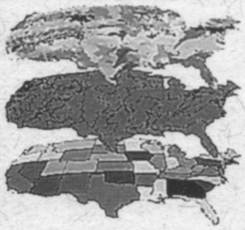

GAP ANALYSIS

BULLETIN

No. 6

A Geographic Approach to Planning for Biological Diversity

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USGS
science for a changing world

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Biological Resources Division

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Director's Corner

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1997 marks the year that GAP graduated from having a research and development status with an unresolved future to having realized its potential as an engine for sound conservation. In moving from the Cooperative Fish and Wildlife Research Units to the Center for Biological Informatics (http://www.usgs.gov/ttc/), GAP moved off of the "R&D" workbench and into an operations mode. The program also finds itself in a new agency with a bright future. A key component of the new USGS is the forging of partnerships between agency and state and local governments, universities, other federal agencies, nonprofit organizations, and industry (Schaefer 1997). This by itself is great news.

That nagging question of what happens after a state GAP project is done can now be answered with a longer-term commitment by the USGS—and hopefully by all GAP cooperators—to continue developing and providing information; continue building the institutional relationships needed to achieve proactive conservation of all biodiversity; continue using GAP data in land use planning, management, and research. This is not to say that the USGS will be able to maintain all state project activities simultaneously or indefinitely. State GAP projects need to have discrete periods of activity to allow products to become stable, to be used and evaluated before a subsequent generation. They also need to continue building a broad base of user support within their respective states.

The status of GAP as an ongoing program means that the seven- to eight-year multilateral venture in research and development has matured rather than being discarded, as so many research projects are. GAP will be there in the future to work cooperatively on updates, to foster state-based capabilities, to find appropriate scales of economy for items such as TM, to regionalize state data, to improve methods and standards, to prospect and explore for new concepts and methods, and to disseminate new and better information about conservation biogeography.

In many ways, it is just now that there has been enough collective experience to support an ongoing national program. Prior to GAP, there was almost no real experience and a very small pool of skilled people who had actually mapped state-sized areas using multiple TM scenes for a base. It is just now that we have a National Vegetation Classification, methods for accuracy assessments (vertebrates as well as land cover), and many of the other basic guidelines needed for a cohesive outcome.

Now that we have a reasonable handle on what can be done, technically and cooperatively, the challenge is to commit to a long-term process of information bootstrapping (more extension and exploration, too). In an operational mode, we need to identify where our information is weak or lacking—spatially, taxonomically, qualitatively—and target those areas for improvement through the ongoing activities of cooperators, guiding new investigations toward areas that need work or queuing them up for the next major update. For example, species can be sorted according to the number and detail of habitat affinity studies that have been done for each, in order to emphasize the information needs of those species that we know little about. Part of GAP should be to identify the gaps in our knowledge of the behavior and geography of each species and each alliance.

In 1998 GAP will have state projects under way or completed in each of the "lower 48," and a pilot project is under way in Mexico. Almost 20 state projects are due to deliver their first-generation products in 1998. In the coming year, the program will begin an effort to update the Southwest states by having analysts in each of the states specialize in a particular ecoregion province, allowing them to spend more time on the alliances within a large landscape type and across the multistate region. One of the most important new activities will be to "take profits" on what has become the largest experiment in remote sensing mapping methodologies by evaluating methods used by different states, then using that collective experience to generate more consistent and efficient methods for land cover mapping. The program has also launched efforts to apply the gap analysis concept to biodiversity of aquatic environments and invertebrate species.

With a lot of data finally coming in, we need to bend to the tasks of applying it to iterative analyses in new ways. Without, of course, ever losing sight of our user-clients and the ultimate need for extension of the information to all sectors of society, because on-the-ground resource planning and management—backyard to statewide—is where the real gains in conservation are to be found. So 1998 will also be a year of attempting progress in developing and trying out a variety of decision support systems that will use GAP data.

Just a few of the highlights beyond 1998: exploration of "smart" land cover updating technologies, better consolidation of specimen locality records, incorporating Mission to Planet Earth data, and generating land stewardship data resolved at the level of individual land management units.

The GAP community has more opportunity than ever to achieve its conservation-through-information goal. GAP would never have gotten this far without hundreds of individuals committed to taking on a big challenge and meeting a very large need. But we've only just set up. GAP cannot realize its potential without the sustained commitment and enthusiasm from you, the GAP community. Imagine that from the development of GAP information and cooperation could come a capability—organizational as well as technical—to develop and implement a unified national strategy for the conservation of biological diversity. Let's go do the next generation!

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Species Occurrence: What, Why, and Where?

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Introduction

What are appropriate scales to use to map species ranges? Why are terrestrial (i.e., non-fish) vertebrates distributed as they are? Where are species likely to occur, and are those occurrences predictable? This is a sample of the questions addressed in a recently completed doctoral dissertation that forms a biogeographical foundation for Maine Gap Analysis. Here we review the research and its utility to GAP. The brevity of this report demands that details be omitted; for more information see Boone (1996) or other publications reporting the research.

Range Mapping and Assessment

Among the many decisions required when mapping species ranges, three are fundamental: 1) the methods used to assess the accuracy of ranges; 2) the size and shape of tessellation (i.e., a regularly- or irregularly-shaped geometric grid) used to map both ranges and distributions; and 3) the tessellation used to map observation data (e.g., atlas data) used in assessments. To address these questions, we defined range boundaries for the 187 bird species that breed in inland Maine, using atlas data, rare occurrence records, literature, and expert review.

We did not use data from the Breeding Bird Survey (BBS) to define ranges, making a decision early on to use BBS information for testing. From the BBS, smoothed relative abundance maps were created for each species for which there was adequate data, using block kriging (following others, e.g., Maurer 1984; Price et al. 1995), based on a 324 km^2 grid, and mean numbers of birds observed from 1984-1993 on 189 routes within a 300-km radius of Maine. Of 186 bird species breeding in inland Maine, 80 had range limits in the state. Of these, 47 species had adequate BBS data to yield smoothed abundance maps. Zero contours (i.e., range limits) are difficult to define in relative abundance maps. Instead, we used an algorithm that identified a boundary having the best fit between the species range map defined for Gap Analysis and the BBS abundance map. An iterative ARC/INFO program compared the number of grid cells in disagreement for abundances until an optimum fit was reached.

When avian range maps were compared to relative abundance maps, the ranges compared reasonably well. For species with high-quality kriged maps (n = 18), the median error between generalized ranges and observed data was 8% of the state's surface area. When the disagreement in area was considered, species with good kriged maps differed by only 3.9% of the state's area; over all species, the error was 4.5%.

When smooth-lined range maps were compared to ranges generalized to tessellations of various block-sizes and shapes (Fig. 1), the error introduced into ranges was modest for block-sizes < 1,000 km^2 (Fig. 2a). As examples, townships (mean size of 93 km^2) introduced a maximum error of 1.5%, EMAP hexagons (640 km^2) introduced 4%, and counties (mean size 4,900 km^2) introduced 20% maximum error.

Observations of species may represent areas larger than the site surveyed (e.g., an observation of a bird in an atlasing effort leads to an entire block of thousands of km^2 to be shown as occupied). The size of these observation blocks affects how much of the state will be labeled as "confirmed breeding" in mapping efforts (i.e., the perceived confidence in the statewide observation data). The proportion of the state with "confirmed breeding" rose steeply for block sizes < 1,000 km^2 (Fig. 2b). For block sizes over 1,000 km^2, perceived confidence did not increase in proportion to block size.

In summary, mapping the ranges of many species requires balancing conflicting utilities—large tessellations used to map ranges increase confidence in the range but introduce error, and large observation blocks increase perceived confidence in species' range maps but may be misleading because of heterogeneous landscapes. Whatever the outcome, decided upon based on the balance of utilities described above, tessellations or observation blocks > 1,000 km^2 should not be used when mapping an area the size of Maine, especially tessellations that are irregularly shaped (e.g., counties in many states).

Biogeographic Relations

We partitioned variation in richness into its components for each terrestrial vertebrate class, i.e., amphibians (n = 17, 6 with range limits in the state), reptiles (16, 13), mammals (56, 20), birds (186, 80), and all species (275, 119). These statewide distributions were compared quantitatively to geomorphology, climate, and woody plant distributions, mapped using a grid of 324 km^2 cells. Amphibian and reptile ranges were related positively to productivity (e.g., heat accumulation, maximum temperature, frost-free period) and negatively to average annual snowfall. Seven mammal ranges were related positively to productivity, and six were positively associated with snowfall and elevation. Many bird ranges (n = 47) were positively associated with productivity and negatively with snowfall, but some (n = 29) were related oppositely (Boone 1996). Birds that were classified as forest specialists, and those classified as early successional, were spatially coincident with the north-south and east-west plant transition zones, respectively. Forest generalists and birds classified as using barren/urban or wetland/water habitats were not associated with either plant transition zone. In models describing variation in total species richness, climatic variation was the best descriptor (r^2 = 92% in tree regression), followed by woody plant distributions (87%) and geomorphology (87%). Reptiles were highly correlated with environmental variables (93%), followed by amphibians (85%), birds (82%), and mammals (81%).

Are Errors in Species Occurrences Predictable?

GAP researchers assessing their predictions of species distributions have tested their work by comparing species predicted for an area to check lists (e.g., Edwards et al. 1996). Researchers report error rates without further interpretation, or relate *a posteriori* the error rates of species to their ecological attributes. Instead, we suggest that species should be ranked as to how likely they would be to occur in future surveys, which is closely related to how likely a species' distribution will be predicted correctly in gap analyses. These rankings become a form of *a priori* hypothesis regarding the relative accuracy of potential occurrence predictions for groups of species.

We created a method that allowed avian species to be ranked as to how likely they would be to occur in future surveys. Attributes (e.g., population level, niche width, population trend, body weight, aggregation) were used to model the incidence of occurrence within the Maine Breeding Bird Atlas (BBA;

Adamus 1987). Likelihood Of Occurrence Ranks, or LOORs, were assigned to each avian species, based upon the modeled incidences, to reflect how likely the species are to be observed in future surveys. To test the utility of the ranks, the occurrence of birds on six areas located throughout Maine, with species checklists and existing vegetation maps or habitat descriptions, were predicted and then compared to the LOORs.

Using the explanatory data in a logistic model, 78.3% of the variation in species incidences within the BBA was explained. Population aggregation, abundance, and species niche width were the three most importance variables in describing incidence. From the model, LOORs were assigned to the 183 bird species, and species were placed into 10 groups based upon LOORs. The number of species correctly modeled using species-habitat associations was highly correlated with grouped LOORs (p 0.68-0.93, $P \leq 0.032$)—species judged *a priori* to be unlikely to be modeled correctly were not (Fig. 3). Sites with checklists from many years (e.g., > 10 years) and from large areas (e.g., > 1,000 ha) yielded the lowest commission error.

These results demonstrate that the confidence levels assigned to Gap Analysis results is dependent on the test sets and on the species included. Small areas or sites with surveys of too few years will yield tests with high commission errors. (Editor's note: see especially Gibbons et al. 1997.) Direct comparisons between different modeling efforts is not straightforward. For example, areas with a high proportion of rare species (e.g., some islands) are likely to have high commission errors, regardless of the accuracy of models. Researchers testing their own results may ensure a checklist is essentially complete using species-accumulation curves, resampling techniques, or expert opinion. Conducting tests on areas of several sizes is helpful. Researchers interested in comparing the results of several modeling efforts may find standardizing species incidence using the BBS helpful. Omission and commission errors for quantiles of standardized incidences, for example, would be comparable.

Significance to GAP and Future Directions

Assessments of ranges using BBS data suggest that the empirical methods used to define vertebrate ranges, at least for birds, worked reasonably well. GAP projects with ample data for defining ranges (e.g., state atlases) might consider reserving BBS for testing. Regarding tessellation shape and size, under Maine conditions, mapping ranges using tessellations up to the size of EMAP hexagons is reasonable, but using irregular shapes or larger tessellations results in a loss of information. In Maine, we will store ranges in three formats: 1) their original tessellation (townships), 2) as smooth range lines, and 3) using EMAP hexagons.

The accuracy of avian species predictions in Maine Gap Analysis will be assessed under the framework provided by LOORs. By stratifying species into those likely to be predicted correctly and those unlikely to be predicted correctly, our omission and commission errors for sites with checklists will be more informative. The biogeographic analyses have led to another method of assessing GAP results that can be compared to using checklists. The correlations described were done with range maps, not predicted occurrences. After predicting the occurrence of species within Maine, the correlations will be recalculated. If species-habitat associations used in Gap Analysis are indeed useful, we would expect the correlations to improve.

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Gap Analysis of the Vegetation of the Intermountain Semi-Desert Ecoregion

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The nation's first formal Gap Analysis of a multistate ecoregion has been conducted for the Intermountain Semi-Desert ecoregion (Bailey 1995).

The Intermountain Semi-Desert ecoregion encompasses approximately 412,000 km^2 in portions of Washington, Oregon, Idaho, Nevada, California, Utah, Wyoming, Colorado, and Montana. Two geographically disjunct subregions make up the ecoregion, the Columbia Plateau in the west, and the Wyoming Basin in the east. The Intermountain Semi-Desert boundary corresponds closely to the limits of Küchler's sagebrush steppe potential natural vegetation type. The southern boundary of the Intermountain Semi-Desert ecoregion grades into the Intermountain Semi-Desert and Desert Province, which tends to be warmer, drier, and with greater topographic relief than the Intermountain Semi-Desert ecoregion. The Cascade and Sierra Nevada mountain ranges bound the ecoregion on the west and the northern Rocky Mountains bound it on the north and east.

This ecoregion was selected for the prototype regional gap analysis for both practical and conservation reasons. From a practical standpoint, the Intermountain Semi-Desert ecoregion was among the first for which the requisite land cover and land management mapping were completed by the individual state-level GAP projects. Additionally, the area provides a suitable testing ground for demonstrating whether GAP can overcome the technical challenges associated with large-area regional mapping that have concerned some program reviewers. Very little land in the Intermountain Semi-Desert ecoregion has been designated for maintenance of biodiversity, while potentially conflicting land uses such as grazing and cultivation are extensive. Enough undeveloped habitat remains, however, for pro-active conservation action to be effective. Thus the Intermountain Semi-Desert ecoregion makes a representative case study that could be applied to other regions throughout the western U. S. Planning for conservation and ecosystem management within this ecoregion is under way by The Nature Conservancy, the Oregon Biodiversity Project, and the Interior Columbia Basin Ecosystem Management Project (a joint effort by the U. S. Forest Service and Bureau of Land Management). Also, BLM is considering wilderness proposals in Wyoming, and proposals for other new wilderness areas and national parks in Idaho and Wyoming are being discussed. A regional Gap Analysis could add valuable information for all of these planning programs.

Land cover was originally mapped independently for each of the states in the Intermountain Semi-Desert ecoregion. Although most state GAP projects used 1990 (+/- 2 yrs) satellite imagery from the Landsat Thematic Mapper sensor, combined with field inventories and existing maps of vegetation in compiling their land cover data, they differed in methods and products. Maps for Idaho and Oregon used photointerpretation techniques with older, lower-resolution Multispectral Scanner images and had larger minimum mapping units than the other states. In contrast, land cover mapping in Nevada and Utah was done with digital image processing of TM image mosaics. This digital classification approach generally achieved greater spatial resolution at some expense in classification detail. The other state projects fall somewhere in between these methods, using manual photointerpretation of higher resolution TM data.

Experienced GAP staffers from states across the ecoregion collaborated to compile and standardize the database and to conduct the analyses. A workshop was held at the University of California, Santa Barbara (UCSB), in June 1996 for the members of this ecoregional team, led by Frank Davis and David Stoms at UCSB. The group first cross-walked the state land cover types to a standardized set of alliances—or to a higher level of classification when necessary. A preliminary regional map was generated by mosaicking the cross-walked state maps together. Then the CA-GAP staff developed an innovative mapping technique to produce a regional land cover map with greater spatial and thematic consistency. Multitemporal satellite imagery from the NOAA Advanced Very High Resolution Radiometer (AVHRR) was used to refine the preliminary map by providing a more consistent spatial resolution (1 km^2 or 100 ha pixel size) across the entire Intermountain Semi-Desert ecoregion while retaining its basic floristic information. This mapping technique is described in Stoms et al. (in review). The team also assisted in compiling a consistent regional land management status map, which required some standardizing of definitions and attributes.

The total amount of land permanently protected in the ecoregion is less than 4%, and most types characteristic of the region have less than 10% of their area represented in conservation lands. Of 48 land cover types, twenty were found to be particularly vulnerable to potential loss or degradation because of the low level of representation in biodiversity management areas and the likely impact of land use activities. The gap analysis data and findings (described in Stoms et al. in press) will be useful in providing a regional perspective in project impact assessment and future conservation planning within this ecoregion.

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Final Report Summary: New Mexico Gap Analysis Project

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This research included all of New Mexico, a 314,920 km^2 landscape that reflects a varied geologic and natural history. New Mexico's diverse array of species is attributable to complex connections of regional biogeographic components from the Great Plains, Rocky Mountains, Great Basin, and Chihuahuan and Sonoran Deserts.

Land Cover Classification and Mapping

We developed our land cover classification scheme in cooperation with the New Mexico Natural Heritage Program and consultation with experts on New Mexico vegetation. The final land cover map has approximately 24,260 polygons representing 42 mapped classes that include 33 terrestrial and riparian vegetation community classes, 2 hydrologic feature classes, 2 aquatic classes, 2 urban classes, and 3 classes of barren, rocky, or mined ground. We assessed accuracy of the final land cover map during February-July 1995 by ground-truthing 1,763 polygons with cooperation from state and federal agencies and a variety of other knowledgeable and interested people. Conservative accuracies among mapped classes ranged from zero to 80% at grouped cover-type level. Highest accuracy was associated with agricultural land cover, high-elevation conifer forest, urban vegetation, desert scrub, and natural surface waters. Accuracy among classes generally improved dramatically by accounting for ecotones and inclusions.

Predicted Animal Distributions and Species Richness

We modeled 584 species (26 amphibians, 96 reptiles, 324 birds, and 138 mammals) relative to species-specific data on associations with land cover types, mountain ranges, watersheds, elevation, slope, water, soils, and known general range. We consulted experts to review first-draft maps of species distribution predictions. To assess distribution predictions, we obtained species occurrence data for birds in a county in the northwest corner of New Mexico and amphibians, reptiles, and birds of a military reservation in southern New Mexico. Comparison of predicted animal presence to records of occurrence ranged from 53.8% to 88.6% accuracy among three taxonomic groups for two locations. Omission errors were more prevalent for the county data, whereas commission errors were more prevalent for all taxonomic groups compared for the military area. These patterns related to degree of recent specific surveys of test areas.

Considering all 584 animal species included in our project, we predicted the richest areas in the state to contain 327 species, 56% of the total. Richest areas among taxonomic groups contained 53.8% of 26 amphibian species, 59.4% of 96 reptile species, 65.7% of 324 bird species, and 47.8% of 138 mammal species. Assessment of data for breeding distribution of birds relative to year-round distribution of birds indicated distinctions between those data sets for drawing conclusions about bird richness.

Land Stewardship and Management Status

We used a public domain map of land ownership categories in New Mexico at 1/4-1/4 section (40 acre or 16 ha) resolution. With additional data about specific stewardship boundaries incorporated from federal and state agencies, several tribes, land trusts, and private landholders, we added 670 polygons to the ownership. Before assigning management status categories, we assessed views about management classification from a work group of various federal and state government agencies, tribal representatives, environmental organizations, and private landholders statewide. From variability in the responses, we concluded that the land management categories are not interpreted and applied in the same way by all individuals. Thus, we developed a dichotomous key to consistently assign status to the stewardship boundaries (Crist et al. 1996).

Private lands (45%) were the dominant category of stewardship; federal stewardship was dominated by Bureau of Land Management, U.S. Forest Service, and military lands. We identified 18 general categories of land tracts represented in management status 1 and 2 lands. These categories included an array of federal, state, and private managing entities. Distribution of management status in New Mexico was estimated as 2,418 km^2 of Status 1 (1%), 19,354 km^2 of Status 2 (6%), 89,833 km^2 (29%) of Status 3, and 203,320 km^2 (65%) of Status 4.

Analysis Based on Stewardship and Management

Management status 1 and 2 represent about 7% of the New Mexico landscape. We identified 11 natural land cover classes each represented by less than an estimated 100,000 hectares. Six of these restricted classes (Madrean Lower Montane Conifer Forest, Madrean Closed Conifer Woodland, Broadleaf Evergreen Interior Chaparral, Graminoid Wetlands, Riverine/Lacustrine, and Basin/Playa) each had less than 10% of their estimated area in Status 1 and 2. Statewide, 20 natural land cover classes each had less than 10% of area in Status 1 and 2. Of these classes, nine (primarily Madrean Forest and Woodland, Interior Chaparral, Broadleaf Sand-Scrub, and various Wetlands) each had less than 10,000 hectares in Status 1 and 2 areas. Management Status 1 and 2 lands were nearly all distributed among a variety of federal agencies and functions. Private and tribal stewardship is significant in the overall distribution of many land cover classes; 5 of the 11 most restricted classes have at least 45% of area on private and tribal lands.

We identified 35 species with no more than 1% of their predicted distribution on Status 1 and 2 lands. Nearly 45% of these species were reptiles and amphibians, despite those taxonomic groups representing 21% of all species included in analyses. Six of the nine species with no predicted distribution on Status 1 and 2 lands were amphibians and reptiles which have restricted distributions in southern New Mexico. Overall, 465 species (79.6%) each had less than 10% of their distribution on Status 1 and 2 lands. Importantly, all users of these data should recognize that some species primarily distributed on Status 3 and 4 lands adequately meet their biological needs there. Judicious evaluation will be needed to determine which species represent biological gaps.

Data Use and Availability

NM-GAP data are presented in a format that will operate on a PC configured to run ARC/INFO and ArcView current to November 1996. However, all possible combinations of data queries were not tested. A workstation may be necessary for some operations. NM-GAP data products and documentation may be acquired from the Resource Geographic Information System (RGIS) of New Mexico at (505)277-3622; Internet at http://rgis.unm.edu:8080, or from the national GAP Home Page on the Internet at http://www.gap.uidaho.edu/gap.

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Final Report Summary: Washington Gap Analysis Project

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We conducted the Washington State Gap Analysis within the context of 31 vegetation zones: 9 steppe, 9 westside mesic-wet forest, 11 eastside dry-mesic forest, and 2 high-elevation zones. Data and results are reported in both hard copy and digital format. The hard-copy format is a five-volume report (in press). Volume 1 is a description of current land cover and its conservation status. Volumes 2, 3, and 4 are atlases for herpetofauna, mammals, and birds, respectively, and Volume 5 is the gap analysis. Digital data will be available through the Washington Department of Fish and Wildlife.

Land Cover

Actual land cover within each vegetation zone was mapped by on-screen digitization using spectrally clustered 1991 Landsat satellite Thematic Mapper (TM) imagery as a backdrop. The protection status of each zone was assessed using: 1) the percent of the zone in Conservation Status 1 and 2 lands, and 2) a Conservation Priority Index: CPI = ((100 - % protected)/(100 - % converted)) * log(total area in the zone) where "% converted" refers to the percentage of the zone converted to agriculture or development and "% protected" refers to the percentage of the zone in Status 1 and 2 lands.

Statewide, the percentage of lands in Conservation Status 1 and 2 is 12%, but protected lands are unevenly distributed among vegetation zones. The six steppe zones (all < 6%, four < 1%) and the four Puget-Willamette Trough zones (all < 3%) have the least Status 1 and 2 lands. The percentage of Status 1 and 2 lands in other zones generally increases with elevation, with the Permanent Ice/Snow zone having > 97% of its area on Status 1 and 2 lands. When vegetation zones are ranked by Conservation Priority Index (CPI), the four zones with highest priority based on low protection status, high conversion, and importance in terms of size, are three steppe zones (the Palouse, Big Sage/Fescue, and Wheatgrass/Fescue zones) and one westside zone (the Willamette Valley zone). Of the seven zones of moderately high CPI, four are steppe zones and three are the remaining Puget-Willamette Trough zones. Thus, seven of nine steppe zones and all four Puget-Willamette Trough zones have high or moderately high CPIs. Overall, 51% of the steppe zones has been converted to agriculture; 70-88% has been converted in the three steppe zones with the highest CPI. In the Puget-Willamette Trough zones (which encompass the major metropolitan areas of the state), 40-67% has been developed or converted to agriculture, and none of these zones have more than 15% of their area in conifer forest, the natural dominant cover.

Vertebrates

Distributions of terrestrial vertebrate species were modeled by intersecting range limits with suitable habitats (Fig. 1). We assigned codes to indicate habitat quality for each species based on ecoregion, vegetation zone, and land cover within the zone. Vegetation zones within an ecoregion were designated as "core" or "peripheral"; core zones were those in which the species was most common and peripheral zones were those in which the species occurred, but was rare or the zone was believed to be a population sink. Land cover was designated as "good," "adequate," or "contingently suitable" (i.e., suitable, contingent upon the availability of habitats below our minimum 100-ha mapping unit).

We assessed the protection status of vertebrates by: 1) calculating each species' total predicted distribution, the percentage of its distribution on Status 3 lands, and the percentage of its distribution of Status 1 or 2 lands; 2) mapping vertebrate species richness of various taxonomic groups and assemblages by overlaying predicted species' distributions; and 3) mapping areas of high vertebrate richness according to Conservation Status (Fig. 2). The effects of basing vertebrate richness analyses on presence/absence versus the most suitable habitats for each species were also explored. We found that presence/absence-based maps obscured the relative importance of low-elevation zones and habitats unaltered by human activity. All subsequent vertebrate analyses were based on the most suitable habitats for each species.

Amphibians: The number of native amphibian species is highest in mid- to late-seral conifer forests in low- to mid-elevation westside forest zones. Mid- to late- seral conifer forests in the Western Hemlock zone on the southern Olympic Peninsula and the southwestern Cascades have particularly high amphibian richness.

Reptiles: Native reptile richness is highest in the steppe zones and low-elevation eastside forest zones in steppe habitats, open forests, and forest openings.

Mammals: Habitats with high numbers of mammal species are riparian areas and forests in the Western Hemlock and Olympic Douglas-fir zones of the westside, and the Interior Western Hemlock, Interior Redcedar, and Grand Fir zones of the eastside, but the patterns of species richness vary greatly among mammalian subgroups.

Birds: Native bird richness is generally highest in low-elevation forests of the eastside and low-elevation wetlands throughout the State; however, the patterns of species richness varies considerably among avian subgroups.

We chose 10% representation on Status 1 or 2 lands to compare the relative protection status of taxonomic groups of vertebrates. For each group, the number of native species with less than 10% of their predicted distribution on Status 1 or 2 lands was:

Amphibians	14 of 24	(58%)
Reptiles	18 or 21	(86%)
Mammals	45 of 102	(44%)
Birds	138 of 230	(60%)

Other groups of interest included low-disturbance associates, state and federally listed species, and Columbia Basin-dependents. For these groups, the percentage of species with less than 10% of their predicted distributions on Status 1 or 2 lands varied between 38 and 100%.

For each species, we also calculated its total modeled distribution in Washington and the percentage of the modeled distribution on Status 1 or 2 lands. Though some caution must be used in comparing modeled areas between species at different trophic levels and in habitats of greatly differing productivity, our data do allow us to determine which species have a combination of low protection status and limited distribution, a warning sign of potential risk of extirpation.

Highest Conservation Priorities

<u>Steppe zones and Columbia Basin-dependents</u>: The most glaring gap in protection of biodiversity in Washington is in the steppe zones. The vegetation zones with the highest Conservation Priority Index (CPI) are steppe zones. Vertebrate species that rely on steppe usually have a correspondingly low percentage of their distribution on areas managed primarily for biodiversity.

