Michael D. Jennings. To receive the bulletin, write to: Gap Analysis Bulletin, NBS/Gap Analysis Program, 530 S. Asbury Street, Suite 1, Moscow, ID 83843, fax: (208) 885-3618.

GAP ANALYSIS

Director's Corner

First of all, thanks to everyone for your understanding and patience during this very uncertain budgetary process we are going through. We hope that fiscal year '97 and the transition of the National Biological Service to the U.S. Geological Survey will be much easier.

As more states complete their projects, we will have increasing opportunities to test predictions of vertebrate occurrences at various thematic and spatial scales. We will also be able to examine representation of species and vegetation types in special management areas across their full range of geographical and ecological occurrence. In addition, our maps provide a sampling framework for more detailed mapping of biological structure and function and thus permit us to gather unbiased estimates of these features. Such efforts should contribute greatly to transboundary planning.

The accuracy assessment of GAP products is an important area in which we can, and have, made important contributions. It is important that we report the results of our work on accuracy assessment in the refereed literature (see Edwards et al. In press and 1996). A small workshop involving researchers from several GAP projects as well as from the U.S. Forest Service reviewed current methods used for accuracy assessment and identified those most appropriate for use with regional mapping efforts like GAP. The workshop was convened by Western States coordinator Patrick Crist in Denver this spring. He will report on the results of this meeting at our Key Largo meeting. In addition, we will continue to budget for further work on accuracy assessment issues. A request for proposals to address issues of accuracy, scale habitat relationships, and other topics that test the assumptions and products of GAP will be sent out October 1, 1996.

During the last five years, GAP investigators have developed new techniques for mapping land cover. It's time to review all that has been done. Jim Merchant will be documenting land cover mapping methods used by GAP investigators, comparing the different methods to identify strengths and weaknesses, costs, etc. and will host a workshop in March 1997. We hope that his findings will be useful to new GAP investigators as well as to our second-generation land cover mapping efforts. As one example of the lessons we have learned, recent land cover mapping efforts in New England and the Midwest have identified the importance of multiple dates for satellite coverage as an aid in obtaining more accurate and thematically more detailed vegetation maps. To meet the need for multiple dates, GAP is joining with its other Multi-Resolution Land Cover Consortium partners to purchase triple-date coverage of the coterminous United States. Scenes will be selected from available dates for summer 1995 to summer 1997. We believe that this second joint purchase of satellite scenes will greatly help coordinate interagency mapping efforts to develop a fully integrated, second-generation land cover map for the country. This map will be pixel-based with a MMU of 2 ha, a 50-fold higher spatial resolution than our current standard.

Ross Kiester and others used results of Idaho GAP to examine use of different algorithms to prioritize the selection of locations for conservation action and research and found complementarity rather than species richness to be the more defensible approach (Kiester et al. In press). Blair Csuti, working with research groups in England and Australia and the Biodiversity Consortium in Oregon, came to a similar conclusion based on a collaborative analysis of the Oregon data set (Csuti et al. In press).

Several GAP project investigators are testing the assumptions of the vertebrate models. Bill Krohn and his group are using information from the various accuracy assessments conducted to date to identify those species that we have difficulty reliably predicting, looking for commonality in life history, behavior, and demographics. It is hoped that this information can be used to develop more reliable vertebrate models. Of particular interest are any shared behavioral and/or life history or demographic characteristics that difficult-to-predict species may have.

Craig Allen, Wiley Kitchens, and the rest of the folks with Florida GAP have put together what promises to be a very interesting and stimulating program for the 1996 Annual GAP Meeting as well as some great field trips after the meeting. I look forward to seeing you in Key Largo!

Literature Cited

Csuti, B., P.H. Williams, R.L. Pressey, S. Polasky, J.D. Camm, M. Kershaw, A.R. Kiester, B. Downs, R. Hamilton, M. Huso, and K. Sahr. In press. A comparison of reserve selection algorithms using data on terrestrial vertebrates in Oregon. *Biological Conservation*.

Edwards, T.C., Jr., E.T. Deshler, D. Foster, and G.G. Moisen. 1996. Adequacy of wildlife habitat relation models for estimating spatial distributions of terrestrial vertebrates. *Conservation Biology* 10:263-270.

Edwards, T.C., Jr., G.G. Moisen, and D.R. Cutler. In press. Assessing map accuracy in an ecoregion-scale cover-map. *Ecological Applications*.

Kiester, A.R., J.M. Scott, B. Csuti, R.F. Noss, and B. Butterfield. In press. Conservation prioritization using GAP data. *Conservation Biology*.

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Some Scales for Describing Biodiversity

One of the first principles of Gap Analysis is that the most efficient overall strategy for biological conservation is to complement intensive species-by-species management, necessary for those species now in danger of extinction, with management of habitat types or natural assemblages of plant and animal species that are still relatively common and viable (Scott et al. 1993). Adequate representation of the full complement of natural habitat types within a network of conservation lands is fundamentally required if we are going to conserve plant and animal species in their natural habitats rather than in zoos (Shaffer 1990).

Because of this, the relationships among and between (a) the pattern of dominant land cover types, (b) vertebrate species diversity, and (c) spatial scale are all critical for Gap Analysis. Measures of species diversity must be expressed relative to biogeographic units of a determined spatial scale if they are to be meaningful (Levin 1981). Unfortunately, confusion about the differences between types of diversity ("thematic resolution") and cartographic scale is persistent (e.g., Short and Hestbeck 1995, Davis 1995, Edwards 1995, Scott et al. 1995). Below, I briefly present some nomenclature that is useful when dealing with the issue of diversity and scale.

Whittaker (1960, 1977) suggested seven categories as a framework for describing species diversity in relation to ecological patterns and spatial scale (Table 1). The linkage between types of diversity and spatial scale makes this framework especially useful. Figure 1 (Stoms and Estes 1993) shows how four of these categories ("inventory diversities") are used to describe species diversity within sampling units of four approximate sequential sizes and corresponding with four hierarchical levels of biotic organization: a single ground sampling point (*point diversity*), a natural community (*alpha diversity*), a landscape (*gamma diversity*), and a large geographic region (*epsilon diversity*). Three other terms ("differentiation diversities") are used when comparing the amount of change in species composition between individual sampling points (*pattern diversity*), natural communities (*beta diversity*), and landscapes (*delta diversity*).

Inventory diversities	**Differentiation diversities**
1. *Point diversity*: A small, or microhabitat, sample of species diversity from within an alpha unit. Generally 10 to 100 sq meters.	
	2. *Pattern diversity*: The change in diversity between points within a community.
3. *Alpha diversity*: A single within-habitat measure of species diversity regardless of internal pattern. Generally 0.1 to 1,000 hectares.	
	4. *Beta diversity*: The change in diversity among different communities of a landscape; an index of between-habitat diversity.
5. *Gamma diversity*: The species diversity of a landscape made up of more than one kind of natural community. Generally, 1,000 to 1,000,000 hectares.	
	6. *Delta diversity*: The change in diversity between landscapes along major climatic or physiographic gradients.
7. *Epsilon diversity*: The species diversity of a broad region of differing landscapes. Generally 1,000,000 to 100,000,000 ha.	

Table 1. Levels and types of species diversity (Wittaker 1977, Stoms and Estes 1993).

The minimum thematic object that Gap Analysis is mapping is the Natural Community Alliance (Grossman et al. 1994). This corresponds most closely with the units of alpha diversity (a sample representing a community regarded as homogeneous despite its internal pattern) in order to conduct analyses at the beta, gamma, delta, and epsilon levels. As indicated by between-habitat diversity, a spatial depiction of beta diversity represents the pattern of landscape heterogeneity. For Gap Analysis, the central concept is that the structural and taxonomic characteristics of vegetation or, in the absence of vegetation, dominant land features, can be used systematically to delineate and map patterns of beta diversity. Models of these patterns are important for generating and evaluating landscape-level conservation options.

Literature Cited

Davis, F.W. 1995. The nature of gap analysis. Letter. *BioScience* 46:74-75.

Edwards, T.C., Jr. 1995. Data defensibility and gap analysis. Letter. *BioScience* 46:74-75.

Grossman, D., K.L. Goodin, X. Li, C. Wisnewski, D. Faber-Langendoen, M. Anderson, L. Sneddon, D. Allard, M. Gallyoun, and A. Weakley. 1994. Standardized national vegetation classification system. Report by The Nature Conservancy and Environmental Systems Research Institute for the NBS/NPS Vegetation Mapping Program. National Biological Service, Denver, Colorado.

Levin, S.A. 1981. The problem of pattern and scale in ecology. *Ecology* 73:1942-1968.

Scott, J.M., F. Davis, B. Csuti, R. Noss, B. Butterfield, C. Groves, H. Anderson, S. Caicco, F. D'Erchia, T. C. Edwards, Jr., J. Ulliman, and G. Wright. 1993. Gap analysis: A geographic approach to protection of biological diversity. *Wildlife Monographs* 123.

Scott, J.M., M.D. Jennings, R.G. Wright, and B. Csuti. 1995. Landscape approaches to mapping biodiversity. Letter. *BioScience* 46:74-75.

Shaffer, M.L. 1990. Population viability analysis. *Conservation Biology* 4:39-40.

Short, H.L., and J.B. Hestbeck. 1995. National biotic resource inventories and GAP analysis. *BioScience* 45:535-539.

Stoms, D.M., and J.E. Estes. 1993. A remote sensing research agenda for mapping and monitoring biodiversity. *International Journal of Remote Sensing* 14:1839-1860.

Whittaker, R.H. 1960. Vegetation of the Siskiyou mountains, Oregon and California. *Ecological Monographs* 30:279-338.

Whittaker, R.H. 1977. Species diversity in land communities. *Evolutionary Biology* 10:1-67.

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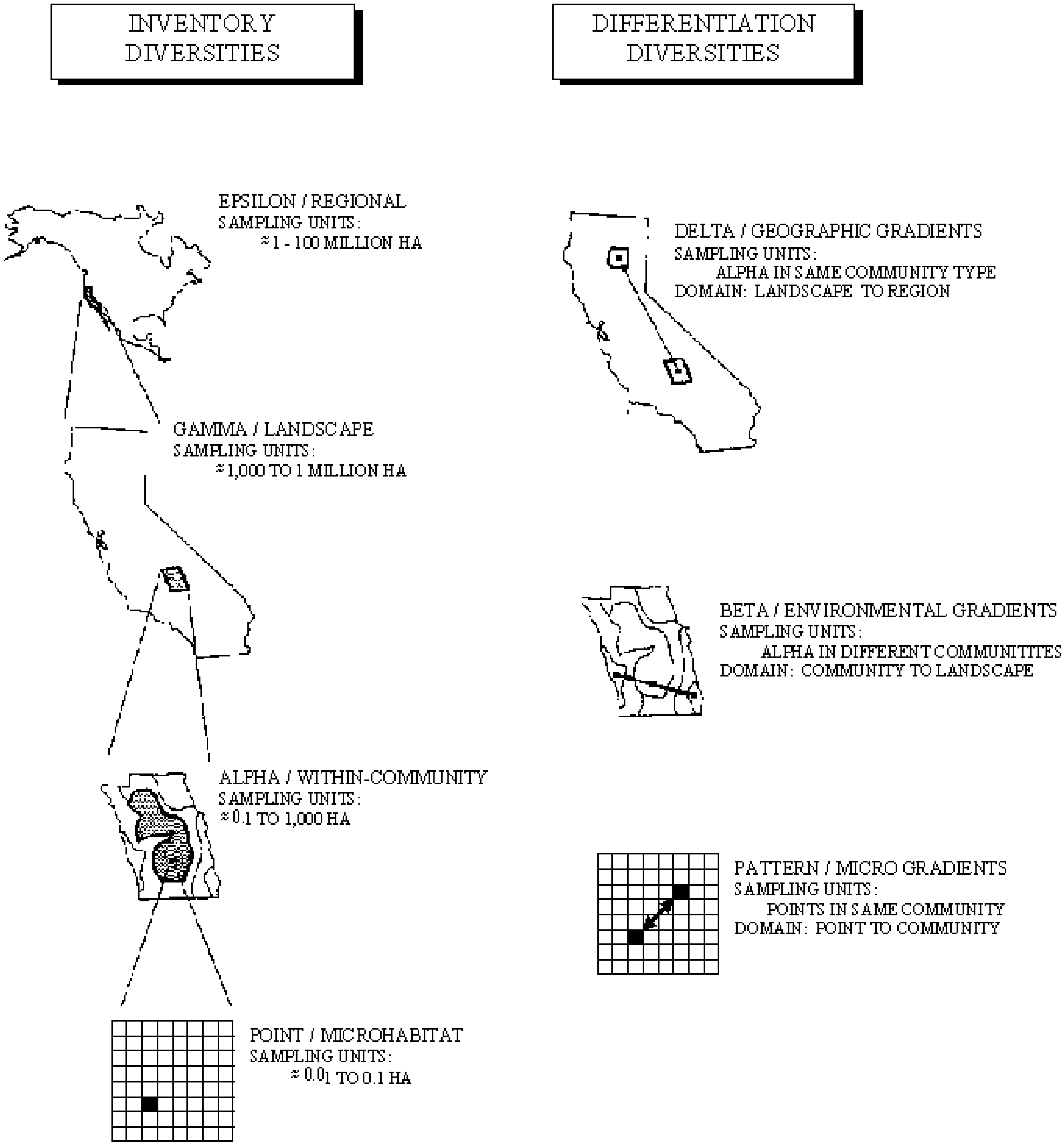

Figure 1. Diagram showing the levels of species richness defined by Whittaker (1977). The icons in the left hand column represent inventory levels of richness, while those on the right show differentitation levels or changes in composition across gradients. Sampling unit sizes indicate the approximate spatial dimensions for each ecological scale. (From Stoms and Estes 1993, with permission.)

GAP Implementation

So where are the gaps, and what should be done about them? When is a Gap Analysis finished, and what constitutes completion? Who are the users of GAP data, and what products do they need to apply the information? These fundamental questions cut to the heart of the Gap Analysis Program as many of the states begin moving from the data gathering and research phase of the program toward implementation.

What is GAP implementation? For the purposes of this discussion, it means application of Gap Analysis results to wildlife and habitat management and land allocation decisions. In the *Draft Recommendations for Implementing Gap Analysis: A Report to the National Biological Service* (Vickerman and Smith 1995), the authors identify three different ways for GAP to be implemented. It can be used in situation-specific applications, in which the data are used to help guide decisions about particular sites or species. It can be integrated into existing land use planning processes already in place and used by local governments and resource agencies. Finally, the information can be used for cross-boundary, ecosystem-oriented landscape-level planning. The authors suggest that this last application potentially makes the greatest contribution to the advancement of biodiversity conservation planning.

Unfortunately, there are few established programs with the responsibility to facilitate cross-boundary planning, although there is increasing interest in ecosystem management, and a number of pilot projects are under way that attempt to consider the broad distribution of ecological resources relative to human activities on the landscape. For example, President Clinton's Forest Plan (FEMAT) addressed all forest lands in the western Cascade Mountains of the Pacific Northwest. The Great Plains Initiative is another multistate effort to restore the biodiversity of the region.

Because of its stated goals, widespread geographic distribution, visibility, broad scale, and impressive list of cooperators from the public and private sectors, GAP is widely seen as an important tool in long-range planning for biodiversity conservation. Wildlife and land managers, policy-makers, private conservation and industry organizations are anxiously awaiting Gap Analysis results to help guide the new, innovative approaches to resource management. Several of these initiatives are described below. The list is not exhaustive, but it provides a few examples of potential applications for GAP data.

Initiated by Defenders of Wildlife, the **Oregon Biodiversity Project** is a public/private partnership working to develop a biodiversity strategy for the state. More than forty cooperators from academia, state and federal agencies, private industry, and conservation groups are involved. Project staff are compiling GAP and other data sets in GIS format to characterize the ecological and socioeconomic landscape and make specific recommendations concerning areas that should receive high priority attention. Emphasis is on the places where there are potential opportunities to accomplish conservation goals in a reasonable period of time and to avoid future "train wrecks." The strategy will be published in atlas format with full-color maps and a poster showing the priority areas in the state. The information will also be produced electronically on a user-friendly CD-ROM.

The **Tennessee Biodiversity Program** was also initiated by the private sector and involves a diverse group of government, academic, and private partners. Given the amount of private land in the state, a strong emphasis is placed on getting information on biodiversity to local land use planners. GAP has helped fund the development of county-level planning guides. The program has also sponsored a series of training workshops for educators and resource professionals.

The **Lower Mississippi Conservation** proposal was initiated by the director of the Tennessee Wildlife Resource Agency, whose vision is to integrate existing conservation efforts focused on species groups (i.e., fish, neotropical migratory birds, bears, and waterfowl) into a conservation plan for the entire lower

Mississippi River Valley. Gap Analysis data could be used to evaluate the distribution of vegetation and habitat types, to address endangered species issues, and to help design the overall strategy. The challenge for this program will be reconciling the different approaches and completion times for nine state GAP data sets.

Another program anxiously awaiting GAP data is the **Klamath Basin Ecosystem Office**. The office supports an interagency effort addressing a broad range of conservation issues in the Klamath province, which straddles the Oregon and California border. GIS data are being compiled at Humboldt State University. The Klamath Project is a high priority of the U.S. Fish and Wildlife Service because of the large number of endangered species and ecological problems in the region. It has a high political profile and could potentially serve as a model for interagency planning at the federal level.

One of the most democratic projects is the **Maine Forest Biodiversity Project**. A large and diverse group of interested parties meets regularly, and has agreed on a mission "to maintain viable representatives of existing native species and communities in Maine." The forest products industry is involved, in addition to academics, conservationists, and public officials. The group is working to identify principles to better maintain biodiversity on managed forest lands and to develop goals and techniques that might be used to achieve them. The focus is on the managed landscape, since most forest land in Maine is used for timber production. Although the project has completed its own biodiversity assessment, GAP data may be used at a later stage.

There are a number of issues common to most of the GAP implementation pilot projects that need to be addressed before Gap Analysis is fully integrated into resource allocation and management decision making. The "completion" timeline is critical. Does GAP provide a snapshot in time, or is it a process that accommodates new and finer-scale information as it becomes available, thereby helping managers implement adaptive management goals? If it is a one-time shot, what constitutes a final product? If it is seen more as a long-term process, then who is responsible for its continued funding and management? Missouri has a unique solution in MoRAP (Missouri Resource Assessment Partnership), designed to collect and update ecological data (including GAP) and socioeconomic information relevant to coordinated resource management planning.

Another important issue concerns the dissemination of information generated by GAP. Who are the target audiences, and what kind of information do they need? Many scientists and resource agencies have the capability to use and analyze electronic GIS data sets. However, most policy-makers, land-use planners, conservation organizations, and the media are more interested in hardcopy map products with spatially explicit recommendations about what areas are most important and why. There has been some understandable reluctance on the part of some principal investigators to provide these recommendations, but decisions are made with or without GAP, so users can become frustrated when the bottom line is so elusive. Utah GAP has produced the most elaborate "products" to date, but the report, CD-ROM, and four maps stop short of identifying specific areas that could be managed to conserve biodiversity.

What socioeconomic information is needed in Gap Analysis, and whose responsibility is it to compile it and integrate it into policy recommendations? Forester et al. (in press) have proposed a process in which "gap locations" are identified first as part of an ecological assessment, then a series of human activities on the landscape are evaluated to help policy-makers establish conservation priorities. Davis (1995) has incorporated a number of socioeconomic factors into an analysis of the Sierra Nevada bioregion. Cogan (1995) is working on models that link county planning and biodiversity indices. Vickerman (1996) describes the Oregon Biodiversity Project, which has collected data on a number of social, economic, and political factors in GIS format to help develop a pragmatic statewide conservation strategy. It is clear, however, that there is no standard approach to the integration of ecological and socioeconomic information in broad-scale conservation planning, and it is not at all obvious who should be responsible for the task.

GAP has gone a long way toward building a national framework for broad-scale analysis of wildlife and habitat conservation needs. It has made great strides in bringing together different disciplines, agencies, and interest groups. But the biggest challenges lie in making sure that the powerful information GAP can provide is ultimately both used and useful. The time to start dealing with implementation issues is now.

Literature Cited

Cogan, C. 1995. California Biodiversity Project: Predicting biodiversity conflicts in California. Unpublished executive summary, 1 pp.

Davis, F.W. 1995. (Personal communication.) Integrating ecological and socioeconomic information in the Sierra Nevada Ecosystem Project. Presentation in Portland, Oregon, June 28, 1995.

Forester, D.J., G.E. Machlis, and J.E. McKendry. In press. Extending Gap Analysis to include socioeconomic factors. In J.M. Scott, T.H. Tear, and F. Davis, editors. Gap Analysis: A landscape approach to biodiversity planning. American Society for Photogrammetry and Remote Sensing, Bethesda, Maryland.

Vickerman, S. 1996. Oregon Biodiversity Project: A cooperative effort to develop a statewide biodiversity management strategy. Unpublished project summary, 30 pp. Defenders of Wildlife, Lake Oswego, Oregon.

Vickerman, S. and K.A. Smith. 1995. Draft recommendations for implementing Gap Analysis. A Report to the National Biological Service. March 1995. 141 pp.

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GAP Implementation Scorecard

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GAP Implementation Scorecard

Try this scorecard to see how prepared your state (or region) is to implement GAP. For each item, pick a number from zero to ten to characterize the current situation:

0 - 2	Not contemplated, no action
3 - 4	Some discussion taking place
5 - 6	Some actions taken, others under consideration
7 - 8	Significant progress has been made
9 - 10	Fully developed and operational

________ GAP data sets for land cover, species distribution, ownership, and management

________ Gap Analysis with spatially explicit recommendations

________ Socioeconomic factors identified and incorporated into recommendations

________ Agreement for long-term updating, management of data sets

________ User-friendly products and easy electronic access to data and GAP results

________ Public involvement opportunities, training, and outreach (i.e. citizens' monitoring)

________ Effective integration into multiscale planning

________ Statewide and/or bioregional planning framework

________ A willingness to consider biodiversity; a demand for the information

________ Funding available for implementation (i.e. landowner incentives, acquisition funds)

________ Total

Where do you rate?

