gap

KEEPING COMMON SPECIES COMMON

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CONTENTS

FEATURES

APPLICATIONS

USGS
science for a changing world

The Gap Analysis Program … in Brief

The mission of the Gap Analysis Program (GAP) <gapanalysis.nbii.gov> is to promote conservation by providing broad geographic information on biological diversity to resource managers, planners, and policy makers who can use the information to make informed decisions.

As part of the National Biological Information Infrastructure (NBII) <www.nbii.gov> – a collaborative program to provide increased access to data and information on the nation's biological resources – GAP data and analytical tools have been used in hundreds of applications: from basic research to comprehensive state wildlife plans; from educational projects in schools to ecoregional assessments of biodiversity.

The challenge: keeping common species common means protecting them BEFORE they become threatened. To do this on a state or regional basis requires key information such as land cover descriptions, predicted distribution maps for native animals, and an assessment of the level of protection currently given to those plants and animals.

GAP works cooperatively with federal, state, and local natural resource professionals and academics to provide this kind of information. GAP activities focus on the creation of state and regional databases and maps that depict patterns of land management, land cover, and biodiversity. These data can be used to identify "gaps" in conservation – instances where an animal or plant community is not adequately represented on the existing network of conservation lands.

GAP is administered through the U.S. Geological Survey. Through building partnerships among disparate groups, GAP hopes to foster the kind of collaboration that is needed to address conservation issues on a broad scale.

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FEATURES

Role of GAP Data in State Wildlife Plan Development: Opportunities and Lessons Learned

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Introduction

Gap analysis is designed to be a proactive approach to conservation. A recent review of how GAP data have been used found that the primary applications have included resource management, biodiversity assessment, planning, site prioritization, and as a component of state Comprehensive Wildlife Conservation Strategies (CWCSs) (Maxwell 2005), now called State Wildlife Action Plans (SWAPs).

The completion of SWAPs, and their approval by the U.S. Fish and Wildlife Service, has established a blueprint for a national strategy for protecting and preserving biological diversity across the United States (Throckmorton 2005). State and regional GAP projects have contributed to this blueprint, and they will continue to make contributions to SWAP implementation and monitoring. I will review here the function of GAP data in SWAP development and discuss the potential role of these data in SWAP implementation, monitoring, and revision.

Background

The federal government mandated that states submit completed SWAPs by October 2005 (IAFWA 2001). Each plan was to include information on state species of greatest conservation need (SGCN), SGCN habitats, threats to species and habitat, research needs, necessary plan actions, and conservation priorities. States that did not meet the deadline risked losing funds they had received through the State Wildlife Grants program, which has allocated nearly $400 million to states for conservation since 2001 (Throckmorton 2005).

GAP's land cover, stewardship, and species richness data, as well as its habitat models and gap analysis results, were used by states as they developed their conservation strategies. Through a short e-mail survey of GAP principal investigators and SWAP coordinators in 2005, I learned that 38 states and Puerto Rico had used GAP data to develop their SWAPs (Maxwell 2005). Based on the information gained from that brief survey, I developed a more detailed survey in 2006 to assess which GAP data were most helpful, which SWAP issues were addressed using GAP data, and what changes natural resources professionals would like see in the data that GAP produces.

Methods

To gain a greater understanding of how GAP data were used in SWAP development and to identify possible future uses of GAP data, the University of Idaho sent the survey to 51 plan coordinators in 50 states and Puerto Rico. The survey questionnaire was designed to address four key issues:

- the extent to which different components of GAP data were used in SWAP development;
- the importance of GAP data for addressing specific SWAP components;
- the extent to which SWAP coordinators plan to use GAP data in the future to update and review their plans; and
- what meaningful enhancements should be made to GAP data.

Respondents were asked to indicate their answers using a five-point scale, which evaluated the importance of the issue or the extent to which GAP data were relied on. The scale ranged from not important/not at all (1) to most important/only used GAP (5).

The draft questionnaire was reviewed by both GAP staff and the University of Idaho Social Sciences Research Unit before being mailed to the 51 SWAP coordinators on February 21, 2006. A reminder postcard was mailed out two weeks later. Nonrespondents were mailed a second copy of the survey on March 21, 2006. On April 10, recipients who still hadn't responded were contacted by e-mail, with the survey and instructions included as an e-mail attachment.

Results and Discussion

A total of 44 coordinators responded, 34 of whom (77 percent) had used GAP data in plan development and 10 of whom (23 percent) had not. This percentage compares favorably with the results of our 2005 survey, which showed that out of all states and Puerto Rico, 12 states (24 percent) had not used GAP data (Maxwell 2005).

Responses from the 2005 survey had been used to develop the questions for the more detailed 2006 survey. In 2005, for example, SWAP coordinators had indicated that they had used a variety of GAP data. In the 2006 survey, I asked to what extent the coordinators had used specific GAP data elements

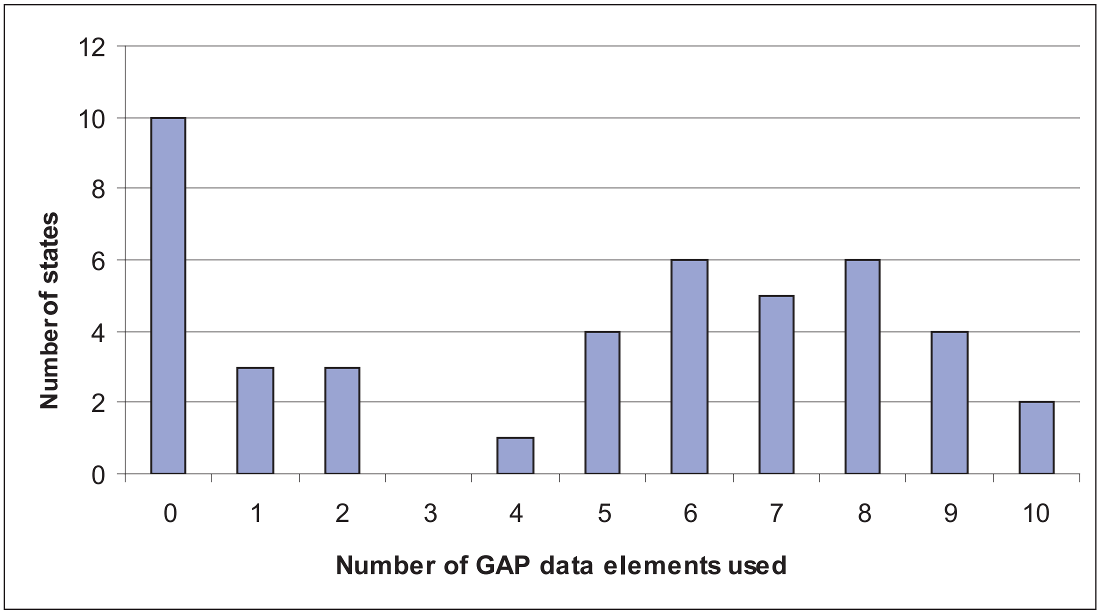

Figure 1. The number of GAP data elements (i.e., data types) used by states in SWAP development. Only the states that responded to the survey are included (n = 44). Most states used at least five elements.

(i.e., data types): land cover data, habitat models, vegetation classifications, species lists, predicted vertebrate distribution maps, habitat narratives, stewardship data, ownership data, species richness data, and aquatic data. Overall, coordinators from 34 states said they had used GAP data elements, and 27 of them said they had used five or more of the 10 data elements (figure 1).

Use of GAP Data

Table 1 shows the percents and the mean responses to question 1, which asked about the extent to which each element of GAP data was used. The percent indicates how many states used each data element, but does not indicate the extent to which the data were used to address specific plan components. For example, if a respondent did not use the aquatic data at all, a score of 1 was given to that item; similarly, if a respondent used only GAP land cover maps and data for their SWAP, that item would have received a 5. Mean scores were obtained by averaging all scores given to a single data item. They indicate the extent to which GAP data were used to address that plan component. For all 44 survey respondents, mean scores ranged from 1.56 percent to 2.91 percent. Higher mean scores indicate that more states used that data extensively or exclusively.

In their SWAP development, respondents relied on GAP land cover data far more than they relied on other elements of GAP data (see table 1). Six states (14 percent) said GAP was their only source for land cover data. Another 16 (36 percent) said they used it extensively. The vegetation classifications and predicted vertebrate distribution maps were also used by 56 percent of respondents.

Other components of GAP data were used less extensively, but still played an important role in SWAP development. Even GAP aquatic data were used by approximately one-third of respondents, despite the fact that few states included an aquatic component in their GAP projects; this indicates how important aquatic data are when they are available.

One reason that the GAP land cover data may be used is because they are one of the main products of a Gap Analysis Project. GAP was one of the first nationwide projects to map land cover on a state-by-state basis. Much of the research conducted by GAP focused on how to map land cover and develop meaningful classifications that cross state lines. State projects were allowed some flexibility in their mapping efforts (Eve, Merchant, and Kroll 1997). In addition, both technology and methodology have improved over the twenty years that GAP has been funding projects. The variability in what state projects produce explains the different uses of those end products in SWAP development.

Plan Elements Addressed Using GAP Data

According to the survey responses, GAP species and habitat distribution models and maps were the most important components of GAP data (table 2). Of the 34 respondents who used GAP data, more than 75 percent used the data to address the SWAP requirement to identify and assess the condition of SGCN. For many states, GAP species and habitat distributions

Table 1. The number of states that used specific GAP data elements in SWAP development. Mean scores were calculated by averaging all scores given to a single data element. The values in the gray columns represent the number of states giving that score to that GAP data element. A higher mean score indicates that the data element was used more extensively. Percent indicates how many states used each data element. N represents the number of respondents. Not all respondents gave scores to every data element.

GAP data element	Mean	Exclusively (5)	Heavily (4)	Somewhat (3)	A little (2)	Not at all (1)	Percent	N (Responses)
Land cover maps/data	2.91	6	16	4	4	14	68.18%	44
Vegetation classifications	2.49	5	9	7	3	19	55.81%	43
Predicted vertebrate distribution maps	2.35	6	5	6	7	19	55.81%	43
Species richness	2.14	2	6	9	5	21	51.16%	43
Habitat models	2.02	1	6	5	11	19	54.76%	42
Stewardship data	1.88	3	5	2	6	26	38.10%	42
Ownership data	1.98	2	6	5	6	24	44.19%	43
Species lists	1.67	0	3	5	10	25	41.86%	43
Habitat narratives	1.79	1	2	8	8	24	44.19%	43
Aquatic data	1.56	0	3	4	7	29	32.56%	43

provided the data they needed to locate the SGCN on the landscape without recreating the information from scratch. They used GAP data, along with other data, to assess the status of particular species in their state. GAP data were also important for mapping species richness, determining habitat associations, and describing habitat, which are key elements for identifying high-priority conservation areas.