<u>Puget-Willamette Trough zones</u>: These zones include the Puget Sound Douglas-fir, Woodland/Prairie Mosaic, Willamette Valley, and Cowlitz River zones. All have been heavily converted to both agriculture and development. The remaining forests are now a patchwork of hardwood, mixed, and early-seral conifer forest. There are only a few small areas of high richness of low-disturbance associates, as most of these species have been extirpated

from these zones.
Ponderosa Pine and Oak Zones: These lowest elevation eastside forest zones have moderately high CPIs with less than 4% of their areas in Status 1 and 2 lands. They are zones of high reptile and avian diversity. Reduction in natural disturbance via fire suppression is a significant conservation problem in these zones.
Sitka Spruce and Western Hemlock Zones: These wet to mesic, westside forest zones have relatively little of their areas in development or agriculture, but logging has been extensive. They are zones of high amphibian and mammal (especially bat) richness, and their remaining mid- to late-seral forests support large numbers of amphibian, mammal, and bird species that adapt poorly to anthropogenic disturbance. Our data indicate that less than 8% of the Sitka Spruce zone and less than 10% of the Western Hemlock zone remain in late-seral forest; an additional 14% of the Sitka Spruce zone and 20% of the Western Hemlock zone were estimated to be in mid-seral forest.

Final Report Summary: Wyoming Gap Analysis Project

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The Wyoming Gap Analysis project (WY-GAP) recently completed its assessment of biological resources for the state. Our results show that less than 10% of the state of Wyoming is classified as Status 1 and 2 lands, and 90% of these lands occur in the Greater Yellowstone Area (GYA). Seven of the 41 land cover types occur at high elevations and are well (> 50%) protected in Wyoming because they occur in national parks and wilderness areas. Sixteen (44%) of 36 natural (nonanthropogenic) land cover types have < 1% or < 50,000 ha of the area they occupy in Status 1 and 2 lands. The highest priority for further protection is recommended for vegetated dunes, active dunes, forest-dominated riparian, shrub-dominated riparian, and grass-dominated wetlands because their current protection is low, and they are the most vulnerable to ongoing land management practices. However, wetland types are not satisfactorily mapped at our current MMU, and further efforts are needed to provide an adequate spatial description of their location before long-term planning for their conservation can be accomplished.

On average, a smaller percentage of the potential habitat of amphibians (8.8%) and reptiles (2.6%) occurs in Status 1 and 2 lands than either birds (14.4%) or mammals (14.5%). Species that have a high level of habitat protection (> 50%) were restricted to the GYA. Habitats of 6 (50 %) amphibians, 8 (31%) reptiles, 25 (22%) mammals, and 41 (14%) birds that are not considered peripheral in Wyoming merit increased management attention. The habitat of most of these species is primarily at low elevations in the eastern portion of the state or in the Green River area where Status 1 and 2 lands are uncommon. Management on multiple-use lands under the stewardship of the USFS in the Black Hills and the BLM in the Green River area, and cooperative efforts with private land owners in both the eastern portion of the state and in the Green River area, will be important to the long-term conservation of a large number of vertebrate gap species in Wyoming. However, we found that additional efforts to survey and map bat and rodent species will be necessary to reliably evaluate their current status.

For more information on the results of the Wyoming Gap Analysis, please obtain a digital copy of the report from the Wyoming Bioinformation Node web site at http://www.sdvc.uwyo.edu/wbn. If you have questions or would like a hard copy of the report, please contact Tom Kohley at (307) 766-2734 or kohley@uwyo.edu.

Mapping the Kansas Grasslands: A Multiseasonal Approach

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Introduction

The extensive grasslands of Kansas dominate the state's natural vegetation. To the west, in the lee of the Rocky Mountains, sparse rainfall generates arid shortgrass prairies, while increased rainfall in the central part of the state yields mixed-grass prairies. To the east, sufficient precipitation occurs to support tallgrass prairie that mixes with oak-hickory deciduous forest in the far eastern part of the state. Most of the grasslands in the western two-thirds of the state are native, having never been plowed, and are primarily used for grazing domestic livestock. In the tallgrass prairie region, grazing is also prevalent, but many grasslands (both tame and native) are managed for hay production. Kansas also contains large acreages of former cropland that are now covered with native and non-native grasses as part of the USDA Conservation Reserve Program (CRP).

According to a recent map of land cover patterns in Kansas (Whistler et al. 1997), the distribution of grasslands is often associated with the moderately sloping terrain of major and minor drainages, whereas the alluvial river valleys and level-to-gentle upland slopes are used for crop production. However, there are several regions in Kansas that contain relatively intact grassland ecosystems, mainly because of high topographic relief and rocky or sandy soils. These include the famed Flint Hills region with its rolling tallgrass prairie in eastern Kansas that stretches from near the northern border into the Osage Hills in Oklahoma. In the south-central region, Red Hills mixed prairie is found on gypsum hills in a scenic landscape dotted with red cedar trees and caves. Another grassland type, chalkflat mixed prairie, occurs in west-central Kansas along Hackberry Creek and the valleys of the Smoky Hill River. This region is famous for its beautiful erosional remnants of Niobrara chalk. Sand prairie and sandsage shrubland occur in the southwest along extensive sand dunes to the south of the Arkansas and Cimarron Rivers.

Development of a Grassland Classification System for Kansas

In 1989, the Kansas Natural Heritage Inventory of the Kansas Biological Survey (KBS) developed a preliminary statewide vegetation classification to identify and plan protection for exemplary occurrences of Kansas' ecological communities. The classification was based on examining Küchler's (1974) potential natural vegetation map in relation to the geology, soils, and physiographic provinces of Kansas. Vegetation types were identified based on variations in physical features (e.g. climate, soils, and topography) that contributed to differences in plant species composition. For example, although sharing the same dominant species, a "northeastern" and "southeastern tallgrass prairie" were formed because of known differences in soil development (i.e. glaciation) and the floristic composition of communities in these areas.

The present grassland classification system used in the Kansas GAP Project and by KBS is a conversion of the 1989 version into the vegetation classification system developed by The Nature Conservancy in cooperation with state, federal, and academic partners (The Nature Conservancy Ecology Working Group 1997). The new classification of the natural vegetation of Kansas (Lauver et al. in prep.) contains 23 grassland community types under 13 different alliances.

Problems Inherent in Mapping Grasslands

Several problems are inherent in attempting to map grassland types using satellite imagery. The first one is the nature of grasses themselves. Individual grass plants are much smaller than trees and shrubs and are below the resolving ability of any commonly used digital or photographic system. Closely related to this is the frequent spatial variation in cover composition within a given grassland type. Unlike crop fields, grassland vegetation is rarely homogeneous unless it has been planted and managed. Each grassland type consists of mixtures of grasses, forbs, and even shrubs. In addition, patches of bare soil often enter the picture, particularly in arid regions. All of these factors create an environment where "pure" pixels are a rarity, and where considerable spectral heterogeneity can be found within a single grassland parcel.

Another issue is that most of the grassland in Kansas is actively managed for agricultural uses, including grazing and haying. Intensity and seasonality or timing of use, especially for grazing, vary widely, depending on the practices of the owner or manager, climatic conditions, and grassland health. Visual inspection of satellite images or air photos often shows clear delineations among land parcels because of differences in grazing intensity. In addition, grassland used for grazing is often burned in the spring to stimulate production. Hayed grasslands, whether natural or planted, also present challenges because haying practices vary by land owner. From the standpoint of land cover mapping, the biggest concern arising from the intensive human management of grasslands is that spectral variations due to management practices may mask the variations among grassland types and cause unacceptable confusion in land cover maps.

A Multiseasonal Approach

To address the problems outlined above, we have elected to use a multiseasonal two-stage approach to land cover mapping. Using a multiseasonal approach in Finney County in southwest Kansas, we earlier produced excellent results in separating grasslands from croplands and in mapping individual crop types (Egbert et al. 1995). Based on that study, we decided to apply a similar approach to mapping grasslands. For each scene center in Kansas, we acquire three dates of Landsat Thematic Mapper imagery over the growing season: spring, summer, and fall. Our rationale for using this approach is that seasonal differences in plant development vary by species, and using multiple dates of imagery will increase the likelihood of sensing the differences among vegetation types. For example, we have found that when we use July images to classify vegetation in western Kansas, croplands like corn and milo are often spectrally confused with some riparian vegetation types, such as cattail and bulrush marshes. When a spring scene is added, however, the differentiation among the classes is simplified because the corn and milo fields are bare soil at that time of year.

Our methodology employs both unsupervised and supervised classification. Unsupervised classification separates cropland from natural vegetation, while supervised classification is used to map vegetation alliances. In initial processing, the images are georectified and registered to each other. The three images are then combined to form a single multidate image. To reduce the volume of data, only bands 3, 4, 5, and 7 are used from each image, resulting in a 12-band image. The 12-band multidate image then undergoes unsupervised classification using the ISODATA clustering algorithm and a maximum likelihood classifier, creating 100 raw classes. Analysts examine the raw classes and assign them to one of two categories: cropland or non-cropland vegetation. Classes with large percentages of pixels in both categories are placed in a third, confused class. The confused classes are isolated and undergo a second unsupervised classification in a "cluster-busting" technique (Jensen et al. 1987); the resultant new classes are then assigned to either the cropland or non-cropland categories. The result of the unsupervised classification phase is a map of cropland and noncropland land cover. This map is used to create an image mask containing only the noncropland pixels, which is retained for further processing.

Supervised classification is applied to the masked noncropland pixels to create a map of GAP land cover categories. Representative field sites are collected and labeled by grassland ecologists using images, maps, and GPS receivers. Two-thirds of the sites are used for training the classifier, while the remainder are used for verification. In the accuracy assessment process, the verification sites are used to create contingency tables, and to calculate user's and producer's accuracies, along with KAPPA.

Credits

Land cover mapping for Kansas GAP is being conducted by the Kansas Applied Remote Sensing Program and the Kansas Biological Survey at the University of Kansas in Lawrence, Kansas. Principal investigators for Kansas-GAP land cover mapping are Edward A. Martinko and Kevin Price. Researchers and staff members contributing to Kansas-GAP include Stephen Egbert, Chris Lauver, Clayton Blodgett, Miguel Ortega-Huerta, Ellen Ellis, Aimee Stewart, and Ryan Boyce.

A poster showing a map of the Kansas GAP pilot project and current land cover mapping status can be viewed on the National GAP home page at http://www.gap.uidaho.edu/gap/posters/Index.htm

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A Preliminary Analysis of GAP Land Cover Mapping Procedures

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Accurate maps of land cover are clearly critical to the GAP Program. In order to facilitate regional and national-level Gap Analysis and to allow for studies of change over time, individual states must be mapped so as to ensure state-to-state consistency. Each state project, however, has a unique blend of technical expertise and capabilities. Each is dealing with a unique mix of land cover types. And, each has a unique set of statewide cooperators and project goals to satisfy. In order to balance all of the needs and create the most useful products possible, the GAP community has shown a great deal of innovation in mapping land cover. A wide variety of methods have been used by individual states to map their land cover. At the Center for Advanced Land Management Information Technologies (CALMIT) at the University of Nebraska, we have been conducting a study of land cover mapping protocols and methods used to develop land cover maps in support of the Gap Analysis Program. This paper is a preliminary report on the findings of this project.

Our working premise has been that land cover mapping is, in many ways, as much an art as a science. As such, the project has been a learning experience and is providing the opportunity to document and synthesize the current development of land cover mapping within the Gap program. The principal objectives of this project are to:

1. Inventory, compare, and (to the extent possible) evaluate land cover mapping protocols and methods used by the states to develop land cover maps for Gap Analysis; and

2. Provide information and recommendations to the National GAP office that will enhance future GAP-related land cover mapping efforts. Furthermore, we have been trying to identify the "common threads" that seem to be woven throughout each of the individual projects. We have used personal communication, published literature, written summaries and reports, and Internet home pages to gather information on logistical issues (such as hardware, software, and staffing); data utilized; land cover classification and delineation, labeling, and accuracy assessment; and data handling, archiving, and dissemination. Following is a sampling of what we have learned thus far.

Cooperators and collaborators have seen the usefulness and importance of the land cover information being generated under the Gap program. Almost every state project reported gaining supplemental funding in some form from other agencies. About 44 percent of the people working on land cover mapping are graduate students, showing that GAP is contributing to education and the development of technological skills. While numerous hardware and software configurations are being utilized, most of the mapping is being conducted in a UNIX environment using ERDAS Imagine and ARC/INFO software. Early GAP projects had to acquire their own satellite imagery, but later projects have had the benefit of the MRLC national Landsat TM purchase. Most states are attempting to utilize multiple dates of TM imagery where they are readily available. Seasonal differences in the vegetation have helped in some cases and added confusion in others.

The actual delineation of vegetation classes has been quite variable. Approaches have included any or all of: photointerpretive techniques, supervised and unsupervised clustering, photointerpretive or machine labeling of the MRLC-generated hyperclusters, and modeling using ancillary data sets. Numerous types of ancillary data have been used to aid the land cover mapping. The most commonly used data are aerial photographs, field data, airborne video, and existing land cover maps. The mapping is being done in most states on a scene-by-scene basis, commonly with each scene being stratified using ecoregions or other physiographic or edaphic data. Each project has had to develop mapping techniques that fit the type of land cover in their area and that matches their level of expertise and specialization. Accuracy assessment has been especially variable. Some projects have not had the time or funding to conduct formal accuracy assessment, while others have spent considerable time and effort collecting and analyzing thousands of field or video samples. No matter what approach or level of accuracy assessment is undertaken, the common thread seems to be the need for some field-based data and collaboration with local vegetation experts.

Overall, the development of the GAP land cover mapping effort has resulted in several very positive things. It has provided seed money for further advancements in land cover mapping, stimulated cooperation and collaboration in mapping, increased the acceptance and adoption of remote sensing and GIS as mapping tools, and assisted in the development of numerous new techniques for land cover mapping.

This success has not come easily, though. Trouble spots have included: getting access to adequate and appropriate seasons of imagery, dealing with shadowing effects and clouds, collecting adequate field and ancillary data, edge-matching with adjoining states, and achieving consistency of vegetation map legends.

At CALMIT, we are currently working on gathering additional project information and synthesizing and analyzing all of the information. We will be finished with our analysis and submit our report to the National GAP office by early 1998. Currently, an Internet home page is under construction for the project. This site is where the project report will be assembled and, as such, will contain all of our findings and analysis, as well as any conclusion or recommendations. The site will also feature a link for feedback, corrections, or other information. The URL for the home page is http://www.calmit.unl.edu/gapmap.

Regionalizing State-Level Data

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An important objective of GAP is to provide the conservation status of biotic elements, not truncated by political boundaries. The potential to analyze the status of an element throughout its entire range is one aspect that makes GAP unique and innovative. This ability will allow data users interested in the status of locally occurring elements to place them in the context of a watershed, ecoregion, national range, or ultimately continental and global range.

Although this capability has not yet been attained, the key to achieving it is the regionalization of the GAP data such that one can use any geographic unit of analysis desired. There are three basic approaches available: 1) merging the tabular results for reporting distribution and conservation status statistics, 2) remapping or remodeling the elements over the larger region using the current GAP coverages in the process, or 3) edge-matching and merging the current coverages as they are. To date, there are few examples of these approaches because only now do we have groups of contiguous states completing GAP projects. Because GAP began in the western states, this is where the approaches have been tested, though over the next few years most state data will be regionalized.

At the University of Idaho's Landscape Dynamics Laboratory, the current effort to regionalize western land cover maps used the tabular merge approach (1 above)(Nancy Wright, pers. comm.). The land cover maps have been cross-walked to a common scheme and then resampled to a 1-km grid. The resulting map, not cartographically edge-matched, shows surprisingly good consistency despite the use of a variety of mapping techniques and thematic and spatial resolutions by the individual state projects. After applying the common scheme to all coverages, the tabular results of the regional gap analysis—to be reported in a forthcoming publication—will provide a first approximation conservation assessment without having to physically edge-match the state coverages. We feel this approach is a useful way to achieve the GAP objectives for these early land cover products.

The remapping approach (2 above) was used by Stoms et al. (1997) to create a seamless land cover map and conduct gap analysis of vegetation types in the Intermountain Semi-Desert Province (Bailey 1995). Here too, the first step involved cross-walking the 7-state classification schemes to the National Vegetation Classification Scheme (NVCS, Federal Geographic Data Committee, 1997). The next step was to use the original state coverages to "train" multitemporal AVHRR (NOAA Advanced Very High

Resolution Radiometer) imagery to create a new land cover map of the region.

The third approach is the actual edge-matching and merging of the original state GAP data sets. This is a difficult task in the western states because: 1) when they began, there were no proven and standardized methods for creating these types of maps, therefore each one was conducted as a pilot research project; 2) there were few, if any, federal standards or protocols for digital data (the FGDC's first protocols on metadata were largely predicated on metadata work done for GAP by Cogan and Edwards [1994]); and 3) with the exception of Nevada, all western state GAP projects were under way before a consensus was reached on using what was then known as the "TNC/UNESCO" vegetation classification system (Jennings 1993).

Through the three approaches described above, we believe sufficient regionalization can be achieved to produce useful gap analyses of biotic elements for multistate regions. However, for newer state projects, we anticipate a much higher degree of compatibility among data sets that will allow true regionalization using the original data without excessive transformation.

Regionalization of vertebrate distribution maps has received less attention to date. A preliminary workshop on Northwest regional vertebrate modeling was held in September 1996 with GAP teams from Oregon, Washington, and Idaho. As a test, ten bird and mammal species that span all three states were mapped by state according to occurrence within EMAP hexagons. Maps from the three states were then joined to determine if there was continuity of distribution at this coarse spatial level. Guidelines were established for progressing with seamless wildlife habitat relationship maps for the Northwest (Nancy Wright, pers. comm.). Generally, we believe it will be impractical to edge-match the hundreds of species coverages for each state, and instead have proposed a remodeling process in the current vertebrate modeling chapter of the GAP Handbook (1997). That process will require states to first edge-match their range extent maps, preferably using the EPA EMAP hexagons and then to rectify differences among the wildlife habitat relation models (WHRMs). After that, the computational part of the distribution modeling should take relatively short amounts of time. Some additional efforts and ideas for regionalization of both land cover and vertebrates are described below.

The Southwest ReGAP project (see the Southwest breakout session report in this bulletin): The states of NV, UT, CO, NM, and AZ were all initiated within a couple of years and all used TM imagery acquired between

1990 and 1993. The projects, however, have had completion dates ranging from 1994 to early 1998. These projects were all conducted prior to the adoption of standards that could aid regionalization such as the NVCS for land cover classification and use of the EPA EMAP hexagonal grid for use in the vertebrate modeling process. The ReGAP project, slated for initiation in 1998, calls for continuation of the state business model, but in a regional cooperative effort to ensure seamless coverages throughout the region. For land cover mapping, the goal is to allow the mapping staff to focus on fewer numbers of land cover types than occur throughout a state by mapping by TM-derived “mapping zones” (Collin Homer, pers. comm.), e.g., “montane” versus “plains grassland.” We believe this approach will eliminate or greatly reduce edge-matching problems for the regional map. For animal modeling, these states will begin the cooperative process by using the EPA EMAP hexagonal grid to delineate species range extents across the region. Next, they will ensure that WHRMs are consistent across the region, or stratified by ecoregions when true habitat association differences occur across a species’ range. The use of these approaches and consistent, regional, ancillary data on which to base the models should ensure seamless predicted animal distributions.

The Mid America GAP Consortium (http://ulysses.unl.edu/midam/) held their first joint land cover and vertebrate modeling workshop on October 21 and 22, 1997. A primary goal was to discuss ways to achieve regionalization of their data during the production process. Though the states involved in the consortium (IA, KS, MO, ND, NE, OK, SD) initiated GAP over a wide timespan, there is less variation in mapping methods and biota than in the 11 western states, and the prospect for achieving concurrent regionalization is good. One impetus to edge-match land cover is an EPA grant that provided approximately $45,000 per state (IA, KS, MO, NE) to help these projects achieve data consistency. The regionalization effort is beginning with the creation of web pages to share land cover classifications and plans to regionalize ancillary data and methods of vertebrate modeling.

Regionalization is a difficult though critical task. While it has been an objective of GAP from the start, some have seen it as an “unfunded mandate” if left to the individual state projects. Yet we know from experience that without a concerted regional effort by groups of states, later regionalization sacrifices some of the quality of the original products and is made more difficult if conducted by remote labs not involved in the original data creation. We urge all GAP projects to aggressively pursue cooperation with their surrounding states to achieve regionalization during the mapping phase. The Great Plains states have, on their own initiative, instituted a regional cooperative approach for both land cover and vertebrate phases. We applaud their efforts and encourage others to follow. If your state project would like assistance in setting up a cooperative effort, contact Mike Jennings or Patrick Crist.

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Progressing Toward a Standardized Classification of Vegetation for the U.S.

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Since 1989, GAP land cover mappers have been in the unenviable position of applying a vegetation classification system before it was well developed. During this time, GAP funded The Nature Conservancy (TNC) regional ecologists to produce first-ever regional classifications of alliance vegetation types. These classifications are now complete for the Northeast (Sneddon et al. 1994), Southeast (Weakley et al. 1997), and Midwest (Drake and Faber-Langendoen 1997). The Western region classification (Bourgeron and Engelking 1994) is being redone by Marion Reid and colleagues (TNC Western Regional Office) to provide full descriptions of each alliance, including California as well.

In Bulletin No. 5, I reported the establishment of the Ecological Society of America's Vegetation Classification Panel (ESA-Veg.). The panel's mission is to provide a standardized, scientifically credible classification of vegetation for the U.S. in partnership with TNC and the Federal Geographic Data Committee (FGDC). This article provides a bit more background about vegetation classification in the U.S. and an overview of the ESA-Veg. status. Some of the following is based on material from a draft ESA-Veg. manuscript discussed below.

Today, the United States is close to having its first fully functional, widely applied vegetation classification, that, based on the tradition of systematics, will be improved upon as our knowledge expands. On October 22 of this year, the Secretary of the Interior, acting as Chair of the FGDC, gave final approval to the *Vegetation Information and Classification Standard* (FGDC 1997). This is now the standard vegetation classification for U.S. federal agencies and their cooperators. Those already familiar with the classification will recall its two-part structure of classifying vegetation by physical and environmental attributes in one part and by floristic assemblage in the other part (Table 1). While the FGDC's "Vegetation Information and Classification Standard" includes a full classification of the physiognomic part, it only describes the floristic classification in concept because this part of the classification is far from being fully developed and requires a very large effort (Loucks 1996).

The ESA has joined with TNC, federal agencies, and others to meet the need for a unified floristically-based classification for the U.S. The intent is in strengthening the existing classification system by providing a mechanism for its refinement through scientific review and by disseminating its standards. These objectives are being accomplished in phases, with the initial focus having been on review and improvement of the original FGDC proposal. The second phase, now in progress, is to provide the basic standards needed to support a floristically-based classification. In addition, a framework for ongoing review of the described types and the system's structure is needed, both initially and as changes are proposed. The common purpose is to provide a recognized vegetation classification system of broad utility for incorporating ecological science in conservation, natural resource management, planning, and research.

Recent History of Vegetation Classification in the U.S.

The United States was late to recognize the need for a unified national vegetation classification. As early as 1973, international scientists working for the United Nations Educational Scientific Cultural Organization developed and adopted a worldwide vegetation classification system based largely on physiognomy (UNESCO 1973). Many countries also had successful vegetation classifications completed or under way (Rodwell et al. 1995). The UNESCO system was not generally adopted in the United States because it was perceived as being not detailed enough to be useful at a local level. At that time, there was little recognition of the parallel importance of regional context with localized content, and the value of a single national classification system was not acknowledged. Some federal land management agencies produced vegetation classifications, maps, and other information about public lands that they administered, but these projects typically were limited in scope and geography (Ellis et al. 1977).

In the late 1970s, TNC initiated state natural heritage programs. Inventories of rare species and community "element occurrences" were produced as part of state agency surveys, and some state-specific community classification systems were developed. Although many state natural heritage programs began collecting descriptions of plant communities by the early 1980s, the development of state-level classifications was not widespread until the mid-1990s, driven largely by a coordinated effort to map existing vegetation.

In the early 1980s, five federal agencies tried to develop a national classification system integrating vegetation, soils, water, and landform (Driscoll et al. 1984). The vegetation criteria were based on a potential taxonomic hierarchy. One obstacle was identifying potential vegetation types for inventory sites when taxonomies and keys for the floristic-based levels were available for only a few regions in the country. A second obstacle was that the system was designed primarily for aggregating plot data; little attention was paid to mapping systems and methods for mapping land cover. Third, the classification could deal only with potential, not existing, vegetation.

In the late 1980s, the U.S. Fish and Wildlife Service initiated a research project that became the National Gap Analysis Program (GAP). In 1990, GAP began supporting TNC's effort to develop a national system (Jennings 1993) which started by compiling and standardizing regional (multistate) classifications from state natural heritage programs. Supported by GAP and the National Park Vegetation Mapping Program, Grossman et al. (1994) drafted the basis for what is now recognized as the National Vegetation Classification (NVC).

The requirement for national spatial information standards, including vegetation, was implemented by the federal government with the 1990 revised Office of Management and Budget Circular A-16, *Coordination of Surveying, Mapping, and Related Spatial Data Activities.* The goals of this circular were to develop the National Spatial Data Infrastructure (NSDI), to reduce duplication, to reduce the expense of developing new geographically based data, and to increase the benefits of using available data through coordination and standardization of federal geographic data. The circular established the Federal Geographic Data Committee (FGDC) to promote development of distributed database systems, information standards, exchange formats, and guidelines, and to encourage broad public access.

Interagency commitment to coordination under Circular A-16 was strengthened in 1994 under Executive Order 12906, *Coordinating Geographic Data Acquisition and Access: the National Spatial Data Infrastructure.* It instructed the FGDC to involve state, local, and tribal governments in development, and to use the expertise of academia, the private sector, and professional societies in implementing the order. Under this mandate, the FGDC established a subcommittee to develop standards for mapping vegetation.

The ESA established its Panel on Vegetation Classification in 1994 (Barbour 1994, Peet 1994, Loucks 1995, 1996), and the panel began by reviewing the draft *FGDC Vegetation Classification and Information Standards.* Completion of the review and publication of the FGDC proposed national classification (the overall framework and details for physiognomic levels; see http://www.usgs.gov/fgdc.veg/) concluded the first phase of the ESA Panel's work. However, the bulk of the ESA panel's work is to deal with the issues of a floristically defined vegetation classification. This is the focus of the second phase of the ESA Panel's activities.

A Point of Departure

An early step in the ongoing cooperative process to develop a national vegetation classification is to recognize the present baseline classification as a point of departure. This must be followed by recommended standards that both require and provide a mechanism for further improvements and complete documentation of named units. To improve these standards, work groups will be established, composed of academic, agency, and private-sector scientists.

Both TNC's classification (Nature Conservancy Ecology Working Group 1997) and the FGDC *Vegetation Classification and Information Standards* must now be recognized as a single, integrated system. A complete review of the floristic levels is required, but a consensus on basic standards is needed first. In August of this year, the ESA panel distributed for review a draft version of *An Initiative for a Standardized Classification of Vegetation in the United States*. This document proposes the first approximation of standards for the categories shown in Table 2. These standards lay the foundation for an enduring taxonomy of vegetation that can be improved upon, in a collaborative way, as our body of knowledge expands.