0 - 25	Long, dusty road ahead
26 - 50	Good potential
51 - 75	Biodiversity has a chance
76 - 100	You must be dreaming...go back and recalculate

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The Indiana Gap Analysis Metaproject Approach

Introduction

Gap Analysis offers a science-based approach for evaluating biodiversity at regional and continental scales and for providing data necessary for the development and application of biodiversity management strategies (Scott et al. 1993). From the inception of the Indiana project, we recognized a design need for applications at a scale finer than continental. We have begun to address the challenges of implementing Gap Analysis by initiating cooperation with the principal Indiana natural resource agencies and key Indiana nongovernmental conservation organizations through the metaproject approach.

In part because of the importance of wetlands within the Indiana landscape, many of our initial metaproject proposals include a wetlands component. Whatever the focus (wetlands, forests, contaminants, agricultural land), an important consideration in implementing metaprojects is the evaluation of the utility of the Gap Analysis methodology. Particularly, its application to development and implementation of a landscape-scale conservation and restoration framework in Indiana has to be considered.

Indiana Landscape

In Indiana, nearly 80% of the nonfederal land (about 98% of the total) is used for cropland, pasture, and development. In Ohio, cropland, pasture, and developed land accounts for nearly 70% of the nonfederal land (about 99% of the total) and in Illinois nearly 88% of the nonfederal land (99% of the total). The figures for Kentucky and Michigan are approximately 54% and 46%, respectively (U.S. Bureau of Census 1993). Modification of the landscape on this scale produces some clearly identifiable problems related to biodiversity: 1) a human-dominated landscape, 2) habitat fragmentation and pollution (Steadman 1991), and 3) isolated populations of naturally occurring plant and animal species with many species depauperate of genetic diversity (Soulé and Wilcox 1980).

Wetlands (but also savannas and prairies) in the Midwest have been especially impacted by anthropogenic changes. Estimates of pre-settlement wetlands and information from the FWS National Wetland Inventory (NWI) suggest that Indiana has lost approximately 1.4 million ha or 86% of pre-settlement wetlands (IDNR 1989). The FWS compiled the following wetland loss estimates for the states surrounding Indiana: Illinois - 85%, Ohio - 90%, Kentucky - 81%, Michigan - 50% (Dahl 1990). Wetlands, moreover, have particular significance for biodiversity. A strong relationship exists between wetland loss and species listed as threatened or endangered. A 1991 National Wildlife Federation report indicates that 43% of the 595 plant and animal species listed by the U.S. Fish and Wildlife Service (FWS) as threatened or endangered in 1991 depend on wetlands (Hair et al. 1992).

Wetlands in Indiana and in the Midwest in general have been and still are key components for biodiversity in both the pre-settlement and modern landscapes. Approximately 2.3 million ha (5.6 million acres) of wetlands covered nearly 25% of Indiana before European settlement in the early part of the 19th century (IDNR 1989). Our experience has been that wetlands protection efforts, as an example of ecosystem level management, have proved to be expensive, difficult, and of questionable success.

Indiana Gap Analysis Metaprojects

Metaprojects are applications of Gap Analysis methodology or data in conjunction with data developed for a specific conservation project or group of projects. Metaprojects are sponsored by cooperating organizations that benefit from the infrastructure and data that exist as part of Indiana Gap Analysis. The fundamental concept is one of synergy among the Indiana GAP Project and partners interested in addressing landscape-scale problems of conservation or restoration.

The metaproject approach has some defined goals. These include establishing cooperative efforts to:

1. "jump-start" the application of the Indiana Gap Analysis methodology and data;
2. serve as pilot projects to evaluate Gap Analysis methodology and data in Indiana;
3. produce products useful in the conservation and restoration of Indiana's biodiversity;
4. solidify partnerships within and outside the Indiana conservation community.

Numerous Indiana Gap Analysis metaprojects are under way or in planning stages. Three metaprojects that reflect the Indiana landscape and the Indiana Gap Analysis approach to biodiversity problems are presented below.

The Nature Conservancy (TNC) Bioreserve Metaproject involves a cooperative effort to provide a landscape analysis of two of TNC's "Hoosier Landscapes." The Blue River in southern Indiana and the Pigeon River in northeastern Indiana are associated with important wetland habitat. Both are areas preliminarily identified by TNC as important for preserving biodiversity in Indiana. Indiana Gap Analysis will provide data through this metaproject to further evaluate TNC's assumption and to enable TNC land managers to approach management on a landscape scale. Cooperative analysis of data with TNC and other partners will function as a pilot for future statewide analysis.

A second metaproject applies a landscape approach to the FWS "Partners for Wildlife" wetland restoration program. The study area for this metaproject encompasses most of the Eel River watershed in north central Indiana. The goal of this pilot project is to identify restorable drained wetlands by watershed, using a combination of satellite imagery and ancillary data. This approach may improve efficiency and effectiveness of wetland restoration. Preliminary results of this project suggest that evaluation of satellite imagery in conjunction with ancillary data can identify poorly and very poorly drained sites. In addition, using the GIS, these data can be placed in context with important habitat features (Mausel et al. 1995).

The third Indiana Gap Analysis metaproject applies the Indiana Gap Analysis methodology and data to an environmental contaminants problem in southern Indiana. GIS is being used to plot the location of contaminants in the physical environment and to model their movement through the biota of several streams in five Indiana counties. Most of the data have been entered into the GIS, and preliminary analysis is under way. This project functions principally to evaluate the utility of the Gap Analysis Project vis-a-vis contaminants issues. Contaminants are ubiquitous in the environment, and the GAP methodology may be particularly useful in this area.

Conclusion

The natural landscape continues to change rapidly under the influence of human development. Biodiversity measured at both the species and ecosystem levels reflects a precipitous decline over the last 200 years (The Keystone Center 1991). Most existing efforts to protect species or even ecosystems lack sufficient breadth to protect and restore remaining biodiversity.

We propose to use Gap Analysis as an integral part of developing the requisite information to formulate the Indiana Landscape Protection and Restoration Framework (Indiana Biodiversity Vision Group's 1996 meeting to develop Phase I, Biodiversity Vision of an Indiana biodiversity protection framework; Bennett et al. 1995). What is more, the Indiana Gap Analysis Project has formalized an approach to implement restoration and protection efforts at a landscape scale. The metaprojects under way with various partners seem to be more efficient (cost effective) and efficacious than existing more traditional approaches.

Literature Cited

Bennett, J., J. McElfish, A. Bale, and R. Fischman. 1995. Indiana's biological diversity: Strategies and tools for conservation. Environmental Law Institute, Washington, D.C. 78 pp.

Dahl, T.E. 1990. Wetlands losses in the United States 1780's to 1980's. U.S. Dept. of the Interior, FWS, Washington, D.C. 21 pp.

Hair, J.D., S.L. Newsome, and J.S. Feierabend. 1992. Endangered species, endangered wetlands: Life on the edge. National Wildlife Federation, Washington, D.C. 49 pp.

Indiana Department of Natural Resources, Division of Outdoor Recreation. 1989. Wetlands . . . Indiana's endangered natural resource: An appendix to Indiana outdoor recreation. IDNR, Indianapolis, Indiana. 19 pp.

The Keystone Center. 1991. Final consensus report of the Keystone policy dialogue on biological diversity on federal lands. The Keystone Center, Keystone, Colorado, 96 pp.

Mausel, P., X. Yang, H. Guo, and Y. Sohn. 1995. Wetland reclamation in the Eel River watershed of NE Indiana. Unpublished Report. Indiana State University Remote Sensing Lab, Terre Haute, Indiana. 30 pp.

Scott, J.M., F. Davis, B. Csuti, R. Noss, B. Butterfield, S. Caicco, C. Groves, J. Ulliman, H. Anderson, F. D'Erchia, and R.G. Wright. 1993. Gap analysis: A geographic approach to protection of biological diversity. Wildlife Monographs 123:1-41.

Soulé, M.E. and B.A. Wilcox, editors. 1980. Conservation biology: An evolutionary-ecological perspective. Sinauer Associates, Sunderland, MA. 395 pp.

Steadman, D.W. 1991. Extinction of species: Past, present, and future. Pages 156-169 in R.L. Wyman, editor. Global Climate Change and Life on Earth. Routledge, Chapman, and Hall, New York.

U.S. Bureau of Census. 1993. Statistical abstract of the United States: 1993 (113th edition). Washington, D.C. 1009 pp.

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Expanding Roles for Gap Analysis Data in Arkansas

In Arkansas, the Center for Advanced Spatial Technologies (CAST) is just completing the production phase of Gap Analysis and will soon be entering the distribution and implementation phase. Efforts are now being directed to the usability of the Arkansas Gap Analysis data, for which the Utah Gap Analysis' prototype CD-ROM package provides an excellent sample methodology. This article concentrates on some extended uses of Arkansas Gap Analysis (AR-GAP) data in the private sector and some methods of information dissemination.

In Arkansas and many other states, Gap Analysis can be much more than "the only land cover mapping game in town" (Loveland 1995); it has the potential to establish or contribute to a framework that fosters statewide communication, data sharing, and exchange (Davis 1995). The National Spatial Data Infrastructure (NSDI) promotes the realization of data-sharing networks by providing policies and standards for transfer, production, and management of geospatial related data and technologies (see "The National Spatial Data Infrastructure" on the Web at http://fgdc.er.usgs.gov/nsdi2.html). Data sharing delivers obvious advantages of cost savings, efficient decision making, and communication among participating organizations. Nedovic-Budic (1995, p. 670) suggests that NSDI may likely follow a "bottom-up approach, building on local and already-established partnerships." Conceived as a bottom-up approach, Gap Analysis relies heavily on support from local state-level partnerships. The spirit of cooperation and sharing inherent in GAP provides an appropriate association with NSDI's mission.

As is the case in other states, AR-GAP is now serving as a mechanism for exchange of data among both private and public entities. AR-GAP, in its early development, forged institutional linkages first among mostly public organizations (Dzur et al. In press). Now, as map products from AR-GAP are being completed, those linkages are expanding to private sector organizations. Some reasons for use of Gap Analysis data by new organizations outside the initial Gap Analysis partnership structure are likely due to timing and acceptance of the technology. When Gap Analysis began in Arkansas, few organizations knew anything about the project. Moreover, few organizations knew much about the emerging technologies of Geographic Information Systems, Global Positioning Systems, and remote sensing. Today there is more awareness of both technology and Gap Analysis.

One of the first applications of GAP data by a private organization emerged from a previously established partnership with the Arkansas Highway and Transportation Department (AHTD). CAST supplied spatial data to an AHTD contractor for application as a framework for defining some EIS mapping goals. Their mapping goals emphasized forested wetlands, emergent vegetation, other wetland cover types, and ponds. Weyerhaeuser is another private entity using AR-GAP data products.

Weyerhaeuser manages close to 850,000 acres of forested land in Arkansas. GAP data were first acquired from CAST's digital spatial data catalog by Weyerhaeuser headquarters in Tacoma, WA. According to Scott Needham, "Our role here at Weyerhaeuser is to facilitate the procurement of spatial data and to redistribute it to our customers, the tree farm operations." In addition to some basic statewide data sets including land forms, geology, soils, and basins, AR-GAP ownership boundaries and spectrally clustered TM data were redistributed to Gary Arpin, GIS Analyst for Weyerhaeuser in DeQueen, AR. According to Arpin, the spectral data provide a regional perspective and show good correspondence with Weyerhaeuser's stand data. Although their pine plantations are identifiable from the data, Weyerhaeuser is not using spectral data for operational use since they rely on finer-scale digital aerial photo data. However, the ownership data are used on field maps. Weyerhaeuser officials acknowledge that data collection can be costly, and welcome organizations such as CAST that maintain digital spatial data archives. Monitoring the digital spatial data catalog via the World Wide Web (WWW) (see "Catalog of

Digital Data Available from CAST" at http://www.cast.uark.edu/local/catalog/arkansas), Weyerhaeuser officials indicated an interest in long-term analyses including mill-route surveys and school district level analyses that take advantage of some of CAST's other archived digital data layers.

CAST has been involved in stimulating and coordinating GIS development throughout Arkansas. The information exchange with both Weyerhaeuser and the AHTD contractor was of a traditional "one-way" and "one to one" mode. CAST is exploring other ways of making these data layers available to a wide array of persons and organizations over the WWW. Starting with a simple example of remote computing, the GIS Interactive Mapper home page (see http://www.cast.uark.edu/products/MAPPER/) will allow users to select a geographic region and produce maps with any combination of layers (raster, vector, and site data) available in the digital spatial data catalog. The resultant map can then be displayed on screen or downloaded to a remote site as a postscript file or gif image. While relatively simple and limited, Interactive Mapper fosters "one to many" information exchange that encourages exploration of a wide assortment of data sets, including GAP products, in an easy-to-use electronic environment.

The exact roles and permanent homes of state-level GAP data sets still require further investigation at both state and national levels. Development at the national level can be seen on the horizon with the advent of the National Biological Information Infrastructure (NBII). Taking a cue from NSDI, "NBII will provide information on and access to biological databases, information products, directories, and guides maintained by Federal, State, and local government agencies, and private organizations" (see "National Biological Information Infrastructure" at http://www.nbs.gov/nbii/ on the WWW).

Leadership at the state level is likely to come from a variety of sources including state universities and state agencies. In Oklahoma, for example, Senate Bill 722 was passed into law in 1994 and directs the Oklahoma Conservation Commission to develop a strategic plan for the implementation of GIS in state government (Danger 1995). The commission's stated objectives are to maximize data sharing between state agencies to avoid duplication of effort while improving public access to information (Danger 1995). Collaboration among agencies, private organizations, and nongovernmental organizations will be instrumental for achieving the mutual benefits of a distributed network of geospatial and biological information sources. Gap Analysis will likely hold a pivotal position in the network of data distribution helping to reduce the obstacles to public data access.

Gap Analysis has served as an "information catalyst" for natural resource professionals (Jennings 1995). Moreover, government downsizing underscores the important role of GAP as information catalyst and stimulus for private and public cooperation. Wide distribution and use of GAP data will help address some important issues, such as "How do we manage our biological resources and avoid crises?" To do so necessitates a broader understanding of relationships occurring at multiple scales of biotic organization and physical extent. New relationships and ideas may be formed and discovered through innovative applications of these data sets. "Where does Gap Analysis data end up?" Hopefully, it "ends up" in the hands of those people who need it most: regional planners, scientists, managers, educators - whoever can use, refine, and ask questions of the data to gain greater understanding.

Literature Cited

Danger, J. "Exhibitors demonstrate technology on 'GIS Day'." The Journal Record (Oklahoma City). April 6, 1995.

Davis, F.W. 1995. Information Systems for conservation research, policy, and planning. BioScience Supplement 1995, 45:S-36 - S-42.

Dzur, R.S., M.E. Garner, K.G. Smith, and W.F. Limp. In press. Gap Analysis partnerships for mapping the vegetation of Arkansas. Gap Analysis: A landscape approach to biodiversity planning. Proceedings of the ASPRS/GAP Symposium, February 27 - March 2, 1995, Charlotte, North Carolina.

Jennings, M.D. 1995. A Discussion of the adoption and diffusion of Gap Analysis as a technical innovation. Gap Analysis Bulletin No. 4.

Loveland, T. Keynote Address. Fifth Annual GAP Investigators Meeting. Fayetteville, Arkansas. August 8, 1995.

Nedovic-Budic, Z. 1995. Mechanisms for coordinating development and use of GIS databases: A research framework. Urban and Regional Information Systems Association (URISA) Proceedings, July 16-20, 1995. San Antonio, Texas.

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MRLC Update and New Rules for TM Access: The Landsat Program Management Agreement

Multi-Resolution Land Characteristics Consortium

In 1993, the Gap Analysis Program (GAP), together with four other federal programs, formed the Multi-Resolution Land Characteristics Consortium (MRLC) to create a venue for addressing issues related to land cover mapping. In 1995, the MRLC was formally recognized via a Memorandum of Agreement between the partner programs' parent agencies, including the National Biological Service (NBS), Geological Survey (USGS), Environmental Protection Agency (EPA), and the National Oceanic and Atmospheric Administration (NOAA). The goals of the MRLC include the generation of a flexible land characteristics database for the conterminous United States that meets the diverse needs of many users. The MRLC partners shared common requirements for a source of satellite data, preprocessing, spectral clustering, and ancillary data acquisition as well as data management, archiving, and distribution.

The MRLC partners could not afford to purchase the data from the Earth Observation Satellite Company (EOSAT) individually. Through the MRLC partnership, the joint purchase of Thematic Mapper (TM) imagery resulted in a direct saving of 4 million dollars with subsequent savings for image processing and data management, totaling 26 million dollars. USGS's EROS Data Center (EDC), a partner in the MRLC, is responsible for the execution of image processing and database management.

In February 1996, EDC completed processing the MRLC TM image data. Metadata for the TM imagery can be viewed using USGS's Global Land Information System (GLIS) which can be accessed via the MRLC home page (see "Multi-Resolution Land Characterization Consortium" on the Web at http://www.epa.gov/docs/grd/mrlc). Future TM imagery purchases by the MRLC partner programs will be directed toward expanding the multitemporal aspect of the original TM database and selecting satellite imagery for the "next generation" MRLC data set.

In order to build a flexible national land cover database of multiple spatial and temporal resolutions, the MRLC is pursuing better integration of the land cover projects that are being carried out by its members. Recently, MRLC completed a classified land cover mosaic encompassing the states of Pennsylvania, West Virginia, Virginia, Maryland, and Delaware. Produced by USGS's EROS Data Center using the MRLC TM imagery, this regionally-based land cover has 12 thematic classes. Our goal is to link this thematically coarser land cover data set with a seamless GAP vegetation layer for the mid-Atlantic states. This is a pilot project, and other regional land cover projects are planned. This thematically coarser but spatially more extensive land cover data set illustrates the importance for the GAP state projects throughout the country to agree on methodologies to successfully "edge-match" their land cover data with those of their neighboring states. The regional land coverages, linked with the GAP vegetation data, will be combined to form seamless multiresolution land cover data sets for the conterminous United States.

Landsat Program Management Agreement

The MRLC data purchase from EOSAT Corp. was bound by the terms and conditions of the original 1993 agreement. These terms and conditions limited MRLC TM data access to the partner programs and their cooperators. However, under the June 30, 1995 Landsat Program Management (LPM) Agreement between EOSAT, NASA, NOAA, and USGS, the original terms of the MRLC data purchase have become less stringent. This new agreement expands the availability of the MRLC Landsat data sets (original raw data from EOSAT and the terrain-corrected data) beyond the partner programs if certain conditions outlined below are met.

The LPM Agreement established the U.S. Government and Affiliated User (USGAU) purchaser group with EOSAT. The agreement defines the USGAU as "U.S. Government agencies; U.S. Government contractors; researchers involved with the U.S. Global Change Research Program and its international counterpart program; and other researchers and international entities that have signed with the U.S. Government a cooperative agreement involving the use of Landsat data for noncommercial purposes." Under the 1995 agreement, the USGAU will have unrestricted rights to reproduce and redistribute, within the USGAU, all unenhanced Landsat TM data purchased by the USGAU for noncommercial use, which includes future and previously purchased data by the USGAU, including the MRLC data.

This is taken to mean that all federal agency programs and their affiliates now have access to both the original 7-band data as well as the preprocessed data. Users must pay for the cost of reproducing the data at the EROS Data Center, which is about $70 per scene. While the MRLC TM database is not a classified land cover product, it is a data set that many programs are utilizing to work on land cover throughout the country. Expanding the availability to other qualified users will further efforts to develop consistent approaches to land cover classification and accuracy assessment and lead to establishing a framework for integrating multiresolution data sets into a national database structure.

For additional information about eligibility under the USGAU and the availability of the MRLC TM image data, contact Kent Hegge, EROS Data Center, at (605) 594-6976 or hegge@edcserver1.cr.usgs.gov.

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The Ecological Society of America's Vegetation Classification Panel

Changes in the natural resources fields (e.g., a shrinking natural resources base, societal shifts in values, etc.) are resulting in demand for an "ecosystems" approach to research, planning, and management (Jennings 1995). Yet, until recently, there was not a consistent set of defined categories for naturally occurring assemblages of species (Orians 1993) that can be reliably used as building blocks for characterizing ecosystems at alpha, beta, delta, and gamma scales of diversity (sensu Whittaker 1960, 1977). There has never been as much land cover mapping activity in the U.S. as there is today. Although the GAP state projects are the principal source of the increase, GAP overall is but one of several major efforts. With all this activity, the development of a broadly accepted classification system that is maintained within a scientific peer-reviewed arena and recognized by government agencies is critical.

At the Ecological Society of America's (ESA)1994 meeting, an ad hoc group of members met to discuss the circumstance of and need for a standardized vegetation classification system. This led to the establishment by ESA of a standing panel on vegetation classification, made up of about 20 ESA members and several nonmember experts. The panel is working under the aegis of and with staff support of the ESA Sustainable Biosphere Initiative (SBI).

The panel's mission is to provide a standardized, scientifically credible North American vegetation classification system, given the following objectives:

- provide a neutral forum for the review and discussion of vegetation classification;
- set standards for hierarchical structure, nomenclature, and definitions for a North American vegetation classification;
- establish a process for modifying the system as knowledge advances;
- establish a peer-review process for recognizing natural communities and natural community alliances;
- identify areas for further research and development;
- provide broad public access to a standardized North American vegetation classification system.

The panel held its first full meeting at the 1995 conference of the International Association for Vegetation Science and began by reviewing the standards being proposed by the Federal Geographic Data Committee's Subcommittee on Vegetation Classification (FGDC-VC). In summary, the ESA panel suggested that FGDC-VS adopt the following language regarding purpose and policy:

"The purpose for these standards is to foster consistency, precision, and clarity in the structure, labeling, definition, and application of a systematic natural land cover taxonomy for the United States. Consistency, precision, and clarity are critical for effective and efficient decisions about resources where the focus is on complex natural assemblages of biotic organisms.

These standards are intended for use by both federal agencies and other user groups, including those engaged in land use planning or management by county and state governments, teaching or research, and uses by the private sector. Widespread use of these standards will facilitate integration of land cover data collected by diverse users into a common national database, enhancing utility beyond single projects and establishing a long-term framework for the nation's natural land cover information."