Conversely, GAP data did not play an important role in identifying threats, determining future actions, assessing SGCN status, or mapping invasive species. GAP projects do not emphasize threatened or rare species, and coarse-scale mapping efforts often do not map threatened or rare habitats. Also, few projects mapped invasive species.

GAP data were also not important for mapping land cover changes. The data may not have been around long enough to be used to assess changing conditions on the ground. Although some states have used GAP to look at changes in land use (Kramer and Elliot 2005), this is a relatively new application of the data.

Additional uses for the data that were mentioned by respondents included placing the state in a regional context and reinforcing the importance of private land conservation. One state reported using the data to derive data sets of predicted distributions, land cover, and known species points.

GAP Data Used to Update and Revise SWAPs

An essential element in each initial SWAP was a description of the procedures that would be used to update and review the SWAP. The third survey question asked whether each state would be using GAP data to accomplish this (table 3). As with previous questions, the list of possible applications for GAP data was compiled from responses to the 2005 survey.

Only seven respondents (18 percent) reported that they were not planning to use GAP data in the future, while 33 (82 percent) said they would address at least one aspect of plan update or review with GAP data. Five states did not respond to the question, though two of those indicated they were waiting to see the data. Sixteen coordinators (41 percent) said they would rely heavily or exclusively on GAP to improve the wildlife habitat mapping done for their SWAP. SWAP coordinators also expected GAP data to make a contribution to identifying knowledge gaps and threatened landscapes. One respondent said that GAP data would be used to help designate critical habitat.

To promote the adoption of GAP data, it is important to facilitate contacts between scientists familiar with the projects

Table 2. The importance of GAP data in addressing specific SWAP plan issues. The values in the gray columns represent the number of states giving that score to that plan component. Mean scores were calculated by averaging all scores given to a single plan component. A higher mean score means that GAP data were more important in addressing that plan component. Respondents who said in question 1 that they did not use GAP data were not included. Percent indicates how many states used GAP data to address the specific SWAP component. N represents the number of respondents. Not all respondents gave scores to every plan component.

SWAP component addressed with GAP data	Mean	Very important (5)	Important (4)	Somewhat important (3)	Of little importance (2)	Not at all (1)	Percent	N (Responses)
SGCN habitat distributions	3.13	4	12	5	6	5	84.38%	32
Develop/update land cover maps	2.91	5	8	8	3	9	72.73%	33
All species habitat distributions	2.85	4	10	4	7	8	75.76%	33
SGCN distributions	2.81	4	9	6	3	10	68.75%	32
Map species richness	2.77	1	10	7	7	6	80.65%	31
Describe habitat	2.75	3	5	11	7	6	81.25%	32
Determine habitat/ species associations	2.74	2	7	7	7	6	80.65%	31
Develop/update vegetation maps	2.55	3	3	7	4	13	60.61%	33
ID high-priority conservation areas	2.55	3	4	8	8	8	74.19%	31
All species distributions	2.47	4	5	6	4	13	59.38%	32
Identify knowledge gaps	2.35	2	5	5	9	10	67.74%	31
ID threats to priority species	2.03	0	6	5	4	16	48.39%	31
Develop/update stewardship maps	2.03	4	2	3	4	18	41.94%	31
Assess land use change/trends	1.94	3	1	3	8	16	48.39%	31
Identify threats to priority habitats	1.94	1	3	4	8	15	51.61%	31
Identify necessary future actions	1.84	0	3	4	9	15	51.61%	31
Develop species lists	1.65	0	2	5	4	20	35.48%	31
Assess species richness	1.72	0	2	5	7	18	43.86%	32
SGCN status	1.71	0	1	6	7	17	45.16%	31
Invasive species distributions	1.23	0	1	0	4	26	16.13%	31

Table 3. Extent to which SWAP coordinators plan to use GAP data in the future to revise and update their plans. The values in the gray columns represent the number of states giving that score to that plan component. Mean scores were calculated by averaging all scores given to a single GAP data element. A higher mean score means that GAP data are more likely to be used to address that plan component. Percent indicates how many SWAP coordinators plan to use GAP data in the future to revise and update the plan component. N represents the number of respondents. Not all respondents gave scores to every plan component.

Plan component that GAP data will be used to address	Mean	Exclusively (5)	Heavily (4)	Somewhat (3)	Marginally (2)	Will not use (1)	Percent	N (Responses)
To improve wildlife habitat mapping done for SWAP	3.00	2	14	12	4	7	82.05%	39
To identify knowledge gaps	2.73	1	9	15	3	9	75.68%	37
To identify threatened landscapes	2.68	2	8	13	6	9	76.32%	38
To establish baselines	2.61	1	8	12	9	8	78.95%	38
To educate the public	2.47	2	7	8	8	11	69.44%	36
To identify/monitor future threats	2.41	2	4	12	8	11	70.27%	37

and other decision-makers. Through a content analysis of the SWAPs, I discovered that GAP-affiliated scientists were involved in the development of SWAPs in 19 of the states that submitted plans. These scientists were principal investigators, co-principal investigators, researchers, or authors for either ongoing or past GAP projects. Their SWAP roles ranged from contributor or technical team member to steering committee member or contributing author. I identified these scientists by reading the acknowledgment and committee member lists in the SWAP reports.

Of the 44 states that responded to the survey, 16 of the SWAPs were developed with the input of GAP-affiliated scientists and the survey showed that these states were more likely to use GAP data (figure 2). These states also placed a higher value on GAP data than did states without the involvement of GAP-affiliated scientists (as measured by overall mean scores; see figure 3). For example, in response to question 1 about the extent to which different components of GAP data were relied on in SWAP plan development, 73 percent of the states with the involvement of GAP-affiliated scientists used GAP land cover data extensively, while only 36 percent of the remaining projects did so (figure 2).

GAP Data Modifications

Question 4 evaluated the perceived importance by SWAP coordinators of modifications to data provided by GAP. A list of possible changes was compiled from responses to our 2005 survey about the use of GAP data in SWAP development. In that survey, comments by states that did not use GAP data reinforced criticisms that had emerged previously (McClafferty 2002). Eight states said they did not use the data because they were incomplete, difficult to get, or otherwise unavailable. Other criticisms were that the data were too coarse, inaccurate, outdated, lacked information about habitat quality, lacked accuracy assessment, or lacked information about rare plant species. Two respondents indicated that GAP staff had moved on, which made it difficult to work with the data. Despite these criticisms, many of these states are still interested in GAP data. Of those that did not use the data, four indicated they had tried to use the data before deciding to use other sources, and five said they were willing to use GAP data when the data become available.

Overall, respondents to the survey felt that each of the identified possible modifications to GAP data would be valuable (table 4). The modifications deemed most important were as follows: more information on habitat change, finer-scale mapping for specific species, more information on habitat condition, and a shorter timeline for project completion. In response to an open-ended question about what other kinds of information respondents would like to get from GAP data, the following modifications were mentioned: improved delineation of grassland types, successional habitats, and wetlands; accuracy assessment; better resolution to help delineate vegetation cover types; threat assessment; progress assessment; and restoration potential. One respondent indicated that GAP would be the cheapest consistent method of monitoring habitat loss/gain.

Some of the issues identified are being addressed and some continue to pose challenges. Not all GAP projects have modeled invasive vertebrate species, nor have they provided assessments

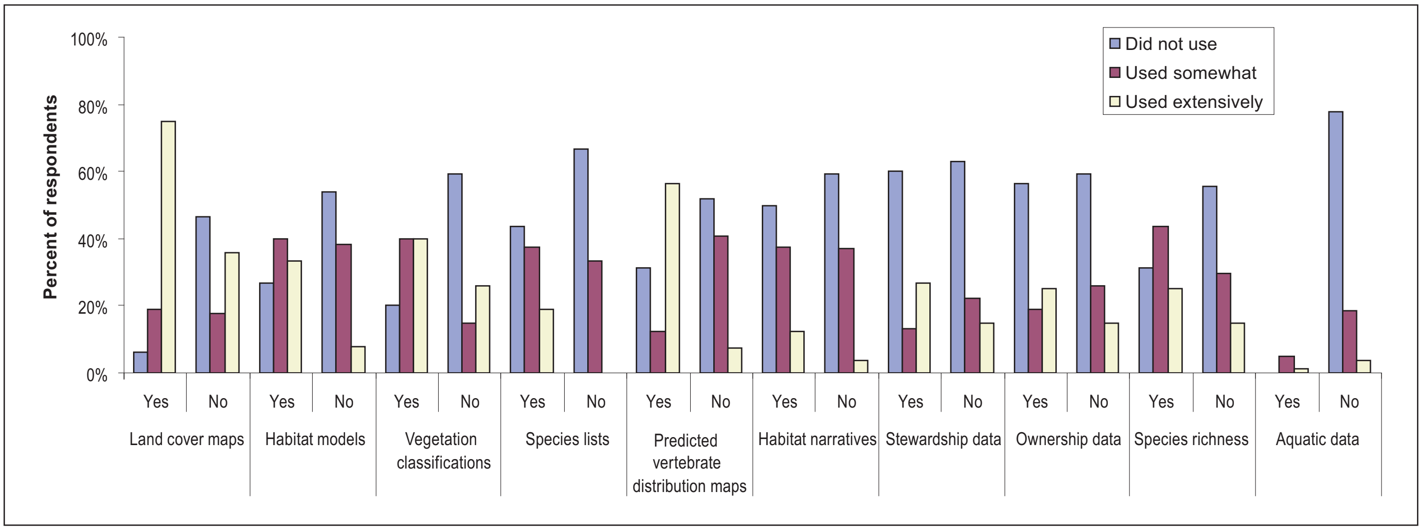

Figure 2. Use of GAP data components by SWAPs developed with (yes) and without (no) the involvement of scientists previously affiliated with GAP projects (GAP-affiliated scientists). Through a content analysis of the SWAPs, I discovered that GAP-affiliated scientists were involved in the development of SWAPs in 19 of the states that submitted plans. These scientists were principal investigators, co-principal investigators, researchers, or authors for either ongoing or past GAP projects. Their SWAP roles ranged from contributor or technical team member to steering committee member or contributing author. These scientists were identified from the acknowledgments and committee member lists in the SWAP reports. Sixteen of the 44 states that responded to the survey developed their SWAPs with the input of GAP-affiliated scientists. Plans developed with the involvement of GAP-affiliated scientists were more likely to have used the data than those developed without input from GAP-affiliated scientists.

of habitat quality. This is why SWAP coordinators could not find data about invasive species for use in their plans. Similarly, because GAP mapped vegetation from satellite imagery, its land cover maps are a representation of what was on the ground in a specific year. For this reason, there is little information on habitat change. However, as regional mapping projects are completed, at least one more land cover map will be available. Also, as the aquatic GAP projects develop in the future, more data will be available about aquatic ecosystems.