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National Vegetation Classification Structure	
Physiognomic criteria:	
Class	Woodlands
Subclass	Mainly Evergreen Woodlands
Group	Evergreen Needle-leaved Woodlands
Subgroup	Natural/Seminatural
Formation	Evergreen Coniferous Woodlands with Rounded Crowns
Floristic criteria:	
Community Alliance	*Juniperus occidentalis*
Community Type	*Juniperus occidentalis /Artemesia tridentata*

TABLE 1. The U.S. National Vegetation Classification's structure.

Terminology. - If the classification system is to be fully understood and available for all to use, associated terminology must be defined consistently.
Inventory methods and plot data. - Information from vegetation stands and plots must be collected and managed using standards, such that data from different plots and sources can be analyzed for description and classification of vegetation units.
Nomenclature. - Names of the vegetation units must be applied through standard nomenclature rules for each hierarchical level of the classification system.
Classification, documentation, and description. - Procedures for classifying, documenting, and describing floristic units are the core of systematic taxonomy.
Peer review, dissemination, and information management. - A credible system must incorporate peer review of its structure and named units, must be continuously revisable to allow efficient reconstruction of its elements from prior dates, and must be relatively easy to disseminate, update, and maintain.
Review and refinement. - We must begin with a clear understanding of the initial structure and set of units, and then implement processes for review and incorporation of newly described units. We must develop and maintain a database to cross reference the units of other classifications.
Institutional structure for maintaining and developing the classification. - The classification can only succeed through cooperation of professional ecologists and their institutions, whose roles must be formally articulated in a Memorandum of Understanding now being developed.

Table 2. Categories for vegetation classification standards.

Use of U.S. Fish and Wildlife Service Easements for the South Dakota GAP Stewardship Layer

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Over the past five years, the Cooperative Fish and Wildlife Research Unit and the Department of Wildlife and Fisheries Sciences at South Dakota State University have been involved in research projects that relate directly to Gap Analysis. Geographic information systems have been or are being developed for wetland basins in eastern South Dakota and bird and amphibian distributions (Johnson and Higgins 1997; Naugle; Bakker; Fischer unpubl.

data). In addition to these data, wetland protection coverages (Estey unpubl. data) are being created that include all lands owned by South Dakota Department of Game, Fish and Parks (SDGF&P), and all U.S. Fish and Wildlife Service (FWS) national wildlife refuges (NWR), waterfowl production areas (WPA), and perpetual easements. These wetland protection coverages will be incorporated into the final stewardship layer of SD-GAP.

In general, most protected lands identified on the SD-GAP stewardship maps include national wildlife refuges, national and state parks, Nature Conservancy land, and state wildlife reserves and management areas. In eastern South Dakota, there are very few GAP Management Status Code 2 areas. For example, four FWS wildlife refuges (Sand Lake, Lake Andes, Waubay, and Pocasse National Wildlife Refuges) and all of the WPAs in eastern South Dakota comprise less than 1% of the land area (Fig. 1). Land protection in this region occurs mainly through the purchase of FWS easements.

Use of FWS easements in a stewardship data layer represents a unique aspect of protection that has developed because of the nature of the prairie pothole landscape. The prairie pothole region covers portions of Saskatchewan, Alberta, Manitoba North Dakota, South Dakota, Nebraska, Minnesota, and Montana. In South Dakota, the prairie pothole region encompasses virtually the entire eastern half of the state. Agriculture is the major land use in this region, and approximately 35% of the prairie potholes in South Dakota have been converted to cropland (Dahl 1990). Protection of remaining wetlands is critical. However, due to the unique geographic pattern of these wetlands (most are relatively small in size and widely scattered across the landscape), fee-title acquisition of large expanses of land for their protection is more difficult than protection by easements.

The majority of easements in eastern South Dakota are either wetland or grassland types. A wetland easement is an agreement between the FWS and a landowner in which the landowner will not drain, burn, fill, or level certain wetlands in return for a one-time payment from the FWS. However, the land is still vulnerable to extractive uses. For example, the land owner can plow the land and plant crops in a given year if the wetland becomes dry. If a grassland easement is purchased, the landowner agrees not to break the soil, however, the land can be grazed or mowed. In South Dakota, all wetland and grassland easements are perpetual.

The Cooperative Fish and Wildlife Research Unit is in the process of producing a digital map containing all wetland and grassland easements purchased by the FWS in eastern South Dakota (Fig. 2). Township maps (approximately 1:21,000) containing wetland and grassland easements, WPAs, and NWRs were obtained from the FWS. Boundaries of these protected lands were transferred to 1:24,000 National Wetland Inventory (NWI) maps and digitized. The protection coverage will be overlaid on a modified wetland basin GIS (Naugle and Johnson, unpubl. data) derived from NWI data. In the coverage, basins were classified as temporary, seasonal, semi-permanent, or permanent.

South Dakota GAP, in cooperation with the Cooperative Fish and Wildlife Research Unit, will use this coverage to aid in the construction of a land stewardship layer. All easements will be assigned a GAP Management Status Code of 3: “Legal mandates prevent the permanent conversion of natural habitat types to anthropogenic habitat types, but area is subject to extractive uses. This includes most nondesignated public lands.” (Gap Analysis Program Handbook). Within the prairie pothole region, the addition of wetland and grassland easements could significantly improve to the stewardship data layers of other GAP state projects.

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An Alternative Approach to Land Cover Mapping in Complex Terrain

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Researchers working for the Virginia Gap Analysis Project (VA-GAP) are developing a technique for forest-type mapping utilizing both remote sensing and abiotic factor modeling. This combined technique will assist in classification of forest types in Virginia where remote sensing alone is insufficient.

The technique uses a base land cover map combined with a landform-based moisture map and a fine-scale physiographic map of Virginia. The base land cover map (Morton in prep.) was synthesized from Landsat TM imagery and ancillary data layers such as DLG roads and NWI wetland maplets. Each image was classified to a modified Anderson Level I scheme, with forest tracts classified as either coniferous, deciduous, or mixed.

Once the Level I map (Morton in prep.) was created, further discrimination of the three forest type classes (deciduous, coniferous, and mixed) was needed. Due to the complex topographic nature of the state of Virginia and the relationships known to exist between forest type distribution and topographic characteristics, we are investigating abiotic factor modeling as an additional method of estimating forest-type distribution.

To produce the component data layers necessary for the abiotic factor modeling, digital elevation models (DEM) for the state corresponding to 7.5 minute topographic quadrangles were obtained from the USGS. The DEMs have a resolution of 30 m, and an elevation value (along 1 meter increments) associated with each raster cell.

The individual data layers used to create the moisture map were slope, aspect, and a landform index (McCombs 1997, McNab 1989). The slope and aspect maps were generated directly from the DEMs. The landform index value was a measure of the convexity or concavity of the land surrounding a location. The landform index was calculated based on the changes in elevation from the point of interest to points located on the edge of a 9 x 9 pixel window. Locations in a cove or a sheltered area would have a lower elevation than the points around it, and thus would have positive landform index value. The opposite would occur on ridge tops or knobs. The more extreme the landform, index value (positive or negative) would indicate the degree of convexity or concavity. The moisture map was created through the analysis of combinations of the slope, aspect, and landform index maps. The resulting map had three classes of moisture: xeromorphic, mesomorphic, and unclassed. For example, a southwest-facing, steep, convex site would be classified as xeromorphic. A north-facing, relatively flat, concave site would be mesomorphic. Many combinations of slope, aspect, and landform index could not be definitively classed as xeromorphic or mesomorphic and were left "unclassed."

There are portions of five physiographic provinces in the state of Virginia—Coastal Plain, Piedmont, Blue Ridge Mountains, Ridge and Valley, and the Appalachian Plateau. The delineation (and naming) of these regions vary by author and by map (Daniels et al. 1973, Fenneman 1938). Physiography is of interest because several forest types are restricted to, or predominantly occur in, only one or two provinces. To simplify the analysis, three major physiographic provinces—Coastal Plain, Piedmont, and Mountains—were mapped. This was accomplished through the use of a relative phenological index value that was computed based on Hopkins' Law of Bioclimatics (1938).

Hopkins studied the effect geographical location (in the Northern Hemisphere) had upon the timing of biological events. He found that for every 1° latitude increase north, 5° longitude increase west, or 122 m increase in elevation, the onset of biological events was delayed 4 days. It was then possible to compare any two points and compute a phenological difference between them. This was done for Virginia using Great Dismal Swamp National Wildlife Refuge in the southeast corner of the state as a base point.

The forest type, landform moisture, and physiographic map were then combined to create a 27-class map. The 27 class values result from the combination of three forest types (coniferous, deciduous, mixed), three moisture classes (xeromorphic, mesomorphic, unclassed), and three physiographic regions (Coastal Plain, Piedmont, Mountain). Possible forest types were then assigned to each class based on known ecological associations with the variables. For instance, only Eastern Hemlock, White Pine, Hemlock/White Pine, Red Spruce/Fraser Fir, or Virginia Pine would be expected to be found at a pixel classified as mountain mesomorphic conifer. To determine the most probable forest type for that pixel, the specific landform data would be re-incorporated. For instance, elevation would provide information which could either include or exclude Red Spruce/Fraser Fir - a type found only at elevations above 1520 m in Virginia. Slope, aspect, and landform index are also used to narrow the classification possibilities.

This technique will not allow classification of all forest types in all regions of the state. Other techniques being investigated include further use of Landsat TM imagery and landscape-scale climate estimations (Klopfer 1997). The 27-class forest type map can be used as a mask for spectral classification of specific types of forest which cannot be delineated from landform alone. With these masks, variability in the Landsat reference data may be lessened. Research into estimating landscape-scale climate factors may also prove useful in future investigations of forest type distribution in Virginia.

Although the development of this technique is ongoing, preliminary indications are that the methods described will allow VA-GAP to produce an accurate forest type map at a fine resolution for Virginia. This technique should prove useful for other state GAP projects attempting to map forest types/alliances in areas with high forest type diversity and complex topography. In addition, the intermediate data layers developed during this research have their own value for land-planning, research, and teaching activities.

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"Merge": Breakthrough Software for User-defined MMUs

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The basic specification of a merge program that would meet the specific needs of digital land cover mapping originated from meetings between Roly Redmond, Zhenkui Ma, and Ray Ford at the University of Montana during summer 1992. Intuitively, Merge is an image transformation operation which takes as primary inputs a raster image, a minimum map unit (MMU), and a similarity function. It then produces as output a transformed image in which all raster areas smaller than the MMU have been eliminated by being "merged into" their neighboring areas. The MMU value is a simple integer that expresses a measure of image resolution, i.e., areas smaller than the MMU are considered as too small to be of interest at this particular level of processing. Both the input and output images are assumed to contain 8-bit classified values, as might result from a prior image classification pass or merge operation (e.g., using a smaller MMU value). The similarity function defines a numerical measure of similarity between each possible pair of class values in the input image; for an image with N class values, similarity can be encoded as a N x N array of real numbers.

Though processing details are quite intricate, the general merge process can be expressed in simple intuitive terms, as (a) all pixels comprising areas in the input image larger than the selected MMU "survive" unchanged in the output image, and (b) all pixels in areas smaller than the selected MMU are subject to being changed, as the areas in which they reside are combined with their larger neighbors. The actual processing details satisfy four additional principles. First, mergers always assign small areas *in toto* to larger neighbors, so that the resulting boundaries exhibit a hierarchical scaling property. Second, the selection of a particular neighbor for a "merge target" is based on maximum similarity between its class value and the class value of the "to be merged" area. Third, additional optional parameters can be used to identify exceptional cases of particular class values or regions of the image not to be altered by the merge process. Finally, a number of specific ordering and special processing rules guarantee that the processing is both predictable and repeatable and does not contain any "random" processing effects.

Though Drs. Ford, Redmond, and Ma continued to develop and refine the precise Merge specification, the basic definition was settled during summer 1992, and the search for an algorithm that could effectively scale-up to allow "large" images to be processed on local workstations began at that time. The initial processing goal was single-pass processing of a complete Landsat TM scene. This target of roughly 8000 x 8000 pixels (an input image of about 64MB) seemed far away at first, but we carefully refined our algorithm to make steady process toward that goal. Some prominent milestones from the development include the following:

- By spring 1993, Dr. Ford had outlined the basic computational issues and approaches and had prototypes running that could process 1/4 TM scenes (roughly 2K x 2K pixels) in about 5 hours of execution time. Revising and re-engineering the algorithms to scale-up to larger images proved to be a laborious task, but progress continued throughout 1993. By summer 1993, Dr. Ford was able to successfully process full TM scenes at small MMUs in a single pass (in about 30 hours).

• By winter 1993/94, one of Dr. Ford's graduate students, Jin Guo, had implemented enhancements that reduced processing time dramatically for small MMUs (to about 2 hours). By spring 1994, another of Dr. Ford's students, Kathy Kahl, completed a project focusing on algorithm animation of the merge process. Later in 1994, Dr. Ma implemented a version of merge with additional enhancements that reduced processing time even more, while adding specific features of interest in land cover mapping. With a continuing sequence of minor adjustments, Dr. Ma's version became the standard used in processing at University of Montana’s Wildlife Spatial Analysis Lab (WSAL) and remained the best available version for several months.

• During 1995/96, Dr. Ford used the "merge problem" as the focus of a year-long system design course for computer science graduate students, and out of that effort emerged a major algorithm design breakthrough that has led to the current best version ("MegaMerge") and its successors. Steve Barsness radically redesigned some critical components of merge, producing a new family of implementations that offered breakthroughs on three processing frontiers:

1) significantly reduced processing time (about 10 minutes for full TM scene),

2) significantly enhanced ability to process imagery larger than a full TM scene in a single pass (from an 8K x 8K maximum to up to 20K x 30K pixels),

3) processing requirements in time and space that are relatively independent of MMU size, image complexity, and other data-specific factors. The versions arising from Barsness' work at last exhibited the sort of reliable and robust execution that had long been lacking in prior versions.

From 1992 through 1996, Dr. Ford and his students had been working on the merge problem without funding from the GAP program. As WSAL analysts and others began to use the Barsness' versions, it became clear that all parties would profit from the creation of a single more robust, standard version of this code. A contract was signed in summer 1997 to fund the creation of an official version tailored to the needs of GAP users (now called "MegaMerge"). The contract calls for the code to be available for the most commonly used GIS platforms, UNIX workstations including Sun, IBM, SGI, HP, and Dec Unix. The implementation team (Steve Barsness and Ray Ford) quickly implemented the desired feature set, then set about assuring that the code would execute reliably on a wide range of input data values, and on the range of supported platforms.

Through the efforts of the implementation team and cooperation of various GAP users volunteering their facilities as "beta host" sites, the code has now been extensively tested on all the targeted platforms. It was officially released in "beta" form to GAP users on September 15, 1997, and is now being used and evaluated, prior to formal acceptance testing. Following acceptance, the implementation team will release a final version of the code and accompanying documentation. Meanwhile, the code and extensive documentation is available on-line at the UM-Merge Project Web site, at http://www.cs.umt.edu/MERGE.

Independently, both Dr. Ford and Mr. Barsness continue research and development efforts to adapt the code to new applications (such as 3-D imagery), enhance performance, and produce versions appropriate for other platforms (particularly PCs running some version of Windows). Additional information on the application of "merge" to other classes of 2-D and 3-D imagery can be obtained via e-mail to "ford@cs.umt.edu". Additional information on Steve Barsness' newest version "GigaMerge" and Windows implementations of "MegaMerge" can be found on the Web at http://www.cyberport.net/glacier/gis or obtained via e-mail to sjb@cyberport.net.

Editor's note: MergaMerge is currently undergoing beta testing. Once we receive all the testers' comments, we will post them on the electronic bulletin board on the GAP home page.

Spectrum Software for Texas Gap Analysis

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Introduction

Due to the size of Texas and the variability of conditions present, it sustains very complex and diverse vegetation. More than 90% of the land is privately owned, and access to the land for surveying vegetation is limited. A project of this magnitude, involving the analysis of satellite imagery, requires specialized computer hardware and software and highly trained personnel for processing and analyzing remotely sensed imagery.

To cope with these problems, TX-GAP has sought to optimize its capabilities by adopting the most efficient tools to automate the process to reduce time and costs. A straightforward, methodological approach has been developed for the analysis of land cover and the production of high-quality, low-cost maps in a relatively short time frame. The progress in TX-GAP has been made possible by applying the hyperclustered Landsat Thematic Mapper (TM) imagery of the Multi-Resolution Land Characteristics Consortium (MRLC) (Loveland and Shaw 1996) and the software program Spectrum (Khoral Research, Inc.), designed specifically as the analysis software for hyperclustered scenes (Benjamin et al. 1996).

MRLC Imagery and Spectrum

The MRLC represents a novel strategy established among U. S. government agencies that combined their efforts to obtain and produce standardized geographic information. This innovative partnership has considerably reduced the cost of imagery through the cooperative purchase and redistribution among MRLC members (Jennings 1996). A significant achievement of the MRLC consortium has been the production of preprocessed satellite images. In addition to the common operations performed to the Landsat TM multispectral data (radiometric and geometric corrections), these scenes are spectrally classified following a special unsupervised classification approach developed by Kelly and White (1993) resulting in a 240-class “hyperclustered” data set. A detailed description of this consortium and their project goals may be found in Benjamin et al. (1996), Campbell (1996), and Loveland and Shaw (1996) (refer also to the MRLC Web page: http://www.epa.gov/grd/mrlc).

The hyperclustering algorithm identifies 240 clusters of data, grouping sets of individual pixels having a similar spectral signature across six of the seven bands. In the resulting image, individual pixel values are representative of the mean values of the clusters produced across the six bands (240 cluster values). These clusters are linked to a statistical codebook which permits calculations to explore spectral properties of the hyperclustered scene emulating the original (raw) multispectral data.

Specific clustering procedures have been reported elsewhere (Benjamin et al. 1996, Kelly and White 1993).

Spectrum is a special image visualization and analysis program developed specifically for categorization of these hyperclustered scenes. Its design and capabilities provide means for the direct interpretation of the spectral pattern observed on the scene, supported by ancillary information or ground-truthing. The use of Spectrum interpretation capabilities are explained in Benjamin et al. (1996) and Myers et al. (1995).

TX-GAP has been one of the pioneers to apply these new tools to land cover mapping. Since its initial stages, TX-GAP personnel worked together with Spectrum software developers to test the program and suggest enhancements to better adapt it to the methodology and specific requirements of Gap Analysis. Some of the suggestions pertained to the correction of programming errors, loading and reading point-location files, and other changes which have made Spectrum a more viable option for landscape-level mapping projects (Sims and Hammer 1996).

TX-GAP Land Cover Analysis Approach

In general terms, the land cover map is generated by digital classification of satellite imagery supported by field surveys and ancillary information. Accuracy assessment will involve a statistical comparison of subset samples from the classified scene to ground observations. The full process is illustrated by Figure 1.

Specifically, our digital analysis is based on the direct interpretation of MRLC hyperclustered TM scenes using Spectrum. Ground control points are used to discriminate among the different pixel cluster values on the scene, individually or by groups (following spectral pattern). After a specific polygon or set of polygons have been identified, all other polygons having the same cluster values are automatically categorized by the program.

For the field survey, we begin planning a tentative itinerary, marking potential sample sites based on a small-scale map of state highways, existing vegetation maps, or a visual examination of the spectral pattern present on the scene (displayed in Spectrum using true-color simulation capability). We do not follow any specific sampling design. Our goal is to attempt the most representative sample of the major vegetation types present in the study area (the area covered by each scene) and enough replication to detect potential variations in spectral patterns of a vegetation type across the scene.

Sampling size is not fixed; intensity depends upon the image analyst's perception and confidence in the progress of the classification process. As scene interpretation progresses, field surveys are restricted to sites with a larger proportion of unclassified pixel clusters or where we are in doubt about the preliminary classes defined. Field trips conclude when 70 to 80% of the scene has been classified (for example, a total of about 50 points per scene have been necessary for the extensively agricultural Texas Panhandle, while more than 100 points have been required in the more biologically diverse Trans-Pecos region).

Sampling points are selected and georeferenced on-site along a preestablished route, considering they are observable at the scale of satellite imagery (30 x 30 m pixels) and that there will be an error factor introduced by the Global Positioning System (GPS) unit (+/- 50 m). A priority is to select vegetation patches sufficiently large and homogeneous that represent characteristic patterns in the image. We also attempt to maximize existing contrast among vegetation types to support our delineation of spectral patterns.

Because of the problem that Texas land ownership confers to site accessibility, sample points are usually within 200 m of selected roads. In addition to GPS coordinates, the distance and bearing from the road to the target communities are also recorded.

Field data includes a list of dominant and co-dominant species observed and the percentage of total cover they represent. Other described characteristics include soil texture and color, slope, aspect and comments on any environmental features that might help to differentiate a particular vegetation, or help to delineate the target community on the image. Videos or photographs are taken of the site, and a drawing is made to support the overall description. The sketch information turns out to be very important; most of the time this drawing provides the basic reference to check if the pixel clusters labeled on the satellite image represent a spatial pattern similar to that observed in the field.

Two different situations commonly occurring during the land cover classification process will illustrate the methodological approach using Spectrum. The first situation is when a spectral pattern is clearly recognizable on the satellite image, and this pattern corresponds to the field data. When this occurs, we use the GPS location (UTM coordinates) as a guide and select a pixel from the polygon area representing the target vegetation observed in the field. Here the "Zoom Window" function is used to magnify a section of the image, allowing precise selection of individual pixels of interest. Then, we use the “Class Operation” function of Spectrum to attribute the corresponding vegetation type to the pixel, and the “Legend” function to assign a specific color. All other pixels with the same values as the ones selected are automatically labeled across the scene. Additional pixels are then iteratively selected or deleted using the “Cluster Operation” function. Sometimes an atypical pixel is selected, leading to an erroneous pattern (relative to our knowledge of the region or the site description recorded in the data sheet). The pixel incorrectly labeled is then eliminated from this class. The process is finished when the labeled pattern resembles the spatial pattern observed in the field.

Second, if the spectral pattern appears inconsistent or incorrect for interpretation of some area within an image, a ground control point is selected and related to a single pixel. The patterning produced by highlighting all pixels in the same spectral cluster is then checked. A decision is made based on field data and the analyst’s knowledge of the region. When an erroneous patterning is produced or when in doubt, we may try using a different ground-control point, working through the labeling process in an iterative fashion.

When a field point, or a set of field points, is used to interpret different areas across a satellite image, they progressively outline those vegetation classes that have no apparent spectral pattern by aggregating the vegetation types that have been labeled. In addition, the “Spectral Response Curve” function may be used to support the interpretation by comparing graphs of those pixels that potentially belong to the same class as the one originally selected for a target vegetation type. Another tool that can also be used “on-the-fly” is the “Display” function, which emulates different band combinations and enhances particular spectral patterns.

The digital classification process is iteratively performed with the field survey. Field trips at this stage also serve to informally review progress and our confidence in the classification process by checking preliminarily labeled sections in the field. This process continues until we are satisfied with the amount of image classified (70-80%), and then we apply the “Auto-Classify Operation” function. This special feature automatically completes the classification process for a partially interpreted scene, based on the spectral similarities between labeled and unlabeled pixels. We apply this function after we are satisfied that we labeled all potential vegetation categories we want to represent for that particular scene. If we are unsatisfied with the results of Auto-Classify, we can simply go back to where we left off and continue with the labeling process.

Finally, the interpreted image with all pixel clusters labeled for the land cover classes of interest is produced and saved as a binary file. The file can be transferred to a geographic information system for further refinement and editing. For example, in the Lubbock area, we reassigned pixels that were incorrectly classified (juniper erroneously mapped as occurring in the High Plains, or orchards mislabeled as riparian). In this process, we used a set of grids with elevation information, ecoregion areas, and buffer zones for streams. A simple decision model was created to transfer pixels labeled as riparian and located outside of stream buffer zones to orchards. The same model was used to transfer pixels labeled as juniper (*Juniperus* spp.) in the High Plains to mesquite *(Prosopis glandulosa)* (Fig. 2). *Editor's note: Because of its detail and color we were unable to reproduce this figure. Readers are encouraged to view it and additional figures on the Web http://www.gap.uidaho.edu/gap/Bulletins/6/).*

Conclusions

The availability of Landsat TM imagery through the MRLC has considerably reduced the costs for TX-GAP. Hyperclustered TM scenes have avoided the need to get involved in complex and time-consuming preprocessing and spectral classification procedures. This has been advantageous for TX-GAP, allowing the employment of ecologists lacking experience in correcting and manipulating remotely sensed raw imagery. In addition, hyperclustered data sets have reduced requirements for computer storage and consequently made our land cover analysis easier and more expedient. The use of Spectrum and the value-added MRLC data have allowed more resources to go into collecting field data.

The selection of quality ground-points during field verification (e.g., controlled by size and contrast among vegetation types sampled) has proved useful for identifying patterns on the hyperclustered images. In addition, the use of a GPS has provided confidence that clusters selected from the hyperclustered TM scene really represent what is found on the ground at the sample points.

Although no formal accuracy assessments have been implemented yet, the iterative process between field and laboratory has permitted us to progressively check the developing classified maps. Preliminary observations have shown a high correlation between the maps under preparation and the vegetation types observed on the field. Overall, Spectrum has proven to be a quick and effective tool for TX-GAP personnel mapping land cover.

Acknowledgements

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A Review of MetaMaker

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MetaMaker and MetaMaker Version 2 are Windows-based programs for working with metadata. Metadata—data elements that describe other data—are the key to cataloging and retrieving the large volumes of geospatial and biological data being collected. Critical to the process is uniformity and accuracy of the data in describing other data. In 1992, the Federal Geographic Data Committee (FGDC) initiated a forum to discuss standards for the metadata used to describe geospatial data. MetaMaker (beta Version 1.11) was developed to help satisfy the requirement that federal agencies meet the standards developed by the FGDC (1995). The National Biological Information Infrastructure (NBII) MetaMaker (Version 2) was then developed to meet the standards for both biological and spatial metadata set by the NBII (Schneider and White 1996). MetaMaker Version 2 is currently the only relational database for geospatial data and biological metadata. Program development was a joint effort by two centers of the U.S. Geological Survey, the Midcontinent Environmental Science Center (MESC, Fort Collins, Colorado) and the Environmental Management Technical Center (EMTC, Onalaska, Wisconsin).

Primary functions of NBII MetaMaker include

Add New Metadata Dataset
Edit Metadata Dataset Menu
Query Menu
Import, Export Menu
Report Menu
Template Menu

all accessible from the main menu. With basic knowledge of NBII MetaMaker and of the data being described, the user can navigate through the program to either input or retrieve information about the primary data. MetaMaker and NBII MetaMaker operate in Microsoft Access. The complete program is available for free at the EMTC Web site (http://www.emtc.nbs.gov/).

The purpose of the **Add New Metadata Dataset** function is to add the name of the new metadata data set to the list of other data sets. This function safeguards the integrity of the database by ensuring the uniqueness of the data set names. A list of existing data set names is available in the window to help the user generate a unique name. Details for the new data set must be entered using the edit feature.

The **Edit Metadata Dataset Menu** function allows the user to duplicate an existing data set, change the name of any data set, and modify any field in the data set. When duplicating an existing data set, which is an alternate method of adding a new data set, the program forces the user to change the name so it is unique. A bonus of this feature is the ease of entering metadata data sets for repetitive data that vary in only a few fields or variables.

The **Query Menu** has six query options: Dataset Name, Theme, Place, Stratum, Temporal, and Taxonomic. A PickList (a predetermined set of names, words, or values) for searching the data set accompanies each query selection button. The Dataset Name button lists the data set names present in the database. The other query options have PickLists with words not necessarily present in the database. If more than one database meets the criteria of the search, the user can select from the resulting list.