The ESA panel went on to comment on and suggest changes to the assumptions, guiding principles, definitions, structure, requirements, and procedures for reaching closure on standards that were then being proposed by FGDC-VS.

At the panel's last meeting (March 17-19) agreement was reached to propose that ESA take lead in establishing the following:

- a standardized terminology for the floristically-based taxonomy and classification of natural communities and alliances of natural communities;
- a database network for all available plot and stand data from which statistical descriptions of natural communities and alliances can be compiled;
- a peer-review process for recognizing the names and attributes of natural communities and alliances, resulting in a brief standardized monograph for each type.

Descriptions of each of these components are now being developed and will be presented to the general membership at the annual ESA conference in August. For more information, contact Bruce Kahn at the SBI at bruce@esa.org or call (202) 833-8748.

Literature Cited

Jennings, M.D. 1995. A confluence of biology, ecology and geography for the management of biological resources. The Wildlife Society Bulletin 23:658-662.

Loucks, O.L. 1996. 100 years after Cowles: A national classification for vegetation. Bulletin of the Ecological Society of America 77:75-76.

Orians, G.H. 1993. Endangered at what level? Ecological Applications 3:206-208.

Whittaker, R.H. 1960. Vegetation of the Siskiyou mountains, Oregon and California. Ecological Monographs 30:279-338.

Whittaker, R.H. 1977. Species diversity in land communities. Evolutionary Biology 10:1-67.

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Landscape Information Infrastructure in Pennsylvania

Statewide spring/summer coverage of Landsat Thematic Mapper (TM) data provided through the Multi-Resolution Land Characteristics Consortium (MRLC) is the foundation of the Pennsylvania-GAP landscape information infrastructure. This foundation consists of hyperclusters which are built with the ISODATA facility of ERDAS Imagine. First, every pixel in each scene is distributed directly among a set of 255 clusters, with no sampling whatsoever. Then complete bandwise signature information is compiled in conjunction with the clustering, and this is used to compute relative brightness measures for visible, infrared, and greenness.

Those brightness values permit us to construct cluster image mosaics across scene boundaries. The clusters, with their tables of averaged spectral attributes, permit us to render generalized image reconstructions—which are export-compatible with the ARC/INFO Grid facility and are free of proprietary restrictions on redistribution. Statewide cluster images will be transferred to CD-ROM as a distribution medium and made available on a cost recovery basis for production of the CD-ROMs. These cluster images preserve visual landscape pattern and are free of thematic focus.

The tables of scenewise cluster properties are kept separate from the CD-ROM on diskette, which permits the tables to be augmented as we proceed with landscape interpretations of the clusters. The first such augmentation is a text-field characterization for each cluster. Next follows cluster categorization according to a modified UNESCO classification of land use/land cover which is substantially compatible with Anderson. This is a northeastern states adaptation of physiognomy and formation levels from a provisional scheme set forth by The Nature Conservancy (TNC). Landscape interpretations of clusters are formulated photointerpretively using the suite of facilities available in ERDAS Imagine.

Floristic categorizations of forest clusters are then assembled as separate relational tables keyed to each cluster. Reference to supplemental information sources and assistance of cooperators is required in the floristic interpretation phase. The base floristic categorization will reflect Society of American Foresters cover types as a point of departure for classification of alliance types. It has been determined that spatial (patchwise) specificity comes later in the analytical scenario.

The first step toward patchwise specificity is contiguity-controlled spatial filtering to merge cluster patches less than one hectare with larger neighboring patches. Another reason for preferring ISODATA clusters is that their numbering and initiation protocols induce strong correlation between cluster number and multispectral composite brightness. Since major land use/land cover differences find expression in composite brightness, attribution criteria for spatial merger can be satisfactorily handled in terms of cluster numbers for micro-patch suppression.

After imposing a one-hectare minimum on patchwise occurrence of clusters, the clusters are next vectorized via the Vector module of Imagine. Imagine is particularly advantageous in this regard by virtue of using the same vector format as ARC/INFO and supporting interactive image-based editing of such coverages. The commonality extends to virtual identity of "Clean" and "Build" operations. The initial attributes for polygons are scene ID and cluster number. These, in turn, serve to index the relational tables of cluster properties and scene metadata.

Floristic categorization is obtained from "multiway" analysis. Categories for recognition are determined from cluster characterizations. Training sets and signatures are obtained directly from the TM image data classified at the pixel level in supervised mode. A supervised strategy is also used to label clusters by classifying the cluster's mean vectors. The map of labeled clusters and the direct supervised classification are then differenced in terms of category numbers. Where the difference map is zero, there is local agreement between cluster-based classification and direct supervised classification. Nonzeros in the difference map indicate localities of disagreement and thus uncertainty. Overlaying the cluster-patch polygons on the difference map shows problem areas for classification. These are investigated with the help of cooperators to determine how GIS variables can be used to formulate rules of reclassification that will treat landscape settings selectively. Appropriate GIS variables are transferred by overlay as cluster-polygon attributes. Reclassification takes place on a polygon-by-polygon basis via ARC/INFO macros. Any remaining problems are resolved by direct interactive editing. Since the rules of reclassification represent elements of landscape understanding, they are saved in text form as well as the AMLs.

Following vegetation analysis, any additional site-level GIS variables required by vertebrate habitat models are also transferred by overlay as attributes for the respective cluster-patch polygons. What results from this phase is a one-hectare minimum database of polygonal landscape segments corresponding to patches of clusters. Since more than one cluster may occur in a particular vegetation class, polygon boundaries are not necessarily vegetation boundaries. To produce a vegetation map, the polygonal database is processed to dissolve boundaries between polygons having the same attribute. This set of "cluster-patch" polygons, then, constitutes the primary framework for the landscape information infrastructure.

Next comes a series of criterion-based polygon aggregations to a coarser scale. The scale change factors, in terms of minimum polygon size, are 5-hectare, 10-hectare, 20-hectare, and 100-hectare minimum levels. One objective in this reductive rescaling is to retain a visual semblance of landscape pattern, corresponding to views from increasing altitudes. Selected mixture and diversity attributes due to rescaling will be computed and entered in polygon attribute tables (PATs). When transferred from coarser to finer scales, such attributes provide vicinity context.

Scale generalization by polygon aggregation ensures that segments from different levels are strictly nested. When landscape interpretations are extracted from imagery of different resolutions, there is usually at least some degree of nonagreement. To overcome this lack of agreement, direct on-screen photointerpretation of TM data at a 100-hectare resolution is being developed to further differentiate between human-caused and natural vegetation types. The two classes being recognized are woody successional matrix versus anthropogenically sustained herbaceous matrix. Islands of either type less than 100 hectares are not delineated. Boundary cutoffs in digitizing are likewise not considered significant if less than 100 hectares. This mapping speaks directly to high-level landscape fragmentation and provides a comparator for the strategy of polygon aggregation.

Each polygon data layer, representing a given scale, has a companion layer of indexing points. The layers of indexing points enable construction of polygon pyramids across scales. With the point indexing approach, pyramids can be constructed for hierarchies of imperfectly aligned polygons. It is also possible to adapt the point indexing strategy for "fuzzy" nesting.

Concurrently with Gap Analysis, a second major application of this Pennsylvania landscape information infrastructure is to formulate ecological land types and land type associations under the Bailey scheme being promoted as ECOMAP by the U.S. Forest Service. Deliberations en route to these formulations will add to the depth of landscape understanding.

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Use of Gap Analysis Data to Establish Goals and Priorities for Individual Land Management Units - National Wildlife Refuges in Washington State

With demands on natural resources increasing, land managers need to adopt a landscape approach in developing management goals and priorities (Fig. 1). Whereas efforts in the past have focused on individual management units in isolation, Gap Analysis data provide a landscape context for land management units, irrespective of land ownership. In this paper, we describe the results of a preliminary analysis of the contributions of three National Wildlife Refuges (NWRs) to the conservation of biodiversity in the ecoregions in which they are located. This project, which will include all of the NWRs in the state when completed, is a cooperative effort between the Washington Gap Analysis Project, the U.S. Fish and Wildlife Service (FWS) Region 1-Refuges and Wildlife, and the FWS's field office in Vancouver, Washington. Our preliminary analyses include the Nisqually NWR in the Puget Trough ecoregion on the west side of the Cascade mountains, and the Turnbull and Little Pend Oreille NWRs in the ecoregion referred to as the Northeast Corner (ecoregional boundaries correspond to those described by Bailey [1980] as refined by the USFS and WAGAP). For each ecoregion, we identified the proportion of land in each vegetation zone, the actual land cover within each zone, and the proportion of each zone in each of five conservation status categories. The latter correspond to the National GAP guidelines, except that for this analysis we divided lands not managed for native species into public, e.g., DOD and tribal lands (conservation status 4) and private lands (status 5). We then identified those vertebrate species predicted to occur within the ecoregions and each of the refuges. Vertebrate distributions were based on each species' association with actual land cover. This allowed us to calculate the proportion of each species' predicted distribution on "reserves" (conservation status codes 1 and 2; lands managed for biodiversity) and to develop a "report card" describing the contribution of each NWR to the conservation of vertebrate biodiversity in their respective ecoregions. And finally, based on ecoregional context, we made recommendations as to the management goals and priorities for each NWR, both within and outside their boundaries.

Nisqually NWR

The Nisqually NWR, like most of the refuges in the Puget Trough ecoregion, is small and not connected to other areas managed for biodiversity. However, the refuge contains examples of most of the major habitat types within the Puget Trough ecoregion. This habitat diversity accounts for the high proportion of Trough vertebrates predicted to be present (see report card), but surrounding development threatens to reduce adjacent habitat patches to where they may not support viable populations of some species. Lowland forest (<2% in reserves) is particularly threatened within the Puget Trough ecoregion, and forested areas on the refuge are in danger of becoming isolated.

Based on modeled distributions, 45 of the ecoregion's native mammals are predicted to occur on the refuge, including 7 of 9 species listed as threatened or endangered by the state or federal government; 90 of the ecoregion's 144 native breeding birds, including 10 listed species; and 13 of the region's 22 native reptiles and amphibians.

The Nisqually River is the refuge's primary link to larger undeveloped areas. Compared to other large rivers within the Puget Trough ecoregion, the Nisqually has the least surrounding developed and agricultural land. Maintenance of this corridor to other protected areas in the watershed via land acquisition or land-use planning appears to be critical for ensuring the continued contribution of the refuge to the protection of biodiversity in this ecoregion.

Turnbull and Little Pend Oreille NWRs

The conservation status of vegetation zones varies considerably within the Northeast Corner ecoregion (see table below). Statewide, 49 percent of the Ponderosa Pine zone is privately owned. Three percent of this zone is managed for biodiversity in the Northeast Corner ecoregion, compared to 12 percent statewide. The Western Redcedar/Western Hemlock zone also has only 3 percent of its area managed for biodiversity in this ecoregion, but 70 percent of its total area is publically owned. In contrast, 44 percent of the Subalpine Fir zone occurs within "reserves," and only 3 percent of its total area in this ecoregion is privately owned.

Turnbull NWR is almost entirely within the Ponderosa Pine zone. One of its major assets is its status as one of the few conservation areas with this forest type. The refuge is, however, on a "peninsula" of Ponderosa Pine forest among agricultural lands and steppe, and development around Spokane threatens to isolate the refuge from other forests. Fifteen of the ecoregion's 16 reptiles and amphibians are predicted to occur on Turnbull NWR, as are 46 of 64 native mammals, and 105 of 160 species of breeding birds (see report card). Ten listed species of mammals and birds are predicted to occur on the refuge. Management recommendations from this preliminary analysis include maintaining existing grasslands and open canopy Ponderosa Pine woodland on the refuge and, if possible, preventing isolation from other forests to the north.

Little Pend Oreille NWR contains all of the major forest zones and forested habitats within the ecoregion. Not only is it the largest refuge in the state, it is bordered by national forest to the north and south. Because of its size and location, it has greater potential than smaller refuges to support large animals or those with large home ranges. Probably the refuge's greatest deficiency is its lack of connection to habitats along the Colville or Little Pend Oreille Rivers. Most of the reptile, amphibian, and mammal species in the ecoregion and 94 species of breeding birds are predicted to occur in the Little Pend Oreille NWR. Our preliminary analysis indicates that maintenance of a corridor to adjacent river valleys would help maximize the contribution of the refuge to biodiversity protection.

Overall, the three refuges are predicted to provide some habitat for 38 percent of the state's listed species and 80 percent of the remainder. We note that predicted presence does not necessarily mean that the species are confirmed as present or that the habitat on the refuge has been confirmed as suitable. More detailed field-level sampling is needed for the next stage of conservation planning. This analysis is an example of how to begin the planning at the ecoregion and landscape levels.

We believe our analysis, when completed, will serve as a model for the application of GAP data to the development of management goals and priorities within the National Wildlife Refuge System. Similar analyses for Fort Lewis and Camp Bonneville (both belonging to the U.S. Department of Defense) have been well received. The latter was recently considered for addition to the National Refuge System.

Literature Cited

Bailey, R.G. 1980. Description of the ecoregions of the United States. USDA Forest Service, Miscellaneous Publication No. 1391. 77 pp.

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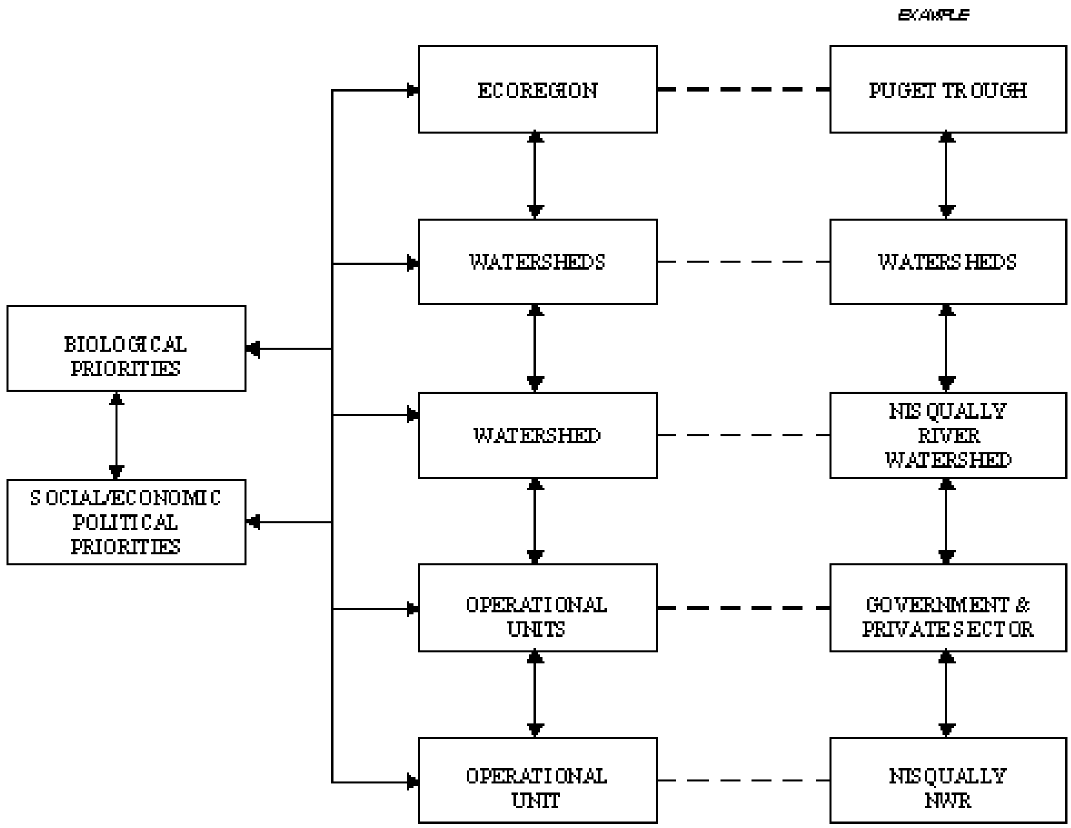

Fig. 1. Landscape approach to land unit management.

REPORT CARD FOR NISQUALLY, TURNBULL, AND LITTLE PEND OREILLE NWRs

	Herps		Birds		Mammals	
	Listed	Other	Listed	Other	Listed	Other
Puget Trough	6	16	21	123	9	41
Nisqually NWR	0	13	10	80	7	38
Norteast Corner	3	13	25	135	15	49
Turnbull NWR	3	12	10	95	10	36
Little Pend Oreille	3	10	11	83	10	43
State	21	24	55	172	31	70
3 NWRs	3	18	19	137	18	59

Listed Includes federal and state listed species

CONSERVATION STATUS IN WASHINGTON STATE FOR ZONES OCCURING IN TURNBULL AND LITTLE PEND OREILLE NWRs

	1	2	3	4	5
PIPO	2	1	25	23	49
PSME & AMGR	6	2	45	13	34
THPL & TSHE	2	1	67	0	30
ABLA & ALPINE	43	1	41	12	3
STATEWIDE	11	1	25	6	57

Numbers are percents.
PIPO = Ponderosa Pine, PSME & ABGR = Douglas-fir/Grand Fir, THPL & TSHE = Western Redcedar/Western Hemlock, ABLA = Subalpine Fir.

Modeling Grizzly Bear Habitat Suitability in Idaho

Many of the issues confronting wildlife managers and scientists are challenging the conventional spatial boundaries defined by administrative units. This holds especially true in the management of large carnivores such as wolverines, wolves, mountain lions, and grizzly bears. Individual grizzly bears range over 400 to 1000 square kilometers in a lifetime, while viable bear populations may require 10 to 30 times as much space. Such scales require a very broad view of habitat conditions. Not insignificantly, understanding these bears requires regional GIS databases that transcend state and even national boundaries.

Idaho is currently grappling with a number of issues related to grizzly bear management, including the potential reintroduction of a population into its central mountain wilderness areas and the management of humans in areas currently occupied by grizzly bears in the Panhandle and in the Yellowstone ecosystem. There has been reoccurring debate over the extent and location of "suitable" habitat. In addition, there are concerns about fragmentation and insufficient overlap between physically productive habitat and wilderness areas secure from substantial human intrusion. Scientists from the University of Idaho's College of Forestry, Wildlife, and Range Sciences GIS Lab and from the National Biological Service's Cooperative Park Studies Unit are trying to answer to these questions and develop a prototype for looking at the suitability of habitat for large carnivores elsewhere.

This research has drawn upon regional GIS databases, including GAP data for the state of Idaho, to model grizzly bear habitat suitability. These data were rasterized and combined in ARC/INFO grid format. Since grizzlies, like most other large carnivores, die primarily because humans kill them, a large part of this model deals with human-related features such as townsites, roads, and trails. This information is integrated into a measure of potential human activity for each map pixel and treated as an analogue of grizzly bear death rate. Information on vegetation, topography, and ungulate populations is integrated into seasonal measures of potential habitat productivity and treated as an analogue of birth rate. These two metrics are then combined in a way that culminates the analogy—by subtracting the standardized index of human activity from the standardized index of habitat productivity, the resulting measure is a direct analogue to population dynamics.

This model has already produced information of value to management deliberations. Maps have been produced that show seasonal habitat productivity for the entire state, as well as the location of "suitable" habitat defined by increasingly restrictive criteria. These maps show that, by most standards, there is abundant well-protected grizzly bear habitat in central Idaho that could potentially support a reintroduced bear population. They have also highlighted the potentially precarious status of existing grizzly bear populations, especially in the Panhandle. These results, as well as a description of the method, are parts of a manuscript that is currently being reviewed prior to submission to a journal for publication.

Even though significant progress has been made with this project, some major work remains ahead. In particular, we are prioritizing efforts to relate model outputs to parameters more directly relevant to management considerations, including actual grizzly bear birth and death rates. To date, we have partially confirmed the model by comparing outputs with delineations of currently occupied habitat and by assessing statistical relationships with bear sightings. We anticipate substantial future progress by extending the method to well-studied bear populations in areas such as the Yellowstone ecosystem and the northern Rocky Mountains of Montana.

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Point Sampling Surveys with GPS-logged Aerial Videography

Obtaining sufficient geographically unbiased data for verification and validation of vegetation communities is one of the greatest challenges in developing vegetation base maps for the Gap Analysis Program. These independent data are essential for classifying the Landsat Thematic Mapper (TM) imagery used in all Gap Analysis projects and for assessing the accuracy of the vegetation maps. Low altitude aerial surveys, combined with video data systems that tag each video frame with geographic coordinates from a global positioning system (GPS), provide a cost- and time-effective method for obtaining high resolution data on vegetation communities over large geographic areas. The Gap Analysis Program in New England is using this technology in conjunction with the hyperclustered, multitemporal Landsat TM imagery distributed through the Multi-Resolution Land Characteristics Consortium (MRLC) to produce its vegetation map of southern New England (Slaymaker et al. In press).

Aerial point sampling was developed to characterize the land cover of a region by interpreting a distributed sample of large-scale aerial images (Norton-Griffiths et al. 1982, Dunford et al. 1983). The Arizona Gap Analysis Program used this approach first to interpret its statewide Landsat TM coverage (Graham 1993), using aerial videography in combination with GPS-logged time code. The Arizona project used a Super-VHS camera flown at 2,000 ft above ground that covered 0.5 km at wide angle and zoomed to 15x magnification once every 10 seconds to collect a point sample image 30 m wide. The New England Gap Analysis Project modified Arizona's pioneering system by using two Hi8 band video cameras attached to a portable mount that can be operated from any highwing Cessna. The mount is clamped to the open window frame, then cranked out and adjusted to vertical with a bubble level. The video cameras are mounted vertically beside each other. One is set at wide angle, the other at 12x zoom, providing a swath of 30 m wide large-scale imagery down the middle of 0.4 km wide-angle coverage when flying 600 m above ground level. This approach provides more flexibility than a single camera in both the selection and density of sample points. Geographic position data are recorded in-flight from a GPS unit to a laptop computer using Geolink software. Flight lines can also be entered into this system for navigational purposes and will appear in correct relationship to the plane's position on the computer screen during filming. Time code is "sipped" from the GPS data stream by a Horita GPS time code generator to provide a matching SMPTE time code for the video tape recorders. SMPTE time code is the standard audible timing signal recorded to the audio track of professional video. Horita's time code generator substitutes GPS code for the normal internally generated signal, allowing each frame to be matched to a geographic position. In our system, time code is recorded directly onto the video images as well as the audio track, simplifying the synchronization of the two tapes during playback. We flew 10 - 24 km spaced transects of all six New England states (3,000 km) in the spring and fall of 1994, so as to capture both phenologies of our deciduous forests.