Other modifications, such as the need for a shorter timeline, finer-scale mapping for select species, and more information on species abundance, are more intractable because they depend on data availability, data quality, funding, and available technology. These are issues that will continue to challenge GAP.

Conclusion

The development of SWAPs has laid a foundation for conservation in the United States. GAP has played an important role in developing that foundation and will continue to play a role in ongoing regional mapping efforts to create a unified land cover map of the United States. The development of the GAPServe data portal <http://gapanalysis.nbii.gov> will make it easier for natural resources planners and other decision-makers to access and use GAP data.

Survey results indicate a widespread willingness to use GAP data once they become available, as well as an ongoing need for new kinds of data, especially on invasive species, habitat change, and habitat condition. There is also a need for finer scale mapping to capture topographic features, such as riparian corridors and small habitat patches. However, GAP data have their limitations and they will never meet all the needs of natural resources professionals. But if used to complement other data sets, GAP data can help natural resources professionals make informed decisions about the conservation and management of many vertebrate species.

A key component of GAP projects is the collaborative approach with which they are conducted on a state and regional basis. The extent to which SWAPs that were completed with the input of GAP-affiliated scientists made greater use of the data indicates the wisdom of continuing to develop such relationships. Continued close collaboration between GAP and state and federal natural resources professionals will lead to increased general awareness and use of GAP data. In return, GAP will benefit in its future research and mapping efforts.

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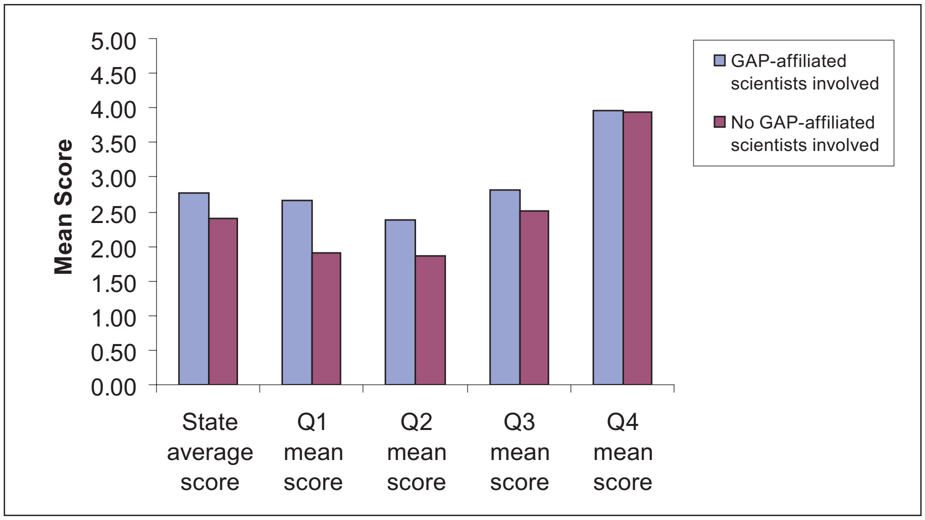

Figure 3. The involvement of GAP-affiliated scientists in SWAP development resulted in a mean score. Mean scores reflect GAP data use and its perceived importance among states with GAP-affiliated scientists involved in SWAP development compared to states without input from GAP-affiliated scientists. SWAPs completed with the input of GAP-affiliated scientists were more likely to have used the data. Q1 = Use of GAP data, Q2 = SWAP components addressed with GAP data, Q3 = Plan to use GAP data in the future, Q4 = Importance of various modifications to GAP data.

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Table 4. The perceived importance of modifications to GAP products. The values in the gray columns represent the number of states giving that score to that modification. Mean scores were calculated by averaging all scores given to a single modification. Mean scores indicate how important each modification is perceived to be. N represents the number of respondents. Not all respondents gave scores to every plan component.

Modification	Mean	Extremely important (5)	Very important (4)	Somewhat important (3)	Slightly important (2)	Not important (1)	N (Responses)
More information on habitat change	4.60	25	8	1	0	1	35
Finer-scale mapping for select species	4.42	21	11	3	0	1	36
More information on habitat condition	4.31	19	12	4	0	1	36
Shorter timeline for projects and between remapping efforts	4.06	19	3	11	0	2	35
More information on invasive species	3.94	13	10	9	3	0	35
Better mapping of linear corridors	3.91	15	7	7	1	3	33
More aquatic data	3.91	14	9	6	1	3	33
More information on threats to habitat	3.82	12	10	8	2	2	34
More information on species abundance	3.59	12	5	11	3	3	34
More information on threats to animals	3.44	9	7	11	4	3	34
Better delineation between forest types	3.44	11	7	7	4	5	34
More regional data	3.21	7	6	12	3	5	33

Using the Southwest Regional Gap Analysis Project Data to Describe Land Cover and Ownership Patterns in Nevada for Wildlife Conservation Planning

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To make the best use of the State Wildlife Grants program, Congress charged each state and territory with developing a State Wildlife Action Plan (SWAP), formerly called a Comprehensive Wildlife Conservation Strategy (IAFWA 2001a). These action plans will provide the foundation for future wildlife conservation across the country. The Nevada Department of Wildlife, The Nature Conservancy of Nevada, the Lahontan Audubon Society, and the Nevada Natural Heritage Program partnered to prepare Nevada's Wildlife Action Plan, which was submitted in September 2005 and approved by the U.S. Fish and Wildlife Service in November 2005.

Although states took varying approaches in structuring their plans, there were specific requirements, which became known as the "eight required elements" (IAFWA 2001b):

1. information about wildlife species numbers and distributions;
2. a description of key habitats and locations;
3. a description of problems that may affect identified species and key habitats;
4. proposed actions for conservation of the identified wildlife and key habitats;
5. proposed plans for monitoring species and the effectiveness of conservation actions;
6. a process for periodic plan review;
7. plans for coordinating with land managers; and
8. a demonstration of public participation in plan development.

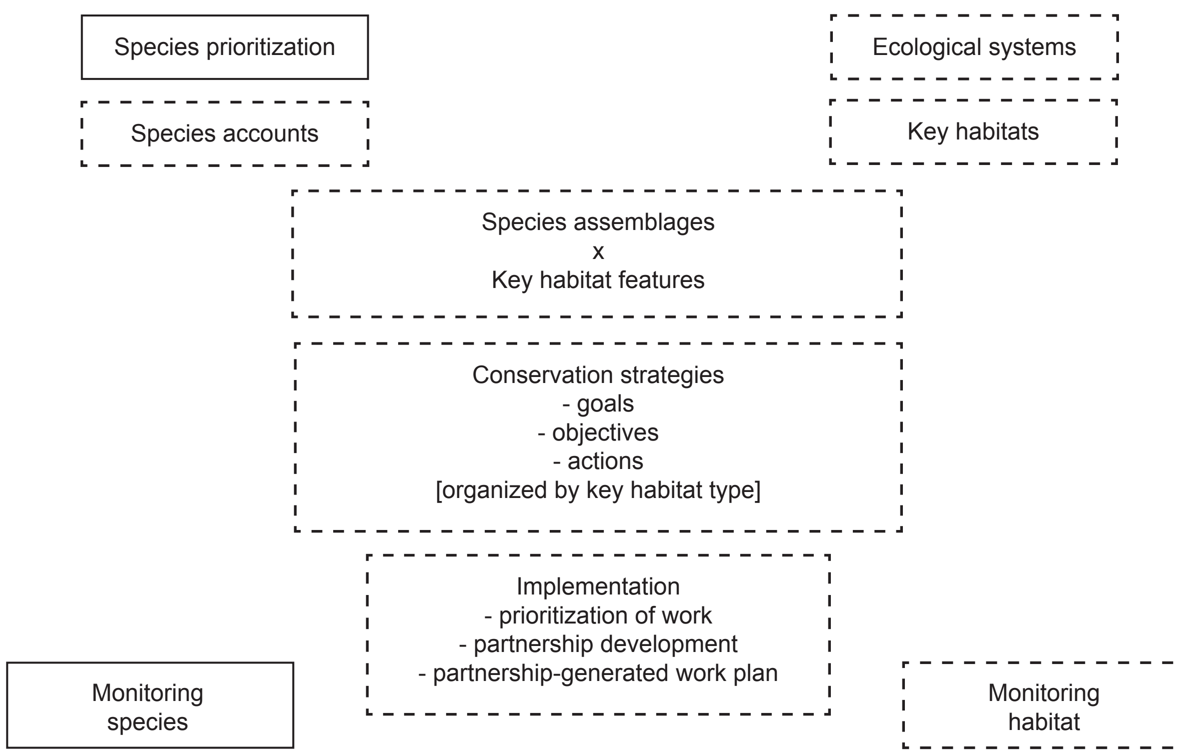

Figure 1. Framework used to develop Nevada's Wildlife Action Plan. Southwest Regional Gap Analysis Project data were integral in the development of most major sections of the plan (dashed boxes above).

To assemble a comprehensive plan for Nevada's wildlife, we considered a multitude of available data sources. For three of the eight required elements (elements 1, 2, and 7), we relied heavily on Southwest Regional Gap Analysis Project (SWReGAP) land cover and stewardship data (Lowry et al. 2005; USGS National Gap Analysis Program 2005). Using these SWReGAP products, the Nevada Wildlife Action Plan development team analyzed patterns of biodiversity and land use to identify species of conservation priority and their key habitats. Nevada's Wildlife Action Plan thus includes discussions of both species and key habitats and integrates the two in the sections discussing the development of conservation strategies, their implementation, and their monitoring (figure 1).

Describing Key Wildlife Habitats

We assessed data to determine how adequately they described wildlife habitats in Nevada (element 2). Available data included a recently developed vegetation geospatial data set from the Humboldt-Toiyabe National Forest, but the data provided incomplete coverage for the entire state because only lands managed by the U.S. Department of Agriculture Forest Service were mapped. Also, the Nevada Natural Heritage Program has geospatial data for the National Wetlands Inventory, but data are limited to only a few aquatic habitats.