The **Import, Export Menu** provides a way for the user to move data from one MetaMaker database to another, including data created in an earlier version of MetaMaker being imported (moved) to a database created in a later version. A dataset to be imported must have been created by exporting from any version of MetaMaker. An exported dataset is an MS ACCESS database containing the single dataset and has a ".mdb" file extension.

The **Report Menu** allows the user three output options. A report built with this option can be sent to the monitor for previewing before printing, printed without previewing, or written to an electronic file for later use. The preview feature includes printer selection and selecting the pages of the report to print. Printing without the preview sends all pages of the report to the default printer. Sending the report to a file creates an ASCII file containing the same information as the report. The **Additional Information Menu** allows the user to see a report on additional comments attached to the database that are not part of the primary data.

The **Template Menu** gives the user the option of modifying the Citation, Time Period, Contact, Keyword PickList, Distribution Disclaimer Statement, and Additional Information fields directly. The program guides the user through the selection and change process.

The program comes with a User Manual, the FGDC Content Standards for Digital Geospatial Metadata, the Content Standard for National Biological Information Infrastructure Metadata, and a Graphical Representation of the NBII Content Standards. These four items are included in the electronic file and can be read from the monitor or printed for hard copy reference.

The NBII MetaMaker (Version 2.1) currently available for downloading from the EMTC Web site has hardware requirements of a 486 or faster IBM-compatible microcomputer with at least 12 megabytes (MB) of random access memory (RAM). MetaMaker Version 2.1 is being used at several universities in the U.S., including Iowa State University and the University of Wisconsin-Madison, and in the U.S. Virgin Islands and several foreign countries, including Brazil, France, Korea, and Sweden. Since its development, MetaMaker has had two versions and four upgrades. The newest version (2.2) will have several significant improvements, including expanded import-export capabilities for multiple files and the capability to run CNS and MP parsers to generate HTML, SGML, Dif, and Text output files. Version 2.2 is expected to be available for beta testing October 31, 1997. For more information about MetaMaker, e-mail David E. Hansen (David_E_Hansen@usgs.gov) or call at (608) 783-7550 ext. 704.

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Partnerships

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In an increasingly diverse society, we, as environmental professionals, are confronted by questions that are by nature more and more interdisciplinary because they involve complex areas needing complex management treatments. It is a challenge to procure the necessary funds and intellectual resources needed to answer these questions. Single agencies often lack both the depth and breadth of such resources, let alone capabilities to map natural resources or ecological processes across ecoregions, biomes, and continents. Thus, we find the U.S. Fish and Wildlife Service turning to volunteers to conduct Breeding Bird Surveys (Bystrak 1981) and several federal agencies joining together to form the Multi-Resolution Land Cover Consortium (MRLC) (Loveland and Shaw 1996), to mention only two examples (see also Trauger 1996). MRLC partners had been making multiple purchases of the same TM satellite scenes where a single joint purchase realized an immediate savings of 6 million dollars to the federal government. In addition, one-stop preprocessing was used to not only save dollars but also create a more standardized final product (Loveland and Shaw 1996). This partnership is facilitating a synoptic and seamless land cover map for the country rather than “dueling” maps which would create needless conflicts and be far more expensive.

The success of GAP was only possible through partnerships with The Nature Conservancy, state natural heritage programs, museums, state fish and game agencies, and many other groups coming together for the purpose of creating wildlife habitat relationship models and maps of predicted animal distributions. Building bridges rather than walls between agencies in joint efforts, and the vision to transcend agency and other political boundaries, are absolutely critical if we are to be successful in future GAP efforts. GAP investigators have been leaders in creating the present environment of cooperation (Dzur et al. 1996).

At our 1996 national meeting at Key Largo, I was remiss in my presentations when I failed to adequately acknowledge the absolutely critical role that partnerships have played in GAP—these partnerships have all too frequently been the result of a single individual going against the institutional paradigm of "do-it-yourself" turf. Their efforts are at the heart of any successes that GAP has had. We need to acknowledge that contribution; thus, my failure to fully recognize the role other agencies have played in the multiagency, interdisciplinary land cover mapping efforts did not serve to strengthen the institutional bridges we have all striven so hard to create.

Partnerships are a necessary and valued part of GAP. Thus, I urge all those involved in GAP to continue to build bridges and partnerships, leverage funds and intellectual capacities, nurture current partnerships, and work creatively to build new partnerships. Give recognition to existing partners when you make presentations on your projects and when you write up the results. Better yet, include your partners in the gathering and analysis of data, in the writing of reports and manuscripts, as well as co-authors for your refereed journal articles.

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Kansas: An Example of GAP Partnering

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> *“I would encourage us to restore the use of the word "partner" in describing the agencies and individuals with whom we work. I admit that like most good words, "partner" has been overworked and trivialized in recent years. Yet it conveys the sense of collaboration, colleagueship, and mutuality of goals and responsibilities that should mark our relationships with others. It is a way of seeing ourselves that I would prefer to cultivate. "Clients" and "customers" encourage a self-image that is not good for the*

long-term health of our scientific enterprise. Consulting firms have clients and profit-making businesses have customers (TQM notwithstanding). To the extent that words create a self-image and self-images have a way of becoming self-fulfilling, I encourage you to encourage us to worry a bit about such matters." (James Kushlan, Director, USGS Patuxent Wildlife Research Center)

When Mike Scott visited Kansas before establishing a Gap Analysis project (KS-GAP) here, I was impressed by his description of the potential for GAP to provide a catalyst for partnerships across the state. GAP provides a research program for university scholars in geography, wildlife biology, botany, and landscape ecology. The value to wildlife management agencies, both state and federal, is obvious. In addition, land cover mapping is useful to state health agencies, water departments, and the departments of agriculture to understand movement patterns of disease vectors, water, and agricultural chemicals. Other state and federal agencies need information about the distribution of biological resources early in their planning processes to keep from running afoul of environmental regulations.

At the beginning, we were faced with some pragmatic choices about how to organize KS-GAP. The Coop Unit, which took the lead in Kansas, was interested in modeling vertebrate distributions, but did not have the level of expertise in remote sensing, geographic information systems, or plant community distributions present elsewhere in the state. Our first decision was to involve people with the greatest skill levels on each topic that were available statewide, rather than to retain the entire project at the Coop Unit, or even at Kansas State University (KSU). Once that decision was made, the truly difficult decisions were to choose among the highly qualified programs and individuals at the state's universities.

The Kansas Biological Survey (KBS) at the University of Kansas houses the Kansas State Heritage Program and the Kansas Applied Remote Sensing Laboratory (KARS). The two programs at KBS recently had completed another statewide mapping project of a level 1 classification of cover types. Although that project only distinguished among six cover classes, the scale was at the pixel level, and the exercise provided valuable experience for the KS-GAP project that was to come. In addition, Dr. Kevin Price, Acting Associate Director at KARS, and his colleagues recently had developed multitemporal analysis techniques that yielded very high accuracy to discriminate between agricultural fields and native vegetation, and among agricultural crop types. Because of their previous experience with a statewide remote sensing mapping project and our desire to use KS-GAP to support and develop new techniques for land cover classification, we were delighted to have KBS as partners to develop the land cover classification map.

The Geographic Information System Spatial Analysis Laboratory (GISSAL) at KSU has demonstrated excellence in Geographic Information Systems (GIS) through its development of a statewide soil map. GISSAL is part of the Department of Geography, under the direction of Drs. H. L. (Sy) Seyler and John Harrington. GISSAL is responsible for developing the GIS system and the land stewardship layer. Both KARS and GISSAL are members of the State GIS Policy Board, which oversees maintenance and distribution of digital data in Kansas.

The three production entities involved in KS-GAP are Kansas State University's Division of Biology, which includes the Coop Unit, the KSU Geography Department, which houses GISSAL, and the University of Kansas, which is the home of KBS. An underestimated benefit of distributing the project among these entities was that each came into KS-GAP with a preestablished set of partnerships. The Coop Unit is linked through its cooperative agreements with the university, USGS-BRD, and the Kansas Department of Wildlife and Parks (KDWP). Our involvement automatically involved those three entities as partners. The GISSAL has close ties to the Natural Resources Conservation Service, the Fish and Wildlife Service, and the State GIS Policy Board. The KBS has close links with NASA, EPA, KDWP, and the State GIS Policy Board. Work that was ongoing with all of these entities automatically became part of KS-GAP.

During the first year of KS-GAP, we recognized the need to hire a coordinator to maintain communication among the producers, as well as to continue contact with existing partners and to develop new partnerships. Dr. Glennis Kaufman, from the Division of Biology, was hired into this position in December 1995. Her first priority was to develop additional partnerships to support KS-GAP. We were helped in these efforts by the fact that the new Secretary of Kansas Wildlife and Parks, Dr. Steve Williams, was very interested in incorporating a computer-based GIS management database such as KS-GAP for resource management within his agency. His office offered to set up a series of meetings with high-level individuals from other potentially interested Kansas agencies. As a result of those meetings, we developed additional partnerships and received financial support from the

State Water Office, the GIS Policy Board, and KDWP.

Once KS-GAP was under way and began to produce some products that could be used to show what gap analysis can provide, we found a very powerful tool in helping to develop new projects with potential partners. For example, we recently began discussions with the Kansas Army National Guard to develop a habitat and wildlife monitoring program for one of their training areas. Our discussions with them were proceeding nicely, but they became genuinely excited when we showed poster material from KS-GAP that could enhance their program and invited them to participate in KS-GAP. I expect many future relationships to benefit similarly when we show people how they can meet their needs in unexpected ways by becoming partners in KS-GAP. Many of the organizations we have dealt with have multiple land holdings in Kansas, and although their initial interests are often at a single site, gap analysis offers them an opportunity to anticipate future planning needs at all of their Kansas sites. This provides a strong incentive for agencies to become involved.

There also is a snowball effect. As more organizations become involved in KS-GAP, it becomes easier for additional groups to believe in the usefulness of gap analysis. Also, as more groups begin to use these products for their planning, I expect the GIS data to become a de facto *lingua franca* among land managing agencies. As Gap Analysis projects move along and more and more groups become involved, it becomes ever easier to establish partnerships.

Several things existed within Kansas from the beginning that predisposed it to partnerships that might not be present in other states. First, there was a preexisting interest in digital data and GIS technology among numerous agencies in Kansas. Second, we had two organizations, KBS and GISSAL, with statewide mapping experience as well as their respective suites of partners. Third, we were fortunate that the Secretary of Wildlife and Parks came into his position with a clear understanding of how a program like Gap Analysis could benefit his agency.

I believe that in order to develop successful partnerships for Gap Analysis we all need to be opportunistic. If you can find agencies that are interested, it is important to get them involved even if they have little or no money to contribute. As more partners refer to Gap Analysis in interagency discussions, you will find more and more people coming to you, but the initial involvement among planners is critical. We all want our products to be useful and, I believe, the best way to realize those wishes is to involve as many partnerships as possible early in project development.

Conservation Planning and Local Governments

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In 1991, the Tennessee Biodiversity Program (TBP) was established by the Tennessee Conservation League (TCL), the state affiliate of the National Wildlife Federation (NWF), to provide decision makers with user-friendly information on the biological diversity of Tennessee. The premise of the TBP is that economic development and natural resource conservation are compatible goals. Furthermore, development decisions should be made with the benefit of accurate, accessible information on Tennessee's natural resources, including habitats of neotropical migrant songbirds, rare plants and animals, wetlands, and other ecologically sensitive areas.

Generally speaking, the information is already available. The TBP coordinates the use of information from the Gap Analysis Program and Partners in Flight. These databases are constantly being updated and reside on the state's GIS located at the Tennessee Wildlife Resources Agency (TWRA).

The TBP targets four key groups to work with: planners and community leaders, landowners, natural resource professionals, and educators. This article focuses on the TBP interface with county governments, primarily through the Committee of Planners and Community Leaders, formed to achieve the following objectives:

1) Provide leadership and direction for the development of new state and county maps identifying local areas significant to Tennessee’s biodiversity.
2) Assist in the development of conservation strategies for these areas.
3) Assist in the implementation of these strategies by using existing mechanisms available for industrial, community, and county planning.

After considerable study and debate, the committee made the following recommendations to TCL:

1) Encourage state agencies to foster a customer-oriented culture that helps local governments, educators, landowners, and natural resource professionals acquire high-quality map-based natural resource information in a timely manner.

2) Promote natural resource conservation at the community level by advocating the use of map-based natural resource information.
3) Work with local citizens' groups to encourage their involvement with TCL and the TBP.

With the support of TCL, GAP, and others, we have begun testing an approach for achieving these objectives. Three pilot counties with varied demographic and socioeconomic characteristics were selected, and we examined the application of planning methodologies at different spatial units (e.g., county and watershed). Using these results for a planning framework, we have begun working with local officials and landowners to determine how GAP data can best be used in a balanced way for economic development and natural resource conservation in Tennessee. Following is an overview of two of the three pilot projects.

Pilot Project # 1 Franklin County

Franklin County, located on gently sloping terrain in south-central Tennessee, is a predominantly rural county with a population of 35,000. Since it was first settled in the early 1800s, Franklin County has capitalized on its rich soils and readily available sources of water to become one of the most agriculturally diverse counties in the state. However, during the past two decades, the county’s economy has diversified. Winchester, the county seat, has historically been the principal agriculture market and trading center of the county. Today, it is a thriving town of 13,000 and the focal point of a regional economy that is based more on manufacturing (textiles, leather, and wood products) and less on agriculture.

Conservation planning in Franklin County is influenced by the following groups: Folks for Positive Growth (FOLKS), the Franklin County Regional Planning Commission (FCRPC), the Board of Zoning Appeals, the County Commission, and faculty and students from the nearby University of the South.

The University of the South has created an interdisciplinary team to study economics, political sociology, tax incentives, and geology. The economics study will identify the relationship between increased tax revenues generated by population growth and increased demands for county services. Using the TN-GAP land cover data as a base map, the team will analyze growth scenarios, impacts, and cost benefit ratios for each.

The study of political sociology will examine changing attitudes, values, and concerns as the county changes from agrarian to industrial. The tax incentives study will evaluate the impact of the Forest Greenbelt Law (a conservation tax incentive) on the county's tax base and on its biodiversity. The study of geology will compare the use of septic tanks versus sewage systems in the county, and the implications for environmental impacts.

One of the most dynamic citizens groups in the county is FOLKS. Their mission is to continuously define, maintain, and improve the quality of life in Franklin County. Their charter is to:

- Define the quality of life in Franklin County.
- Identify the primary determinants of that quality of life.
- Provide an all-inclusive forum for the education of, and discussion among, Franklin County citizens concerning that quality of life.
- Develop guidelines for the maintenance and improvement of the quality of life in Franklin County.
- Provide a "voice" for Franklin County citizens to make known the results and findings of all the above.
- Facilitate interaction and cooperation between this group and political, commercial, and other organizations to continuously define, maintain, and improve the quality of life in Franklin County.
- Evaluate annually the accomplishments of the organization and issue a report to members, media, and elected officials.
- Guard against becoming anything less than all-inclusive

The work of FOLKS, The University of the South, Tennessee Wildlife Resources Agency, and TCL brings together a unique set of forces to shape the way Franklin County addresses issues related to conserving its quality of life. Two immediate products from this collaboration will be a GIS-based interactive planning tool and a symposium to address coordination of objectives among land management agencies.

In the final analysis, one of the most important factors of the Franklin County pilot project is the active leadership provided by the County Executive. On March 4, 1996, The Winchester Herald Chronicle published an op-ed article by the County Executive, Clint Williams, entitled “My View: Franklin County Future Seen as Still Undefined.” In this article, the County Executive voiced his concern over the cumulative impacts of several major projects—the widening of Highway 41-A, construction of a new Wal-Mart Super Center, construction of the new Nissan facility—and how these projects would create a strain on schools and local services. He made a strong and compelling case for continued emphasis on long-range planning in Franklin County, and called for more citizen involvement in the process. In essence, this pilot demonstrates the importance of executive support for effective conservation planning and implementation.

Pilot Project # 2 Fayette County

Fayette County, located in southwestern Tennessee, is in the immediate path of residential and commercial expansion from Memphis and Shelby County. The county, with eight incorporated towns and a total population of 33,000, is typical of many "outer tier" predominantly rural counties that are facing development pressures from nearby urban centers. As new residents move in, new demands are placed on the schools and county infrastructure. New residents often arrive with value systems that conflict with third- and fourth-generation county residents (conservation versus pro-growth and development). Issues related to conservation of biodiversity can become entangled in the politics and dynamics of conflicting value systems. The Wolf River Conservancy, a nongovernment organization (NGO) devoted to conserving the Wolf River (which runs through Shelby and Fayette counties), has become a focal point in the debate over development and biodiversity-related issues in the region.

Against this backdrop, the local leadership in this pilot project has come from the Fayette County Consolidated Office of Planning and Development. The county is experiencing relatively rapid growth and officials have two tools to direct and manage growth and development: 1) a Land Use Plan and county-wide zoning (Fayette is one of 30 counties in Tennessee with county-wide zoning); and 2) extension of water and sewer service, which enables the planning staff to manage direction and density of growth. Only 15% of the county population is on sewer, and zoning regulations require a one-acre minimum lot size if a septic tank must be used. While the Plan enumerates land use goals in only the broadest terms (e.g., “protection of agricultural land”), it serves as the logical vehicle for integrating future policies and initiatives related to conservation of biodiversity in Fayette County. To date, the strategy of the Tennessee Conservation League has been to encourage the formation of a citizens group in Fayette County that can work with TCL and the Wolf River Conservancy to educate and otherwise influence Fayette County government on issues related to conservation, quality of life values, and the availability of map-based information that can be used in goal setting and strategy formulation. The goal is to develop a county-wide conservation plan that complements the community's comprehensive plan.

To support this effort, the Tennessee GAP data are being provided to the Fayette County Office of Planning and Development by the Tennessee Wildlife Resources Agency for planning purposes. Assistance from the National GAP Program is being provided to the county in the appropriate use of the data and in facilitating citizen input in the conservation planning process. Central to the success of this pilot is the demonstrated enthusiasm of the county government and the cooperation of NGOs. In the meantime, the immediate challenge is to educate residents and generate support for conservation planning in this county, which is undergoing a significant transition.

First International Gap Analysis Project

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Background

Approximately half of the United States-Mexico border is defined by the Rio Grande (named the Rio Bravo in Mexico and here referred to as the RG/RB). The river is an important ecological component of the ecosystems it transverses, and the Texas-Mexico border region represents an area of great biological diversity. The Texas Gap Analysis Project (TX-GAP) has been making considerable strides toward completing Gap Analysis for the state, but successful completion of the project would have left a partial picture of the habitats encompassing the RG/RB. Coordinators of the USGS Lower Rio Grande Ecosystem Initiative (LRGEI) (U.S./Mexico Field Coordinating Committee 1996) proposed that Gap Analysis should be extended to include areas in Mexico adjacent to the Lower Rio Grande. The LRGEI's mission is to assist Department of the Interior agencies with transborder inventory, monitoring, and research activities in the Lower Rio Grande basin. During 1996, NBS Director Pulliam provided funding to begin an international Gap Analysis project that extends about 180 km into Mexico. The first meeting between CONABIO (Comision Nacional para el Conocimiento y Uso de la

Biodiversidad) and USGS personnel to plan the project took place in early '97, and CONABIO subsequently provided matching funds.

The Lower RG/RB region along the United States-Mexico border forms a basin that is about 222,000 sq. km in size (61% in the U.S. and 39% in Mexico) (Woodward and Durall 1996), and the region contains a wide variety of rare plant and animal species (Inglis 1996, Diamond *et al.* unpublished report). Since recent economic agreements (e.g., North American Free Trade Agreement) have the potential to promote high rates of economic and population growth on a short-term basis, there has been increased interest in this border region among state and federal agencies in both countries. The environmental impact from the anticipated development may be severe and will require careful binational planning. The viability of many species and natural communities of the RG/RB region will ultimately depend on cooperative efforts of both countries.

Cooperators in the RG/RB Gap Analysis Project include CONABIO, the USGS Environmental and Contaminants Research Center, Texas Cooperative Fish and Wildlife Research Unit, and the U.S. GAP. Additional support and participation is being sought from diverse sectors of both countries (e.g., federal and state governmental agencies, universities, research institutions and nongovernmental organizations) as the project develops. The project is the first international Gap Analysis project supported by the U.S. GAP and is one of the first joint activities undertaken since BRD and CONABIO signed (on January 19, 1995) a Memorandum of Understanding for cooperative participation in the assessment and conservation of biodiversity between both countries.

Project Description and Challenges

RG/RB-GAP will use standard GAP methods (i.e. GAP 1997). Current analyses performed for TX-GAP will be extended to Mexican lands adjacent to the Lower Rio Grande (Gonzalez-Rebeles *et al.* in press). A map of land cover is being produced from satellite imagery and ancillary information. Vertebrate distributions are being predicted and mapped based on knowledge of their habitat associations and the spatial representation of those preferred habitats. Land stewardship, categorized by level of management relative to conservation potential, are also being mapped. This information will be combined as digital layers and analyzed in a GIS to evaluate how the different communities, the sites of maximum species overlap (richness), or individual species distributions are represented in existing managed areas, and to identify potential “gaps” in conservation. In addition, both TX-GAP and RG/RB-GAP biological and geographic data sets will be combined for the integrated analysis and planning of land use and management of this important border region.

The study area proposed involves a region covered by fourteen Landsat satellite scene areas that span the river plus six adjacent scene areas wholly in Mexico, covering northern portions of the states of Chihuahua, Coahuila, Nuevo Leon, and Tamaulipas in Mexico (Fig. 1). *Editor’s note: Because of its detail and color we were unable to reproduce this figure. Readers are encouraged to view it on the Web http://www.gap.uidaho.edu/gap/Bulletins/6/).*

Implementing RG/RB-GAP is challenging and exciting. For example, planning and organizing a program of cooperative participation and data-sharing among the states of both countries will not be easy. As in the U.S., different agencies and institutions within the Mexican states differ in their policies and procedures. In addition, as encountered by GAP in the U.S., the availability of biological information in Mexico and its level of detail and quality varies considerably among states. Fortunately, in recent years biodiversity data have been collected, organized, and further developed by CONABIO in coordination with major museums and universities. However, it will still be a challenge to integrate data sets among states within and between the countries into standard formats appropriate for an international gap analysis.

Linking geographic data sets will be particularly problematic. Maps from each country differ in scale and format. A regional analysis across both sides of the RG/RB will require the development of standardized versions of several map themes to complement those few maps having common characteristics. For example, the most frequently used vegetation classification schemes are fairly general (e.g., Miranda and Hernandez-X 1963, Rzedowski 1988), and vegetation studies are localized and large scale. New descriptions of vegetation formations and alliances are needed.

An advantage for RG/RB-GAP is that it was developed as a regional project from the outset. This is forcing an up-front development of strategies for standardization and merging data sets. Similar to other regional GAP projects in the U.S., this project is creating new opportunities for research and providing options for solving many of the problems facing the region. The project will also provide a better understanding about the applicability of the gap analysis approach when extended across the international boundaries.

Conclusion

RG/RB-GAP in combination with TX-GAP will generate valuable geographical and biological data sets and analyses to support conservation and land use planning of the Lower RG/RB ecosystems. Both projects will provide opportunities for data sharing and standardization of procedures for the assessment and monitoring of this important international region and the shared ecological and economical interests. The adaptation and refinement of techniques and procedures will help CONABIO evaluate approaches needed to apply gap analysis to the rest of Mexico. In general, the associated research and experiences derived from this project will set a benchmark for coordination of gap analysis across North America.

Acknowledgements

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In Pursuit of the Aquatic Component of Gap Analysis

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While GAP has made huge strides in developing information on the biogeography of terrestrial environments for conservation assessments, much less has been accomplished for aquatic environments. The program's initial focus on terrestrial vertebrates and vegetation types was a choice based on what was achievable at that early time in our history. The issue is not which components of biodiversity we might specialize in, rather, how to pragmatically implement gap analysis. In principle, GAP is committed to developing biogeographic information for all species and habitats. How else could we claim to be in the business of assessing the conservation status of biodiversity?

The need to apply the GAP methodology to aquatic environments is now, more than ever, crucial to the survival of many aquatic species. The Nature Conservancy (TNC 1966) estimates that 68 percent of all freshwater mussel species, 51 percent of crayfish species, 40 percent of amphibian species, and 39 percent of freshwater fish species are either vulnerable, imperiled, critically imperiled, or presumed extinct. These numbers of endangerment for aquatic organisms eclipse comparable figures for terrestrial taxa (about 15 percent of mammals and birds combined are endangered). Yet, the information required to relate species distributions to biodiversity management is still poorly organized for most states.

Determining gaps in the management of aquatic biodiversity begins by integrating the GAP terrestrial data, such as land cover and land management, with the following suite of aquatic data sets:

(a) the National Hydrography Dataset (includes the EPA River Reach File; see http://nhd.fgdc.gov/nhdpgs/), which is the spatial framework for aquatic features;
(b) distributions of species by river reach;
(c) the bundle of management scenarios for each river reach, such as county zoning set-back requirements, sport fish stocking, or state water quality regulations;
(d) the distributions of aquatic habitat types by river reach.

One of the most significant contributing factors to the continued demise of aquatic biodiversity is that terrestrial and aquatic environments have been, and still are, managed as separate entities. An important opportunity in developing the aquatic component of Gap Analysis is in creating seamless land-water data sets. As demonstrated by GAP products for terrestrial environments, the combined terrestrial and aquatic data sets will not only be used to identify aquatic biodiversity conservation gaps, they will also be used iterative in everyday land and water management choices as well as opportunistically in ways we have not thought of.

The need for developing the aquatic component of GAP was recognized as early as 1993, when the funds needed to support the effort were allocated by Congress. Those funds, however, were rescinded by the 1994 Congress. GAP still managed to initiate development of an aquatic component of the program in 1995 with the start of a pilot project in the upper Allegheny River Basin in Western New York. This project succeeded in providing a fully developed and practical working example of GAP methodologies applied to aquatic habitats at the river basin scale. For more information, go to the aquatic link on the GAP home page (http://www.dnr.cornell.edu/hydro2/Aquagap.htm) or contact Mark Bain <mbb1@cornell.edu>.

In 1996, in partnership with the Missouri Resources Assessment Partnership (MoRAP) and the USGS National Water Quality Assessment program (NAWQA), a statewide pilot was initiated in Missouri. Recently, the Department of Defense has joined with the BRD in supporting this project.

The Missouri project is assessing aquatic biodiversity at the regional, watershed, and “valley-segment” (Lammert et al. 1997) scales. A major emphasis is on identifying opportunities and techniques for integrating conservation assessments conducted separately for terrestrial and aquatic environments, as well as integrating the foundation data sets for combined analyses. For more information on this project see MoRAP Projects at <http://www.msc.nbs.gov/morap/projects/projects.html#marp>, or go to the MoRAP web site by clicking on Missouri from GAP’s State Project Information page, or contact Scott Sowa <scott_sowa@usgs.gov>.

Although a single discrete source of funds for the development of aquatic data sets in each state has not surfaced (and probably will never come as one sum), this year the BRD awarded competitive funds from its Ecosystem Initiative Program to develop a strategy for making the transition from the pilot project phase to a nationwide program, and to develop the broad-based support needed. This effort will begin with a series of regional workshops to assess the information needs of state and federal agencies, nongovernment organizations, and the academic community. The outcome of these workshops will be to establish a network of communications and support and a series of guidance documents (i.e., a GAP Handbook Chapter for aquatic environments). Stay tuned for a workshop near you in 1998. For more information about this activity contact Tom Muir <tmuir@usgs.gov>.

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Thanks to Mark Bain, Tom Muir, and Scott Sowa for their review and input.