The video tapes from these transects are used to select and label sample Landsat pixel data. Two TV monitors, one each for the wide angle and zoom videos, are set up beside a computer monitor showing the corresponding portion of the Landsat image. The GPS flight data are overlaid on the Landsat image as vector points that can be queried for their time code, allowing the video frames to be matched to that image. As the video tape is interpreted and plant communities identified, specific pixels in the Landsat image are tagged with their forest type or vegetation class. These points are later extracted as a set of attributed coordinates and used as training sites in a supervised classification or, as in our case, systematically modeled for a set of inference rules to relabel the hyperclustered classification. Each selected pixel takes only seconds to tag, and we collect 18,000 or more points per image in a stratified sample by region and by topographic slope. One quarter of the sample points (stratified by vegetation type) are set aside and later used to access the accuracy of the final vegetation map. The remaining points represent only 0.06% of the total pixel population of a Landsat image, but this sample is sufficient for modeling of the probable vegetation types of each spectral class under different conditions of terrain and spectral mixtures.

The models for each vegetation type are developed with a set of Excel templates. The contingency tables sort the sample points by slope/aspect, frequency of appearance within a vegetation type, and the characteristics of their immediate neighborhood (25 pixel block) within those vegetation types. These data are then used in another set of Excel templates to construct inference rules that relabel each Landsat pixel to its most probable vegetation class for its location and spatial context. The templates are available on our World Wide Web (WWW) home page (see "New England GAP Analysis" at http://tove.fnr.umass.edu/gaphome.html, or ftp://tove.fnr.umass.edu/pub/gap), along with complete sets of our rules, a more detailed explanation of the process, and our initial accuracy assessments, which indicate a near 90% reliability for the seven forest types tested so far.

Technical assistance, including on-site workshops, acquisition of aerial video coverage, and assistance in setting up video interpretation stations, has been provided to a variety of Gap Analysis projects such as Colorado, Florida, Maine, Montana, Oregon, Tennessee, Vermont, West Virginia, and parts of California, as well as new applications of GAP methods in Madagascar, Mexico, and Portugal. Several GAP state projects now have aerial video camera systems and are using them cooperatively with other states. Contact Dana Slaymaker at the University of Massachusetts at (413) 545-4853 or dana@tove.fnr.umass.edu for additional information or technical assistance on aerial videography and interpretation of multiseasonal hyperclustered TM data.

Literature Cited

Dunford, C., D. Mouat, M. Norton-Griffiths, and D.M. Slaymaker. 1983. Remote sensing for rural development planning in Africa. The Journal for the International Institute for Aerial Survey and Earth Sciences 2:99-108.

Graham, L.A. 1993. Airborne video for near-real-time vegetation mapping. Journal of Forestry 8:28-32.

Norton-Griffiths, M., T. Hart, and M. Parton. 1982. Sample surveys from light aircraft combining visual observations and very large scale color photography. University of Arizona Remote Sensing Newsletter 82-2:1-4.

Slaymaker, D.M., K.M.L. Jones, C.R. Griffin, and J.T. Finn. In press. Mapping deciduous forests in southern New England using aerial videography and hyperclustered multitemporal Landsat TM imagery.

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Land Management Status Categorization in Gap Analysis: A Potential Enhancement

Gap Analysis as described by Scott et al. (*Wildlife Monograph* No. 123) and by *A Handbook for Gap Analysis* (National Biological Service and University of Idaho) requires that land tracts be categorized according to four status levels describing management for conservation of biodiversity. This component of Gap Analysis has been discussed and evaluated very little because, until recently, few projects had reached this point in the process. As we worked with the land management categories in New Mexico, we found the suggested methods and premises of the four categories to be somewhat inadequate to ensure repeatable results when there were several people involved, especially cooperators in our land categorization work group. This was particularly important in our project because we had spent much time seeking ways to better represent and categorize private lands managed for biodiversity. Thus, we wanted to enhance our categorization of lands of specific note to private interests.

Inconsistency Revealed

In New Mexico, we had 20 cooperators (representing private land holders, state and federal land management agencies, environmental organizations, and Native American tribes) assign land parcels to management categories. These individuals categorized 23 types of tracts by management status (e.g., status 2 - an area generally managed for natural values, but which may receive use that degrades the quality of existing natural communities) and 22 tracts by a name designation (e.g., national park) according to the published Gap Analysis category codes that we provided. While this quick assessment was not conducted as a controlled scientific survey, it did illustrate in general terms that land management categories may not be interpreted and applied similarly by all individuals. From the responses that we received, it was clear that the process of land management categorization was not a simple application of the four categories when attempted by a large group of cooperators. As important, we found that when we (the authors) attempted to settle on specific category assignments for distinct land tracts, we also sometimes made variable assignments. We found that we quickly sought a common way to identify information about tracts and to apply a repeatable process for category assignment.

A Different Approach

Ultimately, we developed a dichotomous key approach to meet this need (see below). This approach has two basic considerations. First, it requires the user to obtain simple information about each tract to be categorized (the revocability of protection; the existence of a specific management plan, policy, or regulation; the relative proportion of area subject to management; and the type of management). Second, it is structured to lead the user through relatively few decision steps that enhance consistent application by multiple users and, as importantly, by the same user if repeat categorization is attempted or requested for a previously categorized tract.

This key approach was described in a poster displayed at the National Gap Analysis meeting in Fayetteville, Arkansas, in August 1995. There was substantial interest in the approach, and discussion on the last day of the meeting indicated that the approach should have more extensive consideration among Gap Analysis projects.

An Opportunity to Participate

A small ad hoc working group of GAP principal investigators (coordinated by Bruce Thompson) was formed to examine this approach and other considerations in developing potential enhanced procedures for incorporation in the handbook. In advance of that group completing its review, there seemed to be a need for broader dissemination of this procedure and stimulation of evaluation and response by project personnel. So, take some time to apply the included dichotomous key to your individual GAP project. Does this key produce repeatability in addressing your land categorization challenge? Another issue seems to be whether there need to be more categories, or perhaps subcategories, such that individual projects can subdivide for their purposes while supporting consolidation to the basic categories nationally. Nonetheless, give this key a go and provide feedback to Bruce Thompson at (505) 646-6093 (office), (505) 646-1281 (FAX), or by e-mail at bthompso@nmsu.edu. Comments will be most helpful to the working group if received before May 15, 1996.

A Dichotomous Key (Draft)

This key is designed to be applied to any land tract, regardless of ownership, assuming that any management status category can apply to land parcels without consideration of public, tribal, private, or other ownership. Other assumptions are that the methods of protection listed are equal, regardless of ownership, and that written management plans are equivalent, regardless of who implements them. When categorizing a tract, recognize that mixed uses will occur; for instance, a natural area may have a visitor center and trails. Such uses need not influence the categorization if they represent 5% or less of the area of the tract. Also recognize that every type of management, ownership, or regulation can potentially be changed, but for this purpose, consider whether the intent infers permanence. When using the key, you may go back to a previous choice if the pathway has led you to an unsatisfactory option.

A-1:

If subject to statutory or irrevocable ecological protection from conversion to anthropogenic use of all or selected biological features by state or federal legislation, regulation, private deed restriction, or conservation easement intended for permanent status, GO TO B-1; if not, GO TO A-2

If ecological protection is revocable, temporary, or lacking but managed by a plan, GO TO A-3; if not, GO TO A-4

A-3:

Management to benefit biological diversity is provided by a written plan in place or in process under an institutional policy requiring a management plan - Status 3

A-4:

Not subject to an adopted management plan or regulation that promotes biological diversity - **Status 4**

B-1:

If total system in tract is conserved for natural ecological function, GO TO B-4; if conservation provisions apply only to selected features or species, GO TO B-2

B-2:

If management emphasizes natural processes including allowing or mimicking natural ecological disturbance events, but also allows low disturbance, renewable resource use, or high levels of human visitation on more than 5% of the tract - Status 2; if not, GO TO B-3

B-3:

Management allows intensive, human disturbance such as resource extraction, military exercises, or developed or motorized recreation on more than 5% of the tract, but includes ecological management for select features - **Status 3**

B-4:

If management strives for natural processes including allowing or mimicking natural ecological disturbance events - **Status** 1; if not, GO TO B-5

B-5:

Managed for natural processes, but some or all disturbance events are suppressed or modified - **Status 2**

Figure 1.

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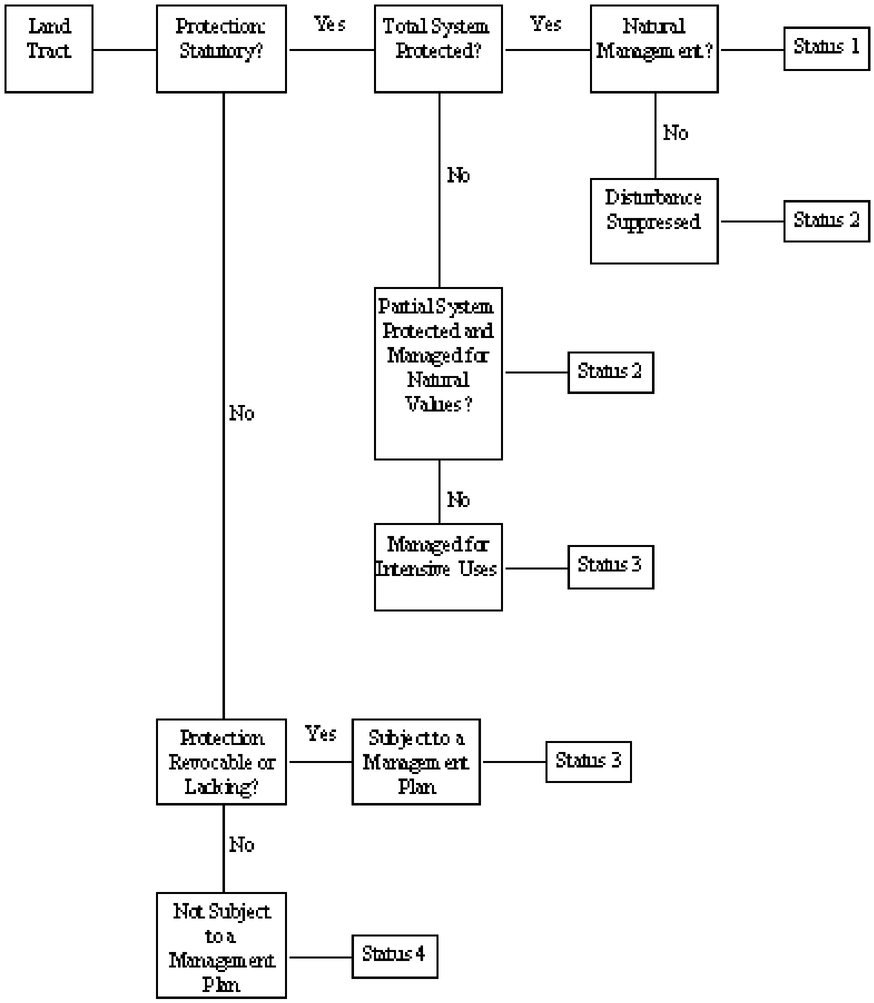

Figure 1. The dichotomous key flow chart for land management status developed by the New Mexico Gap Analysis Project (Crist et al. 1994).

A Preliminary Comparison of MMU Aggregation Procedures for Raster Data

Many Gap Analysis projects are challenged by the need to aggregate their base resolution land cover data to the 40- to 100-hectare minimum mapping unit (MMU) land cover product. Two creative solutions to this challenge have been developed by the Utah and Montana Gap Analysis Projects. In November 1995, the Arkansas GAP Project decided to face this challenge by evaluating these methods, along with some locally-developed procedures. Unfortunately, we encountered software problems with the Utah product that could not be corrected before our project's deadline, so attention was focused on evaluating the Montana method versus locally derived procedures. It became clear that the assumptions underlying the Montana method paralleled the image processing procedures used by the Arkansas project, and it was ultimately selected for statewide use in Arkansas. It is hoped that a more comprehensive comparison that includes the Utah product can be made in the future, but lessons learned to date may still be valuable to other GAP projects.

Before software problems were encountered in the Utah code, the Arkansas GAP team implemented a variety of testing procedures to evaluate both methods. We first tested the "rastelimqueen" program from the Utah Gap Analysis Project (UT-GAP). Rastelimqueen required an input ASCII raster file, a similarity matrix, and a minimum number of pixels in a group. The input and output products were then processed using GRASS GIS software. The ASCII raster files in addition to the existing binary raster files used by the Utah method are very large and require substantial disk space. The data were output from the GRASS binaries to ASCII form and provided as input to the module. The test data were processed successfully by the module, and the resulting ASCII output file was transformed using a conversion shell script to re-transform the header data to the GRASS format. The resulting file was then read into GRASS with the "r.i n.ascii" module. This process was regularly interrupted by an error message which noted that the "data conversion failed at row 1027, column 1878." Although the line with the error could be extracted, the extreme length of the line prevented examination of column 1878, even using a variety of UNIX tools that allow processing of very long lines. Without being able to input the ASCII data back to GRASS, the rastelimqueen program could not be fully tested.

Concurrently, we tested the Montana method. An advantage of the Montana program was that it did not require ASCII import. Instead, a binary cell matrix was used for input. The amount of area that could be processed at one time was an important element of the Montana method and was influenced by the amount of available memory. The work was conducted on a multi-CPU Sparc system with 100 megabytes of random access memory that were allocated to the process out of a total of 320 (mb RAM!). The Montana program utilized four variables that affected memory requirements: (1) number of columns, (2) number of cells, (3) number of categories, and (4) number of output polygons from each aggregation pass. Locally developed interfaces reclassed only those categories which were present in the section (then restored the original category numbers at the end of the process), constructed GRASS supporting files, and did other miscellaneous tasks. To overcome the memory limitations, the state pixel map was divided into seven subsections. Interfaces were written to the Montana program to derive similarity matrices for the seven subsections of the Arkansas map. With these interfaces and 100 megabytes of available RAM, six of the seven subsections were processed in one day. Testing was necessary to ensure that parameters would not exceed memory requirements.

Aggregation levels were 2, 10, 40, and 100 hectares. On some of the wider (more columns) subsections, additional aggregations at the 60 and 80 hectare level were required to further reduce the number of polygons so that the available memory was not exceeded. With the available hardware, the Montana aggregating method was very fast (probably 25 lines/second). At each larger aggregation unit the program was slower than the previous level, which was expected. According to the Montana team, the program can be run with as little as 16 megabytes of RAM, but this would limit the area (or other parameters) considered in each run. Testing in such a situation would be necessary to determine the maximum allowable four inputs to keep from exceeding the 16 megabytes of RAM.

Both the Montana and Utah approaches used similarity indices for intelligent decision-based aggregation. Montana's matrix was formed on the basis of multispectral data. Utah's matrix was a user-defined map classification similarity index defining which mapped categories were most alike (ecologically). This methodological distinction is quite significant, though each matrix can provide acceptable results. Evaluating the actual results from these aggregation methods poses another difficult task. Remember that any clump of cells can be subsumed and its identity changed if it is not large enough to remain at the current aggregation level. For example, cells that are classified as "oak," if not large enough, could be aggregated with other cells into a larger polygon classed as "cedar."

In the Montana method, aggregation occurred on a similarity matrix derived from the underlying spectral values. Thus, pixel groups that do not meet the minimum size limit would be aggregated with adjacent cells that had the most similar spectral properties. In the Utah method, aggregation would occur on the assessment of "similarity" of botanical character. While at first blush the Utah method would seem superior, and it may very well be in some situations, it means that the accuracy of the classification of the spectral class to the information class is central to the success of the aggregation that takes such assignments as a "given." Both techniques permit the "reservation" of certain classes, so that they are not forced into adjacent classes. Water, for example, can be blocked from being aggregated with other classes.

The two techniques reflect quite different underlying assumptions, and it is likely that each can yield successful results but in different mapping strategies. Utah's suite of aggregation algorithms, for example, also included a vector-based aggregation method which is based on the information class assignment and not the underlying spectral class. This is by no means a comprehensive comparison and, while the Arkansas team is satisfied with the results of the Montana method, we have not been able to perform a comprehensive, direct comparison of the two. It is clear that the mechanics of data aggregation are complex and depend on underlying image processing, GIS mapping strategies, and the assumptions that are made about similarities and classification. It is likely that there is no single best method, and what may be most appropriate in one situation may not be in another. More work is needed before these two methods (and perhaps others) can be said to be compared fairly.

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State Reports

(Note: You need to wait for this page to completely load before choosing a state.)

Arizona

All primary GAP data layers were completed in spring 1995. New project teams at the University of Arizona (UA), Tucson, and Northern Arizona University (NAU), Flagstaff, have been funded to conduct accuracy assessment and analysis and to develop a final report. In addition, Arizona is part of two 4-state ecoregion projects. The Four Corners project includes parts of New Mexico, Colorado, and Utah comprising the Colorado Plateau and Southwest Highlands ecoregions. This project will be coordinated by NAU. The Mojave ecoregion project includes California, Nevada, and Utah and is well under way. Assessment of the vegetation map is partially funded by the State of Arizona Department of Game and Fish, which is an active cooperator in the project. The data set will be shared with the state and others through the NBS National Biological Information Infrastructure (NBII) with funding provided by the NBS Division of Information and Technology Services.

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Arkansas

The Arkansas GAP project has completed its statewide land cover, land ownership, and management status maps. The land cover map has been aggregated, and accuracy assessment is now under way. The land cover data have been aggregated using the "Montana" method, which has worked well, given the spectral classification procedures used initially. Data have been aggregated at 2, 10, 40 and 100 hectare levels, with the 100 ha level to be provided to the National GAP effort.

Increased discrimination for the urban mapped areas has been obtained by integrating GAP spectral data with TIGER and STF (Standard Tape Format) data to isolate urban classes from bare rock and similar spectral signatures that are not urban. Cartographically appealing hardcopy products have been developed in addition to the digital maps. Land cover classes have been assigned to the spectral classes using a variety of data sources, including SOFIA, USFS, and state agency data. Twenty percent of the Game and Fish plot data (3,000 plots) and a similar percentage of the U.S. Forest Service's stand/compartment data were excluded for consideration in the information class assignment phase. These plots and compartments/stands were reserved on a random selection basis and were used later in the accuracy assessment phase.

In addition, an important accuracy assessment data set was developed by selecting 2,000 random field plot locations and providing them to the Arkansas Forestry Commission. The Arkansas GAP team developed an innovative method for site selection based on the Utah project and a software application that produces a small hardcopy map for each quad. These maps were given to Forest Commission field staff along with disposable cameras. The field staff recorded the forest types based on the Arkansas GAP land cover classification and made their own comments along with sample photographs for a permanent record.

Land ownership and management status mapping was also conducted in close cooperation with participating agencies. Less than 10% of the state is under public management or owned by natural heritage groups. For the state, less than one-half of a percent is in GAP management class one, less than two percent is in class two, seven in class three, and the remainder in class four (or is unknown). As the land ownership/management effort went forward, it became clear that large portions of the state are managed for various natural and/or wildlife purposes, such as hunting clubs, but are in private ownership. Unfortunately, the location and character of these private lands are unknown and could not be included in the current GAP effort.

Vertebrate distribution maps have been developed for birds, and the work for mammals and herps is largely done. Its final completion has been delayed due to the serious illness of a key participant in the statewide steering committee. Vertebrate distribution accuracy assessment will begin upon completion of the mapping effort. The project focus is now shifting to the development of a detailed final report, metadata, and procedures for the distribution and maintenance of the data. A CD-ROM for distribution is planned along with reports and maps. Availability of the data on the Web is also planned.

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California

Project Status

The California Gap Analysis is nearing completion. Land cover and land management mapping have been virtually completed for all ten planning regions of the state, and we are shifting attention towards data analysis and distribution. In 1996, we will be incorporating revisions of the land cover data suggested by reviewers and then publishing a final report. The current plan is to distribute the database and regional reports on both the World Wide Web and on a CD-ROM. These two media would be used both for locating and transferring data and for common queries of the database. Discussions are still under way to determine who within the state should be responsible for long-term maintenance and distribution of GAP data. The Universal Resource Locator addresses (URL) for California GAP data are: http://www.biogeog.ucsb.edu (for information about GAP and other related research projects at UCSB) and ftp://lorax.biogeog.ucsb.edu (for accessing GAP data as they are completed).

In 1995, one Ph.D. dissertation was completed (Pete Stine) and another is in draft (Kathryn Thomas). Besides two papers at the GAP symposium in Charlotte, NC, last year, several peer-reviewed articles relating to GAP were published or accepted for publication since the last newsletter:

Church, R.L., D.M. Stoms, and F.W. Davis. 1995. Reserve selection as a maximal covering location problem. *Biological Conservation*, in press.

Davis, F.W., P.A. Stine, and D.M. Stoms. 1994. Distribution and conservation status of coastal sage scrub in southwestern California. *Journal of Vegetation Science* 5: 743-756.

Davis, F.W., P.A. Stine, D.M. Stoms, M.I. Borchert, and A.D. Hollander. 1995. Gap analysis of the actual vegetation of California: 1. *The Southwestern Region. Madroño* 42: 40-78.

Hollander, A.D., F.W. Davis, and D.M. Stoms. 1994. Hierarchical representation of species distributions using maps, images, and sighting data, in Mapping the Diversity of Nature, R. I. Miller, editor, Chapman & Hall, pp. 71-88.

Sierra Nevada Ecosystem Project

The California Gap Analysis (CA-GAP) project participated in the Sierra Nevada Ecosystem Project (SNEP) funded by the U. S. Forest Service. The mission of SNEP was to (a) define the spatial extent and dynamics of key structural, functional, and compositional features of the ecosystem; (b) identify the benefits humans draw from it; and (c) identify management alternatives and their effects on ecosystem integrity and its sustained capacity to provide the full range of benefits. A Gap Analysis of plant communities was one of several analyses of regional biodiversity. Others included late-successional/old growth forests, aquatic species and habitats, and significant ecological areas, although these were generally limited to public lands because of data availability. Because of the vast amount of spatial data compiled for SNEP, we were able to refine the standard GAP management class definitions to include permitted land uses on public lands such as grazing allotments and commercial timber harvest from forest plans. The final SNEP report to Congress, including our chapter on GAP, is in press.