A third option we evaluated was the Sage-stitch map (Comer et al. 2002), which includes the current distribution of 10 sagebrush vegetation types. Though geographically comprehensive, the data are intended to provide a broad-scale perspective on sagebrush and related vegetation distribution across the Intermountain West, and the map therefore did not meet our need to describe all wildlife habitats in Nevada.

The Nevada GAP vegetation data (Utah Cooperative Fish and Wildlife Research Unit 1996) have been used in previous conservation planning efforts in Nevada (e.g., Nachlinger et al. 2001; MDEPT 2001), but we decided to use the recently completed SWReGAP land cover data because of their increased accuracy and comprehensive regional coverage (Lowry et al. 2005).

Nevada's landscape is remarkably diverse, varying from huge expanses of salt desert shrublands on valley floors to herbaceous alpine communities above bristlecone woodlands on isolated mountaintops (NDOW 2005). To more readily organize and present conservation strategies in Nevada's Wildlife Action Plan, we chose to aggregate 74 ecological systems mapped by SWReGAP into 27 key habitats.

For organizational purposes, the resulting key habitats were further rolled up into seven major habitat groups. From lowest to highest elevations, the first four habitat groups are:

- basins and desert scrub;
- sagebrush semidesert;
- lower montane; and
- montane to alpine.

The remaining three habitat groups are smaller types not limited to any specific elevation zone because their occurrences are tied more closely to other driving factors. These groups include:

- sand dunes and badlands;
- riparian and wetlands; and
- aquatics.

Although these three groups cover a smaller portion of Nevada, they make a critical contribution to the state's biodiversity. The sand dunes and badlands system group includes sparsely vegetated terrestrial habitat types controlled by substrate factors. The riparian and wetlands group, as well as the aquatics group, encompass ecological systems that are controlled by hydrologic characteristics and either occur at the interface of terrestrial-aquatic systems or encompass the aquatic biodiversity of Nevada.

Nevada's Wildlife Action Plan includes strategies for 27 key habitats that integrate conservation needs for ecological systems, wildlife communities, and as necessary, individual species. Species assemblages (i.e., wildlife communities) were characterized through each species' structural habitat requirements, which enabled us to link Nevada's species of conservation priority to their key habitats. For many key habitats that include aquatic species, assemblages were driven by species isolation and local endemism, as well as by the structural characteristics of aquatic systems within the key habitat.

Land Ownership and Management

To plan the implementation of Nevada's Wildlife Action Plan, we needed to prioritize work, partnership development, and the generation of a partner-based work plan. The SWReGAP stewardship map (USGS National Gap Analysis Program 2005) played an integral role in the development of this section of Nevada's Wildlife Action Plan. We were able to summarize land ownership and management for each key habitat with these data and identify the primary partners for conservation in each key habitat.

Conclusions

The challenges we encountered while developing Nevada's Wildlife Action Plan were partially attributable to a lack of digital land cover maps for many of Nevada's aquatic habitats. Though we did not resolve our need for a digital map for all aquatic systems, we did develop links where conservation and management approaches can integrate aquatic and terrestrial components. Because SWReGAP products have only been released recently, accuracy uncertainties have not been addressed. Our final concern was ensuring compatibility with data used by partners, particularly those using a different habitat classification scheme and data.

Even with these challenges, SWReGAP data provide the most up-to-date land cover and stewardship maps for ecological systems and land ownership across Nevada and two neighboring states, thereby facilitating collaboration across state lines. Nevada's Wildlife Action Plan will be compatible with other ongoing efforts that incorporate the ecological system classification scheme (e.g., ecoregional assessments by The Nature Conservancy, LANDFIRE).

Future uses of SWReGAP data in Nevada may include the incorporation of species model information into later iterations of the Wildlife Action Plan. Collaborating on the implementation of habitat strategies with Utah and Arizona should be essentially seamless because of the regional scope of the data. Finally, we could use the land cover data to conduct more complex analyses, such as a spatially explicit threats assessment or the creation of a habitat viability map.

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Ecosystems Gap Analysis in Paraguay

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Introduction

Signatories to the Convention on Biological Diversity (CBD) are required to undertake a gap analysis of biodiversity protection by December 2006, as mandated the CBD's Seventh Conference of Parties (COP) (Dudley 2006).

Gap analysis requires the assembly of information that can be difficult to obtain. This method of analysis, developed by the U.S. Geological Survey (USGS), Gap Analysis Program (GAP) (Scott et al. 1993), is based on three kinds of data: land cover, species distribution, and stewardship. In this article, we illustrate how we conducted a rapid gap analysis of ecosystems in Paraguay.

Paraguay, especially the Ministry of Environment, has limited data on native species for use in a gap analysis. Because the data are so limited, we developed a rapid gap analysis based on ecosystems and protected wildlife areas included in the Protected Wildlife Areas' National System (SINASIP) (CDC 1990), managed by the Ministry of Environment. The information generated will provide knowledge about protected and unprotected ecosystems in Paraguay and help direct resources and efforts toward effective conservation actions.

Association Guyra Paraguay (Guyra), the non-government organization (NGO) responsible for this gap analysis, has worked cooperatively with the USGS National Biological Information Infrastructure (NBII) for several years. The staff of Guyra, including ecologists, ornithologists, geoprocessing specialists, and others, have learned GAP's goals, objectives, and methods (Scott et al. 1993; Crist 2000).

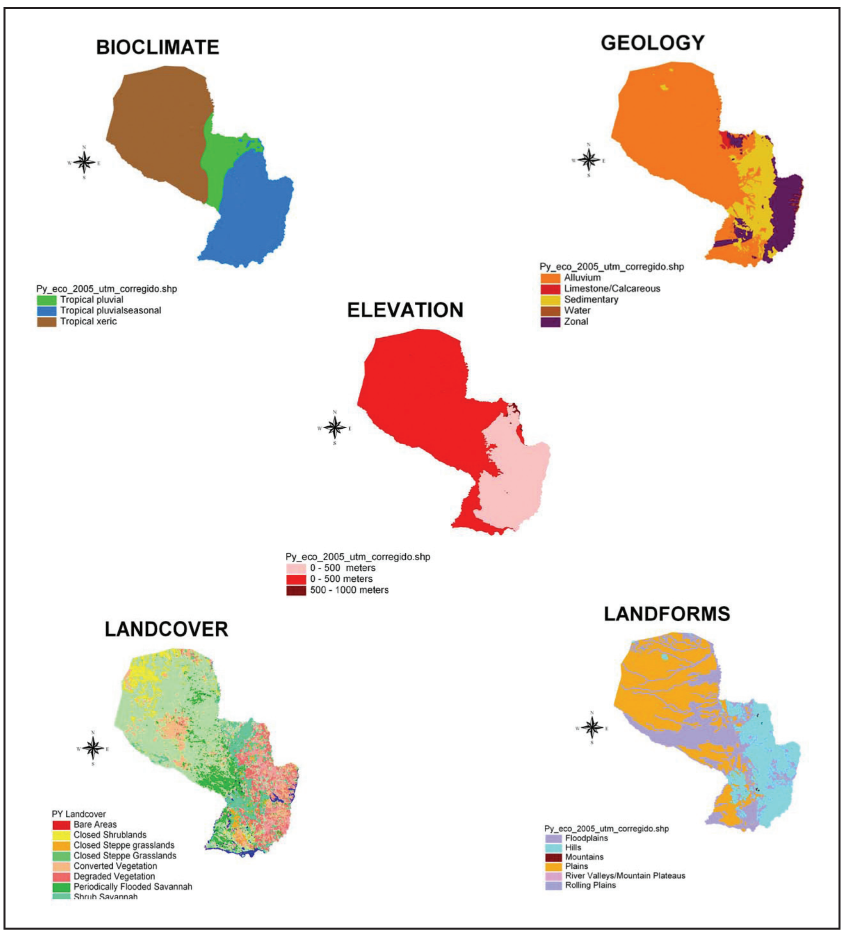

Figure 1. Data inputs used to map ecosystems.

Guyra conducted a gap analysis of 101 Paraguayan terrestrial ecosystems in the national protected area network, with financial support from GAP and technical support and training from the USGS Geographic Analysis and Monitoring Program. This project is part of the Global Integrated Trends Analysis Network (GITAN), a multidisciplinary network of collaborators interested in understanding the types, causes, and consequences of landscape and ecosystem change (Sayre 2005).

The major goal of this project is to provide an institutional framework for gathering data into a decision-support system, which will be targeted at Paraguayan government authorities and civil society organizations interested in biodiversity conservation and sustainable development.

Ecosystems protection will help conserve the species associated with these environments, as well as target species that are endemic, migratory, and endangered. Paraguay is a confluence of five ecoregions (Josse et al. 2003; Clay and Fragano 2005; Guyra Paraguay 2004): Cerrado, Pantanal, Dry Chaco, Humid Chaco, and Upper Paraná Atlantic Forest. The presence of these ecoregions in Paraguay makes it a rich biological region, at both the ecosystem and species levels.

We hope resource managers and public officials will use these data in their land use and land management decisions. In addition, with an increased understanding of the protection status of all Paraguayan species, Guyra can help establish an expanded network of refuges, parks, and other protected areas across the country using scientific information.

Project Goals

We set out (1) to conduct a gap analysis that documents the representation of Paraguayan terrestrial ecosystems in the national and private protected area network; (2) to enhance the access of Paraguayan government authorities and civil society organizations to geo-referenced data on biodiversity in protected areas; (3) to build capacity in Paraguay for conducting ecosystem analyses using systems that support decision making; (4) to demonstrate collaboration within GITAN by providing reliable information to share with researchers of other regions of the world; (5) to contribute toward international biodiversity conservation initiatives; and (6) to provide results in a report to GAP.

Methodology

Ecosystems were mapped as unique physical environments using data on land cover, elevation, landforms, geology, and bioclimate. Ecosystems data were provided for South America by The Nature Conservancy, NatureServe, and the USGS (Bow et al. 2005).

The geospatial database of Paraguayan ecosystems was obtained by clipping Paraguay's ecosystems from South America ecosystems data (Bow et al. 2005). This data layer was reviewed by Paraguayan experts in ecosystems, natural communities, and protected areas. They evaluated the accuracy of the information and determined its relationship with other databases in the country, such as existing land use maps at different scales and previously conducted studies. Experts also verified certain areas using a precise interpretation of vegetation cover through recent high-resolution satellite images provided by Landsat 5 and 7 sensors. This process was necessary to evaluate the quality of the basic ecosystems information in Paraguay.