What’s Hot: Some Recent Applications of GAP Data

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Ultimately, GAP will be measured by the problems and needs to which it is applied. As such, applications of GAP information are the most important items for us to track. It is also critical, though, that we share the wide variety of applications that our work has been used for, so that the GAP community has a full understanding of the actual importance of the program. What follows are just a few brief examples of applications at the state level. All GAP principal investigators, coordinators, and staff are urged to keep records of how their information is being used.

Arkansas

An important initiative in the state is a multiagency wetland prioritization effort where land owners can submit their land for purchase by the state for wetland conservation or remediation. The program has been so successful that more acres have been offered than can be purchased. The problem in this situation is which parcels to buy? A number of state agencies are using GIS methods to create basin-wide wetland prioritization maps that are used to prioritize conservation and remediation locations. A key data element in the effort is the GAP statewide vegetation map. Within the Mississippi and Arkansas River Valleys, bottom land hardwoods are a critical habitat type and these are identified using the GAP maps. Other data included in the modeling effort are soils, inundation, ownership, etc. A sophisticated modeling effort is also applied that includes factors such as habitat connectivity patch size and other factors.

As a result of the clear value shown by the GAP vegetation maps, the Arkansas State Legislature appropriated some $200,000 to develop a detailed land cover/land use map focusing on agriculture in the 27 counties of the Mississippi Delta in the state. Four season TM imagery is being used to identify complex crop rotation patterns and to obtain a highly accurate map. The agricultural maps will be used in addressing critical problems of water use and water quality in the region. The forest cover for the final product will be merged from the GAP vegetation maps.

GAP data are key elements in a number of other research and conservation projects in Arkansas, including fire hazard modeling, regional watershed analysis, and water resources planning.

California

CA-GAP staff, in collaboration with researchers from the Department of Geography at the University of California-Santa Barbara and the National Center for Ecological Analysis and Synthesis, are working on techniques for using GAP data to identify efficient networks of biodiversity management areas. These techniques, adapted from the field of operations research, address the conservation principles of efficiency, representation, irreplaceability, flexibility, and suitability. The first task was to reformulate the iterative, rule-based procedures developed in Australia into a maximal covering location problem (Church et al. 1996), which maximizes the number of species represented in a fixed number of sites. A version of this optimization modeling approach has since been integrated completely into the ARC/INFO environment (Gerrard et al. in review).

CA-GAP also outlined a protocol for the U. S. Forest Service that includes a variation of this model using GAP data to select candidate sites for new Research Natural Areas (Moritz et al. 1997; Stoms et al. in review). They developed a land allocation model that balances the efficiency of the network with the suitability of the selected sites while filling the gaps to some prescribed percentage target level (Davis et al. 1996). CA-GAP is currently working with The Nature Conservancy to adapt this model to help them identify their regional conservation portfolio. The prototype is being applied in the Columbia Plateau ecoregion and was presented at this year's Ecological Society of America meeting in Albuquerque. An overview of CA-GAP's reserve selection research was presented at the Society for Conservation Biology meeting in Victoria, B.C.

Editor's note: For literature cited, see California status report on page .

Florida

The USGS-BRD Across Trophic Level System Simulation (ATLSS) is developing a set of models to integrate lower trophic levels, fish and macroinvertebrates, and large consumers across the freshwater landscape of the Everglades and Big Cypress Swamp. A major objective of these models is to compare the future effects of alternative hydrological scenarios on the biotic components of the systems. The Florida GAP land cover classification is providing the base vegetation map for ATLSS modeling.

Additionally, a high-resolution hydrology GIS layer was needed to adequately simulate plant and animal dynamics in ATLSS. The High Resolution Hydrology (HRH) model uses the Florida GAP land cover map as one of its primary inputs. The HRH model creates a pseudotopography GIS layer with an undulating surface that corresponds to the topography underlying the vegetation as classified by the Florida GAP land cover. The model calculates the volume of water in each grid cell, redistributes it over the high-resolution topographic surface by “balancing” the surface and subsurface volumes, and calculates the water surface elevation. The output of the HRH model is used as a primary input to the ATLSS plant and animal models.

Editor’s note: A figure illustrating the modeling effort can be viewed in the electronic version of this Bulletin on the GAP home page (http://www.gap.uidaho.edu/gap/Bulletins/6/).

Maine

ME-GAP personnel cooperated with the Maine State Planning Office to complete "A Conservation and Public Lands Database" (CAPLD) for the state. The 1:100,000 scale CAPLD includes many revisions and updates to previously released 1:250,000 scale land ownership maps and was constructed to meet GAP specifications. The final coverage contains about 3,130 polygons for 120 owners and includes state and federal lands, tribal lands, private nonprofit conservation lands (e.g., those owned by The Nature Conservancy), and selected public areas not managed for biodiversity (e.g., playgrounds, cemeteries, campuses). Each ownership block is coded as to consideration given to biological diversity in management plans. CAPLD has been provided to cooperators in digital and paper form and has been passed on to the state GIS office for distribution to the public.

Massachusetts, Connecticut, Rhode Island

At the regional level, Southern New England Gap Analysis data sets are being used in the planning efforts for the Silvio Conte National Fish and Wildlife Refuge, a new, multistate, watershed-based effort in New England. Gap Analysis data sets are also being used in workshops to train land use planners in biodiversity conservation in the Connecticut River Valley of western Massachusetts.

The Massachusetts Gap Analysis team also continues to be involved with international initiatives in biodiversity inventory, cooperating with projects in Romania, Madagascar, Mexico, Guatemala, Brazil, and Peru. Curt Griffin is currently on sabbatical in South Africa, working on prioritizing biodiversity conservation efforts in KwaZulu/Natal Province. Vegetation mapping and conservation planning are also being carried out in the Danube Delta, Ukraine, and Botswana.

In cooperation with Conservation International, most of the national parks in Madagascar have been inventoried using high-altitude 35-mm digital cameras in combination with low-altitude georeferenced videography. Similar efforts are being conducted in a number of biosphere reserves and national parks in Central and South America. The goal of these projects is to develop base vegetation maps to provide a tool for monitoring and change detection. The focus is on rapid development of in-country GIS capabilities, making critical data available for resource management decisions, and institutional strengthening within these host countries. The Gap Analysis approach is rapidly being integrated in conservation management programs around the world.

Missouri

The Geographic Resources Center (GRC) at University of Missouri is compiling a risk database to be used in conjunction with GAP data to conduct analyses at the state level. Risk surfaces are being created for the state, addressing population, social, economic, and land use change information that will be used by decision makers as an aid in evaluating the status of Missouri's biological diversity in the context of development and policy change.

Nebraska

A mosaic poster has been created from the GAP TM data and has been widely used within Nebraska to foster collaboration and improve public relations. This image of the state has helped the public understand remote sensing technology and captured imaginations on what can be achieved.

New Mexico

Some applications of NM-GAP information are: biotic mapping comparisons in northern NM mountain ranges; information coverages for county open space evaluation; and incorporation as criteria in land parcel evaluation by NM Department of Game and Fish for conservation planning and acquisition.

New York

GAP information in New York has led to more detailed mapping of land cover of the Hudson Valley corridor, between Albany and New York City. A higher resolution analysis of this region will facilitate conservation planning and decision making for this fast-growing region of New York.

North Carolina

The NC-GAP information is the basis for a “mini-Gap Analysis” project titled “A Model Biodiversity Analysis for Southeastern North Carolina” being carried out by the North Carolina Heritage Program and the North Carolina State Museum of Natural Sciences.

Vermont/New Hampshire

The Gap Analysis Project in Vermont and New Hampshire has become fundamental to biodiversity management in these two states. New Hampshire has established a committee for ecological reserve design, and much of their GAP data and mapping expertise is being incorporated into that project. The Vermont Biodiversity Project is a similar project that has the objective of mapping potential conservation areas that will assure the protection of biological diversity. Coordinated by the Vermont Chapter of The Nature Conservancy, this effort includes a long list of state, federal, private, and university cooperators.

Washington

In a cooperative effort between WA-GAP and the U.S. Fish and Wildlife Service, the role of National Wildlife Refuges (NWRs) in conserving biodiversity in Washington State was examined. The resulting report shows that NWRs often protect habitats and species that are poorly represented on other conservation reserve lands. NWRs provide some habitat for 92% of the native vertebrates breeding in the state; for 16% of native vertebrates, NWRs are the main source of protection. The report presents management recommendations and priorities for individual refuges, based on WA-GAP’s landscape-scale assessment, and indicates research needed for management of specific habitats and species.

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Wyoming

The University of Wyoming's Spatial Data and Visualization Center

(SDVC) and the Biological Resources Division (BRD) of the U.S. Geologic Survey have created a partnership to implement a county-level planning support project. This project will assist Teton County, Wyoming, in creating a biological decision support system in a desktop computing environment to help promote biological considerations in traditional land use planning and management decision-making processes. The system will incorporate the completed Wyoming Gap Analysis databases and other natural resource databases with a simple graphical user interface and custom-designed tools that will not require prior knowledge of GIS or biology on the part of the planning staff.

The support system will be a tool that Teton County's planners may use to 1) assess their current land use plans and zoning in relation to biological resources, and 2) identify potential conflicts between biologically significant habitats and proposed development.

STATE REPORTS (Status as of late summer 1997)

Alabama

Alabama is in an early organizational stage.

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Arizona

Accuracy assessment for Arizona GAP is now being carried out by the Colorado Plateau Field Station at Northern Arizona University for the northern half of the state, and by the Cooperative Park Studies Unit at the University of Arizona for the southern portion of the state. The assessment is being conducted with a number of collaborators, such as the Arizona Game and Fish Department, Indian tribes, and local and county organizations and agencies.

In order to help us with plant community classification and future mapping efforts, relevant data are being collected at a statistically significant number of polygons throughout the state. Vegetation accuracy assessment is being done by field technicians, private volunteers, and agency volunteers. Expectations are that this phase will be completed by early fall and that a final report will be drafted by the end of 1997.

We continue to seek partnerships with state agencies and national museums with whom we can share data to the benefit of both programs. Part of our assessment of the vertebrate distribution maps includes checking the maps against documented collection data from museums and research laboratories. Lists of species occurrence have been collected for more than 22 different areas, and we are now in the process of evaluating the quality of those lists.

To date, three public lectures have been given to agency conferences, and eleven meetings have been held with federal, state, and tribal agencies. Agency commitment toward assessing sampling sites has been slow in forthcoming, although some in-kind help has been provided. Despite this, the personal contact is important in giving these agencies and tribes a sense of investment in the gap analysis process.

Arizona GAP is also increasing its capacity to serve data through the Internet. We expect that in fall 1997, we will have the GAP data sets available on-line, in addition to the CD-ROMs that might be produced with the final report.

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Arkansas

All image processing, classification, labeling, and accuracy assessment is completed. The remaining tasks deal with the production of the final report, due for completion by January 1998.

1. Line smoothing: The state has been tiled into 35 1:100,000 scale

(30' x 60') USGS quadrangles. Each tile has been line-smoothed to convert the pixel polygon boundary to a more generalized polygon boundary that reduces file size and maintains a better scale relationship to the 100 ha aggregated land cover data set. These data were smoothed using Intergraph's Map Finisher software according to an equally weighted moving averages smoothing algorithm. All tiles have been transferred to ARC/INFO where they all individually build proper topology. Thirty-two of the thirty-five tiles have been MAPJOINed together. Only three tiles remained to be joined to the final 100-ha land cover ARC coverage.

2. CD-ROM map production: Three map series are being produced for inclusion on the CD-ROM. Production is completed for both the county and 30' x 60' map series, while the 7.5' map series lacks some 300 maps out of a total of 3,000. For each map series, three background layers are generated: the 100-ha land cover map, the CIR satellite image, and the tasseled cap satellite image.

3. Arkansas Forest Commission field photo scanning: There are just over 400 ground-based photos being scanned for inclusion on the CD-ROM. Testing of various compression and scan rates to determine the most appropriate balance between file size and photo resolution has been completed. The photos will be scanned and linked (hypertext) to their appropriate field site on the tasseled cap field map.

4. Final report: The report text is in the final draft stage, and work is progressing on converting the report to its final Acrobat PDF format.

5. Land ownership and land management status mapping: Land ownership and land management data sets have been completed (Nov. 1995) and moved into ARC/INFO. Metadata has been collected but is not yet in final document format. The final report with statistics for management categories 1 and 2 has been completed.

6. Vertebrate mapping: Vertebrate ranges, habitat mapping, vertebrate models, and accuracy assessment are complete. Analysis of vertebrates with respect to stewardship layer and biodiversity analysis (hexagon mapping of underprotected species) have also been completed. The vertebrate report and biodiversity analysis report have been written.

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California

Land cover and land management mapping for the California Gap Analysis Project (CA-GAP) have been virtually completed. The California Department of Fish and Game is helping with refining the interpretation of habitat types from the land cover data and with final predictions of vertebrate species distributions. Attention has been shifted more towards data analysis and distribution of the database. The current plan is to distribute the database and report on both the World Wide Web and CD-ROM. In addition, an interactive atlas on CD-ROM with a graphical user interface built on ESRI's ArcView software is being developed. This product will allow users without GIS experience to query the CA-GAP database about the distribution of the state's biota and associated land management. The Universal Resource Locator address (URL) for the CA-GAP web site is http://www.biogeog.ucsb.edu/gap/gap.html, which will provide access to GAP data and the report once they are completed. The Department of Fish and Game plans to take over the long-term maintenance and distribution of CA-GAP data.

CA-GAP staff, in collaboration with researchers from the Department of Geography at the University of California-Santa Barbara and the National Center for Ecological Analysis and Synthesis, have continued to work on techniques for using GAP data to identify efficient networks of biodiversity management areas. These techniques, adapted from the field of operations research, address the conservation principles of efficiency, representation, irreplaceability, flexibility, and suitability. Our first entry in this arena was to reformulate the iterative, rule-based procedures developed in Australia into a maximal covering location problem (Church et al. 1996), which maximizes the number of species represented in a fixed number of sites. A version of this optimization modeling approach has since been integrated completely into the ARC/INFO environment (Gerrard et al. in review). We also outlined a protocol for the U. S. Forest Service that includes a variation of this model using GAP data from which to select candidate sites for new Research Natural Areas (Moritz et al. 1997; Stoms et al. in review). We developed a land allocation model that balances the efficiency of the network with the suitability of the selected sites while filling the gaps to some prescribed percentage target level (Davis et al. 1996). CA-GAP is currently working with The Nature Conservancy to adapt this model to help them identify their regional conservation portfolio. The prototype is being applied in the Columbia Plateau ecoregion and was presented at this year's Ecological Society of America meeting. An overview of our reserve selection research was presented at the Society for Conservation Biology meeting in Victoria, B.C.

In the past year, one Ph.D. dissertation (Thomas 1996) and one master's thesis (Thorne 1997) were completed, representing GAP-related research in the Mojave Desert and Northwestern California regions, respectively. Several peer-reviewed articles relating to CA-GAP were published, accepted for publication, or submitted since the last newsletter. The final report of the Sierra Nevada Ecosystem Project was submitted to Congress. The report contains a chapter on a Gap Analysis of plant communities (Davis and Stoms 1996) and one on an approach for selecting an optimal system of biodiversity management areas to fill conservation gaps (Davis et al. 1996).

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Colorado

The GAP team completed comparative reviews of White River National Forest and San Juan National Forest vegetation base lines to get the CO-GAP vegetation map ready for vertebrate modeling activities. We worked closely with Ken Driese and Dr. William Reiners of the University of Wyoming, Laramie, to push ahead on joint air-videography based validation for both Colorado's and Wyoming's GAP vegetation base lines. Fifteen of sixteen statewide transects have now been flown, with over 400 sample video frames produced, to develop the sampling scheme.

The land ownership map is undergoing major review as changes have occurred in over 400 State Land Board parcels since the original map was prepared for the land stewardship model of CO-GAP. Additionally, various forest and range management plans, as well as park plans, are under review. A methodology is under development for consideration of various land trust parcels in the state.

For vertebrate modeling purposes, ancillary data sets from the Wildlife Resource Information System (WRIS), Colorado Bird Atlas Project (CBAP), Scientific Collections Permit Database (SCICOLL), Colorado Herptile Database, Aquatic Database Management System (ADAMAS), Colorado Vertebrate Ranking System (COVERS), and Colorado Wildlife Heritage Database (CWHD) have been developed for use in the geographic information system. CO-GAP activities have been coordinated with Colorado Natural Heritage Program endeavors to facilitate mutual review of report materials. Site occurrence plots have been generated for over 600 species, and preliminary predictive habitat distributions maps have been prepared for over 80 "prototyping" vertebrate wildlife species.

A series of review workshops for species experts were held in June to provide an update on CO-GAP progress to West Slope cooperators and to gather their input. As a result of the workshops, an electronic form has been developed to collect updates from the experts on the habitat links being used for each vertebrate species model. The electronic collector form complements the multipage habitat affinity tables produced for each species, as well as providing additional means to tag the affinities as being primary or secondary in nature. The forms are intended to be used to further note whether the links are directly to those landscape habitat features mapped for Colorado's vegetation layer, or actually to some microhabitat feature within the land cover features mapped. Additional workshops are being scheduled for the Front Range as well as the San Luis Valley. We are truly grateful, after all our preparations, to be in the thick of the vertebrate modeling activities. Project completion is anticipated for early 1998.

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Connecticut

(see Massachusetts, Connecticut, and Rhode Island)

Delaware

(see Maryland, Delaware, and New Jersey)

Florida

Land cover classification is mostly complete for seven Landsat TM scenes covering all lands south of Orlando. Some areas require a revisit, but there will be little overall change. The next row of TM scenes is expected to be classified within the next couple of months. The Florida GAP Project is experimenting with digital color infrared aerial photography as an alternative to videography. Some advantages of color IR are better resolution and better vegetation discrimination. The digital format copies and is archiveable without image degradation. The images are also easily enhanced and integrated with an ArcView interface for interpretation and field visits. There are problems with developing a batch process for conversion of the proprietary file format to something useful. Accuracy assessment of the south Florida classification began in summer 1997.

Habitat descriptions and range maps are complete for all the vertebrates, ants, butterflies, and skippers in Florida and have been reviewed by experts. Habitat-species matrices are complete for all but the reptiles, amphibians, and birds. These groups are being completed in summer 1997. In addition, minimum critical area and dispersal estimates have been compiled for all mammals and most birds. An ARC/INFO AML script has been written and tested to model potential habitat based on the above data themes.

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Georgia

Funding for GA-GAP will start in FY98, and the project is getting under way.

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Idaho

Idaho was the first GAP prototype state project. This project helped establish the early standards and methods, as well as being the source for numerous publications that launched the national program. The techniques and standards have evolved greatly since the Idaho project was conducted, and now it is time for an update. This began with the redesign of Idaho's wildlife-habitat relationship (WHR) models. A study of available primary literature revealed that little more is known now about the habitat selection criteria for Idaho species than ten years ago, when the prototype GAP project was completed. We are moving toward innovative WHR modeling, using probability indexes that include inferred relationships between species' habitats and variables such as slope, elevation, aspect, canopy closure, and forest density.

The land cover update is being accomplished through participation in two regional Forest Service projects. Region 1 of the USFS mapped northern and central Idaho through Roly Redmond's lab. The southern portion is being mapped by Collin Homer at Utah State University. By January 1998, the Landscape Dynamics Lab at the University of Idaho should have both maps and will begin the edge-matching phase. Thereafter, the vertebrate distribution modeling can begin.

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Illinois

The Illinois GAP project was formalized in November 1995. Personnel were in place by January 1996. The first year was spent organizing, building working relationships with other agencies, seeking additional funding, performing pilot studies, and vegetation classification.

A general land cover classification for the state was completed in October 1995 as the first step in the state-funded Critical Trends Assessment Project (CTAP) and released in mid-1996. The CTAP classification identified 19 broad land cover classes: four urban, three forest and woodland, three agriculture, two grassland, five wetland, and two "other" categories (water and barren). The GAP vegetation classification will be performed for separate natural cover elements of the original imagery using a boolean mask for specific CTAP classes (forests, forested wetland, and rural grassland). Classification protocols are similar to protocols for UM-GAP (described in Bull. No. 5, p. 35). Classification efforts have been concentrated in the Shawnee National Forest of southern Illinois and are proceeding northward.

Cooperative agreements have been established with the U.S. Forest

Service and Illinois Department of Natural Resources (IDNR) to perform ground truth verification of completed 1:100,000 land cover tiles. IDNR district biologists are currently assisting in the collection of vertebrate distribution data for the state. Additionally, teams of field biologists from the Illinois Natural History Survey (INHS) collected GPS-controlled data for all natural resources (terrestrial and aquatic) as part of the CTAP Long-term Monitoring Project implemented during summer 1997. We have been extensively involved in the sampling design and field protocols for this 5+ year program. Field data collected will be used in the classification and accuracy assessment phase for GAP as well as trend analysis in CTAP.

The IDNR has recently changed the status of many of its public lands, therefore affecting our state lands coverages. Updates to this coverage are nearing completion. The coverage for all local- and county-owned preserves is also near completion. We are, lastly, working on creating an Illinois GAP home page which will soon be accessible via the Internet.

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Indiana

The Indiana Gap Analysis Project is nearing completion, with all data layers in place. Analysis will begin in earnest over the winter 97/98, along with accuracy assessment of the vegetation map and predicted vertebrate distribution data. We plan to have the final report finished in the spring of 1998. GAP data continues to be used in metaprojects that are in various stages of completion. The GAP data also serves as a cornerstone of the Indiana Biodiversity Steering Committee's planning efforts.

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Iowa

The Iowa Gap Analysis Project officially started on April 1, 1997 shortly after receiving the first year's funding. A search has been initiated for a GIS coordinator, and equipment has been ordered. One graduate research assistant has been appointed to help with the vertebrate databases and habitat models. Another graduate student is being recruited to assist with mapping stewardship lands. Kevin Kane, Manager of Iowa State University's GIS support facility, has agreed to serve as co-principal investigator for GAP. Tom Rosberg, Biology Department, Drake University, has agreed to assist with vegetation mapping. The Iowa Department of Natural Resources (DNR) is assisting in organizing a statewide field survey to identify and locate vegetation alliances on state and county lands.

Iowa GAP obtained a 1992 set of TM imagery for Iowa from the EROS Data Center in October 1996. Using the hyperclustered imagery processed for the Multi-Resolution Land Characterization Consortium (MRLC), the Iowa DNR's Geological Survey Bureau, a major cooperator, began a general land cover classification of the state using counties as mapping units. About 20 counties have been completed. Jim Giglierano is supervising this work for the DNR.

Iowa GAP has joined Missouri, Kansas, and Nebraska as a member of the Mid-Western Remote Sensing Consortium to facilitate coordination and standardization of procedures in mapping vegetation. We have received some additional funding from Region 7, Environmental Protection Agency to help us achieve 2-hectare resolution in mapping vegetation alliances.

Potential cooperators among federal, state, county, and nongovernmental organizations have been contacted. A committee of plant ecologists has been formed to draw up a working list of vegetation alliances for the state following the recent list for the Midwestern U.S. authored by Drake and Faber-Langendoen.

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Kansas

The Kansas Gap Analysis Project (KS-GAP) is at the beginning of its third fiscal year. The primary cooperators are the Division of Biology and Department of Geography at Kansas State University (KSU) in Manhattan and the Kansas Applied Remote Sensing (KARS) Program and Kansas Biological Survey (KBS) at the University of Kansas (KU) in Lawrence. Jack Cully at KSU continues to serve as the Principal Investigator (PI) of the project, and Edward A. Martinko has become the PI at KU. Glennis Kaufman at KSU continues to serve as the State Coordinator and oversees activities among KARS/KBS, Geography, and Biology.

Major accomplishments during the past year include the establishment of partnerships with state and federal agencies, the publication of the first newsletter, the completion of the land cover classification for the pilot area of study, the mapping of lands for stewardship, and the first step towards vertebrate modeling.

KS-GAP has developed partnerships with state and federal agencies and the universities involved (KSU and KU). State and federal agencies are interested in acquiring detailed land cover maps of Kansas and/or in applying results of the overlay of data within a GIS system for management of natural resources. Kansas Department of Wildlife and Parks, the U.S. Environmental Protection Agency-Region VII, the GIS State Policy Board (through the Kansas Water Office), and the Natural Resources Conservation Service have made funding commitments. In addition, we have received in-kind support from the National Aeronautic Space Administration (NASA). This ongoing support from NASA is a significant contribution of satellite imagery over Kansas.

The first issue (Winter 1997) of the KS-GAP newsletter, Kansas Maps and Gaps, was produced in March. The newsletter will be published on a semi-annual schedule. Kansas Maps and Gaps was sent to over 350 individuals and agencies. The response was very favorable.

During this past year, KARS completed the pilot land cover project of KS-GAP which focused on a ten-county area in southwest Kansas. Our mapping methodology was a two-stage or hybrid process using multiseasonal Thematic Mapper imagery (late spring, early summer, and late summer). In the first stage, unsupervised classification was used to separate crop land from natural vegetation. In the second stage, supervised classification was used to map the natural vegetation classes. We currently are evaluating post-classification methodologies to refine the classification accuracies of some of the classes mapped, including floodplain woodland and Conservation Reserve Program (CRP) grasslands.

Also, during the past year, KARS/KBS has published a detailed vegetation classification system for Kansas, preprocessed about 50% of the satellite imagery remaining to map land cover in Kansas, and presented results and exchanged ideas on methodologies at a number of conferences. An ancillary project to identify lesser prairie chicken habitat is under way in southwest Kansas. This project is conducted by a KARS graduate research assistant and will contribute to the land cover map of Kansas.

During this past year, the Geography Department at KSU traced the boundaries for 196 managed areas in Kansas onto Mylar and then scanned these data into a GIS stewardship layer. Attribute data, including the name, owner, and manager of the area, also were attached. We estimate that this layer is 80% complete. We now are in the process of contacting local, state, and federal agencies to determine if additional areas exist that need to be added to the database.

Work on the vertebrate layer is beginning in summer 1997 with the initiation of species lists for mammals, birds, reptiles, and amphibians which include species element codes, scientific names, common names, and state and federal ranks and status. We also are beginning to work on habitat relationships for mammals in southwest Kansas (the area of the pilot project) based on literature review. We plan to hire several graduate students in the fall to begin work on development of habitat relationships for birds, reptiles, and amphibians in southwest Kansas. An ancillary project, a digitized soil map produced by Geography at KSU for the state of Kansas, is expected to be used to help model vertebrate distributions in Kansas.

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Kentucky

The Kentucky Gap Analysis Project (A Landscape Assessment of Kentucky's Biodiversity) is officially under way as of June 1, 1997, when the Cooperative Agreement with the USGS was formalized. The Kentucky Department of Fish and Wildlife Resources, lead agency for KY-GAP, and Murray State University signed a Memorandum of Agreement to begin the vegetation portion of the project. Interviews have been held to fill two positions, Vegetation Ecologist and Image Analyst.

Air video data, collected in the fall of 1996, has been built into coverages and duplicated. A spatial data set of geology (1:500,000) has been acquired and will be used as a mask for image analysis. Ground-truthing is under way at several sites in the state: Pennyrile State Park, Fort Campbell, Land Between the Lakes, and Westvaco Timberlands. Agreements are being arranged with several state agencies to combine property boundary information and conservation status into a single conservation lands data set.

As outlined in the workplan, the vertebrate portion of KY-GAP will not be officially started until the project's second year. However, the Kentucky Fish and Wildlife Information System (KFWIS) staff have begun to organize archived data into appropriate sets for spatial data set creation.