Biodiversity Management Area Selection

Besides Pete Stine's dissertation, the Biogeography Lab at UCSB undertook two additional studies of reserve selection algorithms. The first study reformulated the reserve selection models in the conservation literature as a classical Maximal Covering Location Problem (MCLP) as described in the operations research and regional science literature twenty years ago. The MCLP can be solved optimally (that is, no better solution exists), and most problems of the size described for reserve selection can be solved with reasonable computer resources. We solved the MCLP model for a real application using vertebrate distribution data prepared for the Gap Analysis of southwestern California. The areas are defined by each of the 280 7.5' quadrangles, and the regional species pool contains 333 native vertebrates. Therefore, the species-site matrix consists of 280 columns by 333 rows. A maximum of twelve sites are required to cover all species at least once, although 327 species can be covered in just 7 sites. "Solutions" on an IBM RS-6000 workstation took an average of 2.8 seconds of CPU time over the 12 solutions, with none taking more than 9 seconds. This analysis is being published in Biological Conservation (see Church et al., above).

The second study recognized the limitations of the simple "covering" model. An optimization model was developed for SNEP (in collaboration with Rick Church and B. J. Okin at UCSB and Norm Johnson at Oregon State) that selects new areas for biodiversity management. The model, dubbed BMAS (Biodiversity Management Area Selection), minimizes total area and maximizes overall suitability of the selected sites while meeting predefined levels of representation (e.g., 10%) for each community type (or wildlife species). Suitability was defined for this study by habitat quality (road density and human population density) and management factors (proportion of private ownership and the degree of fragmentation of land ownership). These factors were chosen for their potential impact on biodiversity management as well as the availability of data across the entire ecoregion. The SNEP study was not authorized to make formal management recommendations. Instead, we used BMAS to explore the dimensions of the problem by looking at a number of alternatives. The alternatives varied by their assumptions (which lands are considered currently protected), target levels of representation, biodiversity elements (communities versus vertebrate species), and the suitability factors. This study will be included in the SNEP report to Congress, and two journal articles are in preparation.

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Colorado

The final draft of the land cover layer for Colorado has been completed and will be under review through this summer. Current efforts are dealing with edge-matching with Utah, Wyoming, and New Mexico and with development of the data dictionary as part of a manual explaining the processes followed. The land cover layer will be further reviewed by field biologists and vertebrate modelers in the subsequent months for revision during the final six months of the contract period. Accuracy assessment is planned to begin this summer in coordination with Wyoming and will use aerial video.

Meanwhile, Colorado Gap Analysis vertebrate modeling efforts began in earnest with assemblage of the modeling team. A team of six biologists and ecologists has joined Colorado Division of Wildlife (CDW) staff, and we are now building links between data sets and coverages available through the CDW's Wildlife Resource Information System (WRIS) and the land ownership and vegetation data coverages developed specifically for Colorado's Gap Analysis Project.

The main data fields being linked from the Colorado Division of Wildlife's species database for GAP modeling efforts relate to county-based distributional records, wildlife habitat relationship information, and physical habitat descriptors related to species' environmental requirements and life histories. Ancillary information from other WRIS databases will provide more site-specific information from the Scientific Collections Permit Database (SCICOLL), the Herptiles Observations Database, the Colorado Raptor Database (CORAPTOR), the Aquatic Database Management System (ADAMAS), and the Colorado Latilong Distribution Studies (WILDATA).

Additional information from partnering groups will come from the Colorado Bird Atlas Project (CBAP) and the Colorado Wildlife Heritage Database (with the Colorado Natural Heritage Program). The

Natural Resources Ecology Laboratory at Colorado State University will provide integration opportunities with the Division's Species Ranking Project and provide additional information for GAP project use in evaluating management considerations relative to protection of Colorado's biodiversity. Special thanks go to the state programs in Wyoming and Utah for sharing observations from their Gap Analysis endeavors, and New Mexico for evaluation of the commonality of land cover mapping efforts in New Mexico, Colorado, Arizona, Utah, and Wyoming.

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Connecticut

(see Massachusetts, Connecticut, and Rhode Island)

Delaware

(see Maryland, Delaware, and New Jersey)

Florida

The Florida Gap Analysis Program has completed land cover classification of about a fourth of the state, from Lake Okeechobee through the Keys. This area is now being reviewed for a final iteration of the classification. The TNC Southeastern Region classification scheme was used to delineate classes to the alliance level or better. Analog videography played a major role in providing the volume of ground data necessary for a detailed classification at the alliance level. We expect to complete about half the state (all lands south of Orlando) by early summer of 1996. This effort is being greatly assisted by additional funding from the Florida Game and Fresh Water Fish Commission. Ground-truthing and mapping assistance have also come from a variety of agencies and individuals, most notably the U.S. Army Corps of Engineers. The NOAA C-CAP National Ocean Program is gearing up to also offer significant assistance in a cooperative effort to map Florida's land cover and land cover change. Auxiliary mapped information (existing land use, NWI, and SCS county-level soils) is being prepared ahead of classification. Coverages for over half the state have been reviewed, cleaned, and/or modified.

We are mapping/modeling all native and exotic terrestrial vertebrate species in Florida, as well as butterfly, skipper, and ant species. Breeding and wintering birds in the state are being treated separately. Distribution maps for all species are now being externally reviewed for accuracy. Distributions were determined from museum and other records and published literature, with interpolation and extrapolation used as necessary. Databases of species' habitat use are complete for all species except birds, which are nearly complete. Habitat information was compiled from over 1000 sources. Our next step will be to generate a matrix of species with habitat, utilizing the TNC classification scheme. Information necessary for species-specific modeling, where available, has been collected for most species. This information includes home range size and dispersal distances.

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Hawaii

The State of Hawaii Department of Land and Natural Resources (DLNR) was awarded a National Biological Service (NBS) State Partnership Grant to utilize satellite imagery for land cover classification and mapping. A major objective of the project is to lay the groundwork for the re-establishment of GAP in Hawaii. Satellite imagery covering the major islands of the Hawaiian archipelago is being provided by SPOT. The DLNR is one participant in a group-purchasing program which includes 26 state, federal, and private participants.

Due to problems with cloud cover over significant portions of the islands, SPOT has not been able to provide coverage in the time frame originally agreed upon. We are hopeful that complete coverage will be available by February 1996. Currently, project participants are setting the groundwork for the project, which will begin in earnest once the imagery is available.

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Idaho

The Idaho Gap Analysis group is continuing to analyze the original 200 ha MMU data set while remapping the state using a MMU of 2 ha. This land cover remapping is a cooperative effort of the U.S. Forest Service and others. Roly Redmond's GAP group in Montana and Tom Edwards's GAP group in Utah are doing the actual mapping and completed the draft map on March 15. The GAP group at Idaho is revisiting the vertebrate models using ecological themes unavailable in 1989. Work is being conducted in conjunction with the Idaho Heritage Program. We have plans to compare maps of predicted vertebrate ranges at different levels of spatial and thematic detail.

Gerry Wright and several co-authors have published articles on the use of the Idaho GAP maps for assessing what additional protection of cover types and vertebrate species is obtained under various proposals for new National Parks and Wilderness areas (Merrill et al. 1995). The Idaho vegetation map has been edge-matched with the Oregon and Washington maps by Michael Murray, Troy Merrill, Kelly Cassidy, and Blair Csuti. They were able to map 95 cover types in three states, mostly at the undifferentiated level. Chuck Peterson and graduate students at Idaho State University conducted a two-year field check for herptiles on Craig Mountain as part of a master's thesis. Overall accuracy was 85%, compared to 65% for the best available field guides. The results are being written up for publication. Now that we have a 2 ha land cover map, we will compare predictions for vertebrate species at the two very different MMUs.

Troy Merrill, Mike Murray, and Mike Scott are examining the distribution of cover types within special management areas to assess representation across the entire geographical and ecological range of each cover type. Mike Jennings, Patrick Crist, and Angie Evenden (US Forest Service Natural Areas program manager for eight western states) will conduct a conservation assessment of US Forest Service Research Natural Areas by comparing their distributions and sizes with GAP data. Kevin Gergely is just starting a project that asks which biological and ecological processes can be accommodated on differently sized management areas and, if areas are too small, what *ex situ* or transboundary management activities are required to maintain biological objectives of the area.

Dave Mattson and Troy Merrill have used the GAP land cover maps and maps of human activity to predict habitat suitability in areas of potential conflict between bears and humans. These maps are being used to help design conservation strategies for grizzly bears in Idaho.

As part of the second generation GAP effort in Idaho, we are collaborating with the Idaho Department of Fish and Game, Heritage Program, and The Nature Conservancy to revise the vertebrate distribution maps using hexagons as our unit of geographical occurrence. Plans are under way for a collaborative effort with adjacent states and The Nature Conservancy to produce a monograph of the ecological and cultural features of Bailey's ecoregions.

Literature Cited

Merrill, T., R.G. Wright, and J.M. Scott. 1995. Using ecological criteria to evaluate wilderness planning options in Idaho. *Environmental Management* 19:815-825.

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Illinois

The Illinois GAP Project started in November 1995. The Illinois Natural History Survey (ILNHS) received Thematic Mapper (TM) scenes for the state to conduct the Critical Trends Analysis Project (CTAP). The "first cut" vegetation map for Illinois was produced for CTAP using a Boolean mask and vector field segementation.

Landscape Stratification

When utilizing full TM scene data, experience has shown that clustering algorithms often fail to adequately discriminate landscape elements which individually constitute small proportions of the entire scene. This is especially true where urban and built-up lands constitute a small overall percentage of the landscape. To ensure that the spectral signatures for the urban and built-up lands are properly characterized during the unsupervised training stage, these lands are extracted from each TM scene utilizing a Boolean mask created from the block-level, rural-urban classification contained within the 1990 Census TIGER/Line and STF1B files. This Boolean mask was subsequently used to perform two separate classifications, one for the urban portion and a second for the predominantly rural portion of the TM scene. Luman and Ji (1993) determined that a similar approach is effective in improving classification accuracy.

Image Segmentation

Conventional approaches to unsupervised image classification use pixel classifiers that assign unknown pixels to a spectral class using no contextual information. Thus the spatial domain, expressed within the image as geometrically homogeneous areas (e.g., agricultural lands), is ignored. Yet, such information is important to the conventional photointerpretative process. Research has shown that the inclusion of spatial structure into the classification process can improve discrimination when used for some remote sensing applications (Woodcock 1992, Nichol 1990). This approach used massively parallel deterministic relaxation optimization algorithms to partition an image into a set of regions which correspond to objects on the landscape, and is generally referred to as image or vector field (VF) segementation. Research using VF segementation extends back to the 1970s and was applied to large portions of the Illinois landscape in a cooperative study conducted by the ILNHS and the University of Illinois, Beckman Institute for Advanced Sciences (Kerfoot and Bresler 1993). It has been ascertained that VF segmentation is effective in discriminating homogeneous landscape elements within Landsat TM imagery. Extensive analysis using two TM full-scenes subjected to VF segmentation strongly indicates that unsupervised clustering and subsequent classification based upon image data is better compared to the same analyses using the original TM image data. In additon, it is anticipated that the application of VF segmentation will improve classification accuracy by minimizing the within-class variance.

Second Cut Classification

The CTAP vegetation map identified 19 broad land use classes in Illinois, covering urban areas, woodlands, grasslands, agricultural lands and wetlands. Using the natural cover delineations from the CTAP classification, a Boolean mask will be used to further classify the broad natural CTAP classes into community/alliance classes where applicable. A total of 140 spectral signatures for each Boolean masked area within each VF-segmented TM scene will be extracted utilizing an unsupervised isodata K-means clustering procedure (Duda and Hart 1973). Final unsupervised classification of each TM scene will be achieved from use of a maximum-likelihood classifier, which improves the classification accuracy over other classifiers (Gong and Howarth 1990). A pilot project has been completed on a portion of the Shawnee National Forest in southern Illinois using the methodology described above. An accuracy assessment will be conducted once spring leafout has occurred.

Additional Coverages

Boundaries for all federally- and state-owned lands has been completed. Attributing is nearly complete, and management status codes are currently being input and verified. The ILNHS has extensive vertebrate distribution records, and wildlife habitat relationship models are being developed for several test species. Distribution maps and occurrence records are currently being linked to the ILNHS home page.

Literature Cited

Duda, R.D., and P.E. Hart. 1973. Pattern recognition and scene analysis. J. Wiley and Sons, New Yourk. 482 pp.

Gong, P., and P.J. Howarth. 1990. An assessment of some factors influencing multispectral land cover classification. Photogrammetric Engineering and Remote Sensing 56:597- 603.

Kerfoot, I.B., and Y. Bresler. 1993. Design and analysis of an information theoretic algorithm for vector field segmentation. Proceedings, IS&T/SPIE Symposium of Electrical Engineering and Technology 1904:1-12.

Luman, D.D., and M. Ji. Accepted. The Lake Michigan ozone study: An application of satellite-based land use and land cover mapping to large-scale emissions inventory analysis. Photogrammetric Engineering and Remote Sensing.

Nichol, D.G. 1990. Region adjacency analysis of remotely-sensed imagery. International Journal of Remote Sensing 11:1089-2101.

Woodcock, C., and V.J. Harward. 1992. Nested-hierarchical scene models and image segmentation. International Journal of Remote Sensing 13:3167-3187.

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Indiana

The Indiana Gap Analysis Project is in the middle of project year two as of the end of 1995. Work during the second year has focused on the challenging task of developing a meaningful map of actual vegetation from TM imagery and available ancillary data. Considerable time was expended to establish a remote sensing methodology that will produce a defensible land cover classification. A useful preliminary classification for much of the forested southern part of the state has been produced. We have now begun to produce a final vegetation map of Indiana, using concurrent aerial photography interpretation, in conjunction with the Natural Resources Conservation Service and detailed ancillary data analysis.

Thanks to the support of the Indiana Department of Natural Resources (IDNR), Division of Fish and Wildlife, we have made significant progress on the development of vertebrate models for the 539 vertebrate species in the state. A preliminary methodology has been established to incorporate these data into ARC/INFO for analysis. We could complete this work by late summer of 1996. Agreements have been in place since year one for IDNR Natural Heritage data and managed areas data; revision of these data for use in Gap Analysis began this winter. Metadata protocols have been established and standardized across labs at Indiana University and Indiana State University.

Metaprojects (see feature article) have, as expected, manifested a variety of administrative and technical problems. The drive for client-oriented metaproject products, however, has indicated a weakness in the Indiana Gap Analysis methodology that we have attempted to strengthen. Our efforts to improve the methodology have focused on improving coordination among the principal GAP partners. Early metaprojects have begun to yield results. For example, the copperbelly water snake metaproject delivered hardcopy to the FWS in January. The landscape-scale wetland restoration project has produced preliminary products and reports and continues to generate interest among Indiana's conservation community. The Nature Conservancy metaproject at Blue River approaches completion. The TNC project at Pigeon River will become part of a larger TNC/IDNR/FWS cooperative study funded in part by EPA. Other metaprojects, including Population Viability Analysis, are ongoing. At least two new metaprojects appear to have funding and should go forward this spring. Discussions with the Indianapolis Zoo and the Indianapolis Children's Museum to establish a biodiversity education metaproject appear promising as does a proposal to evaluate the importance of agricultural landscapes to biodiversity.

We will carry out an expert review of land cover maps and vertebrate models this spring, which should guide us toward a final product. We will also design a formal accuracy assessment of the land cover map toward the end of project year two. Finally, the Indiana Gap Analysis Project will continue to pursue metaprojects as funding becomes available and as metaprojects are feasible with respect to producing basic Gap Analysis products.

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Kansas

The Kansas Gap Analysis Project (KS-GAP) is in the early stages of map development. The primary cooperators involved are the Kansas Biological Survey (KBS) at the University of Kansas (KU) and the Geography Department at Kansas State University (KSU). Jack Cully of the Cooperative Fish and Wildlife Research Unit at KSU is coordinating these efforts. The Kansas Applied Remote Sensing Program of KBS began work on developing a prototype land cover layer in late 1995. A multitemporal classification approach involving three TM scenes (late spring, early summer, and late summer) will be used to identify natural land cover types in southwest Kansas. The goal is to map land cover to the alliance level using the modified TNC-UNESCO vegetation classification developed by KBS in cooperation with The Nature Conservancy's (TNC) Midwest Regional Office.

The Geography Department at KSU has begun work on tiling USGS 1:24,000 quadrangle maps across the state. The purpose is to create mylar overlays upon which protected land areas can be traced and then scanned into a GIS land management layer. Maps showing protected lands in Kansas are available from KBS, and the resulting GIS layer will serve to secure this data set in digital format. The quadrangle maps were originally used to develop a statewide soils map for the USDA Natural Resources Conservation Service. The soils map will provide a useful layer for the vertebrate distribution models and will facilitate identification of natural vegetation types.

KS-GAP recently hired Dr. Glennis Kaufman, who received her Ph.D. in Biology at KSU, as a 1/2 time coordinator. Dr. Kaufman, a long-time resident of Kansas, has particular expertise regarding vertebrate distributions in the state. She is also well-connected with other biologists and biological collections in Kansas. This year, her responsibilities will be focused on developing partnerships and developing support for the project. Beginning next year, she will become involved in developing the animal distribution layer.

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Louisiana

The Louisiana Gap Analysis Project is currently in its third fiscal year. The entire state has been divided into a grid of 332 unclassified cluster panels of 900 x 900 pixels each. Strategies to insure connectivity among classified TM panels and also between classified TM panels and National Wetland Inventory (NWI) data panels are being developed. Recently, members of the LA-GAP team completed an initial ground-truthing survey for post-visual classification of the vegetation map. Cognitive, or on-screen, classification of the land cover map was completed in late August 1995. The GAP team is currently compiling the ground-truth data into a database. This database, along with the NWI database, and the use of color infrared (CIR) aerial photography will be used to refine the visual interpretation of the TM data. The CIR photography is currently being indexed, scanned, and stored on CD-ROM. Another auxiliary data set that is being compiled is a TM/SPOT merge. These two auxiliary data sets will provide a means of performing a Classification Accuracy Assessment statement. Definitions to the land cover classification terms are in progress.

Three GAP meetings were held during 1995, involving cooperators and individuals interested in the GAP project. Two of the meetings took place at the NBS Southern Science Center and one at the Corps of Engineers' New Orleans office. Attending were representatives from Louisiana Natural Heritage Program, The Nature Conservancy, Louisiana Department of Natural Resources, Louisiana Department of Wildlife and Fisheries, Louisiana Department of Environmental Quality, University of Southwestern Louisiana, Louisiana State University, University of Northeastern Louisiana, University of Northwestern Louisiana, Tulane University, Loyola University, Corps of Engineers-New Orleans District, U. S. Fish and Wildlife Service, Environmental Protection Agency, U. S. Forest Service, Natural Resources Conservation Service, National Marine Fisheries Service, and U. S. Geological Survey.

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Maine

Phase I of Maine Gap Analysis is almost complete (awaiting the final habitat map from the University of Massachusetts). Phase II is well under way with the development of the habitat map using aerial videography and ancillary databases as training information. Dr. Steve Sader, a remote sensing specialist from the University of Maine, has joined as a co-principal investigator. Dr. Zhangshi Yin has joined the team as a research associate experienced in processing satellite data.

In phase II, 1993 TM imagery will be used to identify habitat types. During the upcoming months, all TM images will be converted to the same format, coordinates, and grid size. A mosaic of images, including a 10-km boundary around the state, will be developed from the 1993 imagery. Clouds will be masked out, and a principal component analysis of the six TM bands will be used for data reduction. Ultimately, supervised, unsupervised, and guided clustering algorithms will be used to classify habitats within individual ecoregions. These ecoregions will be stitched together, and the resulting habitat map will be tested using aerial videography and ground-truthing.

Aerial videography with the video frames positioned geographically using a Global Positioning System will be used to identify satellite image signatures. Videography transects totaling 7,100 km statewide were obtained in summer and fall 1994. Maine was divided into 8 regions, and 6 to 8 examples of each habitat within each region were ground-truthed. Habitats on videography were printed out, and 120 sites along public roadways were visited to check the relationship between videography and ground observations. A catalog of videography has been developed to use as reference in classifying satellite data and in testing the resulting map.

As part of Maine Gap Analysis and for use in other research, we have contracted for the acquisition of aerial videography along 48 Breeding Bird Survey routes. During fall 1995, 26 of these routes were flown; we anticipate completing the flights in 1996. This videography will be used to assess the accuracy of the predicted distributions of birds in Maine based on Gap Analysis.

Species synopses have been developed for each of the 278 terrestrial vertebrates that breed in Maine. The amphibian and reptile synopses are finalized, mammals have been reviewed and await final editing, and bird synopses are being reviewed. Synopses have been used to assist personnel of the Maine Forest Biodiversity Project and commercial forest industry personnel. After being finalized, the species synopses will be used in Randy Boone's doctoral research. He plans to use the range maps to research the effect of generalizing distributions to coarser political units (e.g., counties). Ultimately, they will be reformatted to be more concise and published in two volumes.

Efforts to develop scores for how well species should be predicted by Gap Analysis have expanded. We will be developing predictability scores for the species of Maine and selected western states where Gap Analyses have been completed. Predictability as assigned, using ecological variables, will be compared to species lists from conservation areas to test agreement. Should correlations be high, others conducting Gap Analysis will be able to judge a priori which species should require more effort during modeling.

A digital database of land ownership and an accompanying paper map were purchased from a local contractor. We are coordinating with the Maine State Planning Office to ensure that Maine conservation lands are accurately mapped and made current to 1993. During the upcoming months, we will classify public lands as to the level of biodiversity conservation they provide. We will be finalizing the species synopses that we have developed for Maine, and Randy Boone will be completing a thesis. We may meet with other GAP personnel late this winter to further the research on predictability scores for vertebrates.