Field technicians of Guyra Paraguay are also integrating an ecosystems verification protocol into ongoing field exercises across the country using the ecosystem map made by Bow et al. (2005) and adapted by Guyra Paraguay, in combination with recent satellite images, to verify information quality and to collect other data that can be used to get a better classification of the ecosystems. This field information has been georeferenced and used in the first basic analysis of spatial correlation between fauna elements and the database of ecosystem distribution.

During the analysis, ecosystem maps were overlapped with the SINASIP map to obtain the percentages of the ecosystem protected in the Protected Wildlife Areas' National System, and to determine the conservation status for each ecosystem in each protected area.

Results

There are 101 ecosystems[1] in Paraguay distributed among five ecoregions (table 1)[2].

Our analysis showed that 55 ecosystems out of the 101 identified are not protected. An additional 14 ecosystems (not including the above) are poorly protected, with less than 5 percent of their area under protection. Another 8 ecosystems have between 5 and 10 percent of their area under protection, and only 24 ecosystems are well protected, with more than 10 percent of the total surface area of the ecosystem in protected areas.

Conclusion

Our results were presented at the Eighth COP in Curitiba, Brazil, in March 2006. Although preliminary, our results were well received because they provided information to the decision-

Table 1. Number of ecosystems identified for each ecoregion in Paraguay.

Ecoregion	Area of ecoregion (hectares)	Percentage of Paraguay area	Number of ecosystems
Dry Chaco	17,484,326	42	41
Humid Chaco	12,858,489	32	33
Upper Paraná Atlantic Forest	8,591,121	21	11
Cerrado	819,101	2	11
Pantanal	198,494	1	5
Other areas	723,669	2	
Total	40,675,200	100	101

[1]Ecological system formed by the interaction of individuals and its environment.

[2]Group of natural communities geographically delimited that shares ecological process (Dinerstein et al. 1995).

makers in government and civil society who are working to protect and sustainably manage Paraguay's ecosystems within protected areas.

Our intent is to improve our products by collaborating with local and international experts and by incorporating information from other maps and reports available for Paraguay. Field validation of a minimum of five sites per ecoregion will continue for several months. The initiative will end in a standardized database that will be compatible with regional and global ecosystems maps and will be served through the GITAN Data Toolkit <http://rockyitr.cr.usgs.gov/gitan/>.

We believe other countries could also conduct gap analyses using ecosystems and we are open to inquiries from interested institutions.

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Developing a Scientifically Rigorous Framework for Enhancing and Evaluating Vertebrate Models

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Introduction

The Southeast Regional Gap Analysis Project (SEReGAP) is exploring the potential for enhancing GAP vertebrate models to address specific needs of the conservation community. Our goal is to develop a framework for modeling accurate and precise estimates of habitat suitability, population sizes, and viability for multiple priority species at a small spatial grain (e.g., 1 ha) over large regions (i.e., multiple states).

A pilot project (Williams and McKerrow 2005) has resulted in a scientifically rigorous foundation for these spatially explicit predictions. Specific activities have focused on:

- reclassifying land cover maps into avicentric classes;
- developing an extensive database of spatially explicit species-habitat-population relationships;
- developing toolboxes for fitting predictive models;
- conducting sensitivity analyses to determine which species distribution model inputs have the greatest influence in predicting species' occurrences areas;
- locating and integrating existing bird survey records from multiple sources into a spatially explicit database;
- extrapolating bird species occurrences using occurrence data and inductive modeling techniques; and
- validating SEReGAP occurrence and suitability models.

Pilot project objectives and a list of focal species were established at a meeting in Asheville, NC. Meeting participants included regional researchers, managers, and bird species experts. It was decided to limit the pilot study region to the portion of the Appalachian Mountains Bird Conservation Region falling within North Carolina and to focus on six forest bird species to reduce computer-processing time and streamline the pilot project. Focal species included those listed as a conservation priority by Partners in Flight (Rich et al. 2004). Because most disturbances in the study region are typically associated with forest loss or conversion due to timber harvesting and residential development, particular species were selected whose habitat associations differed within a wide range of forest ages and composition. Focal species included Acadian flycatcher (*Empidonax virescens*), golden-winged warbler (*Vermivora chrysoptera*), hooded warbler (*Wilsonia citrina*), scarlet tanager (*Piranga olivacea*), worm-eating warbler (*Helmitheros vermivorus*), and yellow-breasted chat (*Icteria virens*). Once suitability models are developed for the pilot species in the mountains of North Carolina, the methods will be applied to these and other species over the entire SEReGAP region.

Avicentric Classes

Landscape analyses of species-habitat associations should be conducted using maps representing functional differences in how focal species perceive and respond to landscape composition and structure (Morrison et al. 1998; Wiens et al. 2002). For this reason, U.S. Fish and Wildlife Service biologists generated a list of avicentric land cover classes to spatially partition the southeast region based on published habitat descriptions and commonly used terms. The avicentric classes were cross-walked to various vegetation maps including National Land Cover Data (NLCD) (Homer et al. 2004). Existing vegetation maps, however, are not expected to provide the classification precision and predictive accuracy of soon-to-be-released detailed GAP vegetation maps based on NatureServe ecological systems (Comer et al. 2003). During the interim, avicentric classes were mapped for the study region using a combination of two available data layers: we intersected NLCD classes with 13 terrestrial landform classes. The resulting groups were aggregated and/or reclassified into avicentric classes (figure 1).

Literature Review Database

SEReGAP has developed a new method for documenting literature reviews by multiple persons that creates synergy from their activities through the use of a relational database. Research details recorded in the database are spatially and temporally explicit and divided into modular units. Each record can therefore be queried for information describing a study's date, location, method of data collection, species studied, land cover types, and landscape relationships (e.g., patch size, distance to water), as well as qualitative descriptions of habitat suitability and quantitative demographic parameters (e.g., density, daily nest survival) under those conditions. Efforts are currently under way to make the database forms and queries available online so that ecologists can work together to limit redundant efforts and build a robust repository of research result descriptions for macroecological investigations and predictive modeling.

Predictive Model Toolboxes

Spatial models based on habitat affinities derived from the literature review database and expert review are being created for

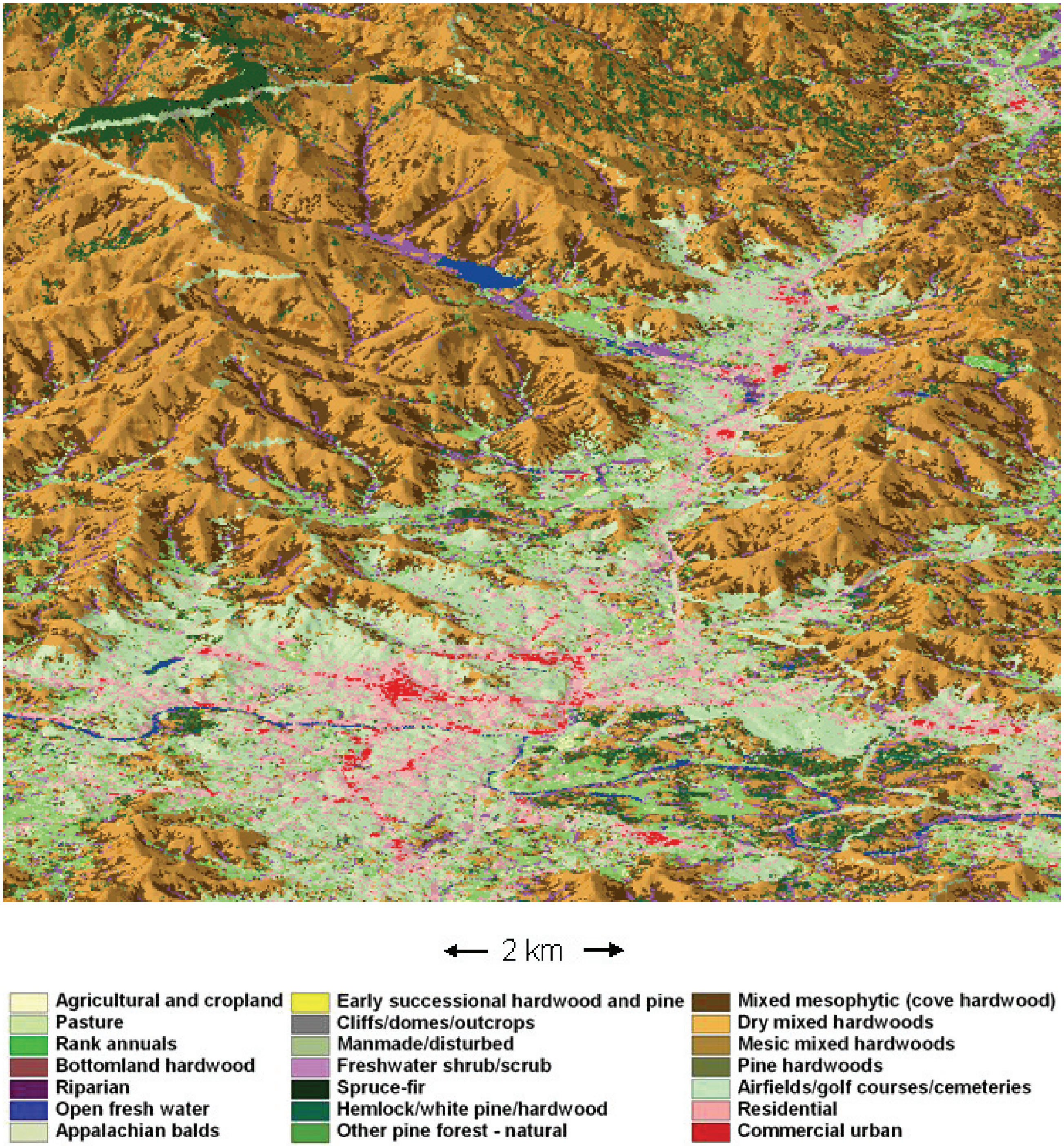

Figure 1. 3-D projection of avicentric land cover classes in the Asheville region of North Carolina. Pixels are 30 m x 30 m.

each of the priority bird species. The models consist of multiple map algebra expressions defined within ArcGIS 9.0 toolboxes (Environmental Systems Research Institute, Inc., Redland, CA). Similar to the methods presented by Larson et al. (2003), data layers used to predict presence/absence of species in traditional Boolean gap models are scored by suitability levels ranging from 0 to 1. Suitability scores will be determined through an evaluation of relevant research results summarized in the literature review database mentioned above. For example, if a species is predicted as present given a particular land cover class and distance to water, both of these inputs are scored from 0 to 1. Scores are based on a review of the species' response to these conditions in terms of standardized variations in density, nesting success, predation rates, and so forth. Categorical variables (i.e., avicentric classes and their categorical modifiers) are ranked as a discrete score. The suitability of continuous variables (e.g., elevation, patch size, distance to water) are fit to one of many possible response curves. The ranked data layers are then combined using habitat suitability modeling techniques (see Larson et al. 2003) to describe spatial gradients of habitat suitability for focal species across the study region.