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Louisiana

The Louisiana Gap Analysis Project is currently editing/refining the final vegetation map layer. This step will insure connectivity between classified TM panels and also between classified TM panels and National Wetlands Inventory data. The vegetation classification process is scheduled for completion in summer 1997. The Louisiana GAP team is continuing the compilation of the ground-truth data into a database. To help facilitate the process of collecting ground-truth accuracy data, the GAP team purchased a Rockwell PLGR+96. This product will allow us to get real-time GPS coordinates in the field, with a reasonable resolution. A digital camera to collect photos of ground-truth locations was purchased. Definitions to the vegetation classification terms are still in progress.

The Louisiana Breeding Bird Atlas Survey was completed this year. The draft report has been reviewed, and the final report is in press. Vegetation data collected in the field during the breeding bird survey are currently being entered into a database for use in the vegetation accuracy assessment.

Members of the Louisiana GAP team were invited to attend the first Mississippi GAP meeting (April 29, 1997) to discuss cooperation between the two states and other issues that might help them with their project. The Louisiana GAP team presented a paper at the 1997 ESRI User’s Conference, entitled “Louisiana GAP Analysis Project: Usage of Auxiliary Data Sets” during the Basic Method’s for National GAP Land Cover Mapping session.

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Maine

Maine Gap Analysis (ME-GAP) has entered its final year. Land cover mapping is progressing well, much of the vertebrate information needed is in hand and compiled, and land ownership and management status databases are complete. We have begun preparation of the final report, have made ME-GAP products available to cooperators and on the Web (http://wlm13.umenfa.maine.edu/progs/unit/gap), and have presented preliminary results to a variety of state and private conservation organizations.

Land Cover Map

Landsat Thematic Mapper (TM) imagery for the state is being used, along with ancillary GIS data, to delineate approximately 45 habitat types. A classification scheme was developed that represents a compromise between habitats required as input into wildlife-habitat models and the classes we felt we could discern from the TM imagery and available ancillary GIS layers.

Supervised, unsupervised, and hybrid approaches to image classification are being used. Training samples for the supervised portions of our image classification are derived from statewide aerial videography flown in June and October 1994. Approximately 11 million frames of wide angle (210 ha coverage) or zoom (0.09 ha coverage) are available from the videography for use in training TM data and testing of the resulting map. Spectral confusion occurs among some habitat types, requiring ancillary GIS data to differentiate these classes. Ancillary data sources include aerial videography, wetland polygons from the U.S. Geological Survey's (USGS) Land Use/Land Cover Digital Analysis (LUDA) database, transportation network derived from the USGS Digital Line Graph database, and field-checked locations for blueberry fields and hay fields in eastern and central Maine.

Once the statewide classification is complete and all TM scenes are mosaicked together (anticipated in August 1997), the map will be tested using polygons defined from the aerial videography. Eighty percent accuracy is desired for all major habitat types. To date, three TM scenes in northern Maine have been classified with all three techniques, and classes are being labeled by habitat type.

Vertebrate Data

We had previously compiled range and ecological information for each of the terrestrial vertebrate species that breeds in Maine into synopses. We continued to receive feedback on the synopses, including a review of the information with our neighboring states to improve edge-matching. The information compiled has been useful to many public and private land managers in the state. We have used the information and other sources in a publication on Maine herpetofauna, and provided data to an author summarizing ranges for all vertebrates in New England. Species ranges, conservation ranks, and general habitats used are provided on our Web site.

Land Stewardship

ME-GAP personnel cooperated with the Maine State Planning Office to complete "A Conservation and Public Lands Database" (CAPLD) for the state. The 1:100,000 scale CAPLD includes many revisions and updates to previously released 1:250,000 scale land ownership maps and was constructed to meet GAP specifications. The final coverage contains about 3,130 polygons for 120 owners and includes state and federal lands, tribal lands, private nonprofit conservation lands (e.g., those owned by The Nature Conservancy), and selected public areas not managed for biodiversity (e.g., playgrounds, cemeteries, campuses). Each ownership block is coded as to consideration given to biological diversity in management plans. CAPLD has been provided to cooperators in digital and paper form and has been passed on to our state GIS office for distribution to the public. More details of how CAPLD was developed are presented in our home page cited above.

Other Progress

Randy Boone completed a thesis that forms a biogeographical foundation for ME-GAP, described elsewhere in this bulletin. Randy and Jeff Hepinstall, a remote sensing specialist, have joined ME-GAP as Research Associates, and two graduate students will be joining the team. One of the new students will assist in completing ME-GAP and test the predicted vertebrate distributions; the second student will assess the representativeness of Maine's conservation lands. As products are generated from ME-GAP, conveying results has become paramount. We constructed a Web site which contains extensive information on ME-GAP. Finally, we have formally presented preliminary results to professional organizations, personnel from state and private nonprofit organizations, and, most exciting, to a Land Acquisition Priorities Committee convened by the Governor of Maine.

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Maryland, Delaware, and New Jersey

During this past year, construction of the land cover map went into full frenzy. Substantial video was flown throughout the project area during fall 1996, including a special mission to get coverage of several freshwater wetlands in New Jersey which would have been simply mudflats during the regular flights. Initial mapping has been done on the barrier islands of Maryland and Virginia, which proved challenging. The first draft of the land cover map for Maryland and Delaware should be completed in early spring of 1998. No time frame has yet been established for New Jersey.

The land stewardship part of the project has begun in earnest. The project is following the key developed by New Mexico and working with the individual land managers to develop the status assignments for each property. Later this year, a meeting among the various land conservation organizations will be held in Delaware to review land ownership boundaries and determine management status for publicly and privately owned conservation areas in Delaware.

In 1996, GAP investigators in Delaware provided assistance to the Delaware Natural Heritage Program (NHP), a GAP cooperator, in a project to inventory breeding birds in the Great Cypress Swamp (GCS), a 10,000 acre forested swamp in southern Delaware and Maryland's upper eastern shore. Up to this time, thorough inventories of the swamp had not been undertaken. GAP investigators initially accompanied NHP staff to bird point-count locations and trained NHP staff in the use of GPS receivers to record the locations. Assistance was then provided in converting the GPS data to GIS coverages and in producing final maps. The results of the inventory include a GIS coverage of breeding birds detected at 47 point-count locations. Seven of the ten most abundant nesting birds were forest-interior neotropical migratory species, and a total of twelve warbler species were discovered within the GCS during the nesting season (Heckscher and Wilson 1996). Additional surveys in the GCS are being conducted this year, as well as surveys in other important natural areas in Delaware.

In 1996 and 1997, GAP investigators continued small mammal live-trapping, bird and amphibian surveys, and other survey work in the Blackbird Creek National Estuarine Research Reserve watershed in Delaware. This watershed is being considered as a reference site for various purposes.

The Biodiversity Research Consortium Project for Maryland and Delaware has been completed. The project was funded by EPA and carried out by GAP investigators and cooperators from TNC, Maryland DNR Wildlife and Heritage Division, Delaware Natural Heritage Program, and the U.S. Fish and Wildlife Service. The hexagon-based maps of distributional limits for all vertebrate and butterfly species have gone through expert review and are ready to be used in the species distribution modeling phase of GAP.

The newly released Atlas of New Jersey Butterflies (Iftner and Wright 1996) was obtained and will be used in developing distribution maps for butterflies in New Jersey.

GAP biologists participated in the first year of the North American Amphibian Monitoring Program. These data will likely be used in validating models for frogs and toads. There are also data from a calling frog and toad survey in Maryland, conducted by using the Breeding Bird Survey methodology, which could be used much like the BBS data.

The Natural Heritage Programs in Delaware and New Jersey continue to provide biannual updates of the Biological and Conservation Databases to GAP for use in mapping the distributions of rare, threatened, and endangered species. The Delaware NHP has been a key cooperator thus far, and the New Jersey NHP will likely take on an official cooperator role this year.

Progress continues toward completion of the habitat requirement models for all of the vertebrate and butterfly species to be modeled.

Investigators are in the process of developing a preliminary species-habitat association matrix to be used in initial modeling of bird species distributions in Delaware. The purpose of this effort is to test various GIS modeling approaches and to provide preliminary maps to county planners who are in the process of developing comprehensive land use plans. Breeding Bird Atlas GIS coverages developed by GAP investigators will later be compared to distributions that are based on the standard modeling approach, which uses the hexagon-based distributional limits map.

Mid-Atlantic GAP (MidA-GAP) has participated in two regional coordination meetings to establish a better working relationship, plan for edge-matching, and work on proposals for funding regional assessments using the GAP products. This has vastly increased the project staff's ability to coordinate aerial videography equipment, share insights on methods, and pursue related research together. Additionally, MidA-GAP is developing a pilot project with NASA and the U.S. Navy to apply GAP land cover mapping methods to more finely resolved base imagery.

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Massachusetts, Connecticut, and Rhode Island

A primary focus of the Southern New England Gap Analysis Project has been development of a systematic approach for mapping deciduous forests.

The region is extensively forested with a wide variety of forest types. Due to land use history, forest stands are relatively small and not generally closely associated with elevation or moisture gradients. These regional vegetation characteristics posed new challenges for developing an efficient and reliable methodology for developing base vegetation maps in New England and much of the eastern deciduous forested region of the U.S.

Our approach was to use hyperclustered, multitemporal Landsat TM imagery in combination with aerial videography. The MRLC program provided a 12-band hyperclustered image that combined spring and summer coverages. Ground reference of vegetative cover was obtained from a grid of large-scale, GPS-logged videography flown over the region. 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. Vegetation communities were identified to the alliance level (Anderson level IV), and 30 distinct classes were identified. Through an iterative process, inference rules were developed and the image 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%.

With the completion of the vegetation map for southern New England, our attention focused on applying the range distribution maps and species-habitat models for the 284 vertebrates species for which habitats were modeled. Standardized EPA-EMAP hexagon range maps for each of the species, provided by the VT Gap Analysis Project, were modified through expert review, and ranges were established for modeling vertebrate species in southern New England. Predicted species distribution maps are nearly complete for all vertebrate species being modeled. Additionally, the conservation lands overlay has been developed for the region, and conservation status labels are being verified. All rare species locations from state Natural Heritage Programs are being generalized to the EPA-EMAP hexagon grid. The gap analysis has been initiated for several groups of taxa, and project completion is scheduled for early 1998.

The Massachusetts Gap Analysis team also continues to be involved with international initiatives in biodiversity inventory, cooperating with projects in Romania, Madagascar, Mexico, Guatemala, Brazil, and Peru. In cooperation with Conservation International, most of the national parks in

Madagascar have been inventoried using high-altitude 35-mm digital cameras in combination with low-altitude georeferenced videography. Similar efforts are being conducted in a number of biosphere reserves and national parks in Central and South America. The goal of these projects is to develop base vegetation maps to provide a tool for monitoring and change detection. Our goals focus on the rapid development of in-country GIS capabilities, making critical data available for resource management decisions, and institutional strengthening within these host countries. The Gap Analysis approach is rapidly being integrated in conservation management programs around the world.

At the regional level, our Southern New England Gap Analysis data sets are being used in the planning efforts for the Silvio Conte National Fish and Wildlife Refuge, a new, multistate, watershed-based effort in New England. Gap Analysis data sets are also being used in workshops to train land use planners in biodiversity conservation in the Connecticut River Valley of western Massachusetts.

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Michigan, Minnesota, and Wisconsin
(Upper Midwest Gap Analysis Project)

Classification of the northern half of Michigan's Lower Peninsula is expected to be completed by July 1998. National Wetland Inventory (NWI) data, used in the image processing protocol, is currently being digitized in the southern half of the Lower Peninsula. Digitization of NWI in the eastern half of the Upper Peninsula began in October 1997. The conversion of public ownership data from a large mainframe database to a GIS is under way. TNC lands have been mapped for the stewardship data layer. We are still waiting for digital coverages of USFS and USFWS lands and national parks. Vertebrate data is being evaluated. Breeding Bird Survey data at 1/4 township scale and the recently revised "Michigan Mammals" are being used.

In Minnesota, current land cover mapping is continuing with recent acceleration of the pace due to increased state DNR contribution - two new image processing analysts were recently hired. Stewardship mapping should be completed this calendar year. Vertebrate modeling for MI, MN, and WI was initiated by the Environmental Management Technical Center (EMTC).

Land cover mapping for Wisconsin is almost completed, including accuracy assessment. ARC/INFO coverages are being transferred to EMTC for distribution over the Internet. Stewardship is completed at a nominal 1:100,000 scale, though there is state interest in greater resolution.

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Mississippi

Mississippi GAP (MS-GAP) is now in full gear. Although funding was initiated in June, assembling of employees had already started in January. The first meeting of cooperators took place in April and had 30 organizations represented. Currently, MS-GAP has verbal cooperation in the form of data, manpower, or money from over 75 organizations, including private timber corporations.

Vegetation mapping has been progressing fairly smoothly. We currently have 2-3 TM scene dates for the entire state (circa 1992). We plan to work on these data to completion and utilize the new 1997-1998 TM data for development of a second land cover map. It has been determined that the best procedure for vegetation mapping in Mississippi will be partitioning the state into major physiographic regions, using a combination of manual and automatic classification for each region. We are using visual identification to mask harvest/regeneration areas prior to running clustering algorithms to circumvent what appears to be the largest source of classification error: confusion of harvest/regeneration and unimproved pasture. We have elected to purchase color infrared stereo aerial photography for 5% of the state. This imagery, along with field-collected vegetation samples, will be used to refine the clustering algorithms in order to get as close as possible to the alliance level.

Vertebrate range maps have been developed for 388 avian, 84 reptilian, and 62 amphibian species. Bird range maps include summer and winter ranges. Museum records from around the country, as well as local expertise, have been used in the development of range maps. Habitat matrices and models for these species are currently being assembled. Mammal range maps will be developed in fall 1997.

The Mississippi Ornithological Atlas has been placed under the MS-GAP umbrella and is starting its first field season in summer 1997. The atlas will examine the distribution of both breeding and wintering birds in the state. Approximately 30 volunteers have been assembled to test procedures and protocols in summer 1997 and winter 1997/98.

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Missouri

Missouri GAP is finally coming down the home stretch!

Land Cover

The Missouri Resource Assessment Partnership (MoRAP) is generating the land cover map for the Missouri GAP project. We have divided the state into groups of 6 to 9 counties and have buffered these groups to create tiles within which the land cover map will be delivered. This enables us to compare the modeling of the vertebrate species between tiles (utilizing the overlap area) and assess the process of land cover generalization for the purposes of QA/QC. The vegetation classification via TM image analysis has been taken to the subclass or group level of the NVCS. Some land cover classes will be at the formation or alliance levels. Further definition of formation or alliance associations will be done through the use of ancillary data (i.e., NWI, landscape, floodplains, etc.). The GRC is planning on creating 2-ha, 5-ha, 20-ha, 40-ha, and 100-ha versions of the land cover map.

Animal Modeling

The GRC now has received all the information we will use in this first-pass version of the Missouri GAP analysis. Range maps and point distributions for reptiles, amphibians, birds, and mammals have been compiled and tiled to USGS 7.5 minute quadrangles. Museum records have been obtained for birds and mammals as a means of spot-checking these species groups. We have also examined the national perspective on the avian species that occur in Missouri to provide a perspective on Missouri's role nationally for those species. The Missouri Department of Conservation was very important to our success with the Breeding Bird Atlas information.

The modeling criteria are drafted, and procedures tested for implementation. Criteria for modeling are established. In addition to the land-cover-derived data layers to be used in the habitat associations, we are also looking to use many abiotic, land form, and ancillary data sets within the vertebrate modeling framework. We have also implemented a home-range-driven landscape perspective/species view of its environment.

Stewardship

The GRC and MoRAP have compiled a stewardship layer for use in GAP analysis. Units for which information were obtained include National Forest, National Park Service, U.S. Fish and Wildlife Service, Army Corps of Engineers, Missouri Department of Conservation, Missouri Department of Natural Resources, The Nature Conservancy, University, County/City, Army/Air Force bases, and the National Guard. Management status has been assigned to the majority of these tracts.

Analysis

The GRC is compiling a risk database to be used in conjunction with these data to conduct the analysis at the state level. A risk surface(s) is/are being created for the state addressing population, social, economic, and land use change information that could be used by decision makers as an aid in evaluating the GAP information in the context of development and policy change.

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Montana

Montana Gap Analysis began in 1991 and is slated for completion in mid-1998. A land cover map of western Montana at 2 ha MMU was completed in March 1996; since that time, we have made minor updates to improve mapping of cover types like burns, mines, and urban areas. Meanwhile, work has focused on eastern Montana where we have 19 TM scenes to be processed. The first stage of our process, an unsupervised classification/merge to delineate polygon boundaries, has been completed for all scenes. Ground-truth data are being compiled from a number of sources, including the BIA, BLM, NRCS, USFS, USFWS, and MT-FWP, to be used in the second stage (assigning cover-type labels to polygons), which was finished in fall 1997. Next we will create a statewide land cover layer, recode cover types to simplify the classification scheme, and merge to 100 ha MMU, maintaining smaller mapping units where merited, as with riparian vegetation. Map accuracy will be assessed using a method that allows users to evaluate spatial differences in accuracy levels (currently under development).

Once the land cover layer is done, we will immediately begin producing species distribution maps. We started with a list of 565 terrestrial vertebrates and whittled this down to about 410 species for which distributions will be constructed. Of these, habitat relationships have been documented for about two-thirds. Habitat databases are being built using FileMaker Pro software, which has proven very effective. Please contact us if you would like more information.

To map known ranges, the Montana Natural Heritage Program populated EMAP hexagons for amphibians, reptiles, and mammals under subcontract to MT-GAP. For birds, we are using latilong-based distribution maps published by the Montana Bird Distribution Committee (1996) instead of hexagons. Although latilongs are roughly 12 times larger than hexagons, the cost of populating hexes for birds made this existing data source more palatable. Our greatest challenge in constructing species distributions may be the review phase, largely because of the short window between the completion of our land cover layer (and thus the beginning of our wildlife modeling) and the delivery date of our contract. To expedite the process, we hope to make our models and maps available to reviewers via the Web.

The land stewardship layer is virtually complete and has been released for review. We used 100K ownership tiles prepared by the BLM as our starting point. Tiles were appended, edited, and extensively updated to include management-related features, then scored according to the 4-level protection scheme. To date, we have used the stewardship layer to calculate preliminary statistics on ownership and protection of western Montana's cover types.

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Nebraska

The Nebraska Gap Analysis Project (NE-GAP) has been funded for two years. Two dates of TM imagery have been acquired for each of the 18 scenes for the state. A mosaic poster has been created from the TM data and has been widely used within Nebraska to foster collaboration and improve public relations. We currently have cooperative agreements with about 15 agencies and organizations across Nebraska and at least 17 individual cooperators who have agreed to collect some field data or provide land cover map review for their area of the state. A Nebraska Gap Analysis home page has been developed (http://www.calmit.unl.edu/gap); many parts of the page are still under construction.

Land cover

Following protocol development and testing in several counties, image processing to develop the land cover layer is progressing in western Nebraska. Path/row locations in western Nebraska have been mosaicked together so that classification is being conducted on large regions of the state. Currently, data are being merged and classified for portions of central and eastern Nebraska. Extensive field data were collected in summer 1997 for use in cluster identification and labeling. We continue to seek and acquire ancillary data sets that will assist in image processing and land cover mapping, such as NRI data from USDA-NRCS. A preliminary legend has been developed in accordance with the FGDC standard vegetation alliances that exist in Nebraska. Communication has been initiated with projects in South Dakota, Wyoming, Kansas, Missouri, and Iowa to facilitate data sharing, polygon edge-matching, and/or legend compatibility.

Animal Modeling

Collection records of terrestrial vertebrates, 1980 to present, held by the University of Nebraska State Museum, have been identified and converted to digital form. Recent records for Nebraska have been sought from numerous other museums nationwide and are being incorporated. Vertebrate characterization abstracts, bibliographic information, and occurrence information have been received from the Nebraska Natural Heritage Program for all Nebraska species. Other sources of vertebrate species information are being sought, and a bibliography is being built.

Land Stewardship

Work on the land stewardship layer continues. We are working collaboratively with the Nebraska Game and Parks Commission as they build their managed lands database. Recently, we obtained the USFWS digital coverage of wildlife refuge lands in Nebraska. Additional sources of ownership and management information continue to be sought. Contact has been made with BLM in Wyoming, BIA in South Dakota, and TNC in Minnesota to obtain additional land ownership information for Nebraska. Much of this information is not in digital form and will need to be digitized or converted from legal descriptions.

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Nevada

The NV-GAP Project was conducted by the UT-GAP researchers at Utah State University. This year, they released the data sets and will be producing a CD-ROM product available early 1998. Meanwhile, the Biological Resources Research Center (BRRC) at University of Nevada-Reno has committed to conducting the project update in cooperation with the Southwest ReGAP project. The BRRC is home of the Nevada Biodiversity Institute and is very well placed scientifically and cooperatively to conduct the work. Their staff attended the 1997 annual GAP meeting and is enthusiastic about the project. We welcome them into the Gap Analysis Program!

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New Hampshire

(see Vermont and New Hampshire)

New Jersey

(see Maryland, Delaware, and New Jersey)

New Mexico

The New Mexico Gap Analysis Project (NM-GAP) was completed at the end of 1996, about 54 months after it started. Distribution copies of the final report and all data on tape were sent to National GAP in January 1997. NM-GAP lived through a major evolution in gap analysis during our more than 4-year tenure. We were not able to meet every current expectation but did many things beyond what was anticipated back at our start in 1992. While it was difficult at times, the NM gappers are pleased to have played a role in developing some of the protocol and prototype along the way.

Finishing the basic project requirements gives a feeling of relief, but all does not stop there. In April 1997, the New Mexico Resource Geographic Information System in Albuquerque, under agreement with NM-GAP, completed a prototype of all NM-GAP data and the report on a 2-CD set for distribution to those requesting the data. Sets of those CDs were provided to the 14 major agency and university cooperators that had participated throughout NM-GAP. National GAP is currently working to put NM-GAP data on the GAP home page and on CD-ROM in a format consistent with national desires for broad dissemination for public use. In intervening days, there have been numerous requests to clarify data sets and to explore ways to apply GAP data. There is excitement in that but also difficulty in responding to something for which there is no longer an active project.

In summer 1997, we initiated a small new GAP-related project to assist surrounding projects with exchanging and interpreting edge-match data, perform some more detailed analyses on existing coverages and databases, and to aid extension of NM-GAP data to conservation planners statewide. Some activities already in planning stages or under way are to use NM-GAP data for biotic mapping comparisons in northern NM mountain ranges, information coverages for county open space evaluation, and incorporation as criteria in land parcel evaluation by NM Department of Game and Fish for conservation planning and acquisition. NM-GAP looks to the future phase of data application. Exciting times.

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New York

During 1996/97, the major focus of the New York Gap Analysis Project (NY-GAP) continued to be upon developing and validating an up-to-date land cover map for New York State, using multitemporal Thematic Mapper imagery. We met with plant ecologists of the New York Natural Heritage Program to discuss our procedures and plans for combining some community associations into alliances and superalliances, following the National Vegetation Classification System. Identifying alliances within the mix of northeastern deciduous forest types in the fragmented landscape of New York State remains challenging, but we continue to make progress. Very productive collaborative and cooperative efforts continue with the NY Natural Heritage Program and our New York State Department of Environmental Conservation (NYSDEC).

Other highlights of our work during 1996/97 include establishment of a Memorandum of Understanding (MOU) with the Northeast Forest Experiment Station of the U.S. Forest Service to work collaboratively with forest inventory plot data. This MOU provides a mechanism for access to data from approximately 3000 randomly located forest plots across NY that are surveyed periodically by USFS. This information will be useful in helping us to identify and validate forest alliances for vegetation mapping.

An additional 73,028 records of occurrence were added to our coverage for the mammals of NY. Our mammals database now includes 98,833 records, spanning the period from 1834 through the present, with 68,590 records of occurrence since 1965. This is the first time such an extensive, comprehensive, and spatially referenced database has been developed for the mammals of NY. With cooperation from NYSDEC, an additional 15,926 records of occurrence were added to our amphibians and reptiles coverage, bringing the total records in that database to 20,334. This information results from an ongoing herpetological atlas coordinated by NYSDEC, begun in 1990 and scheduled to be completed by the year 2000.

A contract was established with NYSDEC to provide funding for more detailed mapping of land cover for the Hudson Valley corridor, between Albany and New York City. A gap analysis of this region will be performed to provide information to facilitate conservation planning and decision making for this fast-growing region of NY, with an objective of maintaining or enhancing biodiversity for the region.

Plans were initiated for the second NY Breeding Bird Atlas, scheduled to begin in 1999. This project will be fully integrated with our NY Gap Analysis and will provide up-to-date information about the breeding birds of the state and an updated breeding bird coverage for future GAP efforts. The project is expected to require 5-6 field seasons and be completed by 2004. The first NY Breeding Bird Atlas was conducted from 1979 through 1984 and published in 1988. Completion of NY-GAP is anticipated near the end of 1998.

Publications

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Wairimu, S. 1996. Spatial analysis of white-tailed deer wintering habitat in central New York. Ph.D. Thesis, Cornell University, Ithaca, NY. 238 pp.

Weber, J.T. 1997. Development and use of a landscape-scale habitat quality index and a conceptual model for measurement of red fox density. M.S. Thesis, Cornell University, Ithaca, NY. 143 pp.

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North Carolina

The current focus of the North Carolina Gap Analysis Project (NC-GAP) is the development of the land cover map. We are nesting our map into the land cover classification being done by the Multi-Resolution Land Characterization Consortium (MRLC). We are using the nonvegetated 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 of vegetation in 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 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 data sets (i.e., National Wetlands Inventory and Natural Resources Conservation Services's Detailed County Soil Maps). We are in the process of summarizing the results of the preliminary mapping efforts following the National Vegetation Classification System. We will also be reviewing their potential for use in ongoing conservation planning in the region.

In addition to 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 data layer we are developing will be an important contribution to this effort. We are in the process of developing a 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 under way.

This year we will continue 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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North Dakota

Funding for ND-GAP will start in FY98, and the project is getting under way.

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Ohio

Funding for OH-GAP will start in FY98, and the project is getting under way.

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Oklahoma

It has been a productive year for the Oklahoma Gap Analysis Project (OK-GAP). Dr. Xiandong Meng from the University of Maine joined the OK-GAP team and is working on the land cover layer with Mark Gregory and Holly Hovis, a botany graduate student at Oklahoma State University. Dr. Mark Lomolino, Ian Butler, Dan Hough, and zoology graduate student Dave Perault of the Oklahoma Biological Survey and University of Oklahoma have continued to make significant progress on the vertebrate animal distribution and land stewardship layers. At present, we seem to be on target for project completion by the end of 1998.

Thematic Mapper (TM) scenes for southern Oklahoma have been classified using Spectrum software and videography data. Our protocol is to classify video images along flight lines through each TM scene and use these data to perform a preliminary classification of the scene. Random and problematic points classified on the scenes are being verified by a field team. In addition, we are also organizing a group of cooperators to classify vegetation throughout the state for use in assessing the accuracy of the vegetation map.

Geographic range maps of all 427 vertebrate species have been mapped, verified, and digitized. Habitat associations have been encoded for all species, and locational databases have been compiled. Vertebrate-vegetation association models have been developed for all species and are being tested using a previous vegetative land cover map of Oklahoma.

The land stewardship map has been completed. Work continues on verifying the stewardship status for each tract of land that is under some management regime.

Cooperators continue to play an important role in OK-GAP. Experts from around the state have been enlisted to verify maps from all three layers. We look to involve them further in the coming months as we begin to generate additional map products.