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Maryland

(see Maryland, Delaware, and New Jersy)

Maryland, Delaware, and New Jersey

In 1995, the Mid-Atlantic Gap Analysis Project (MidA-GAP) finalized cooperative agreements with three museums to obtain data for vertebrate species modeling. Mammal data were also acquired from the University of Delaware's mammal collection. A Memorandum of Agreement (MOA) was completed with the Delaware Natural Heritage Program, and a complete copy of their Biological and Conservation Database (BCD) was obtained. As a result of this latest MOA, the MidA-GAP now has BCD data for its entire project area. A cooperative agreement was also entered into with the Birds of Delaware Publication Committee, and a complete digital copy of the Breeding Bird Atlas (BBA) data has been acquired. Some butterfly data have been obtained, including Opler's county-based data (Stanford and Opler 1993) and data from the University of Delaware, and other data sets have been identified.

Several GIS coverages have been developed or acquired, including a coverage of Delaware Natural Heritage element occurrence locations, as well as a previously developed element occurrence coverage for New Jersey. The Biodiversity Research Consortium (hexagon) project is under way in Maryland and Delaware, with several draft range maps completed (see Master and Jennings 1993). Preliminary GIS database structures have been designed for all vertebrate distribution coverages.

A University of Delaware graduate student is conducting a pilot project involving random sampling of vertebrates, including live trapping, in a variety of habitats within a small watershed in Delaware. A hand-held GPS receiver is being used to record precise geographic positions of occurrences and attribute data about habitat features. Preliminary field work has yielded some bird and amphibian data, some of which have been converted to GIS coverages. Another University of Delaware student, working as an intern, will be conducting small mammal live trapping in another watershed. The data from these projects will be used in accuracy assessment. Volunteers from the University of Delaware's Wildlife Program spent 60 hours in the field using standard field data forms to collect data on vertebrate breeding and associated habitat.

In Maryland, an NBS state partnership project is developing protocols for censusing reptiles and amphibians in different physiographic provinces of the region. The data collected during the study will be used for accuracy assessment. Breeding Bird Survey route stops are being digitized for Maryland in order to make use of the BBS data.

Expert reviewers have been found for the bird, herptile, butterfly, and bat models and distribution maps. Literature syntheses of habitat requirements have been completed, in a standardized format, for approximately 25 percent of all species to be modeled, and most of the remaining work will be completed this winter. MidA-GAP investigators in Delaware are involved in the development of a state desk-top mapping, database, and decision management system which will eventually include GAP data sets.

The air video project began in late fall after working through unexpected hardware problems. West Virginia GAP is conducting flights for MidA-GAP, and a second flight is planned for spring of 1996 after leaf-out. Video will be instrumental in developing the vegetation maps using protocols as set forth by Slaymaker (in press) and others.

The majority of the MRLC TM scenes have been received. These were re-registered after the registration accompanying the files was found to be off by more than 250 meters. All hyperclustered data received have been registered, and work has begun on these for use with the video. Preliminary land cover maps are expected to be completed in mid-summer 1996. MidA-GAP is working to collaborate on other projects in the region such as the NPS-TNC effort to map vegetation for national parks. Opportunities to do more of these projects are expected as we get farther along with the vegetation mapping process.

Literature Cited

Master, L., and M.D. Jennings. 1993. Hexagons: A new way to display predicted distributions of vertebrate species. *GAP Analysis Bulletin No.* 3:6-7.

Opler, P.A., compiler. 1994. County atlas of eastern United States butterflies. National Biological Service, 1201 Oak Ridge Drive, Suite 200, Ft. Collins, CO 80525.

Slaymaker, D., K. Jones, C. Griffin, and J. Finn. In press. Uses of aerial videography in Gap Analysis for deciduous forests in New England. In J.M. Scott, T.H. Tear, and F. Davis, editors. Gap Analysis: A landscape approach to biodiversity planning. American Society for Photogrammetry and Remote Sensing, Bethesda, Maryland.

Stanford, R.E., and P.A. Opler. 1993. Atlas of western USA butterflies including adjacent parts of Canada and Mexico. Denver and Fort Collins, CO.

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Massachusetts

(see Massachusetts, Connecticut, and Rhode Island)

Massachusetts/Connecticut/Rhode Island

The University of Massachusetts and the Massachusetts Cooperative Fish and Wildlife Research Unit are cooperating with the Vermont and Maine Cooperative Fish and Wildlife Research Units in the New England Gap Analysis Project. A primary focus of the Gap Analysis activities in Massachusetts has been development of a systematic approach for mapping deciduous forests. The New England landscape is 50 to 95% forested, with a wide variety of forest types occurring in relatively small stands interspersed throughout the region. These regional vegetation characteristics pose new challenges for developing an efficient and reliable methodology for developing base vegetation maps in New England and for much of the eastern deciduous forested region of the U.S.

Our approach has been to use hyperclustered, multitemporal Landsat TM imagery in combination with aerial videography. The MRLC program provided us with 12-band hyperclustered TM images that combined spring and summer coverages. Ground reference of vegetation cover was obtained from a grid of large scale GPS-logged videography flown over the region. Video data were collected along a 20 km-grid pattern using two Super 8 video recorders mounted on a Cessna 172. One video camera was set at wide angle, the other at 12x zoom, providing a swath of 30 m wide large-scale imagery down the middle of a 0.4 km wide-angle coverage when flying at 600 m above ground level. The GPS time code was recorded onto the video images and the audio track.

After developing a visual key of forest types obtained from video prints and field visits to training sites, the flight line was displayed over the hyperclustered image. The corresponding video images were used to label the vegetation at nearly 18,000 sample points from approximately 2,300 locations. Thirty Natural Community Alliances were identified. Through an iterative process, inference rules were developed and the image was classified. Accuracy was determined by an error matrix using a stratified subsample of video points that had been set aside during the video interpretation phase. The overall accuracy for all classes was nearly 90%.

We believe that the hyperclustered TM image represents a considerable improvement in the discrimination of spectral classes, especially in forested regions. Further, GPS-logged aerial videography provides a time- and cost-efficient method for obtaining sufficient samples of ground-truthed data to label the spectral classes in the TM scene. A measure of this methodology's usefulness is its applicability to other Gap Analysis projects. We have conducted training workshops, set up interpretation systems, or flown aerial videography for other GAP projects in 9 states. Regional workshops in the Northeast are ongoing to standardize video interpretation criteria, vegetation classification, and species habitat models.

The Massachusetts Gap Analysis team also continues to be involved with international initiatives in biodiversity inventory, cooperating with projects in Romania, Madagascar, Portugal, Ukraine, and Mexico. Our efforts center on providing technical tools and training to small groups of foreign scientists and development of GIS-based products that contribute to their conservation planning needs. Our goals focus on the rapid development of in-country GIS capabilities, making critical data available for resource management decisions and strengthening institutions within these host countries. The Gap Analysis approach is rapidly beginning to be integrated into conservation management programs throughout the world.

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Michigan

(see Michigan, Minnesota, and Wisconsin)

Michigan, Minnesota, and Wisconsin

(Upper Midwest Gap Analysis Project)

The Upper Midwest Gap Analysis Program (UM-GAP) has received most of the Landsat Thematic Mapper (TM) scenes necessary for classification of actual vegetation of Michigan, Minnesota, and Wisconsin. All scenes were reviewed at the Environmental Management Technical Center (EMTC) for quality control and were converted to an ERDAS Imagine format before being distributed to state partners. The Departments of Natural Resources of Minnesota and Wisconsin are in the process of classifying scenes for their states. Michigan is soliciting contractual support to classify the northern half of the Lower Peninsula. The EMTC will retain responsibility for classification of the Upper Peninsula of Michigan and has recently begun that effort. UM-GAP coordination efforts now also include Illinois, and the EMTC is working with Indiana and Iowa to encourage regionally compatible vegetation classifications. A series of meetings to promote that effort was held this winter.

The U.S. Forest Service has contributed to the UM-GAP vegetation mapping effort by assisting in the acquisition of additional TM imagery for the Lower Peninsula of Michigan. The Forest Service's Great Lakes Assessment will benefit from the use of UM-GAP-developed GIS coverages of current vegetation and predicted species distribution. In addition, the North Central Forest Experiment Station has signed a Memorandum of Understanding with the EMTC to share TM imagery and Forest Inventory and Analysis (FIA) plot data. The Forest Service will use the imagery to georeference their FIA plots, and UM-GAP will use FIA plot information for accuracy assessment.

In an effort to develop a uniform, current vegetation map for the Upper Great Lakes Region of the United States, UM-GAP has developed a common image processing protocol and a common classification scheme for Michigan, Minnesota, and Wisconsin. The classification scheme was developed in accordance with National GAP standards, following The Nature Conservancy/UNESCO design. Dr. Thomas Lillesand, Director of the Environmental Remote Sensing Center, University of Wisconsin-Madison, developed the protocol in cooperation with the GEO Services Division of the Wisconsin Department of Natural Resources. Technical approaches of the protocol include (1) use of multidate TM scenes, (2) use of GIS-assisted preclassification stratification into urban/nonurban and upland/lowland categories, (3) use of an extendible classification scheme which can be cross-walked to other classification systems, (4) preclassification stratification of scenes into spectrally consistent geographic subscenes based on ecoregion boundaries, (5) use of guided clustering techniques for classification of nonurban uplands, and (6) use of geographically stratified, systematic, nonaligned sampling for collection of training and accuracy assessment data. UM-GAP also will be testing the aerial videography system acquired by the National GAP office for acquisition of training site and accuracy assessment data. The protocol, in a compressed Postscript format, can be downloaded from the EMTC's anonymous FTP site (ftp://emtc.nbs.gov/pub/misc/umgap/protocol.zip). In an effort to coordinate TM scene classification among UM-GAP's three state partners, the EMTC has also established an e-mail technical discussion list (umgap-tech@emtc.nbs.gov). By using the list to discuss TM scene processing issues, state partners share experiences in solving problems with corner coordinates, file headers, and software–saving much time, frustration, and duplication of effort.

UM-GAP has also established a home page on the World Wide Web (see http://www.emtc.nbs.gov/umgaphome.html). The image processing protocol can also be retrieved directly from that page. A false color-infrared composite of the Landsat TM satellite imagery covering the Chippewa Plains Ecoregion Subsection in Minnesota is also available through the UM-GAP home page. The coverage is available as single-band ERDAS Imagine files, clipped to 1:100,000-scale USGS quadrangles. The files can be used as image backdrops in GIS programs, including ARC/INFO. These files have been used to assist in the delineation of land type associations, the ecoregion unit below the subsection level.

A unified regional effort to develop species-habitat associations and predicted vertebrate distributions is being coordinated by the EMTC with the University of Wisconsin-Madison providing technical assistance and oversight. A committee is currently being formed to oversee this effort, with membership including representatives of the U.S. Forest Service, the National Biological Service, and the Michigan, Minnesota, and Wisconsin Departments of Natural Resources. In addition, UM-GAP is working with Illinois, Indiana, and Iowa in exploring the potential for a larger regional effort to map predicted species distributions.

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Minnesota

(see Michigan, Minnesota, and Wisconsin)

Missouri

Missouri GAP has been integrated into the Missouri Resource Assessment Partnership (MoRAP). In doing so, some of the timelines have had to be readjusted. The new MoRAP Director, Dr. David Diamond, is now on board and is coordinating the GAP program within MoRAP.

All of the TM imagery for the state was received in November and December 1995. We have purchased PCI image processing software which resides on both workstation and PC platforms. An additional 8 gigabytes of memory for these scenes and their analysis have also been bought, and the imagery has been loaded onto disk. The final land cover classification scheme is under development for these images. Once finalized, the classification process will be initiated on these scenes. Two pilot areas are being examined to investigate different protocols for the detailed classification.

The first iteration of the public lands database and vertebrate distribution mapping should be completed by the end of May. These will then be sent out for review. We are also in the process of creating a mechanism for the continual update of the public lands database with our cooperators. The socioeconomic database development is nearing completion for the state and will aid in the assessment of priorities for biodiversity mapping.

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Montana

The Montana GAP project began in the fall of 1991. Due to the size of the state relative to the amount of available data, much work remains to be done. Contingent on the availability of sufficient funding, we anticipate a completion date of December 1997.

To date, we have developed a 2-step digital process for classifying existing vegetation. The first step is discerning the pattern of spectral polygons and delimiting their boundaries. A classification algorithm, developed by Dr. Zhenkui Ma, accomplishes this by mimicking a TM false-color composite. The resulting unsupervised classification is then aggregated to a user-defined minimum mapping unit (MMU) using an object and rule-based merging algorithm. The second step entails a supervised classification to label the polygons. We have used these methods to map existing vegetation in western Montana at 2 ha MMU according to cover type, size class, and canopy closure. Forest Service field crews provided most of the ground-truth data used to train the supervised classification. We completed a land cover map of western Montana in March 1996 and began work on eastern Montana.

To fully utilize our detailed vegetation data, we intend to develop correspondingly detailed habitat models and species distribution maps and, in the process, build a wildlife habitat relationships (WHR) database specifically for Montana. Limited comparisons of habitat at 2 ha and 100 ha suggest that much could be gained by investing additional time and money in construction of a WHR executed at 2 ha MMU. However, given limited resources, we may opt to map distributions directly at the standard 100-ha MMU. Species distribution will be mapped by mid-1997.

The BLM has just finished a digital statewide land ownership layer, which we will recode to reflect management status as of the end of 1996. State cooperators include the Department of Fish, Wildlife, and Parks, Department of Natural Resources, Department of State Lands, State Library, and the University of Montana. Cooperating federal land management agencies include the Forest Service, Fish and Wildlife Service, Bureau of Land Management, and Natural Resource Conservation Service.

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Nebraska

The Nebraska Gap Analysis Project was initiated in October 1995. Three graduate research assistants and one undergraduate assistant have been assigned to work on GAP. A full-time GAP coordinator was hired recently. Progress has been made in the following areas:

1. A statewide mosaic of MRLC Landsat TM data is 85% complete. The mosaic and ancillary data sets have been co-registered in preparation for land cover analysis. The mosaic will also be used to prepare a poster to be printed by the Conservation and Survey Division, University of Nebraska-Lincoln.
2. A cooperative agreement has been established with the State Museum of Natural History to automate faunal collection records, and data entry has begun.
3. Nebraska GAP staff are working with the Nebraska Game and Parks Commission to acquire and augment digital data on land ownership and land management.
4. An article on the Nebraska GAP project was published in the magazine Resource Notes, a publication of the Conservation and Survey Division, University of Nebraska-Lincoln.
5. A cooperative agreement has been developed with the Natural Resources Conservation Service (NRCS) to cooperate on development of ancillary data sets. A formal request has been made to gain access to primary sampling unit data acquired for the NRI to facilitate GAP.

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Nevada

The initial mapping of Nevada vegetation for Gap Analysis has been completed at the pixel level. There are 65 mapped cover-type classes statewide that have been identified. Accuracy assessment is currently under way. Once completed, the weighting matrix for vectorization of the raster layer into the GAP-specified 100-hectare MMU polygons will be developed. All animal models are completed and await the aggregation of the land cover map to the 100-ha MMU.

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New Hampshire

(see Vermont and New Hampshire)

New Jersey

(see Maryland, Delaware, and New Jersey)

New Mexico

Land Cover Mapping and Assessment

A land cover map comprised of 42 categories of vegetated and nonvegetated cover was completed during early 1995. We mapped 33 categories at the GAP standard of 100 ha MMU. Two vegetation communities were mapped at 2 ha and seven at 16 ha to ensure that their general distribution was not lost during aggregation to a larger MMU. This mapping effort resulted in a statewide map with approximately 26,000 mapped land cover polygons. We subsequently drew a stratified random sample representative of the mapped categories. Standardized polygon evaluation instructions, a data form, and location maps (with polygons numbered but unlabeled) were distributed to 43 assessment coordinators representing more than 100 assessment cooperators statewide. Final analysis and development of accuracy statements regarding the land cover map were pending at report time.

Animal Distribution

We are predicting the distribution of 602 vertebrate species based on associations with mapped land cover, watersheds, soils, elevation, precipitation, hydrology, and slope. Our basic approach was to develop a "hypercoverage" consisting of the intersection of all polygons in the previously listed themes. Each vertebrate species is then assigned a presence or absence value for each hypercoverage polygon based on an algorithm of theme associations in a database system. Preliminary distributions were predicted, graphed, and submitted to expert cooperators representing bird, mammal, and herpetozoan expertise statewide. Wildlife models were altered based on expert comment, the hypercoverage was updated to represent corrections needed in individual themes, and these revised maps were distributed at the end of 1995.

Management Categorization

Specific management descriptions and tract boundaries were received from a wide array of public resource management agencies and private interests statewide. These data were integrated with the previously obtained "Public Land Survey System and Ownership" data files compiled jointly by Bureau of Land Management, New Mexico Land Office, and the Earth Data Analysis Center at the University of New Mexico. The resultant land tract boundaries and descriptors were then converted to management status categories. We developed a dichotomous key to provide a repeatable method for assigning status categories. This is a draft process that was described in a poster presented at the Arkansas coordination meeting in July 1995. See page 20 for a more detailed description of the dichotomous key and opportunities for critique and improvement.

Analysis

Analysis will follow the format described in the recent standard final report outline. In addition, NMGAP will explore the variation in avian richness between processes including and excluding wintering distribution. Overall project completion and reporting is expected by spring of 1996. Activities are under way to coordinate with the Earth Data Analysis Center in Albuquerque to be the in-state repository and distributor for the final digital files and metadata.

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New York

New York now has all the GIS coverages required for a state-level Gap Analysis of species either in hand or promised for delivery during 1996 by reliable cooperators. These coverages include breeding birds, mammals, reptiles, amphibians, butterflies, threatened/endangered/sensitive species, and public lands (state and federal, including large DOD holdings). The mammals database has been made available through cooperation with the New York State Museum and the USFWS Region 5 office. We continue to have excellent cooperation in developing the GAP database from our principal state cooperator, the New York State Department of Environmental Conservation (NYSDEC). The reptile and amphibian data are the most recent available from New York State, based on an atlas being produced by NYSDEC, and will be updated through 1996. Birds and butterflies are complete and linked to the GIS. We still are negotiating for additional, more up-to-date state forest boundaries. We also have compiled a digital elevation model for New York State, a model of growing degree days, digital soils information, and a compendium of published information about edaphic factors relating to vegetation types, all to assist us with developing and refining our vegetation classification.

We have completed a provisional, first-cut vegetation classification derived from Landsat TM imagery and using a single-scene clustering algorithm based on 100 clusters. The delivery of additional multitemporal, processed TM imagery from the EROS Data Center under our MRLC agreement, along with associated 240-cluster spectral data, was completed late in 1995. However, several problems need to be solved before we can use the EROS data to the fullest extent. Obtaining and installing Spectrum/Khoros software has been difficult, and some of the EROS-processed scenes were not accurately georeferenced.

In November 1995, representatives from the Pennsylvania, New York, and New England GAP projects met at the University of Vermont to discuss a land cover classification that would be appropriate for the Northeast. We incorporated elements of the modified UNESCO and TNC vegetation classification schemes into an expanded northeastern classification. We currently are reviewing the provisional vegetation classification scheme which expands upon both the modified UNESCO and TNC Heritage Program schemes, taking into account the extensive land use/land cover patterns that result largely from the activities of humans on the northeastern landscape of the United States. Additional meetings to discuss vegetation classification, vertebrate range delineation, and edge-matching are planned for 1996, prior to the national GAP PI meeting in Florida.

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North Carolina

The current focus of the North Carolina Gap Analysis Project is the development of the vegetation data layer. We are nesting our vegetation datalayer into the landcover classification being done by the Multi-Resolution Land Characterization Consortium (MRLC). We are using the non-vegetated classes from the MRLC classification as a masking tool and processing only those areas identified as natural vegetation. We have spent the past year gathering ancillary data, testing methodologies, and applying those methods to the classification vegetation for the Southern Atlantic

Coastal Plain Flatwoods of North Carolina. Based on past experiences we knew field data would be a limiting factor to mapping vegetation at the alliance level. Our solution to this was to gather aerial videography data for areas known to be dominated by natural vegetation, use plant community data available from the North Carolina Natural Heritage Program, and get field ecologists into the computer lab to help develop an extensive point database of vegetation types. These points are then used to determine the correspondence between the alliances and the combinations of clustered Landsat TM imagery and ancillary datasets (i.e. National Wetlands Inventory and Natural Resources Conservation Service's Detailed County Soil Maps). We are in the process of summarizing the results of the preliminary mapping efforts with respect to the National Vegetation Classification. We will also be reviewing their potential with respect to ongoing conservation planning in the region.

In addition to the vegetation mapping, we have been developing cooperative relationships with agencies within the state, as well as with neighboring Gap Projects. Two of our cooperators, the North Carolina Heritage Program and the North Carolina State Museum of Natural Sciences are currently involved in a study titled "A Model Biodiversity Analysis for Southeastern North Carolina". Essentially, this is a mini-Gap Analysis. The vegetation datalayer we are developing will be an important contribution to this effort. We are in the process of developing an Memorandum of Understanding with the North Carolina Center for Geographic Information and Analysis, which serves as the state clearing house for geospatial data. A joint MOU between NC-GAP, The Natural Heritage Program and the North Carolina Wildlife Commission is also underway.

In this year we will continue the interpretation of videography and image processing for the northern coastal plain, as well as the piedmont of North Carolina. The mountains will be the focus for the 1998 field season. Vertebrate species range mapping and habitat modeling will begin in the southern coastal plain.

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Oklahoma

During the second operational year of the Oklahoma Gap Analysis Project (OK-GAP), team members Mark Gregory and David Gade of Oklahoma State University and Mark Lomolino, Ian Butler, Dan Hough, and David Perault of the Oklahoma Biological Survey and University of Oklahoma have been working diligently on production of the vegetation, animal distribution, and land ownership and management data layers. This phase of the project has been challenging, mainly because of the size and complexity of the data and analyses. Needless to say, we are all anxious to print our first set of maps.