Sensitivity Analysis

Each ranked data layer included in habitat suitability models will be assessed for its influence on modeled occupancy areas. For example, if a species is known to occur within 100 meters of water, then this occupancy rule will be tested for its independent contribution to the total area classified as species presence by the model. Independent contributions of each model parameter will be summarized for all species to identify parameters that are commonly making large contributions to model predictions. Similarly, data layers that show no significant contribution to the model's predictions can be dropped, thereby reducing the overall complexity while retaining a similar level of accuracy.

Locate and Integrate Data

To validate SEReGAP presence/absence maps and create a repository of data for the development of more sophisticated data-driven models, occurrence data are being collected and organized for the priority species throughout a three-state area (North Carolina, South Carolina, and Georgia). Data sources so far include the North Carolina Wildlife Resources Commission, the National Park Service, state breeding bird atlases, the U.S. Geological Survey's Breeding Bird Survey, Natural Heritage Programs' element occurrences, the U.S. Forest Service R8Bird data, the Monitoring Avian Productivity and Survivorship program, museum records, and any other digital data sets that may become available. These diverse data are imported into a relational database to derive spatially and statistically appropriate data sets for creating and validating models.

Inductive Modeling

Several powerful techniques have recently become available for extrapolating wildlife distribution patterns using relationships between locations where species have been observed and mapped environmental conditions at those locations. Important predictors for individual species can be identified by several methods, including principal components analysis, hierarchical partitioning (Mac Nally 2002), and classification and regression tree analysis (CART) (De'Ath and Fabricius 2000), as well as expert opinion. Using these new modeling techniques, locations that have not been surveyed will be labeled for species presence or absence based on their "similarity" to locations within the survey data repository. However, the model algorithms differ in how "similarity" is defined, as well as in their predictive accuracies and in the interpretability of the mechanisms behind the predicted patterns.

For these reasons, SEReGAP will investigate the appropriateness of these techniques under different conservation objectives. Depending on data availability, some species will be selected for model development and evaluation. Only species with adequate data quality, quantity, and dispersion throughout the study area will be modeled. However, the "gap" in data availability for other species will be noted as a future research priority. Several inductive modeling techniques may be explored for each species, including DOMAIN (Carpenter et al. 1993), PHASE1 (Laurent et al. 2005), multiple logistic regression, CART, and maximum entropy (Phillips et al. 2004). Each of these techniques has advantages and disadvantages that could make it suitable for a particular species or data set. In addition, multiple models may be used for each species, providing a more robust evaluation of habitat suitability, including the possible use of deductive rules, such as land cover use.

Model Validation

Species occurrence records from the survey data repository will be used to validate suitability and inductive models. Because the occurrence records were obtained using different sampling methods over various spatial scales, the data will be stratified into multiple categories and each category will be used to validate predictions in different ways. For example, species occurrences within a 100-m radius point count surveys will be compared to occurrence predictions and/or suitability estimates summarized over a spatially representative area.

Conclusions

The utility and popularity of the GAP mapping products that have been developed are matched by the chorus of calls for more products of greater detail and information content. This pilot project responds to those calls by developing a scientifically rigorous foundation for enhancing the utility of GAP vertebrate models. Regional habitat suitability relationships and maps for a subset of priority species could better inform resource managers when they are prioritizing areas for conservation activities. Sensitivity analysis will help refine the predictions, while existing data sources will be used to evaluate their accuracy and posit new hypotheses of species-habitat relationships. Furthermore, we approach the mapping of habitat suitability as an intermediate step toward more difficult predictions of population size and viability across large regions.

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Appendix. Avicentric classes developed by U.S. Fish and Wildlife Service biologists for describing functional landscape heterogeneity in the southeastern United States for landbirds.

Avicentric Classes	Level 1	Level 2	Level 3	Code
Eastern grasslands	I			10000
Tamaulipan prairie	I	A		10100
Tall grass	I	B		10200
Meadows/Florida and Georgia prairies	I	C		10300
Agricultural and cropland	I	D		10400
Pasture	I	E		10500
Rank annuals	I	F		10600
Freshwater wetland communities	II			20000
Non-forested	II	A		20100
Freshwater emergent marsh	II	A	1	20101
Bogs/fens/ephemeral wetlands	II	A	2	20102
Mudflats/sandbars	II	A	3	20103
Forested	II	B		20200
Bottomland hardwood	II	B	1	20201
Cypress-tupelo	II	B	2	20202
Atlantic white cedar	II	B	3	20203
Pocosin/Carolina bays	II	B	4	20204
Riparian	II	C		20300
Open fresh water	II	D		20400
Eastern shrub-scrub	III			30000
Xeric Florida scrub	III	A		30100
Tamaulipan scrub	III	B		30200
Interior cedar/pine/oak barrens and glades	III	C		30300
Appalachian balds	III	D		30400
Early-successional hardwood and pine	III	E		30500
Cliffs, domes, outcrops	III	F		30600
Manmade/disturbed (e.g., hedgerows, ROWs, old fields)	III	G		30700
Freshwater shrub/scrub	III	H		30800
Coastal communities	IV			40000
Maritime shrub/scrub	IV	A		40100
Maritime forest	IV	B		40200
Chenier/oak motte	IV	C		40300
Estuarine emergent marsh	IV	D		40400
Beaches and dunes	IV	E		40500
Tidal mudflats	IV	F		40600
Coastal prairie	IV	G		40700
Mangroves	IV	H		40800
Pine communities	V			50000
Pine flatwoods	V	A		50100
Pine savanna	V	B		50200
Xeric pine scrub	V	C		50300
Pine plantations	V	D		50400
Other pine forest	V	E		50500
Other pine forest - natural	V	E	1	50501

Avicentric Classes	Level 1	Level 2	Level 3	Code
Pine sandhills	V	F		50600
Upland hardwood/pine hardwood communities	VI			60000
Spruce-fir	VI	A		60100
Northern hardwood	VI	B		60200
Mixed mesophytic (cove hardwood)	VI	C		60300
Hemlock/white pine/hardwood	VI	D		60400
High elevation oak/oak-pine	VI	E		60500
Mixed hardwoods	VI	F		60600
Dry mixed hardwoods	VI	F	1	60601
Mesic mixed hardwoods	VI	F	2	60602
Pine hardwoods	VI	G		60700
Oak-cedar	VI	H		60800
Oak savanna	VI	I		60900
Hardwood plantation	VI	J		61000
Tropical hardwoods	VI	K		61100
Pelagic	VII			70000
Continental shelf	VII	A		70100
Deep open water	VII	B		70200
Gulf stream	VII	C		70300
Cities/towns/suburbs	VIII			80000
Residential	VIII	A		80100
Commercial urban	VIII	B		80200
Airfields/golf courses/cemeteries	VIII	C		80300
Additional classes	IX			90000
Quarries/strip mines/gravel pits	IX	A		90100

Partnerships Fostered by the Multi-Resolution Landscape Characteristics Consortium: EDC, GAP, and NOAA C-CAP Come Together on Land Cover Mapping

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The timing for initiating the Southeast Regional Gap Analysis Project (SEReGAP) provided a unique opportunity for collaborating with the Earth Resources Observation and Science (EROS) Data Center (EDC) and the National Oceanographic and Atmospheric Administration's Coastal Change Analysis Program (NOAA C-CAP). While the federal agencies involved in the Multi-Resolution Landscape Characterization Consortium (MRLC) have been working together for years toward the common goal of the National Land Cover Datasets (NLCD) (both 1992 and 2001), the collaboration involved image acquisition and supported mapping efforts through research and development, funding, and an advisory role. For the NLCD 2001, the areas of common interest were expanded with the adoption of the NLCD 2001 land cover classification as the basis for the general land cover classes for both SEReGAP and C-CAP.

In 2003, SEReGAP agreed to actively partner with the U.S. Geological Survey (USGS) on the mapping of the general land cover classification using the NLCD 2001 protocol. The collaboration benefited GAP in two ways: it ensured the timely delivery of image mosaics of the Landsat Thematic Mapper imagery for the mapping zones within the region, a protocol for general cover classes that would guarantee a common framework with neighboring regions, and it provided for two products, impervious surface and canopy closure, that would help in mapping detailed land cover, as well as in habitat modeling. In turn, the NLCD 2001 gained a partner to anchor a relatively large region of the United States early in the database-development process. In addition, with GAP involvement in Alabama, Georgia, and North Carolina, NLCD gained local expertise about the patterns of land cover throughout the Southeast.

Just prior to SEReGAP's adoption of the protocol, C-CAP expanded their commitment to working with MRLC to develop a common framework that would meet the programmatic needs of both C-CAP and NLCD 2001. A major step toward that framework was an agreement to adopt a common map legend with the incorporation of standard wetland classes for the coastal portions of the NLCD 2001. Once the coastal legend was adopted, SEReGAP agreed to incorporate the additional wetland classes for two of the coastal zones (zones 55 and 58). The added wetland classes, while requiring extra effort to map, provided GAP with a common framework on which to base the ecological systems mapping in the coastal region. For those two mapping zones, C-CAP is now using the NLCD 2001 land cover developed by SEReGAP as one of the end points in their coastal change analysis for those zones.

This cooperative work in the Southeast is just one example of the strength and commitment of the many partners involved in the MRLC. In this case, by fostering collaboration, the MRLC has had a positive impact on three key land cover mapping programs: the Land Cover Characterization through the NLCD 2001, the Gap Analysis Program through the work of SEReGAP, and C-CAP.

APPLICATIONS

Current Applications of Southwest Regional Gap Analysis Project Data: A Summary from the 2005 National Gap Analysis Program Conference

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Introduction

Part of the mission of the Gap Analysis Program (GAP) is to facilitate the application of GAP data and information to land management activities. To do this, GAP strives to make all project information available to the public and those individuals charged with land use research, policy, planning, and management.

The Southwest Regional Gap Analysis Project (SWReGAP) has been providing provisional data to the public for use pending final data and report completion. Feedback from a variety of users is demonstrating how SWReGAP data is being applied to various natural resource issues in the southwestern United States. Current and planned applications are summarized below.