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Oregon

Oregon was a pilot Gap Analysis Project and completed its first-generation land cover map in November 1992. In 1994, an upgrade of the vegetation map, based on Landsat TM imagery and using current GAP methods, was begun by the Oregon Department of Fish and Wildlife. This upgrade will be completed in 1998. The 1992 map and its manual are now available on the Gap Analysis World Wide Web home page. During the past year, the Oregon land stewardship data layer has also been upgraded through the efforts of several cooperators (U.S. Forest Service; Oregon Biodiversity Project, Defenders of Wildlife; and Oregon Natural Heritage Program).

A major project of Oregon GAP during 1996-1997, in cooperation with the Biodiversity Research Consortium (BRC) and the Oregon Department of Fish and Wildlife, has been the completion of a state wildlife atlas. This atlas combines standard Gap Analysis vertebrate species distribution maps with line drawings and accompanying text describing taxonomy, global range, habitat, reproductive biology, food habits, general ecology, and selected references for each species in a one-page format. All species maps were subjected to an additional round of expert review for this publication, adding an extra layer of quality control to our predicted species distributions. The breeding range of each species is shown in the main body of the book, and an appendix contains simplified winter bird distribution maps. The 492-page Atlas of Oregon Wildlife is a hard-cover book published in July 1997 by Oregon State University Press. The book sells for $39.95 through commercial outlets; however, a 20% discount is available for government agencies.

The last year also saw publication of a paper using the Oregon BRC/GAP vertebrate distribution data set to examine the properties of various types of site selection algorithms (Biological Conservation 80:83-97). This work was carried out as a collaborative effort of laboratories in Australia (New South Wales National Parks and Wildlife Service), the United Kingdom (Natural History Museum and Institute of Zoology, London), and the U.S. (University of Cincinnati and Oregon State University). Nineteen different algorithms, falling into five broad categories, were compared. This paper complements earlier work carried out by our co-authors, Robert L. Pressey in Australia, and Paul H. Williams and Melanie Kershaw in the United Kingdom. Because the vertebrate data were still undergoing review, we caution that the spatial solutions presented do not represent our selection of priority areas for conservation. However, a follow-up analysis, sponsored by the BRC, is under way with reviewed data that should allow us to identify potential sets of complementary areas in Oregon in which we predict most or all unprotected vertebrates would be represented. This analysis will follow the model published by A. Ross Kiester and others in Conservation Biology (10:1332-1342, 1996). The Oregon Natural Heritage Program has assumed responsibilities for completion of the OR-GAP update. Final reporting is anticipated in early 1999 and will be followed by aggressive outreach and extension efforts.

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Pennsylvania

Pennsylvania's Gap Analysis Project is moving along unconventional paths toward the common goals of GAP, and uncovering some novel things *en route*. We are tying down our land cover map, which is one aspect of GAP that has been approached in fairly conventional fashion. Some of the smaller and more difficult pieces are still being addressed, and the metadata work is also continuing.

Unlike many other states, we have clung tenaciously to the idea of basing as much of our other mapping work as possible on thematic mapper data. Coupling Gap Analysis with a more theoretically oriented project on "multiscale statistical approaches to critical areas in watersheds and landscapes" (jointly funded by NSF and EPA) has enabled us to rethink ways of handling such image data. We have used the Spectrum idea (but not Spectrum itself) as a springboard for developing new scenarios of compressed image analysis and portrayal. We hypercluster differently and treat the result as a hybrid dataform between a multispectral image and a grid coverage. Our raster consists of a single "layer" of (byte) cluster IDs linked to relational tables of multispectral properties. This gives us a nonproprietary image-based dataform that accommodates substantial analysis in the table domain while being compatible with ArcView and mappable on an HP DesignJet with ArcPress.

With sponsorship by Digital Equipment Corporation and cooperation of other spatial data centers at Penn State, we are putting ten compressed images covering Pennsylvania along with vector coverages of roads, streams, major watersheds, floodplains, physiographic provinces and counties on a single CD-ROM for integration with ArcView or simple imaging via an onboard viewer for PCs. This provides reasonably comprehensive landscape-level viewing of Pennsylvania from a single source. Our renderings of the compressed images have been very well received.

The above gives rise to a new version of land cover mapping. We label hyperclusters in eight vegetative cover stages by a kind of supervised classification of centroids which does not require that individual pixels be processed. "Training clusters" are chosen from an image display, and suitability of thematic assignments is likewise assessed interactively. The development aspect of land use is captured by on-screen digitizing and analytically combined with the vegetative cover raster to give a four-class vector overlay showing high intensity developed, low intensity developed, rural nonforest, and rural forest. A further breakdown of vegetation with regard to forest types is on tap for summer 1997. Our mode of accuracy checking is through aerial videography.

The aforegoing products have considerable spatial detail, from whence comes our final challenge of how to conduct a reasonable map generalization to the level that vectorization becomes feasible. Here again, our other project kicks in with its "multiscale" component.

Our habitat models for birds, mammals, and herps are well along. We do, however, continue to struggle with how (and how much of) the surrounding landscape should be linked with watercourses and waterbodies with respect to generalized models for fish. We are really seeking a landscape perspective on fish rather than a detailed channel analysis of stream reaches. A substantial database of fish collection records is available, but this does not resolve the landscape linkage problem. Is there a happy medium between painting entire watersheds or just coloring streamlines? Insightful suggestions would be appreciated.

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Rhode Island

(see Massachusetts, Connecticut, and Rhode Island)

South Carolina

The South Carolina GAP Project officially began in May 1997 when our research work order was approved and finalized. We have hired a remote sensing specialist to work with the SC Department of Natural Resources to develop our land cover layer and are currently interviewing candidates for a postdoctoral GAP Coordinator position. One graduate student started at Clemson University in the fall to work on issues surrounding the development of the vertebrate species layer. We also are beginning to develop communication and working relationships with the NC-GAP Project and those that will be involved in the Georgia GAP Project.

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South Dakota

Cooperative efforts have been established between South Dakota State University and state, federal, and private organizations to conduct South Dakota GAP (SD-GAP). The USGS EROS Data Center has provided SD-GAP with a work station, satellite imagery, and expertise in image processing to construct our vegetation map from a total of 34 satellite scenes (two dates per scene). We obtained the UNESCO Vegetation Classification System from The Nature Conservancy and determined vegetation associations likely to occur in South Dakota. Land cover data sets for various areas in the state were acquired from the USDA Forest Service, South Dakota

Department of Game, Fish, and Parks, South Dakota Farm Service Agency, and Ducks Unlimited to aid in interpreting satellite images. Three scenes have been georectified, classified as perennial vegetation or agriculture, and National Wetland Inventory data overlaid on scenes to isolate natural vegetation for classification to the alliance level.

We obtained vertebrate distribution data from South Dakota Department of Game, Fish, and Parks. A Ph.D./M.S. candidate has been selected to develop vertebrate distribution models. Coverages containing State Game Production Areas, Waterfowl Production Areas (eastern South Dakota), and U.S. Fish and Wildlife easements were created as part of the stewardship layer for SD-GAP. A database containing fish distribution records and associated stream habitat characteristics and a stream system coverage obtained from EROS Data Center will be used to develop SD Aquatic GAP.

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Tennessee

Land Cover Classification and Mapping

The statewide coverage of the Anderson Level II land use/land cover for Tennessee is complete. Classification of the forest classes is also complete for the entire state. Computer-generated accuracy assessment of the detailed vegetation layer and the application of the aggregation algorithm will be performed in January 1998.

Predicted Animal Distributions

Distributions for the state’s terrestrial vertebrate species have been mapped by county and physiographic province and translated to the EPA hexagonal grid. Habitats for vertebrate species have been associated with the land cover classification. Review and accuracy assessment of vertebrate distributions are not complete.

Land Stewardship

This data layer is completed and includes the addition of newly acquired lands with assigned land management status. Analysis of gaps based on public land stewardship and land management status overlaid with species richness is pending completion of previously listed phases.

Metadata and Final Report

Using the GAP-approved Metamaker software, final metadata development for land cover is 50% complete. Metadata for vertebrate species distributions is 15% complete. Metadata for the land stewardship data layer has not been developed yet. Approximately 20% of the final report has been written in draft format using the template provided by National GAP. Anticipated project completion date is spring 1998.

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Texas

During the last year, the Texas Gap Analysis Project (TX-GAP) has suffered unexpected changes in personnel and problems with deliverables from cooperators (e.g., georeferenced aerial videography) which have altered our original schedule and required modifications to our methodological approach. Due to the time required for training and reorganization, changes in personnel have most affected the project. Nick Parker, the principal investigator for TX-GAP, has been forced by the departure of Raymond Sims (Project Coordinator) to assume a more active role in daily operations. We have a complete new team working for TX-GAP and are now moving forward in partnership with a program at the Museum at Texas Tech University.

The National Science Research Laboratory of the Museum (directed by Dr. Robert J. Baker), provides data and many of the ancillary records used in the vertebrate modeling program at TX-GAP and the Rio Grande Gap Analysis Project (RG-GAP) in Mexico. The state funding for the Museum has been provided to develop a natural resources database to complement the wildlife database being developed by the Texas Parks and Wildlife Department.

Land cover mapping is now being developed based on intensive field surveys of vegetation (ground-control points) and the direct interpretation of preprocessed Multi-Resolution Land Characteristics Consortium imagery (hyperclustered Landsat Thematic Mapper scenes). Digital classification of the hyperclustered TM scenes is performed using Spectrum (Khoral Research, Inc.). For more details on TX-GAP methodologies, see the corresponding section in this bulletin. At present, we are working in the Panhandle and Trans-

Pecos regions of West Texas and expect to produce preliminary vegetation maps for West Texas by the end of this year. Together with the participation of several East Texas cooperators, we will begin land cover analysis for East Texas next year.

In order to provide experts with an easy tool for building habitat profiles, to allow for data continuity, and to automate the modeling process, TX-GAP developed a Habitat Profile Database Application using Microsoft Access. This application prompts the user to answer "yes," "no," or "unknown" when asked if an animal is associated with a particular habitat characteristic. The habitat characteristics are presented in a hierarchical list (e.g., The Nature Conservancy vegetation classification scheme) thus allowing the user to define the habitat profile at any level within the hierarchy. The user is also prompted to list the references used to support the data and is given several opportunities to include detailed comments throughout the application. Although we have just begun to receive data, it appears that the application is working well and serving the goal of assimilating habitat affinities for Texas vertebrates. The true test of the application will come when we begin the modeling process later this year.

We are currently in the process of building our land stewardship coverage. To date, we have obtained digital data on both federal and state lands and are evaluating the completeness of these data.

An initiative from the USGS-BRD's Environmental and Contaminants Research Center (former Midwest Science Center) and the Texas Cooperative Fish and Wildlife Research Unit at Texas Tech University has been funded to implement RG-GAP in Mexico. For further details, see the corresponding section in this Bulletin. Contacts with local Mexican research institutions have been established to define the strategy for the vegetation survey in Mexico, and we are now expecting the official approval notification to start with field work.

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Utah

As most of you know, in spring 1994 the UT-GAP project was the first "standard" GAP project to be completed. Since that time, they have gone on to produce several interactive and educational CD-ROM products (contact Becky Sorbel at National GAP if you would like to receive a copy). The original UT-GAP researchers have signed on for an update of the project in cooperation with the five-state Southwest ReGAP project. They are also working through their very well developed state and federal agency relationships to conduct the project as a multiagency cooperative effort.

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Vermont and New Hampshire

We continue to coordinate our land cover mapping with similar efforts in the other Northeast states. The goal is to complement rather than duplicate other efforts and assure that we have an accurate map that will match well with those from surrounding GAP projects. We have collected and interpreted extensive aerial videography data and are using these for supervised classification of TM imagery and for accuracy assessment. Our recent emphasis has been on a high resolution map with only six land cover types. Focal analyses of the raster coverage of this map have produced contour maps of landscape metrics that are especially suitable for modeling the distribution of vertebrates that respond to landscape-level measures. For instance, we found that harvest data for black bears correlate well with focal measures of core forest and road density.

We are assessing the use of biophysical regions (Subsections in the Bailey scheme of ecoregions) for the mapping of vertebrates, instead of counties, towns, or hexagons. Although we plan to submit a final report with hexagons as the basic units of analysis, we believe that biophysical regions provide a logical unit for predicting the distribution of species where there is uncertainty, then translating to the hexagon tessellation.

The Gap Analysis Project in Vermont and New Hampshire has finally become an important part of other efforts to assess biodiversity in these two states. New Hampshire has established a committee for ecological reserve design, and much of our GAP data and mapping expertise is being incorporated into that project. The Vermont Biodiversity Project is a similar project that has the objective of mapping potential conservation areas that will assure the protection of biological diversity. Coordinated by the Vermont Chapter of The

Nature Conservancy, this effort involves a long list of state, federal, private, and university cooperators. Funds for the project are being sought mostly from private foundations.

Land stewardship mapping has taken on a new dimension. Although Vermont and New Hampshire are small states, and we have reported previously that we were “nearly finished” with this task, we have now identified more than 3,000 parcels of land that should be part of our database of protected areas. Fortunately, several of our cooperators have recognized the utility of this effort and have contributed funds. We may have been “98% complete” with this task two years ago, but today we find that we are only 60% complete.

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Virginia

The land cover mapping of VA-GAP is two-thirds complete. A basic Anderson et al. (1979) level 1+/- map has been completed and will be distributed to cooperators soon, along with aggregated wetlands and urban layers. An accuracy assessment, using almost 2400 videography points, has been performed. Videography data taken in fall of 1995 and spring of 1996 were used in this process. Additional videography flights recorded during fall of 1996 (along with the previous flights) are currently being interpreted to aid in creating and assessing the next map iterations. Drafts of the second iteration have been delineated for the western part of the Commonwealth. This second stage relies more on ecological modeling than spectral data. Topographical and climatological forest-type profiles have been identified using available literature, the US Forest Service’s FIA data set, expert review, and several digital land cover maplets. The third and final mapping stage will involve additional Landsat TM imagery. These scenes have recently arrived and are being processed. We now have a nearly complete set of leaf-off and leaf-on imagery.

A working hierarchical land cover classification for Virginia has been outlined and reviewed. This system incorporates the NVCS along with intermediate land cover classes that work well in Virginia. A crosswalk to other classification systems will be completed once our mapping efforts are reasonably finished. Our final land cover map should be completed in early 1998.

The land stewardship layer has been updated. Mapping of state-owned lands is complete. A map of the boundaries of several federal lands is expected to arrive shortly. The two maps will be merged as soon as all of the data are available. A biodiversity management ranking system will be discussed shortly.

The review and update of species information for use in the development of potential distribution maps for the terrestrial vertebrate species is continuing. Virginia Department of Game and Inland Fisheries (VDGIF) staff have completed work on the reptile and amphibian species (approximately 150, including subspecies) and have completed assessments for over half of the breeding birds. The relatively sparse information on Virginia mammals has challenged the reviewers, but cooperation and information/data from two prominent mammalogists (Dr. Charles Handley and Dr. John Pagels) have proved extremely valuable to overcoming this hurdle. VDGIF personnel are continuing to contact other researchers and institutions for additional mammal data.

The WildlifeMapping project in Virginia is off to a great start. Two workshops have been held so far and six more are planned for the fall. We are also in the process of developing our data entry software and our Internet web page. A video about the program highlighting Virginia habitats and species is in the works as well. All those who have heard about the program are excited about its potential in the Commonwealth.

VA-GAP has worked closely with regional biodiversity and land cover mapping efforts. We currently maintain a listserver for Mid-Atlantic GAP projects, which has aided in developing regional videography missions, research proposals, and accuracy assessment methodology. Virginia is proud to have hosted the 1997 GAP Principal Investigators' Conference in Reston.

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Washington

(see Final Report Summary: Washington Gap Analysis Project, page)

West Virginia

Efforts are proceeding in all areas of the project. The stewardship mapping, wildlife habitat model development, and wildlife habitat extent components of the project are essentially complete. Wildlife habitat mapping has been completed for a number of herptiles. Alliance mapping is also continuing. We continue to add cooperators—both nongovernmental organizations (NGOs) and local and state agencies.

For assigning stewardship classes, we have used the dichotomous key from New Mexico GAP. A number of land managers and planners from federal and state agencies have assisted in this effort. We have also prepared a questionnaire to identify each agency's perceptions of their stewardship and management levels. These data have been provided to a number of agencies and NGOs as they represent the first digital accumulation of conservation or natural resource management areas data for West Virginia. Several agencies (in particular the West Virginia Division of Natural Resources) have provided tremendous assistance in this effort.

Wildlife habitat models have all been at least initially developed and continue to undergo review as we identify new cooperating biologists and field naturalists. As the models come from a variety of data sources, we are currently cross-walking the final models to our working list of alliances. The major field scientists that should be participating in the project have been identified and have been at least presented with the opportunity to participate in the development and refinement of the models.

Wildlife range extents have also been completed and are being revised as needed using a thorough outside review of our data. The initial EPA/TNC hexagon-based extent data have been greatly expanded upon and are now much more complete. We have also incorporated a more complete literature and expert source bibliography into our initial work. The TNC work omitted a number of key species, and we have incorporated additional species into the database. During the next quarter, we plan to work with adjacent states on edge-matching the hexagon data.

Distribution mapping continues for the herptiles. These models are based primarily on wetland and hydrologic features and general cover types and not the detailed alliance polygons. A herptile map atlas has been prepared and is out for review by a number of our key scientific cooperators. Other wildlife mapping efforts will proceed once detailed alliance-level mapping has been completed.

Vegetation alliance/cover mapping is proceeding using a methodology that we describe as spatial sorting. Based on ecological unit and not on TM scene, it relies on existing landscape knowledge in conjunction with videography sampling (using an approximation of the methodology developed by Massachusetts), existing plot data, FIA data (USDA Forest Service), and limited new plot sampling and data analysis. We are labeling spectral clusters (from ISODATA routines) using the above data sources. We have also registered our imagery with the various MRLC products that have been produced with the idea that the MRLC products are multistate and as such may present a suitable framework for state-to-state edge-matching. However, this strategy may not prove to be as fruitful as we anticipated.

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Wisconsin
(see Michigan, Minnesota, and Wisconsin)

Wyoming
(see Final Report Summary: Wyoming Gap Analysis Project, page)

NOTES AND ANNOUNCEMENTS

Next Annual GAP Meeting

Make your plans now for the 1998 Annual GAP Investigators Meeting, to take place on July 20-24, 1998. The meeting will be hosted by the California GAP Project, headed by Dave Stoms and Frank Davis at the Department of Geography, University of California-Santa Barbara. The sessions will be held on the picturesque UCSB campus, beautifully located among palms and eucalyptus trees on a plateau overlooking the Pacific ocean, about 10 miles from downtown Santa Barbara. Accommodations in dormitories as well as hotel rooms will be are available.

The meeting is open to GAP investigators, their staff, project collaborators, and others interested in GAP methods and results. Please consult the following Web site for more information on the Santa Barbara area: http://www.biogeog.ucsb.edu/projects/gap/gap98. Information on the meeting will be posted to that site as it becomes available. A call for papers will be sent out in January.

A Progress Report on WY-GAP Extension

With the official completion of the Wyoming Gap Analysis Project (WY-GAP) this past February, we are now developing a coordinated approach to provide access to these valuable data via the Internet and through a coordinated extension program. This effort is known as the Wyoming Bioinformation Node or WBN. The establishment of the WBN is funded by the USGS and is part of a distributed federation of biological data and information sources, also known as the National Biological Information Infrastructure (NBII).

The WBN (http://www.sdvc.uwyo.edu/wbn) is also part of a larger spatial data clearinghouse effort being developed by the University of Wyoming's Spatial Data and Visualization Center (SDVC). Through the natural resources data clearinghouse of the SDVC, WY-GAP data has found a home. All of the spatial databases being served through the SDVC and WBN include metadata documentation in accordance with the FGDC Content Standard for Digital Geospatial Metadata for implementation under the Z39.50 service protocol which utilizes I-Site and I-Search "browse and search" software.

Another important component of the WBN is the "bioinformation extension program" which is designed to promote the use and integration of the WY-GAP databases into natural resource planning, management, and education. A portable ArcView demonstration of the WY-GAP databases is in development to showcase the utility and integration of these data with other natural resource databases. Also included in the extension program is a county-level planning support project. This pilot project will assist Teton County, Wyoming, in creating a biological decision support system (DSS) in a desktop computing environment to help promote biological considerations in traditional land use planning and management decision-making processes. The system will incorporate biological and other natural resource databases with a simple graphical user interface and custom designed tools that will not require prior knowledge of GIS or biology on the part of the planning staff. We anticipate having the biological DSS operational early next spring.

Tom Kohley
University of Wyoming, Laramie

GAP Data Distribution on CD-ROM

Two innovative CD-ROM products from Arkansas and California are being added to those developed in Utah as model data dissemination and education products. Arkansas is developing the prototype for state final report CDs that will feature hypertext plus linked graphic images of all the GAP data and interpretive analysis maps. California is working with ESRI to develop a CD with GIS functionality built in. Both products are scheduled for release in late 1997. In the meantime, interactive and educational CDs that are very popular continue to come out of Utah (see http://www.usu.edu/~cliff/UGA.html, the Utah Geographic Alliance's "Utah GAP Education Project" CD for a great example).

On the national front, the EROS Data Center has agreed to provide Internet access to the GAP data. The New Mexico GAP data will be used to develop and test the interface this winter. The National GAP office plans to produce a standard set of CDs for each completed project that will contain HTML and Adobe Acrobat versions of the report and graphic versions of all coverages (if provided by the project) on one set of CDs, and the GIS and other ancillary data on another set (perhaps with GIS query capability built in). State projects may produce any other CDs they feel appropriate and can develop with their cooperators.

We plan to provide a number of CDs for each state to deliver to cooperators. Further requests for CDs will be met by in-state distribution if a center is available, or a "press/print on demand" center linked through the GAP home page. Because the CDs will not contain any proprietary software, we anticipate being able to sell them for the cost of the media and pressing, plus a small handling fee, by the distribution centers. It is critical that states follow the data delivery protocols to facilitate easy and quick production of the CDs because we will not have a budget for data reformatting. In the coming year, we plan to issue more detailed protocols for directory structures to aid this process. If you have any questions or comments, contact Patrick Crist (gap@uidaho.edu).

Patrick Crist
National Gap Analysis Program
Moscow, Idaho

Arkansas Vegetation Map Wins 2nd Place in Contest

The Arkansas Statewide Vegetation Map received a second place in the prestigious 1996 International Intergraph Users Conference. The conference brings together some 4,000 users and developers of Intergraph systems from around the world. According to Dataquest, Intergraph is the worldwide leading producer of GIS software and hardware. Each year the conference organizers sponsor a cartographic map production contest. Winning this contest is particularly significant since

Intergraph map production software and hardware is used by the great majority of commercial map production companies, most national mapping agencies (particularly in Europe), and many universities offering cartographic degrees.

The cartographic part of the Arkansas Statewide Vegetation Map was done by Stephan Pollard, a graduate student in the University of Arkansas' Geography Department and an employee of the Center for Advanced Spatial Technologies at the University (home of AR-GAP). The map won second place in the "Best Overall Page Layout and Design" category as judged by an international panel.

The map displays the GAP vegetation which has been derived from classified TM imagery and extensive ground-truth data at a scale of 1:600,000. Thirty-seven vegetation and land cover classes are represented. In addition to the map data, Pollard also developed an innovative legend structure which visually displays the structure of the vegetation classification as well as extensive marginalia improving the usefulness and readability of the map.

W. Fredrick Limp
Center for Advanced Spatial Technologies
University of Arkansas, Fayetteville

Use of SPOT and CIR by Louisiana GAP

Typically, federal and state efforts to maintain biodiversity have relied on protecting species once they become threatened or endangered. While it is important to protect these valuable species, a better approach is to examine entire regions for native animal and plant species distributions in conjunction with current management practices of conservation lands. Gap analysis provides this regional assessment of animals and plants giving land managers information that extends beyond their jurisdictions to facilitate better management decisions. While gap analysis provides a regional view, it should not be seen as a replacement for intensive site-specific inventories and assessments.

The Louisiana GAP project is using Landsat TM imagery along with auxiliary data sets (SPOT, CIR, field survey data) to classify the 23 vegetation formations in Louisiana. Ten TM scenes were needed to provide complete coverage of the state. There are many circumstances to consider when classifying imagery, especially when dealing with such a large amount of data. We decided on using an unsupervised classification scheme using the ERDAS 7.5 software. The individual TM scenes were subsetted into 900 x 900 25-m pixel blocks, because we prefer the method of having images match our computer screens at a 1:1 ratio to facilitate class identification. Otherwise, when working with a full TM image, the off-screen portions of the image containing a vegetation class being manipulated are not visible.

In 1995, the National Biological Service's Southern Science Center acquired 1:65,000 color infrared (CIR) aerial photography for the entire state. CIR aerial photography is being used to augment visual interpretation of the TM data. Contact prints were made to aid survey team members in the field and in the office. The CIR aerial photography has been scanned and stored on CD-ROM, and these CIR images will be made available on the Web.

Field survey teams collected ground-truthing data in several areas of the state to help the image analyst classify the clustered data sets. The locations were picked to provide best coverage of the different vegetation types within the state. Dozens of points were collected throughout the survey areas, most of which were near roads due to access restrictions for private lands.

Approximately the lower third of Louisiana is covered with wetlands, and the National Wetlands Inventory (NWI) provides high-quality, detailed information for these complex

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wetlands. The data were delineated using 1988 NASA 1:62,500 CIR aerial photography which is also used in classifying the TM imagery. The NWI data sets were segmented to reflect the Louisiana GAP vegetation classification. Aerial photography and other imagery, such as merged TM/SPOT data, will be used along with ground point data for accuracy assessment.

Steve Hartley, Pat O'Neil, and Jimmy Johnston
Biological Resources Division/Southern Science Center
Lafayette, Louisiana

GAP and Local Government Planning

In the last year, the recognition of the critical role local government must play in biodiversity conservation has spread rapidly throughout the scientific, planning, and conservation communities. At the 1997 Annual GAP Meeting in Reston, USGS Chief Biologist Denny Fenn echoed this need through a quote from *In Our Own Hands* (Jensen et al. 1993): "County and local governments have the greatest effect on natural resource management in the U.S., yet they have the least access to good science. They also have the least access to biological information that covers large areas which often stretch beyond their jurisdictions."

The role of local government stems from the fact that approximately 80 percent of the land area of the coterminous U.S. is privately owned, and local governments have nearly exclusive jurisdiction over those lands. That jurisdiction influences habitat conservation or destruction most directly through land use planning and zoning. More importantly than area alone, however, privately owned land contains the lower elevation, highly productive, and most threatened ecosystems (repeatedly being confirmed by Gap Analysis projects, e.g., Merrill et al.1996, Davis et al. 1995, Thompson et al. 1997, Edwards et al. 1994).

In response, the application of GAP information to county land use planning is being explored in four county pilot projects. A biological decision support system is being developed for Teton County, WY, by Patrick Crist and Tom Kohley that will allow planners to easily consider impacts on biological resources when reviewing development proposals. In Santa Cruz County, CA, Chris Cogan is using GAP data to aid the county in determining those elements requiring conservation planning in the context of the ecoregion. Daryl Durham is leading a three-county effort in Tennessee to integrate the results of GAP in assessing development projects and comprehensive planning. In Washington state, a two-county planning assistance project is working with the counties to incorporate biodiversity into their open space planning programs. These projects each take a somewhat different approach to spatial and temporal scales and planner needs, whether it is data and tools, planning assistance, or education; but they are all contributing to the "tool box" of methods to make biodiversity a routine consideration of local government planners.

National GAP is solicited frequently by planning-related publications for tools, methods, and case studies that apply our data to local government needs. We plan to form a national repository and working group for such work and welcome all input and interest. If you would like more information or would like to be on the working group, contact Patrick Crist.