Land Cover Layer

A land cover classification scheme, prepared last year, is currently being modified to incorporate recent changes made by state botanists. So far, we have received 22 data sets of Thematic Mapper (TM) satellite data from USGS-EROS. These data sets cover 16 different scenes or locations: 11 scenes with data of a single date and five scenes with multitemporal data. In addition to the TM data, hyperclustered data of 6 and 12 channels have also been received for most of the scenes. Processing and preliminary analysis of the TM data have been initiated. We also received airborne videography data consisting of geocoded images from 17 north-south transects covering Oklahoma, flown in June and July 1994. These data will be used to interpret vegetative cover types and verify the TM analysis.

Animal Distribution Layer

The central database of vertebrates has been created and populated with species element codes, scientific names, common names, state and federal ranks and status, descriptions of habitat and environmental associations, and related information. Except for a few species, geographic ranges of mammals, birds, reptiles, and amphibians have been mapped, verified, and digitized. Locational databases are being compiled. Habitat associations have been encoded for all reptiles and amphibians and are being completed for birds and mammals. We are currently conducting a pilot study using a preliminary vegetation/land cover map to test procedures for overlaying vegetative cover, vertebrate distributions, and land ownership/management layers.

Land Ownership and Management Layer

We have digitized 379 public and private managed land units, including all 44 school land parcels. This represents about 95% of the public and private managed areas, open spaces, and wild lands in Oklahoma. The remaining major task will be to code each managed land unit using either the existing or revised national Gap Analysis land classification system. We will seek reviews of these code designations from individual landowners. As always, cooperators have played an important role in OK-GAP. For example, over 30 experts in the vegetation of Oklahoma reviewed and commented on our vegetation classification scheme. We plan to involve even more cooperators in the coming year to assist us in reviewing the first set of draft maps.

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Oregon

The Oregon actual vegetation map is being upgraded to current GAP standards. Twenty-three full or partial TM scenes cover the state. All scenes west of the crest of the Cascade Mountains are scheduled to be completed by April 1996. We anticipate the TM-based vegetation map will be completely classified and labeled by October 1996. An accuracy assessment is planned for 1997. Our land ownership and managed area data layers have also undergone minor updates. We are scheduled to complete 420 vertebrate distribution maps, based on vegetation cover type polygons and ancillary data (DEMs, hydrography) by June 1996.

We continue close cooperation with the Biodiversity Research Consortium (BRC). Several analyses of current Oregon data layers have already been conducted, including a preliminary gap analysis of 66 aggregated (to the alliance level) vegetation types. Five cover types were not represented in natural areas, and another 12 had less than 2% of their area in natural areas. These were mostly desert shrub and oak woodland cover types. Four of six types with more than 50% of their area in natural areas were high elevation forests and alpine communities. We are also cooperating with the U.S. Fish and Wildlife Service's Klamath Basin Ecosystem Restoration Strategy. In response to their needs, we have labeled our first TM scenes in the Klamath region and may embark on higher resolution mapping for the area.

In cooperation with researchers in Australia and the United Kingdom, we have used the BRC species distribution database to compare the efficiency and spatial outcomes of 19 reserve selection algorithms. Linear integer programming, only recently applied to this problem, provides optimal solutions to "cover the set" within a reasonable run time. Surprisingly, far simpler heuristic algorithms also perform very well. Most species (90%) are represented in five areas (EMAP 635 sq. km hexagons), but 23 areas are needed for complete coverage. We found that species peripheral to the state tended to guide the selection of the last dozen areas. This finding underscores the need to carry out bioregional analyses. A paper describing this research is in press in *Biological Conservation*.

Oregon GAP, the Oregon Department of Fish and Wildlife, and several other cooperators are beginning work under a $550,000 grant from EPA entitled, "Multiscale Biodiversity Conservation: A prototype process for Oregon." Part of the funding will support a graduate student in the Geosciences Department, Oregon State University, who will carry out more detailed gap analyses of our data sets. The Geosciences Department has recently created a new GIS lab called Terra Cognita (the name comes from our cooperator Ross Kiester) to support this type of research.

Much time and effort over the past year has gone into the preparation of a book-length manuscript, "Atlas of Oregon Wildlife." This is a natural spin-off of GAP species distribution maps and will make one of our products available to a general audience. Most reference works on Oregon vertebrates are over 50 years old, so this new synthesis of ecological and distributional information on Oregon species is a major contribution. We are negotiating to have it published by Oregon State University Press.

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Pennsylvania

Extended Gap Analysis

Gap Analysis in Pennsylvania (PA-GAP) is viewed as the outset of a cooperative and comparative multiscale landscape information infrastructure initiative. Assessment of conservation status and opportunities for vertebrate habitats is only one among many motives for undertaking the initiative. The overarching goal of the initiative is one of landscape understanding.

Rather than choosing among various technological approaches to spatial information, we have conceived a progressive scenario of spatial technologies and information sources whereby analytical alternatives become mutually reinforcing. As the scenario proceeds from finer spatial scale to coarser scale, thematic content and landscape insight grow deeper. Thematic errors and/or uncertainties occurring earlier in the scenario can be redressed at later stages in different modes. Gap Analysis itself does not require that our full informational vision be realized, so the Gap Analysis time frame is one stage in a developmental odyssey of indefinite duration. Funding has been secured for a sequel to Gap Analysis that is concerned with statistical approaches to multiscale analysis of critical areas in watersheds and landscapes. The land cover portion of PA-GAP is described in detail in a feature article elsewhere in this bulletin (see page 14).

Biotic Occurrence Information

Digitized range maps have been superseded by The Nature Conservancy compilation that shows the level of evidence for species occurrence in each of the EPA 635 sq. km hexagons in Pennsylvania as part of a pilot project sponsored by the Biodiversity Research Consortium. These data sets have been recompiled to show species richness by hexagon for selected groups of taxa. We have, however, developed a new approach for representing and analyzing these data–as a surface having at least ordinal metrics. We refer to the results from this approach as "echelons." For example, the representation of species richness as a surface is one echelon.

An initial comparison is that of combined echelons for all vertebrates against separate echelons for mammals, birds, and fishes. These comparisons show obvious regional differences between the major groups of taxa. These differences are consistent with general knowledge of the respective taxa. The contrasts are sufficient to negate prospects of finding any single group of species that can serve to guide conservation work in general. From this initial comparison, we suggest that those conducting an analysis of conservation gaps revisit this issue carefully. The occurrences of birds were compiled from Pennsylvania Bird Atlas information into the EMAP hexagon grid. For the avian taxa, then, the hexagons provide a coarser scale view that is consistent with views for other taxa.

The Pennsylvania Game Commission has contributed its entire Fish and Wildlife Database to the PA-GAP effort. Occurrence information for this database is county-oriented. As with the EPA hexagons, the Pennsylvania Bird Atlas was a major source of information for this database as well. Awareness of overlap between databases is important for Gap Analysis and conservation work in general.

Land Management Information

Land ownership GIS data layers compiled by consultants for a low-level nuclear waste siting in the Commonwealth provide us with a point of departure. Some cooperators in Pennsylvania have expressed a desire for finer land management categories. The status of relatively small tracts is often of interest, particularly in a larger landscape context. To insure thorough consideration of alternatives and their merits, we have formed an internal task force on land management status. Meeting GAP standards is not an issue, but we want to accommodate the needs of cooperators and promote research. The best course may lead toward multiscale architectures accommodating incomplete information.

Habitat Models

This is one sphere in which our attempts to expand the knowledge envelope are very selective. We will seek consistency with New York and New England states relative to habitat models. Current New England work is being shared with Pennsylvania, and we have enlisted a new fisheries faculty member to fill a gap in our GAP team.

The prospective models are operable and respond primarily to generalized landscape variables. A lot is taken for granted with respect to habitat elements at finer scale. Apparent habitat as seen by these generalized models will provide a reference against which to compare more incisive models arising from research. More sophisticated habitat modeling is under way in related projects for bobcat and woodcock. As components of the multiscale landscape information infrastructure become available, they are being steadily incorporated into the advanced habitat modeling research.

Biodiversity/Conservation Planning

An initial biodiversity plan for Pennsylvania has been formulated by the Pennsylvania Biodiversity Technical Committee. Formation of a council to consider the recommendations of the plan is under way. These initiatives provide an immediate context for utilization of GAP results in Pennsylvania conservation programs.

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Rhode Island

(see Massachusetts, Connecticut, and Rhode Island)

Tennessee

Vegetation Mapping

The initial land cover map for the entire state was completed March 1995 using a hybrid unsupervised/supervised classification method in ERDAS Imagine. Twelve Landsat TM scenes from 1990 to 1993 were used to produce the Anderson Level II classification with an overall accuracy of 85%. Except for adding wetland data for just a few quadrangles, the land cover map of the state is completed. Refinement of the vegetation categories into a plant community-based map is under way using aerial videography.

The use of aerial videography for detailed mapping of the forest classes was adopted from Slaymaker et al. (in press). Approximately 4,600 km of video transects were flown over the forested lands in Tennessee during mid-April. Nearly 24 hours of video were gathered with two cameras providing continuous 0.5-km wide angle and 30-m zoom coverage. Almost 400 sites were visited throughout the summer and early fall. Interpretation of the video footage is currently under way. Video interpretation and additional classification of the TM scenes is being performed in states by physiographic province in order to take advantage of the variation across the state.

Interpreted video for the Mississippi Alluvial Plain and the Loess Plain of West Tennessee have been used to complete the labeling process of the unsupervised forest classification. Refinement of the spectral classification is being done to code confused spectral classes using information about the surrounding pixels (maximum, minimum, diversity, and majority values) as well as ancillary data (NWI, DEM, geology, soils, and buffered streams). The plant community classification developed by The Nature Conservancy's regional office is being used for general guidance. Limitations of our methodologies and differences in scale make it difficult to conform strictly to that classification.

Vertebrate Species Mapping

Distributions for the state's terrestrial vertebrate species were based on the county, physiographic province, and watershed of occurrence and then translated to the EPA-EMAP hexagonal grid. Range data from the Tennessee Animal Biographies System (TABS) and the Vertebrate Characterization Abstracts (VCA) were used to produce range maps for the 70 mammal, 55 reptile, and 65 amphibian species in the state. Range maps for 1,709 breeding birds were produced from the Tennessee Breeding Bird Atlas data, TABS, and VCA. Distributions of rare species are based on buffered point data provided by the Tennessee Natural Heritage Program. Reviews for rare species data will be done in cooperation with the authors of "Tennessee's Rare Wildlife." Reviews for the non-rare species will be conducted by state biologists.

Work on the habitat relationship models for west Tennessee has begun. The models will be cross-walked for each physiographic province as the vegetation classification becomes available. Data sources for the habitat model include TABS, VCA, and "The Land Manager's Guide to Birds of the South" (P. Hamel).

Land Ownership and Management

The public land coverage has been updated through a cooperative effort between the Tennessee Department of Environment and Conservation's Recreation Planning Division and the Tennessee

Wildlife Resources Agency. A subcommittee of the Tennessee Biodiversity Team has categorized the majority of the lands as to their management status. Final revisions are scheduled for the spring.

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Texas

Dr. Nancy Mathews, the Texas GAP Coordinator and Assistant Unit Leader for Wildlife left for a faculty position at the University of Wisconsin in August 1995. Raymond Sims was hired as the principal investigator of the Texas Gap Analysis Project (70% time) and Southwestern Regional Coordinator (30% time) in November. Raymond, a native Texan, comes to the GAP program from Blackstone, Virginia, where he was a GIS coordinator at Fort Pickett Military Reservation.

Land Cover Mapping

Land cover classification and mapping efforts are progressing. Texas A&M University has begun vegetation mapping for the eastern portion of the state, while Texas Tech University prepares to begin vegetation mapping for western Texas. A minimum mapping unit of 40 ha has been chosen for the entire vegetation map with an accuracy target of 80%. Vegetation classification will follow the UNESCO format with the addition of lower levels. To date we have received 29 TM images in raw format and 21 clustered TM images in Spectrum format. The total number of images we are slated to receive is 52. The projected completion date for the vegetation map is June 1998.

Because over 90% of Texas consists of privately owned lands, access for ground-truthing and accuracy assessment is limited. Airborne videography has provided a method of acquiring periodic georectified high-resolution images that can be utilized as a ground-truthing and accuracy assessment tool. SkyKing software, developed at Texas A&M's Mapping Sciences Lab (MSL), is utilized to interactively assign vegetation cover types to points within contiguous vegetated areas on georectified video frames. SkyKing writes files containing UTM points and the corresponding cover type. This file is then read into an enhanced version of Spectrum. Spectrum applies the cover types to all similar clusters in the hyperclustered TM files and reports errors. The final classified images are then aggregated up to the minimum mapping unit of 40 ha.

Texas A&M - Land Cover Map of East Texas

TX-GAP contracted with TX A&M's Mapping Sciences Lab (MSL) to map vegetation in the eastern portion of the state. Due to delays in receiving imagery, processing contracts, and utilizing Spectrum software, image processing is only now beginning. However, the MSL has accomplished several key goals including: collecting ancillary vegetation data, loading and compiling Spectrum 1.5, converting clustered data to Spectrum format, developing framework for state-mandated metadata files, checking and archiving TM raw and clustered imagery received to date, developing a vegetation photo key from airborne videography, and giving several presentations on current efforts.

Land Ownership

Of the federally managed lands in Texas, only national parks and U. S. Army Corps of Engineers lands have boundary data. Boundary data for state forests are complete, while state park and refuge boundary data are expected to be provided by Texas Parks and Wildlife Department.

Vertebrate Distributions

Experts in the various fields of Texas vertebrates have been contacted, and cooperators have been identified. Animal scientists and ecologists from universities and state and federal agencies are among cooperators identified thus far. Ancillary data is being collected, and mapping of vertebrate species distributions will commence in FY 96.

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Utah

Utah Gap Analysis was completed in spring 1995 and consists of a 1,138-page report plus two CD-ROMs containing all digital information. Effort has been focused on completing manuscripts and making presentations. Thus far, three manuscripts have been published, two are in press, and two in review. Eleven presentations have been made. Currently, work is emphasizing the optimal placement of reserves, given the existing reserved land, and assorted analyses of the pending wilderness bills for Utah.

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Vermont

(see Vermont and New Hampshire)

Vermont and New Hampshire

After three years of compiling data for six states, the New England Gap Analysis Project has now subdivided the territory so that the Vermont Cooperative Fish and Wildlife Research Unit is coordinating the analysis for Vermont and New Hampshire. A major effort of the VT/NH project for the past year has been to gather and process aerial videography that is being used for a supervised classification of TM imagery for land cover maps of the two-state region. Transects have been flown over Vermont and New Hampshire during late fall, early spring, summer, and early fall 1994-1995. GPS codes, linked to time codes on the videotapes, have been corrected with base station data, then converted to ARC/INFO and ERDAS files. The quality of the videography is quite satisfactory and lends itself to detailed vegetation classification. We are concentrating on interpretation of videography for Vermont and classification of two scenes of TM imagery from the MRLC acquisition. We await additional TM scenes for New Hampshire.

Last October and November, separate meetings were held with cooperators in the two states. Both states have now initiated biodiversity projects that complement Gap Analysis. In Vermont, the Fish and Wildlife Department is funding a pilot project in the four southern counties that will bring Gap Analysis to a scale more useful for identifying conservation lands within the state, exclusive of a bioregional context. Private organizations, such as the Vermont Land Trust, also are cooperating. Initial plans were made at the cooperators' meetings for an assessment of the accuracy of predicting vertebrate distributions. Several cooperators have agreed to compile thorough lists of species in the hexagonal analysis units used in predicting species occurrence.

There have been some changes in personnel for the Vermont/New Hampshire GAP Project. In September, Ken Williams left the Vermont Cooperative Fish and Wildlife Unit, and David Capen assumed responsibility as Principal Investigator. Joel Schlagel, Systems Manager and Research Specialist, also left for a new position. Ernie Buford continues as a graduate research assistant, and is joined by Chris Boget, another graduate assistant, and Eric Lambert, a GIS and remote sensing specialist. Tom Allen, an assistant professor in Geography is leading the image processing effort. Some of our Gap Analysis products are displayed on the World Wide Web site for the Spatial Analysis Laboratory at http://www.snr.uvm.edu/.

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Virginia

The Virginia Gap Analysis Project started in September 1994 and now involves three graduate students (Dave Morton, Scott Klopfer, and John McCombs), a part-time systems analyst (Blair Jones), a part-time GIS technician (Steve Phillips), and the principal investigator (Jeff Waldon). In addition to the main project, we have begun two associated projects with the Dept. of the Army at Fort Pickett and Fort A.P. Hill to collect verification data for vegetation and vertebrate distributions. We have received considerable support from cooperators, especially the Virginia Department of Game and Inland Fisheries. Two state coordination meetings were held, and our mailing list now contains over 60 biologists and land managers in Virginia. We participated in the Southern Appalachian Gap Analysis Coordination Meeting and agreed to cooperate with the other states in the Southern Appalachian Man and the Biosphere (SAMAB) region on classification consistency and edge-matching.

Hardware and Software

We have developed a network of Pentium-based microcomputers with multiple 1 gigabyte (gb) hard disks. One file server with 4 gb of on-line space and a 1.3-gb optical cartridge drive for near-line storage are available. Peripherals include an 8-mm tape drive and an HP 650C Designjet plotter. We have purchased one license of the Map and Image Processing System software (MIPS) for map composition and vector layer integration. Two licenses for EASI/PACE image processing software by PCI, Inc. were acquired for classification, rectification, and other processes.

Base and Validation Data

We have received and preprocessed all Landsat imagery available through MRLC and are pursuing additional scenes through SAMAB. All SPOT panchromatic imagery for Virginia was also received and preprocessed. We maintain complete copies of the 1:100k DLG transportation and hydrography layers, all available National Wetland Inventory Maps, the best available public lands layer, and a variety of other coverages. The Virginia Department of Game and Inland Fisheries is developing vertebrate distribution maps for all vertebrates and some invertebrates in Virginia. They are currently developing a review process and metadata guidelines for final map development.

Approximately 15 cover type maps from public lands in Virginia were received and processed. Nine of these areas were chosen as intensive test areas for vegetation model development. We just completed our test run of airborne videography and now have 19 hours of film to evaluate. We completed the first simple classified maps of study areas and are working through the process of model development.

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Washington

WA-GAP is nearing completion. The land cover map has been completed but has not been assessed for accuracy. All vertebrate data layers have been completed, and predicted distribution maps have been created for each species. The land ownership map has been completed. Analyses of the gaps in conservation for land cover types and vertebrate species have also been completed. A final report is in preparation and will be completed early in 1996.

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West Virginia

Our land cover mapping efforts are near completion in an intensive study area that was used for methods development (Allegheny Mountain Transitions subsection), and we are now proceeding with the rest of the state. Methods for videography in the mid-Appalachian area were developed, and West Virginia and some areas in contiguous states were filmed in October 1995. We plan to fly West Virginia again in May 1996 as part of a unified airborne video project covering MD, DE, NJ, VA, WV, and NC. The ecoregion map that we will use for stratifying the state was updated. We evaluated the utility of supervised vs. unsupervised classification for the Allegheny Mountain Transition subsection and found that a strategy of post-classification sorting, with elevation and slope/area index included as derived bands, is the most efficient use of the limited ground data we have for community alliances in this area. When the fall videography has been processed, we will proceed with a "hybrid" classification for the rest of the state. Ground vegetation surveys were completed during summer 1995; the data are being used to improve TNC alliances for West Virginia. Additional surveys will be conducted in 1996 for ground checks of the videography images. We have presented talks and training sessions on our methods for remote sensing to the Smithsonian Institution Conservation Research Center, at a U.S. Forest Service course on methods for ecosystem management, at the ACSM/ASPRS meeting in Charlotte, NC, in several classes at West Virginia University, and at an Earth Day booth.

The vertebrate species/habitat relationship database structure for West Virginia is complete. The database from the Virginia Department of Game and Inland Fisheries has been converted and merged with our database, and the data from DeGraaf et al. 1992 (New England wildlife: management of forested habitats) have been entered. Our wildlife database is based on the Society of American Foresters (SAF) forest cover types, The Nature Conservancy's (TNC) classification scheme (in progress), and the Cowardin et al. (1979) wetland classification scheme. We are using the SAF types because TNC's classification is not complete. As TNC data are made available, we will incorporate it into a cross-walk, so our database can be converted when all the TNC types are completed for West Virginia. The West Virginia Division of Natural Resources (WVDNR) and TNC are assisting with collecting locational data for the hexagons-of-occurrence for each species in the state. WVDNR has finished collecting the locational data on all species except butterflies and skippers.

Aquatic Diversity

Our goal is to inventory the level of aquatic diversity within certain drainages in West Virginia and to identify stream reaches or watersheds that offer high conservation potential. The initial study area includes the Monongahela and Potomac river basins, which together cover the northeastern third of the state. Data have been compiled for 94 watersheds within the study area for a number of environmental and human influence variables such as land use, elevation, bedrock geology, and population density. In addition, a fish collection database has been created to incorporate collection records from the West Virginia Division of Natural Resources, U.S. Forest Service, U.S. Environmental Protection Agency, U.S. Army Corps of Engineers, West Virginia University, and museum records into both the EPA River Reach coverage and the watershed coverage. Initial analysis of the watershed level data indicates that mining activities and limestone bedrock geology are related to fish species diversity at the watershed scale.

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Wisconsin

(see Michigan, Minnesota, Wisconsin)

Wyoming

The Wyoming Gap Analysis Project will submit a draft of its final report this summer. At this point, the three major WY-GAP databases (land cover, land ownership/status, and species distributions) are complete. The land cover database is already available on National GAP's WWW home page, and the other two databases will also be available on the Internet as soon as their documentation is complete.

Our recent efforts have been directed toward completing an expert review of the habitat associations and species range maps. We modeled the predicted distribution of 445 species in Wyoming using land cover, elevation, and riparian associations to create our final distribution maps. The review of these maps involved nearly 60 biologists/bird experts across the state. Several experts on a particular taxonomic group met to conduct the review to arrive at a general consensus on species distributions. In most cases, reviewers were satisfied with the maps but acknowledged that not enough is known about some species' distributions to produce a distribution map with much confidence. We are currently comparing our predicted species distributions with published species lists for several areas around the state to get a better idea of the amount of omission/commission error in our model predictions.