Applications of Land Cover Mapping Data

Provisional land cover data are currently being made available by the regional land cover mapping lab at Utah State University <earth.gis.usu.edu/swgap/>. Land cover data and related data sets, such as landform, geology, mapping zone boundaries, and training site data, are available. As of May 2006, 313 users had registered before downloading the provisional data. Federal agencies represented the largest group of registered users (46 percent). Department of the Interior agencies using the data included: the Bureau of Land Management (BLM), U.S. Fish and Wildlife Service (USFWS), National Park Service (NPS), U.S. Geological Survey (USGS), U.S. Bureau of Reclamation (USBR), Office of Surface Mining and Reclamation, and Bureau of Indian Affairs (BIA). Other federal agency users include the U.S. Department of Agriculture Forest Service (FS), Natural Resources Conservation Service (NRCS), U.S. Army Corps of Engineers, and U.S. Environmental Protection Agency (U.S. EPA). In addition, commercial (12 percent), nonprofit (12 percent), state agencies (11 percent), and other organizations (19 percent) were identified as user groups. Tribal natural resource professionals, universities, and local governments are included in the “other organizations” user group.

Approximately 59 percent of users were interested in subsets of regional data, while 41 percent were interested in using the entire five-state regional data set. The top four uses of the data were: (1) research and education; (2) resource/land use planning and management; (3) inventory and reference; and (4) habitat assessment and modeling. Fire/fuels assessment modeling and watershed/hydrological modeling and assessment were also mentioned as important uses of land cover mapping data. In addition, users noted that land cover data would support archaeological studies, environmental analyses for border protection activities, the representation of mine areas and surrounding landscapes, and the evaluation of impacts of energy development operations on ecosystems (Lowry et al. 2005).

Ecoregion Delineation

Since 1994, U.S. EPA researchers have collaborated with other federal agencies and states to refine Level 3 ecoregions and develop larger-scale, Level 4 ecoregions on a state-by-state basis. U.S. EPA has noted that these efforts are greatly aided by coordinated, multistate databases such as SWReGAP because land use and land cover data are important components of ecological regions.

In Colorado, SWReGAP data were used to modify drafts and final versions of Level 3 and 4 ecoregions. In 2004 field verification to examine ecoregions and boundaries used SWReGAP land cover data overlaid by ecoregion boundaries, the road network, and global positioning system (GPS) tracking to help with boundary revisions and explain variations in characteristics from region to region. Colorado GAP principal investigator Don Schrupp was able to participate in this field verification, viewing many miles of the classification accuracy of land cover data. Final ecoregions of Colorado were much improved by the use of SWReGAP data. These data also helped with the listing of vegetation and land cover in the table of characteristics.

In New Mexico, the use of SWReGAP land cover data in ecoregion mapping was facilitated by Ken Boykin and Scott Schrader of SWReGAP. Both New Mexico GAP and SWReGAP data were examined in developing the initial draft of New Mexico ecoregions, mapped at 1:250,000 scale. Draft ecoregion boundaries were plotted on a statewide map of SWReGAP land cover for the ecoregion review meeting, exhibiting the close relationship between land cover, ecoregions, and boundaries. Scott Schrader also participated in the statewide ecoregion field trip to help develop the final draft map.

Ecoregions of Nevada and Utah were completed before SWReGAP data were available, but the U.S. EPA plans to use SWReGAP data for ecoregion mapping in Arizona. The data were also valuable in a recent effort to join some Level 3 boundaries with Mexico in a project with the Commission for Environmental Cooperation to revise North American ecoregion maps (G. Griffith, U.S. EPA, personal communication).

Fire and Watershed Ecology Applications

BLM state fire management officers from Utah and Nevada were tasked with developing a map of fire regimes and condition classes (FRCCs) for their lands. They used SWReGAP land cover data to categorize vegetation layers into FRCCs. The 30-meter-resolution FRCC maps provide a strategic look at the degree of departure from historical fire regimes. The resulting analysis will assist in fire management planning and with establishing hazardous fuels project priorities. A joint statewide map for Utah and Nevada will promote consistency in fire management planning and in actions across state lines (Sheffey and Pollet 2005).

LANDFIRE, also known as the Landscape Fire and Resource Management Planning Tools Project, is a five-year, multipartner wildland fuels and fire regime mapping project. The mapping of existing vegetation and structure is an important component of LANDFIRE, and SWReGAP field data were used to train decision-tree models for the project (Kost 2005).

The Nature Conservancy (TNC) in Arizona recently presented a map of historic fire return intervals (FRIs), pre-European settlement (1890), for Arizona and New Mexico. FRIs describe the number of times that fire has occurred within an area. TNC aggregated 98 land cover types from SWReGAP data into 21 potential natural vegetation types (PNVTs). The PNVTs were based on similar land cover type descriptions, locations within mapped boundaries of current and historic vegetation, and on-the-ground knowledge of TNC ecologists. Historic FRIs were then assigned to each PNVT based on current scientific literature. The historic FRI map was used to conduct analyses of FRIs by land tenure using SWReGAP stewardship data and USFS Region 3 forest boundaries. Results showed that 64 percent of land within state boundaries falls into high or moderate frequency FRI classes. A majority of high-frequency class PNVTs occur on federal lands, with the FS managing the largest proportion (48 percent). These results will be useful to land managers responsible for fire management and restoration activities in Arizona and New Mexico (Schussman et al. 2006).

The USDA-Agricultural Research Service, the U.S. EPA, and the University of Arizona have developed a geographic information systems (GIS) tool to facilitate modeling runoff at different spatial and temporal scales. The Automated Geospatial Watershed Assessment (AGWA) tool is a GIS interface designed to input digital land cover information, to automate the parameterization and execution of the Soil Water Assessment Tool and KINEmatic Runoff and EROSion (KINEROS2) hydrologic models, and to spatially display model results for evaluating watershed conditions. SWReGAP land cover data were used in the AGWA tool for watershed assessment (Hernandez et al. 2005).

Other Applications

The Nevada Natural Heritage Program used 17,000 plots of SWReGAP ground data to map invasive annual grasses across Nevada. These data provided a large number of plots and vegetation data collected for an independent project. SWReGAP data may also be used for accuracy assessment (Peterson 2005).

The Sagebrush Vegetation Mapping Project, an effort of the USGS and Oregon State University, mapped sagebrush and steppe vegetation in the western United States. SWReGAP data were integrated with data from other vegetation mapping efforts in the region. Mapping was based on map zones used in the SWReGAP effort (Kagan et al. 2005).

The Grand Canyon Wildlands Council used SWReGAP land cover data to analyze the distribution of more than 70 ecosystems that provide habitat for 2,577 plant and animal species in the Grand Canyon ecoregion (GCE). They found that current land management practices do not protect all ecosystems in the region. GCE scrublands on the southern Colorado Plateau are among the most extensive ecosystems, but only 3.4 percent exist in core protected areas. Wetland, riparian, and springs habitats are rare and support relatively high levels of sensitive species, but only 5 percent of springs habitats and only 9 percent of riparian habitats lie in protected core areas (Burke et al. 2005).

Applications of Other SWReGAP Data Sets

State Wildlife Action Plans

In Nevada, land cover data were used to organize and present the State Wildlife Action Plan (SWAP). Seventy-four ecological systems mapped by SWReGAP were aggregated into 27 key habitat types. Conservation strategies were then developed for these key habitat types. Stewardship data were used to analyze patterns of land use and facilitate a summary and spatial depiction of land owners and managers for key habitats in the state. For example, the intermountain rivers and streams habitat was determined to have the following landowner/manager composition: private 56.7 percent, BLM 18.6 percent, FS 18.6 percent, tribal 3.8 percent, and other 2.3 percent. Since the data are regional, Nevada will be able to collaborate with Arizona and Utah on their conservation strategies (Abele et al. 2005).

New Mexico's SWAP used SWReGAP data for a variety of purposes. Species of greatest conservation need (SGCN) were associated with land cover types, thus providing expert review for SWReGAP habitat models while also providing a method to identify key habitats for the SWAP. The stewardship layer provided the most current spatial stewardship information for the state and was used in combination with other data layers to provide an assessment of conservation prioritization. In Colorado, SWReGAP wildlife habitat relationship (WHR) models were used to identify key habitats for SGCN, while also comparing those key habitats identified by the previous Colorado GAP effort. During the mammals session of the Colorado Comprehensive Wildlife Conservation Strategies Science Forum, the "online" SWReGAP vertebrate modeling outputs were accessed to provide regional landscape perspectives in the identification of key habitats and species distributions (Young et al. 2005).

SWReGAP data will benefit future regionalization of SWAP efforts by providing: (1) regionally consistent spatial data layers for modeling purposes; (2) a landscape-level model repository; and (3) a test-bed for inductive/deductive model comparisons. In addition, when considering SGCNs that are common across all five state strategies, the regional data set will provide an opportunity to develop shared strategies to effect species conservation across state boundaries. The spatial habitat models, when used in conjunction with the stewardship mapping data layer, can also help identify the need for and the benefits of "partnered" strategies for conservation. The regional nature of SWReGAP data sets complements the ecoregional frameworks described in many of the state strategies (Schrupp and Boykin 2005).

County-Level Conservation Planning

A project is under development with Clark County, NV, to provide data for their Multi-Species Habitat Conservation Plan (MSHCP). SWReGAP is proposing to provide predicted habitat distributions for 37 amphibians, reptiles, birds, and mammals addressed in the MSHCP. These distributions could be improved for Clark County and the surrounding Mojave Desert region by incorporating additional information that was not used in SWReGAP (e.g., Soil Survey Geographic [SSURGO] soils data, Nevada Breeding Bird Atlas) and by using known locality records and local knowledge. These improved distributions would be useful in planning surveys of selected species. These surveys would benefit Clark County in its evaluation of the status and distribution of species, and they would benefit SWReGAP by providing data to evaluate the accuracy of the original models (D. Bradford, U.S. EPA, personal communication).

Ecoregional Conservation Planning

The Southwest Region of USFWS is conducting ecoregional analyses to set goals and objectives for species populations and natural vegetation communities. They are using SWReGAP data to help determine which priority species and communities occur within permanently conserved areas. The stewardship data set has already helped set coarse-filter conservation objectives for natural communities in the Lower Colorado River watershed. These data will be used for a similar process in the Middle and Upper Rio Grande watersheds (R. Dietz, USFWS, personal communication).