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Patrick Crist
National Gap Analysis Program
Moscow, Idaho

Status Report on MRLC Activities for 1997

The goal of the MRLC is to provide its partners and other federal users with high-quality remotely sensed data and characterized land cover data for the United States in an on-line database (MRLC National Land Characteristics Database). These data will be accessible to federal, state, and private groups for comprehensive and multiscale natural resource research, planning, and management. The first TM-based national land cover data set, circa 1992, is being generated on a federal region basis and will be completed by December 1999.

Current Status of the MRLC TM Archive:

Basic or "raw" scenes	876 (incl. GAP contributions)
Preprocessed scenes	856
Terrain-corrected scenes	619
GAP-contributed scenes	10
DEM scenes	618
Multitemporal scenes	656
Clustered scenes	1903
1-km MRLC composites	339

Descriptive data about the MRLC TM imagery are available through the Global Land Information System (GLIS) which can be accessed through the MRLC home page (http://www.epa.gov/mrlc).

MRLC Data Clearinghouse

A MRLC on-line data clearinghouse is being designed at the EROS Data Center. The objective is to provide users with the ability to either order or download TM-based derivative

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products from the MRLC partners, including: the regional land cover data sets, GAP state or regional natural vegetation data sets, and C-CAP land cover and change detection data sets. A draft Data Dissemination Plan has been produced, and we expect construction activities to begin in the fall of 1997.

For further information contact Nick Van Driel, EROS Data Center, at (605)-594-6007, e-mail: vandriel@igssn003.cr.usgs.gov.

Pete Campbell
MRLC Coordinator
BRD/EPS, Research Triangle Park, North Carolina

Building a Wildlife Habitat Relationships Database with FileMaker Pro

For states where information on habitat relationships has not been compiled for some species, constructing a database is one of the larger tasks required by GAP. However, a user-friendly software package can make it much more manageable. At MT-GAP, we are using FileMaker Pro, a database developed by Claris for both Mac and PC environments.

Disclaimer: Although it may seem like one, this is not an infomercial. Several other packages undoubtedly offer similar advantages. However, FileMaker Pro has a number of features that can simplify the task of building a wildlife habitat relationships database:

• It's easy to learn and to use. (And after getting a handle on the usual GIS packages, who wants to struggle with more software?)

• It functions as a true relational database. If a field is updated in one file, the changes take effect in every other file where that field is used. If this sort of dynamic relationship is not desired, you can opt to use “lookups” instead; then, information remains static until it's updated all at once.

• It handles one-to-many relationships. For example, you can store all references in one database and assign codes for related species to each, then access the set of references for a given species and bring it into the species account using a portal (a layout feature that displays multiple records).

• It handles large, variable-length text fields (up to 64,000 characters) like state ranges and habitat descriptions.

• It allows formatting of text within fields (e.g., italicizing scientific names or separating paragraphs).

• It can store images or links to images within the database. Species distribution maps, land cover maps, and photos can be included readily in EPS, TIFF, or PICT format (for Macs; PC options may vary). As a result, a vertebrate atlas can be built within a single database, including text, photos, and maps. Audio is also an option (bird songs, anyone?).

• It allows you to design and maintain a number of layouts using the same information for different applications, such as species accounts in a vertebrate atlas or reports monitoring progress of species modeling. You don't have to move to a separate word processing or publishing package to produce reports. For documents such as vertebrate atlases where there are numerous entries, all with the same format, it's relatively easy to keep information up-to-date. When you change a layout, you only have to do it once, not throughout the document.

• It imports and exports dBase files. Because ARC/INFO can convert between dBase and INFO, this simplifies translation between the two packages (for those fields that can be handled by INFO). In general, however, FileMaker Pro's import options are limited. Aside from dBase files, tab- or comma-delimited files are the main options.

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• It permits network file sharing, so that more than one person can work on a database at once.

• It is used extensively for database publishing on the Web and so provides an excellent way to disseminate typical GAP products like land cover or vertebrate atlases. Using CGI (common gateway interface) software, you can link FileMaker Pro databases to your home page.

More information on FileMaker Pro can be found at the following sites.

Product description:
http://www.claris.com/products/claris/filemakerpro/filemakerpro.html

Web publishing:
http://www.claris.com/support/techinfo/fmcgi/article.html

Links to CGI software and FileMaker Pro databases on the Web:
http://www.claris.com/support/products/filemakerpro/docs/cgi.html

Melissa Hart
Montana Gap Analysis
University of Montana, Missoula

Alliance Level Classifications for Southeast and Midwest

Two new reports on regional vegetation alliances were produced by The Nature Conservancy (TNC) for the National Gap Analysis Program (GAP) in May 1997. *An Alliance Level Classification of the Vegetation of the Southeastern United States* by Alan Weakley and others describes each alliance that is found in Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia. *An Alliance Level Classification of the Vegetation of the Midwestern United States* by Jim Drake and Don Faber-Langendoen includes alliances found in Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin. Digital copies of these reports have been distributed to all GAP projects in these states. For additional copies, contact Elisabeth Brackney at 208/885-3560 or brackney@uidaho.edu.

The national vegetation classification developed by TNC classifies existing vegetation hierarchically, with physiognomic units at the higher levels and floristic units at the lowest levels of the classification system. Descriptions of the lower, floristic levels had not been available until GAP provided support to TNC for this work. The first region to complete alliance descriptions was the East (Sneddon et al. 1994). A revision of Bourgeron and Engelking's (1994) *Preliminary Vegetation Classification of the Western United States* is currently under way. (See the article on vegetation classification on page ___ of this Bulletin for more details and literature cited.)

Elisabeth Brackney
National Gap Analysis Program
Moscow, Idaho

Predicting Plant Species Distributions in Wyoming: A GAP Pilot Project

The initial gap analysis has been completed for Wyoming. That project involved the development of coverages for land cover, land management status, and distributional

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modeling of terrestrial vertebrates (Merrill et al. 1996). Now, a new initiative will explore potential distributions of sensitive plant species and state and regional endemics.

During the past 20 years, the Rocky Mountain Herbarium has systematically inventoried most of the state (200,000 new collections). This, combined with 100,000 specimens from the preceding 80 years, provides an extensive database on location and ecological parameters for more than 3,000 taxa. Likewise, the Wyoming Natural Diversity Database (WYNDD) contains a wealth of information on sensitive plants. The first phase of the project is to capture relevant data on about 1,000 target taxa (20,000 earlier collections, 30,000 obtained since 1977).

The second phase will be modeling the biogeographic properties of these taxa, based in part on the herbarium and WYNDD databases. This will be done by Walter Fertig (WYNDD employee and Botany Department Ph.D. student) in collaboration with Reiners. The modeling fundamentally will be correlative; the potential locations of a species will be based on similarity with environments of locations in which they are known to occur.

The third phase is to perform "gap analysis" of sensitive plants in terms of protection status of common environments of clusters of species. Using modeled distributions of plant species in aggregate and in groups clustered according to similar site requirements, we will compare these distributions with the land status coverage available from the original Wyoming GAP Project, similarly to the models used for terrestrial vertebrates.

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Ronald L. Hartman and William A. Reiners
University of Wyoming, Laramie

Use of Low Cost, Commercial GPS for Field Data Collection in Nebraska

This article is not intended as endorsement of a specific product but portrays our attempt to find low-cost global positioning system (GPS) support for our field mapping efforts.

This summer, we had teams of graduate students collecting field data in support of the Nebraska Gap Analysis land cover mapping effort. We used GPS technology to obtain accurate locations in the field. We anticipated having more than one team out at a time, but only had one GPS rover unit. Therefore, we needed a low-cost second unit that could be used as needed for a second field team. For this purpose, we selected Trimble's ScoutMaster Flash, their low-end GPS rover designed primarily with the backpacker and recreational user in mind. The unit is under $500, but has some very nice features, including the ability to store, download and upload points, and the ability to navigate to pre-selected points.

For our purposes, the most important feature was the ability to average readings at each point. In the setup, the user can specify the logging rate and the number of points to be averaged at each site. While the output from the ScoutMaster is not differentially correctable, by averaging numerous records at each site we gained real-time readings that were accurate enough to meet our project objectives. Our accuracy was best when we averaged at least 100 readings per site (we were taking a reading every 5 seconds, so total time for the average was about 10 minutes). Increasing the number of readings to 150 and

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to 300 did not seem to increase our accuracy, but cutting back from 100 to 50 drastically reduced our accuracy. With at least 100 records our average error was about 26 meters in the easting and 18 meters in the northing.

While our sampling was not extensive, and the error for any one site was as much as 40 meters, we feel confident that the unit is giving us field locations that are within about 1 TM pixel in any direction. The low cost of the unit and the time saved in not needing to download base station files and conduct postprocessing have made this unit a very economical field tool for our project. To date, we have used the unit extensively in our field reconnaissance efforts. As we move into assessing our land cover map accuracy, we will need to reevaluate the level of positional accuracy required and the ScoutMaster's ability to provide it. Clearly, it will not replace our primary rover unit, but it has been a valuable supplement to it.

Marlen D. Eve, James W. Merchant, and Michael J. Bullerman
Center for Advanced Land Management Information Technologies (CALMIT)
University of Nebraska-Lincoln

Posters at 1997 Annual GAP Meeting

Our most recent annual meeting featured a large number of excellent posters. Many of the 34 posters presented at the meeting are available for viewing on the Web at http://www.gap.uidaho.edu/gap/posters/Index.htm.   We encourage readers to look at these posters, as they contain a lot of valuable information. The titles and authors are listed below.

Landscape-level habitat modeling for amphibians and reptiles in West Virginia (J. Rowe and C. Yuill)

Application of TX-GAP data for agricultural assessment (N. Parker, R. Leyva, and R. Estrada)

A multiseasonal approach to mapping Kansas' natural vegetation (C. Blodgett, S. Egbert, E. Martinko, K. Price, C. Lauver, A. Stewart, M. Ortega-Huerta, and R. Boyce)

Incorporating minimum viable population criteria into GAP models (L. Pearlstine, C. Allen, W. Kitchens)

Avenue Script application for GAP in ArcView (S. Painton, C. Allen, and L. Pearlstine)

The TNC vegetation classification and vegetation mapping in Florida - Simplifying the complex (J. Stenberg, L. Pearlstine, and W. Kitchens)

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Small-format digital aerial photography (L. Pearlstine)

Linking land cover to the Aquatic GAP habitat classification (M. Meixler and M. Bain)

Mapping land stewardship in Montana (C. Tobalske)

Mapping land cover classification errors (B. Steele, J.C. Winne, and R. Redmond)

Broad-scale correlates of vertebrate richness as a biogeographic foundation for Maine Gap Analysis (R. Boone and W. Krohn)

Forest birds and woody plants: Broad-scale habitat relations in the North Maine woods (R. Boone and W. Krohn)

Mapping land cover on barrier islands using airborne videography (A. Rasberry)

Predicted and known distributions and species richness of mammals in New York as determined by comparison, aggregation, and temporal analysis of data from three different sources (J. Weber, M. Richmond, and C. Smith)

Assessment of reptile and amphibian species richness in New York as influenced by mapping unit (M. Richmond, J. Weber, A. Breisch, J. Ozard, and C. Smith)

Louisiana GAP Project - Lake Pontchartrain Basin (S. Hartley)

A comparison of actual vs. potential natural vegetation in the western U.S.: An interpretation of the differences (S. Mann, G. Wright, M. Murray, T. Merrill, and J.M. Scott)

Elisabeth Brackney
National Gap Analysis Program
Moscow, Idaho

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MEETING SUMMARIES

GAP Symposium at 1997 ESRI Users' Conference

National GAP has been cooperating with the ESRI Conservation Program on a variety of activities. This year, we approached the program about giving GAP a room for a day at the annual Users' Conference. Charles Convis, program director, was very receptive to the idea. Every year, many GAP projects present papers at the conference, but putting them all in one room would give attendees the chance to follow a "GAP track" in a planned sequence. Papers were invited from all GAP projects and many cooperators.

The symposium began with a one-hour overview of GAP nationally, followed by technical sessions on land cover and animal distribution mapping, analysis, and applications. As a first-year effort, the symposium went quite well. We would have liked more submissions to choose from, especially applications of GAP data, and hope we get the chance to repeat the symposium in following years. The overview session was particularly well attended and well received, with about 70 people attending, as were sessions on county land use planning applications (see the planning article in this bulletin). In the coming years, we would also like to staff a demonstration in the Conservation Program booth with the interactive CD-ROMs being produced by GAP. If you have any questions or comments, contact Patrick Crist.

Patrick Crist
National Gap Analysis Program
Moscow, Idaho

Regional Breakout Sessions at 1997 Annual GAP Conference

Northeast

Representatives from Maine (Bill Krohn, Randy Boone), Vermont and New Hampshire (David Capen), southern New England (Dana Slaymaker),

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and New York (Steve DeGloria, C. R. Smith) Gap Analysis projects were present.

The following issues and concerns were discussed: Shifting the responsibility for production of GAP final report CDs from the state projects to USGS was believed by the group to be a good idea. Likewise, development of an outline for preparation of final reports by GAP administrators also was applauded by the Northeast Group. In general, it was believed that there could be a more open, interactive discussion of standards as they are emerging, perhaps at annual meetings. The focus should be on desired attributes and characteristics of final products, rather than on the process or procedures for developing those attributes and characteristics.

The rationale for the MRLC effort remained unclear. The appearance or reality of duplication of effort to produce products (i.e., habitat or land use/land cover maps) was perceived as a problem and could lead to controversy. At this time of tight federal budgets, the question becomes, "Why are three or so agencies producing land use/land-cover maps from the same data?"

The widely staggered start and stop dates for northeastern GAP projects make edge-matching a challenge. For example, the conclusion of the southern New England vegetation mapping effort and absence of GAP funding for staff now based at University of Massachusetts will make edge-matching between NY and southern New England difficult if staff at University of Massachusetts decide to leave the area before edge-matching can be accomplished. Funding to support edge-matching was considered a currently unmet need by the group.

There was discussion about the extent to which it is possible, realistic, or necessary to map vegetation at the alliance level and, when mapping is not possible, to model wildlife/habitat associations at the same level. It was agreed that vegetation mapping for GAP Phase I in the Northeast should focus on mapping those habitats needed to predict vertebrate occurrences. If a GAP Phase II is funded by BRD, emphasis could be placed on developing a more detailed habitat map with more vegetation types (ideally to the alliance level).

With the transfer of Gap Analysis responsibilities to the Biological Resources Division of USGS, the apparent vagueness of the distinction between research and operations, both administratively and programmatically, is causing some uncertainty among cooperators

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that can lead to reduced productivity and an absence of continuity if not addressed by GAP administrators.

It is important to keep the current technical expertise of GAP projects that are finishing, or have finished, in the GAP analysis planning loop and to be more explicit about what is implied by discussions of a "GAP II." A lot of time, effort, and money have been expended to assemble state-level Gap Analysis teams, and it would be unfortunate to lose that expertise if some plan for low-level continuity of state projects within USGS is not developed. Not all states are eager or interested in assuming responsibility for management of Gap Analysis databases in the absence of funding from USGS. Again, if GAP projects were minimally funded on a continuing basis, there would be greater opportunity to demonstrate uses of GAP databases and to get states to realize the utility of becoming the keepers of GAP data sets.

Charles R. Smith
New York-GAP

Mid-Atlantic

We discussed the level of detail of alliance-level vegetation mapping required for edge-matching. The level of detail could be fairly general - as reflected in the cover type categories that are driving the wildlife models. A super alliance/general cover type level was agreed upon for multistate activities. This would not affect the development of detailed state classifications which appear to be both alliance- and FIA-based.

The group agreed on sharing habitat models and species extent data. A standard format using hexagons will be the base for sharing all range extent data between the states. The data will be collected and served to the listserve from Virginia Tech. The models will be worked on at the next regional meeting in October at the Smithsonian. Virginia Tech is gathering this information anyway, so it was decided that they would collect the models as well.

We discussed the MRLC accuracy assessment with Pete Campbell, and he indicated that there would be no support for a regional accuracy assessment of their product. A review of the accuracy work

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completed by WV indicated some major problems with the MRLC Mid-Atlantic product. Too few clusters and a multi-image approach result in far too much confusion/mixing.

Developing an aquatic component of GAP was of interest to all states at the meeting. We felt we could possibly develop a regional strategy (perhaps with help from National GAP) for procuring EPA support for aquatic work - given their emphasis on the region. WV-GAP already received limited support from WVDNR to finish our aquatic GAP pilot, and this work has been completed. We noted that our work relied much more heavily on existing collections data than the work presented by the aquatic pilot project in New York. This will also be discussed in October.

Charles Yuill
West Virginia-GAP

Southeast

Approximately 20 individuals participated in the southeastern breakout session. Florida, Texas, Mississippi, Tennessee, Kentucky, South Carolina, and North Carolina were represented.

Vegetation mapping: Currently aerial videography is being used by TN, FL, MS, TX, and NC. Florida has started working with a digital camera system in conjunction with the wide-angle hi 8 mm video. Mississippi is conducting a pilot project using a digital camera and is optimistic about the potential for using stereo pairs for interpretation of vegetation types. South Carolina is in the midst of a pilot study using NAPP (1:40,000 CIR) photography and expert knowledge in labeling vegetation types for sub-watersheds in the coastal plain.

Vegetation classification: There was a general consensus that the state projects should actively communicate about their results with respect to mapping alliances. Shared lists of groups of alliances that accurately represent the land cover units being obtained by the mapping activities will be developed, shared, and revised based on the experiences within the region. Communication will be facilitated by posting results and questions on a newly established southeast GAP listserver.

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Multi-Resolution Land Characterization : NC, SC, GA, and MS are using MRLC imagery for their vegetation data layers. FL, KY, TN, and LA are using imagery already available in those states. The MRLC regional land cover classification will be evaluated for its potential use by the GAP projects on a state-by-state basis. There was some discussion that the state projects might benefit from the collection of a consistent set of higher resolution data (air photos, digital camera data, aerial videography) across the region. There was no single answer put forth by the group, but the need for temporally and spatially consistent data was recognized.

Vertebrate Species Modeling : Florida is the furthest along with this and has posted references used in developing their models on their home page. Mississippi is currently doing vertebrate species modeling on an as-needed basis to meet the objectives of some of their cooperators. Tennessee has developed models on a physiographic province basis as the vegetation maps have been developed. Several states are using museum records as secondary checks on the range maps. Mississippi has collected digital records from museums throughout the country. North Carolina has a joint project with the Museum of Natural Science and the North Carolina Heritage Program that has resulted in the digitization of museum records for the southeastern portion of the state. Kentucky's Biodiversity Committee has worked with experts throughout the state to develop lists of those species for which enough information exists to model the species distribution and a list of those for which information is lacking. For the latter, the group has decided to put the effort toward cataloguing existing information.

The southeast will be very active in the years to come and will benefit greatly from sharing ideas, data, methods, and results. In order to help this along, the southeast GAP listserver has been established (request information from listserv@listserv.ncsu.edu). In addition, it was agreed that regional meetings are a must. The proposal is to hold a meeting in the winter to complement the national meeting held in the summer.

Alexa McKerrow
North Carolina-GAP

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Great Plains

The Great Plains regional breakout session began with a report on the status of mapping land cover, modeling vertebrate distributions, and digitizing stewardship layers from each state. It became evident very quickly that a question/answer period for a land cover subgroup and a vertebrate subgroup was needed to use the time effectively.

Before breaking into subgroups, we discussed the apparent trend of many individuals who are involved in mapping land cover attending the national GAP meeting, but few individuals responsible for the stewardship layer doing so. The number of individuals modeling vertebrate distributions was intermediate between these two. The consensus was that the past two meetings were very expensive, and we would prefer to hold meetings on university campuses and stay in dormitories so that more individuals from each project could attend. Our group also preferred to have the national meeting held at the site of a GAP project so that field trips could be used to tour facilities or do a service project. Additional suggestions were that the meeting be shortened by one day, and that interactive demonstrations be held concurrently in the same room as the poster session. It also was suggested that the poster session with authors present be held in the evening and early in the conference, but not during the welcoming mixer.

Individuals within the land cover subgroup agreed that mapping land cover in the grasslands at the alliance level was a difficult task. Ideas on what works and what doesn't were exchanged. This subgroup also examined Iowa's experience with land cover and then answered questions from state projects that are just beginning to map land cover.

Within the vertebrate subgroup, a more detailed description was given of the status of each state’s structure for modeling vertebrate species. These reports were used as a framework to formulate an agenda for the first Great Plains Vertebrate Working Group meeting. It was decided that the Vertebrate Working Group would meet with the Land Cover Group during the first year. Our first meeting will consist of sessions that both subgroups will attend; these will be followed by breakout sessions. Pre-meeting assignments will be made for each

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state project so that we will be able to make maximal use of time during these meetings.

The reporting of commission errors was discussed without reaching a consensus on the issue of whether reporting this type of error is worthwhile. We also discussed the lack of awareness of the Gap Analysis Program (GAP) by the scientific societies interested in terrestrial vertebrates, e.g., American Society of Mammalogists, American Ornithological Union, Wilson Society, Society for the Study of Amphibians and Reptiles. The subgroup recommended that the national office take a proactive role in making these and similar societies and their memberships aware of the general program. This awareness of GAP should make it easier for states to get cooperation and help from experts within each taxon. It also was suggested that the national vegetation list be sent to groups that are working on surveys or species accounts (e.g., North American birds) so that these groups can help us as we produce our vertebrate models (i.e., habitat descriptions would not have to be cross-walked to match our land cover classification).

Glennis A. Kaufman
Kansas-GAP

Rocky Mountains

The Rocky Mountain breakout session was attended by representatives from the Colorado, Idaho, Montana, and Wyoming GAP projects, all of which have completed or are near completion of first-generation GAP. Interest centered around "life after GAP" and was dominated by a discussion of a proposed collaborative effort to extend state-by-state assessments of land cover types vs. land status to a larger region. We agreed to embark on this project and are currently mobilizing to gather and combine the appropriate data. We briefly discussed "ReGAP" for the region, but felt that it was still too early and uncertain to define specific discussion issues. All of the represented states, however, expressed interest in "ReGAP" and would like to be involved in discussion as plans and time tables solidify.

Finally, Brand Niemann of the EPA visited our group and expressed some of the data needs associated with the Greater Yellowstone

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Ecosystem. In particular, a consistent, edge-matched land cover map is needed for the area. Brand suggested that EPA dollars may be available to help achieve this goal.

Ken Driese
Wyoming-GAP

West

The western region breakout session included representation from Washington, Oregon, and Idaho. Washington has completed its gap analysis data sets. The final report will consist of five volumes (Land Cover, Birds, Mammals, Reptiles & Amphibians, and Gap Analyses) which will be printed and distributed. Oregon is conducting a land cover accuracy assessment using videography and should be finished around January 1998. This is the second version of a land cover map in Oregon. Idaho's second version of a land cover map is finished for northern Idaho, and Utah is producing a land cover map for southern Idaho, which should be finished in late 1997. The vertebrate models for Idaho are being developed through literature research and incorporating elevation, slope, DEMs, forest size, and classes.

Karen Dvornich
Washington-GAP

Southwest

Attendees: Kathryn Thomas (facilitator/note taker), Sarah Jacobs, David Charlet, Eric Holt, Kelly Allen, Carlos Gonzalez-Rebeles, Roy Hobbs, John Mangiameli, Bruce Thompson, Don Schrupp. Most of the discussion covered issues of a tightly coordinated second-generation GAP effort for the Southwestern states, referred to as "ReGAP."

Vegetation Classification

1. The TNC list of dominant vegetation types for Western states (Bourgeron and Engelking 1994), originally funded by GAP, is being revised significantly by Marion Reid of TNC Western Region Office. Reid's work will parallel the comprehensive treatment of vegetation

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alliance description and classification that GAP has funded in the Northeast, Southeast, and Central U.S. Her effort should be complete toward the end of 1998.

2. Action needed: There needs to be clearer interaction between GAP, TNC, USGS-BRD/NPS Park Mapping Program, and ESA in development of alliance lists and descriptions.

Ecological Stratification for ReGAP

1. Labs will be assigned ecoregions for vegetation mapping. Land cover mapping will extend across state boundaries; capabilities of labs should be assessed.

2. Action needed: A group meeting of labs and/or PIs is needed to discuss the best way to stratify for mapping. Bailey's ecoregions are not necessarily the determining boundary; TM imagery should play a role in the stratification.

Vertebrate Modeling

1. Bruce Thompson suggested that species extending across state boundaries could be allocated among state projects to prevent several states doing the same species. He also suggested that a matrix should be created listing species that are shared among states, coverages that are commonly used between states, and the source and scale of these coverages that are being used by each state. This is already planned for the 4-Corner ecoregion project being conducted at the Colorado Plateau Field Station (CPFS). NM used 1-7 information layers in its wildlife habitat relationship models (watersheds, mountain landforms, elevational limits, hydrology, soils, land cover, slope).

2. TNC categories of confirmed, probable, and possible presence are recommended for the remodeling effort.

3. The ReGAP states of Nevada, Colorado, New Mexico, Utah, and Arizona are all in different stages of product development for the vertebrate component.

4. Vertebrate models will reside at state level; the hexagon range map will be used as a base stratification.

5. Action needed: Clarification is needed on the use of the hexagon stratification - are the hexagons to be repopulated with distribution models developed at finer resolution or are the hexagons to be the native resolution layer?

(Director's Note: The hexagons are used as a raster tool for displaying and adjusting range maps. As such, they can be used to bound distributions at a continental scale. However, it is the 1:100,000 scale predicted distribution data that should drive population of the hexes. -MJ)

Coordination Between ReGAP States

1. Discussion of role of regional coordinator. Various ideas include:

• Minimize number of labs doing land cover mapping and use extra money to pay for regional coordinator.

• Coordinator position could rotate between state PIs - however, the general feeling is that it will not provide the needed consistency and that PIs may be busy enough anyway.

• Role of regional coordinator could include organizing workshops with state PIs and relevant GAP staff; monitoring project time schedules and project progress; identifying difficulties and facilitating interactions that might solve these problems; acting similarly to a project manager; acting as liaison with Patrick Crist in the southwest ReGAP effort; developing and maintaining regional GAP home page.

2. Discussion of ReGAP as a production vs. research project: Problems still exist in mapping of arid lands and grassland. If PIs want to include a research component, it should still be in the context of meeting deadlines and meeting production requirements. National GAP will not be building labs with ReGAP money, rather, they will be looking for labs with longevity and mostly existing infrastructure.

Miscellaneous Problems and Issues

1. Where precursory data is missing for GIS coverages, the info file and/or logs may give insight into the genealogy of the coverage.

2. The cost of video interpretation should not be discounted in project budgeting; adequate video interpretation is not a trivial task.

3. Texas is using field work to classify the MRLC imagery since the video they have has not been delivered by Texas A&M.

4. Nevada has a variety of issues they are grappling with. They do not have any of the previous GAP materials - we told David Charlet to talk with Collin Homer. They feel very "behind," as GAP has not been directed in-state. They are skeptical about the use of Landsat imagery. The biogeography of many of the species in the state is not

known. As 87% of the land base is public, they do not see the potential for much collaborator support.

5. Texas is not doing a ReGAP but wants to keep in the communication circle, as they are an adjoining state and will be looking for adequate edge-matching of their efforts with the ReGAP states.

Literature Cited

Bourgeron, P.S., and L.D. Engelking, editors. 1994. A preliminary vegetation classification of the Western United States. Unpublished report prepared by the Western Heritage Task Force for The Nature Conservancy, Boulder, Colorado.

Kathryn Thomas
Northern Arizona-GAP

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