We have also just completed a state review of the assignment of protection status codes for which we used the key for categorization of land management developed by the New Mexico GAP project. We asked land managers from different state, federal, and private agencies to evaluate the protection status categories given to the lands under their jurisdictions. In most cases, the reviewers found the New Mexico key helpful in the categorization process. One exception occurred where mixed ownership and management objectives existed for the same area. For instance, private lands occurred within the boundaries of National Parks, Recreation Areas, and other management units. The private lands are not managed in the same manner as the federal lands and, as a result, were given a different protection status.

We expect to complete our Gap Analyses this spring and have a draft copy of our final report available by summer 1996 for review by our cooperators. Besides the three digital databases in ARC/INFO format and our final report, we will produce a book of range maps in the form of a black and white atlas, along with habitat associations and references for each species. In addition, a full-color land cover atlas for Wyoming has been developed, and opportunities for publication and distribution are being considered.

Upon completion of the WY-GAP project, the Wyoming Water Resources Center (WWRC) has been designated as the state repository for the WY-GAP databases. The WWRC's GIS lab is petitioning for the establishment of a data node under the National Biological Information Infrastructure (NBII). In December, the WWRC hosted a meeting of the WY-GAP cooperators to discuss objectives and priorities of the proposed data node. Sara Vickerman of the Oregon Biodiversity Project also discussed aspects of implementation of Gap Analysis to biodiversity at the state level and shared insights and recommendations for the implementation process in Wyoming.

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The Role of Winter Bird Distribution in Conservation Planning

While some large mammals are capable of seasonal migrations of some distance, most amphibians, reptiles, and mammals do not migrate. Many of these species avoid harsh weather by becoming inactive for considerable periods. Many birds, on the other hand, migrate considerable distances from breeding areas to warmer regions where they spend the winter. During breeding season, birds have a limited home range around their nest. Many species are also associated with specific habitat types during their breeding season, and these frequently correspond to vegetation cover types that can be mapped using remote sensing technology. As a result, GAP has emphasized mapping the breeding distribution of birds. As M. D. F. Udvardy notes in his book *Dynamic Zoogeography* (1969:154-155), "In many respects the most important area is that on which successful propagation of the species regularly occurs. The distributional area of the animal therefore usually coincides with the breeding area (breeding range, reproduction area)."

It is undeniable, however, that *in situ* conservation of a species must deal with maintenance of its habitat throughout the year. There is, therefore, a sound argument for mapping winter distribution of a species as well as its breeding distribution. However, winter distribution of birds is less predictable than their breeding distribution. Birds tend to move from one area to another during the winter, often in response to changes in the weather. Some species that ordinarily migrate south may remain on their breeding grounds during mild winters.

Although Christmas Bird Counts, sponsored by the National Audubon Society, provide the best information on winter distribution of birds, they take place over a span of weeks in late fall and early winter, which introduces variability into these data. National maps based on these records have been compiled by Root (1988). Birds also tend to use a wider variety of habitat types during the nonbreeding season, making habitat-based mapping more difficult. For example, many passerine species with specific breeding habitats occur opportunistically throughout agricultural areas during winter. Finally, the individuals of a species that breed in an area may migrate south, only to be replaced by individuals of the same species that breed farther north. This has been documented for species with recognizable subspecies, such as the Fox Sparrow (*Passerella iliaca*).

As a result of the many factors which influence winter distribution of a species, it is inadvisable to combine the breeding and winter distributions of migratory species into a single data layer. Those state programs that elect to include winter distribution of birds in their data sets should maintain them separately from breeding bird distribution data layers. This will preserve the information content of breeding bird maps while addressing the desire to incorporate important bird wintering grounds in biodiversity planning. In Oregon, for example, many bird species have a chance of being seen at virtually any low elevation site during the course of a winter (although they may not remain in most areas throughout the winter). A map of this type of winter distribution has a low information content. Mapping winter distribution of birds may fail to highlight important migratory stopovers, such as major wetlands. Such areas important to many migratory species should also be maintained as a separate data layer.

Literature Cited

Root, T. 1988. Atlas of wintering North American birds: An analysis of Christmas Bird Count data. University of Chicago Press, Chicago.
Udvardy, M.D.F. 1969. Dynamic Zoogeography. Van Nostrand Reinhold Company, New York.

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Plant and Animal Species Data Useful to GAP Investigators

State Natural Heritage Programs (also referred to as Conservation Data Centers) compile and maintain data on elements of biodiversity, including plant species, animal species, plant communities, and other features. The primary task of these programs is to develop detailed information on and track specific occurrences of the elements that are known or suspected to be rare, endemic, disjunct, exemplary, threatened, or endangered throughout their range or within states. Most programs also have extensive information on common vertebrate and vascular plant species, areas under special management, and bibliographic citations. Of particular use to GAP investigators will be species data on population, habitat association, sighting locations, and element codes. An example from the California World Wide Web (WWW) page (Table 1) shows how data are organized for "special" status plants. Full code descriptions are given in associated tables.

A good starting point for information is the Central Natural Heritage and Conservation Data Centres Network home page, WWW address: http://www.abi.org/. This home page is the result of a joint effort by the Association for Biodiversity Information (ABI) and The Nature Conservancy (TNC). Support for the home page is also provided by the U.S. National Biological Service (NBS). ABI was formed by and works to benefit the network of biodiversity data centers across the Western Hemisphere known as the Network of Natural Heritage Programs and Conservation Data Centres. This network currently includes 85 biodiversity data centers (including Hawaii). These programs and data centers exist in the United States, Canada, Latin America, and the Caribbean and collectively represent the largest ongoing effort to collect standardized data on endangered plants, animals, and ecosystems.

By selecting the state of interest within the four regions of the Heritage Program, it is possible to directly access species and other information from the WWW. Currently, there are 13 state programs on line. To obtain species data and element codes for use with Gap Analysis, contact the State Heritage Program in your area. Multistate information can be coordinated through these staff or through TNC regional offices. A list of contacts is published on the WWW (see "State Heritage Programs in the U.S." at http://www.abi.org/nhp/directry/states.html).

Christopher Cogan
University of California-Santa Cruz

Table 1. Sample of species data from the California Natural Diversity Data Base (NDDB) Special Plant Element List. CNPS stands for California Native Plant Society.

Plant Names (scientific [element code]/common)				Records in NDDB
ABIES AMABILIS [PGPIN01010]				No
PACIFIC SILVER FIR		Global Rank: G4	CNPS List: 2	
Listing Status - Federal: None	State: None	State Rank: S2S3	CNPS Code: 2-1-1	
ACANTHOMINTHA DUTTONII [PDLAM01040]				Yes
SAN MATEO THORN MINT		Global Rank: G1	CNPS List: 1B	
Listing Status - Federal: Endangered	State: Endangered	State Rank: S1.1	CNPS Code: 3-3-3	
ACANTHOMINTHA ILICIFOLIA [PDLAM01010]				Yes
SAN DIEGO THORN MINT		Global Rank: G1	CNPS List: 1B	
Listing Status - Federal: Proposed Endangered	State: Endangered	State Rank: S1.1	CNPS Code: 2-3-2	

Application of Gap Analysis to Aquatic Biodiversity Conservation:

Aquatic GAP Pilot Project of the New York Cooperative Research Unit

Methods for the application of Gap Analysis to aquatic systems are being developed and demonstrated in the Allegheny River watershed of western New York. This aquatic GAP pilot started last June and is now focused on two primary tasks: constructing a GIS to predict relative levels of biodiversity, and enhancing the GIS with available biological, physical, and chemical data. In addition, we have constructed the basic GIS structure to interface aquatic Gap Analysis with the terrestrial GAP. Tasks for the immediate future include testing our aquatic biodiversity predictions with available survey data, and the development of a World Wide Web (WWW) site reporting our protocols with examples of finished work. This site will be linked to the National GAP home page.

Our most significant accomplishment to date has been the development of an aquatic habitat classification system for flowing waters that is linked to faunal lists. The system is compatible with the National GAP guidelines (e.g., 100,000 scale) and practical to implement with readily available data. We began with stream and river habitats because flowing waters support a large majority of the aquatic biodiversity across the United States. The classification system has twelve stream and river habitat classes, defined by three attribute sets: stream size (headwaters, large streams/small rivers, large rivers), physical structure (dominated by natural geomorphological processes, human dominated), and water quality (acceptable for life support, degraded). Stream size will be defined by drainage area using the GIS; physical structure is being determined from USGS maps and land uses in the stream corridor; and water quality will be rated using the STORET water quality database of the USEPA and states. Habitat classes can be mapped using the EPA River Reach File as the base GIS layer. As we finish the GIS development, examples of the habitat classification system will be illustrated on our WWW site showing predicted levels of biodiversity.

This Aquatic GAP pilot project is being developed in close consultation with New York state and federal agencies involved with fish and wildlife, water quality regulation and monitoring, land management, and biological surveys. Prior to the start of the Aquatic GAP Project, a small-scale, intensive watershed GIS project was well under way with support from The Nature Conservancy. This joint venture between the NY Cooperative Fish and Wildlife Research Unit and The Nature Conservancy is now embedded in the Aquatic GAP work and provides a means to thoroughly test predictions and methods in a small watershed with extensive, high-resolution biosurvey and land use data.

For further information, see the Aquatic Gap Analysis portion of the National GAP WWW in 1996 or contact the author. site early

Mark B. Bain
New York Cooperative Fish and Wildlife Research Unit

Status of Spectrum Software

TX-GAP was able to compile Spectrum version 2.0.2 for Sun Workstations (with operating systems Solaris 2.4 and SunOS). Initial work with Spectrum revealed that the program could not integrate external data (e.g., videography output from SkyKing software, UTMs and vegetation types from ground verifications). As a result, we contacted the developers of Spectrum in August/September 1995 to investigate the possibility of adding some command language and allow input of external data (see Khoral Research contract, below). An additional problem with Spectrum 2.0.2 was encountered while attempting to load a file previously saved in Spectrum into Spectrum. All attempts at loading such a file caused the program to crash. This problem was encountered at both Texas A&M and Texas Tech Universities. Rick Hammer of the Texas GAP Lab contacted programmers at Khoral Research. An enhanced version of Spectrum 2.0.2 was made available to TX-GAP. The problems with loading a saved file have been corrected in this version. The enhanced version of Spectrum 2.0.2 will soon be available from the GAP home page.

Khoral Research Contract

TX-GAP established a contract with Khoral Research, Inc., the developers of Spectrum, to add command language that will allow Spectrum to integrate external data. As part of our contract with Khoral Research, TX-GAP has agreed that the enhancements paid for in our contract will be released to the general Khoros user community, free of charge, via anonymous ftp (or CD, etc.) at the next release of Khoros 2 (Spectrum is a part of Khoros).

Raymond Sims and Rick Hammer
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Texas Tech University, Lubbocknia-Santa Cruz

1995 Annual GAP Meeting

Thanks to everybody who helped make the Annual Meeting in Fayetteville a success - especially the Arkansas crew! Below is the list of 13 "to do" items that came out of the meeting, along with annotations on the progress that has been made in addressing each.

1. Review the manual guidelines for modeling prediction of vertebrate distribution.
    - Several research projects on this topic are ongoing. Bill Krohn (ME-CFWRU) is identifying species whose distribution can be easily predicted versus those difficult to predict. John Ratti (ID-CFWRU) will be conducting a study of "The impact of land use practices on vertebrates of Western states." Chuck Peterson (Idaho State University) is upgrading models for herps.
    - Patrick Crist sent a request for methods statements to all GAP PIs. He will extract the most practical methods and develop new standard methods that will be reviewed by a working group.
2. Utah and Montana researchers have developed algorithms for aggregating the land cover maps from 30 m pixels to 100 hectare polygons.
    - Fred Limp of the Arkansas project has made a preliminary comparison of the two methods (see page 22, this volume).
3. Idaho, Utah, and Massachusetts have all developed accuracy statements of their vegetation maps, and guidelines for accuracy assessment are detailed in the GAP Handbook. However, more work is needed. A workshop will be held to make progress on developing one standard technique for accuracy assessment.
    - A regional accuracy assessment meeting was held April 9-10, 1996 in Denver to review the experience of states that have done accuracy assessment and to advise new start-ups.
4. GAP researchers have been at the cutting edge of developing and improving techniques for pattern delineation and polygon identification of land cover maps. How can the wide variety of experiences be "harvested" for better, more consistent results?
    - One of GAP's objectives in 1996 is to review and synthesize this experience. The evaluation of all methods used by GAP projects for land cover mapping will be spearheaded by Jim Merchant of NE-GAP.
5. The four land management categories used for the Gap Analysis project may be too limited. There is a need to revisit our thinking on land management categories and provide more detailed guidelines for designation of land use categories. NM-GAP developed a dichotomous key that could possibly serve as a basis for development of finer levels of land management categories.
    - Bruce Thompson is chairing a working group to prepare revised guidelines for the GAP manual (see page 20, this volume).
6. A standardized state project final report outline needs to be developed.
    - The standard report outline is done. A disk with the outline and all boiler plate text is available from the National GAP Office by request.
7. Aquatic guidelines: Dr. Pat Heglund of the University of Idaho and Mike Jennings developed a draft copy of an aquatic manual for GAP. Mike Jennings presented its contents at the meeting. These guidelines will be revised based on comments received at the meeting and circulated for further review.
    - Pat Heglund is completing work on the guidelines for Aquatic GAP.

8. The GAP Handbook chapter on metadata was revised to include more detailed examples.
   - The updated version was distributed to handbook recipients and is also available on the GAP home page.
9. Regionalization of state land cover maps by Bailey's ecoregions is currently under way for the Mojave and Great Basin ecoregions. New regionalization efforts will focus on the Colorado Plateau, Sonoran, Arizona, and New Mexico mountains and semi-desert.
   - Regionalization between Colorado and Utah land cover maps was recently completed. Tom
10. Thompson shared his experience on the GAP Bulletin Board. Efforts in other states are ongoing.
    - The National GAP Office is obtaining Bailey's subsection boundaries from ECOMAP that may be used to segment the landscape for ecoregion analysis. These will be available by request.
11. A digital copy of the TNC master list of animal names and codes will be distributed to all GAP principal investigators.
    - Completed (see page 48).
12. Several PIs indicated that they were unable to get a crisp, sharp version of the GAP logo from the GAP home page.
    - The logo has been enhanced and can be downloaded from the home page. The logo is available in ARC/INFO.gra form as well as in raster form.
13. Edge-matching of vertebrate distributions for the different states will be conducted on an ecoregion basis, with the first ecoregion matching done for the Sonoran and Great Basin ecoregions.
    - Tom Edwards and Blair Csuti are working on edge-matching of vertebrate distributions. Tom O'Neil, with Blair Csuti and Chris Grue, is updating Jack Ward Thomas's paper on the Blue and Wallowa Mountains, Oregon.
14. The home page will be reviewed and a variety of new discussion sections set up for regions and topics of interest.
    - The home page has been reviewed and modified. Further improvements are forthcoming.

The results or status of all these action items will be presented at the next annual GAP meeting. There will be an opportunity for further discussion on how to best accomplish these goals.

Mike Jennings and Elisabeth Brackney
National Coordinator and Program Assistant

GAP Symposium at ASPRS Annual Meeting

In 1994, Maury Nyquist, then President of the American Society for Photogrammetry and Remote Sensing, invited the Gap Analysis Program to present a symposium at their 1995 annual meeting in Charlotte, North Carolina. We saw this as a great opportunity to build a stronger relationship with the remote sensing community. During the symposium, 28 papers were presented under five general headings: Scale and Content of Gap Analysis; Land Cover Mapping; Modeling Vertebrate Distributions; Practical Applications of Gap Analysis; and Technological Issues. Dr. Ron Pulliam made the introductory remarks in which he challenged those of us working with GAP to make greater use of the data sets in developing and testing demographic models for vertebrates and to reach out to more partners. Dr. Jack Estes, the Senior Visiting Scientist with the Mapping Division of the U.S. Geological Survey, summarized the history of GAP and identified present and future challenges to the program. After peer review of the papers, they were sent to the editorial office of the Society for Remote Sensing and Photogrammetry for final editing. We anticipate publication in early May. Following is the full citation:

Scott, J.M., T. Tear, and F. Davis, editors. 1996. Gap Analysis: A landscape approach to biodiversity planning. American Society for Photogrammetry and Remote Sensing, Bethesda, Maryland.

J. Michael Scott, Director
National Gap Analysis Program

GAP Homepage -

1996 Gap Analysis Annual Meeting

The sixth annual meeting will be hosted by the Florida Biodiversity Project. The meeting will be held from Monday, July 15 through Friday, July 19, 1996 in Key Largo, Florida. The preliminary agenda has been mailed out; registration and hotel information will follow. All state GAP projects are encouraged to present a poster to share their experience. To submit poster abstracts and for further information, contact: Craig Allen FL Coop. Fish and Wildlife Research Unit University of Florida P.O. Box 110450 Gainesville, FL 32611 e-mail: craigr@gnv.ifas.ufl.edu

WELCOME Patrick Crist and Becky Sorbel to the National GAP Office!

In late summer 1995, Patrick and Becky joined the National GAP staff. Patrick is a full-time coordinator focusing on the Western states and comes to us from the New Mexico GAP Project. Becky is now the GAP secretary and comes to us from Washington State University's Department of Agricultural Economics. This is an exciting development for us because we can now serve state projects and national partners better. To contact either of them: Patrick Crist, pcrist@uidaho.edu, (208) 885-3901; Becky Sorbel, rsorbel@uidaho.edu, (208) 885-3555. You can contact anyone at the GAP national office by e-mail at gap@uidaho.edu or by mail at 530 S. Asbury, Suite 1, Moscow, ID 83843.

Award for NatureMapping

Congratulations to Karen Dvornich, who recently received a certificate of environmental achievement from Renew America for her development of NatureMapping. This is the fourth national environmental award the program has received since its initiation in September 1993. NatureMapping is an educational outreach program that involves the general public and school children in field-testing maps and generating new information for Gap Analysis. A collaborative effort between the Washington Gap Analysis Project and the Washington Department of Fish and Wildlife, the program has grown to involve an estimated 50,000 people, including 500 teachers. The goal of NatureMapping is to facilitate exchange of information between natural resource agencies, academia, land use planners, local communities, and schools through public education and participation in data acquisition. The Oregon Biodiversity Project and Virginia Fish and Game are now getting started on NatureMapping, nine other states have expressed interest in beginning the program. For more information on NatureMapping, contact Karen Dvornich at (206) 685-4195 or kgap@salmo.cqs.washington.edu. The contact person for Oregon's NatureMapping program is Wendy Hudson, (503) 697-3222 or whudson@defenders.org.

ASPRS's Award for Best Scientific Paper

Zhenkui Ma and Roland Redmond of the Montana GAP Project won the 1995 ERDAS Award for Best Scientific Paper in Remote Sensing from the American Society for Photogrammetric Engineering and Remote Sensing for their paper entitled "Tau Coefficients for Accuracy Assessment of Classification of Remote Sensing Data" (*Photogrammetric Engineering and Remote Sensing* 61:435-439). Dr. Ma accepted the award at the society's annual convention in Baltimore, MD, in April and presented a separate paper entitled "Integrating Remote Sensing and GIS to Map Land Cover Across Large Areas".

Recent GAP Publications

The following list of citations is a brief sampling of recent publications related to GAP that may be of interest to you.

Caicco, S.L., J.M. Scott, B. Butterfield, and B. Csuti. 1995. A gap analysis of the management status of the vegetation of Idaho (U.S.A.). *Conservation Biology* 9:498-511.

Davis, F.W., P.A. Stine, D.M. Stoms, M.I. Borchert, and A.D. Hollander. 1995. Gap Analysis of the actual vegetation of California - 1. The southwestern region. *Madroño* 42:40-78.

Edwards, T.C., Jr. 1995. Protection status of vegetation cover-types in Utah. Pages 463-464 in E.T. LaRoe, G.S. Farris, C.E. Puckett, P.D. Doran, and M.J. Mac, editors. Our living resources. National Biological Service, Washington, DC.

Edwards, T.C., Jr., E.T. Deshler, D. Foster, and G.G. Moisen. 1996. Adequacy of wildlife habitat relation models for estimating spatial distributions of terrestrial vertebrates. *Conservation Biology* 10:263-270.

Jennings, M.D. 1995. Gap analysis today: A confluence of biology, ecology, and geography for management of biological resources. *Wildlife Society Bulletin* 23:658-662.

Jennings, M.D. 1995. Habitat assessments: Overview. Pages 461-462 in E.T. LaRoe, G.S. Farris, C.E. Puckett, P.D. Doran, and M.J. Mac, editors. Our living resources. National Biological Service, Washington, DC.

Loveland, T.R., and H.L. Hutcheson. 1995. Monitoring changes in landscapes from satellite imagery. Pages 468-473 in E.T. LaRoe, G.S. Farris, C.E. Puckett, P.D. Doran, and M.J. Mac, editors. Our living resources. National Biological Service, Washington, DC.

Ma, Z., and R.L. Redmond. 1995. Tau coefficients for accuracy assessment of classification of remote sensing data. *Photogrammetic Engineering and Remote Sensing* 61:435-439.

Merrill, T., R.G. Wright, and J.M. Scott. 1995. Using ecological criteria to evaluate wilderness planning options in Idaho. *Environmental Management* 19:815-825.

Stoms, D.M., and F. Davis. 1995. Biodiversity in the southwestern California region. Pages 465-466 in E.T. LaRoe, G.S. Farris, C.E. Puckett, P.D. Doran, and M.J. Mac, editors. Our living resources. National Biological Service, Washington, DC.

Stoms, D.M., F.W. Davis, and A.D. Hollander. 1996. Hierarchical representation of species distribution for biological survey and monitoring. Pages 445-449 in M.F. Goodchild et al., editors. GIS and environmental modeling: Progress and research issues. GIS World Books, Ft. Collins, Colorado.

Wright, R.G., J.G. MacCracken, and J. Hall. 1994. An ecological evaluation of proposed new conservation areas in Idaho: Evaluating proposed Idaho National Parks. *Conservation Biology* 8(1):207-216.

Yang, X., P.W. Mausel, and F. Clark. In press. Identification of drained wetlands for wetland restoration in the Eel River watershed of Indiana using remote sensing and GIS analysis.