An example of a species habitat objective using SWReGAP data can be described as follows: Maintain enough hectares of Bell's vireo (BEVI) habitat in GAP status 1 and 2 lands within the study area to support a population of 21,935 individuals. Add 14,986 hectares of BEVI riparian habitat to GAP status 1 and 2 lands to support an estimated population of 1,123 individuals; habitat patches of at least 27.6 hectares are suggested. Add 90,402 hectares of BEVI upland habitat to GAP status 1 and 2 lands to support an estimated population of 20,315 individuals; habitat patches of at least 8.9 hectares are suggested (Dietz and Stockenberg 2005).

Forest Stewardship Program

The Forest Stewardship Program (FSP) was established under the 1990 U.S. Farm Bill to encourage nonindustrial private forest land owners to take a more active approach to managing their forests and related resources. The goal is to enhance the long-term stewardship and conservation of private forest lands. The Utah Division of Forestry, Fire, and State Lands worked with the Remote Sensing/GIS Lab at Utah State University to incorporate SWReGAP stewardship and land cover data into the FSP Spatial Analysis Project in Utah. The data were used to identify privately owned forested and nonforested open space that could potentially benefit from the FSP (Langs et al. 2005).

Wind Energy Development

Recently land and wind resources on the Navajo Reservation were analyzed to determine suitable land for wind energy development and potential wind energy capacity. Sustainable Energy Solutions (SES) of Northern Arizona University used SWReGAP data to assess wind energy development exclusions on Navajo lands. (See Brummels et al, "Navajo Wind Energy Development Exclusions," p. 38.)

In particular, three exclusion categories (urban/developed land, wetlands, and open water) were based on SWReGAP data. Previous studies were only able to use 1 km resolution data, but the resolution of SWReGAP data enabled SES to identify wetlands and small rural communities as exclusion areas. Because wetlands provide an indication of potential bird habitat, excluding these areas from wind energy development addresses concerns about birds using areas near wind turbines. Highlighting the presence of small rural communities offers stakeholders an understanding of where people live on the land.

SES will be using SWReGAP stewardship data in their next study of wind energy development exclusions, which will cover the entire state of Arizona. SES believes the SWReGAP stewardship data will be important for increasing their understanding of wind energy development exclusions because many of the exclusion layers are based on ownership. Furthermore, the stewardship data contain the most current and accurate assessment of owners/stewards and will improve the overall quality of their work (G. Brummels, Sustainable Energy Solutions, Northern Arizona University, personal communication).

Conclusion

To date, federal and state agencies make up the majority of SWReGAP data users, and there is also some use by nonprofit, commercial, tribal, and academic groups. It will be important to promote GAP data use to these nonfederal/nonstate groups, who may not be as familiar with the data. Users want the ability to access both region-wide data and subsets of this data. While it has been crucial for GAP to begin developing regionally consistent data sets, it will also be necessary to provide access to state-level data.

Land cover data, WHR models, and stewardship data have been used for a variety of purposes, both as separate data sets and in conjunction with each other. In particular, land cover and stewardship data are often used together. At the state level, SWAPs have demonstrated the use of multiple GAP data sets to support species conservation planning. Users have also expressed interest in ancillary data sets from SWReGAP. For example, many projects noted the use of ground-truth data to support their own mapping efforts. GAP should continue to educate users about potential uses of the data sets, both individually and in conjunction with other GAP data sets. In addition, users should be informed of the variety of ancillary data sets that could be used in their own research and mapping efforts. To facilitate the application of SWReGAP data, it will be important to monitor current uses to gain a better understanding of how GAP can continue to educate the public about this vast data resource.

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GIS-Based Niche Modeling for Mapping Species Habitat

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Introduction

Ecological "niche modeling" combines species occurrence data and geographic information systems (GIS) environmental variables into a powerful tool for identifying and mapping suitable habitat for species over large spatial extents. We are currently developing and testing ecological niche models for use in conservation planning. We presented our partitioned Mahalanobis D2 modeling technique at the National Gap Analysis Conference in Reno in December 2005. This approach was originally developed by James Dunn, John Rotenberry, Steven Knick, and Lynette Duncan (Knick and Rotenberry 1998; Dunn and Duncan 2000; Duncan and Dunn 2001; Rotenberry, Knick, and Dunn 2002). A detailed description of the model and corresponding SAS code will soon be available for use by researchers (Rotenberry, Preston, and Knick 2006).

The Center for Conservation Biology (CCB) at the University of California, Riverside, is using this modeling approach to assist with conservation planning in southern California (Allen et al. 2005). In this article, we briefly describe the Mahalanobis D2 modeling approach and the basic steps involved in constructing our niche models. We discuss potential uses of niche models for conservation planning and for adaptive management and monitoring activities, using our current research as an example.

Conceptual Basis of the Partitioned Mahalanobis D2 Modeling Approach

The partitioned Mahalanobis D2 model is a multivariate statistical modeling approach that identifies a minimum (rather than an optimum) set of basic habitat requirements for a species. It is based on the assumption that it is the constant environmental relationships in a species' distribution (i.e., variables that maintain a consistent value where the species occurs) that are most likely to be associated with limiting factors. Environmental variables taking on a wide range of values over locations where a species occurs are less informative because they are not restrictive of a species' distribution.

Mahalanobis D2 is an index of habitat suitability that represents the standardized difference between the values of a set of environmental variables for any point and the mean values for those same variables calculated from all points where a species occurs. Smaller differences indicate a point lying closer to the overall mean, and imply more similar habitat to that generally occupied by the species. Dunn showed that Mahalanobis D2 could be partitioned into a set of independent, additive distances. This partitioning is achieved through principal components analysis of the set of variables measured at all points where the species occurs. Each component (linear combination of variables) describes a hyperplane; the eigenvalue of a component describes the variance in the distance of all the points from that hyperplane. Thus, the component ("partition") with the smallest eigenvalue represents the linear combination of variables for whom the variance of points at which the species occurs is at a minimum, and thus most likely represents the limiting factors we are looking for.

In contrast, increasingly higher components with greater eigenvalues are linear combinations of variables around which points have higher variances, and hence they are less likely to represent limits to distribution. For any point, the distances associated with each component are additive (principal components are independent) and overall components sum to the original Mahalanobis D2. Recognizing that more than one set of combinations could be limiting, we also examine the components with the second smallest eigenvalue, the third smallest, and so forth until variances become substantially larger.

A benefit of this technique is that inclusions of environmental variables unassociated with limits to a species distribution (and hence with high variances) have less impact on the model results. Likewise, by focusing on those components with minimal variance, we should be able to identify similar habitat outside of the spatial range sampled in the original study area and apply the model to new areas or to changing environments. By examining eigenvector values, we are able to identify which specific environmental variables seem important in determining a species distribution.

The Basic Components of Niche Modeling

In constructing our models, we create two related data sets. First, we compile a "species location" data set that includes geographic coordinates for each location where a species was detected. In contrast to presence-absence habitat modeling techniques, there is no need to determine where a species is absent. To determine that a species is absent requires specific data-collection methodologies and extensive survey effort, often involving repeated sampling. With presence-only modeling approaches, we can include data that come from a variety of sources and that have been collected with differing methodologies and levels of effort. Presence-only data sets can include species location information from museums, herbaria, government natural diversity databases, and experts in the field, as well as from more formal survey efforts.

Second, we develop a "map points" data set consisting of geographical coordinates of a grid of points overlaying the entire study area. In our own work, we use a grid spacing of ~ 250 meters between points, reflecting tradeoffs between the biology of the species being modeled, map precision, the area to be covered, and computational convenience. Using GIS we calculate the value of selected environmental variables for each map point in the study area and for each species location. We summarize environmental variables at both local (within 125 meters of the point) and landscape scales (within a kilometer of the point). Some of the GIS layers we use to derive our environmental variables include temperature, precipitation, digital elevation models, vegetation type, land use, soils, and hydrology.

Once environmental variables are calculated for each species point and for all map points, we are ready to construct our niche model. For each model, we include environmental variables we hypothesize a priori to be important to that species distribution. As a general rule, we use 10 observations per environmental variable in the model. We run the principal components analysis to create the partitions (this is, in essence, the model), and examine the distribution of eigenvalues to determine whether our final model should consist of the last component, the last two components, etc. We also examine eigenvector values to see which environmental variables are most closely associated with selected components. We then use the selected model to calculate Habitat Similarity Index (HSI) values for every grid point on the map. The HSI values represent on a scale of 0 to 1 how similar each point in the landscape is to the hyperplane that describes the limiting combination of variables where the species was originally detected.

Once a model is developed, it is tested to determine how well it predicts suitable habitat for the target species. One method of testing a model is to randomly withhold a subset of points from the species location data set when creating the model and to use this "validation" data set to evaluate model performance. A second, higher standard of testing is to use an independent data set specifically collected from areas where there is no location information for the species being modeled.

Application of Niche Models to Conservation Planning

CCB is currently revising and testing niche models for invertebrate, plant, reptile, bird, and mammal species conserved by Western Riverside County's Multiple Species Habitat Conservation Plan. The plan seeks to protect 146 sensitive plant and animal species in a rapidly urbanizing study area of ~ 490,000 ha. We are conducting fieldwork this spring to collect independent data sets to evaluate our models.

Figures 1–3 show untested, preliminary models for three sensitive bird species inhabiting coastal sage scrub habitats in the plan area. These models illustrate differences in suitable habitat even among species generally thought to co-occur within the same vegetation community. To facilitate conservation planning, we have used our niche models to develop "community" models. We overlay individual species niche models to create community models that predict the potential for lands to support multiple species of conservation interest. The community model is simply the sum of the individual HSI values for the s species being considered, and ranges from 0 to s. Figure 4 is a community model constructed for the three sensitive coastal sage scrub bird species illustrated in figures 1–3.

Once the models are tested, they will be used to identify suitable habitat for species of conservation interest and can be used to assist with the reserve assembly process. The models can be used to provide a preliminary assessment of candidate lands for acquisition and inclusion in the reserve system. They can also be used to quantify how well the reserve system has achieved species conservation goals in terms of the amount and configuration of suitable habitat conserved. An emerging use of niche models is to predict habitat suitability under changing environmental conditions resulting from global climate change, nitrogen deposition from air pollution and agriculture, and other anthropogenic processes. We can use these models to make predictions about how effectively reserve systems may be expected to conserve suitable habitat for sensitive plant and animal species in the future.

Once we have identified important relationships between environmental variables and species occurrences, we can use them to guide future research into habitat relationships and to develop adaptive management plans and prioritize management activities. Niche models of relevant species can be used to identify lands suitable for restoration of native vegetation or for the introduction of species of conservation interest. These models can also be used to identify lands vulnerable to invasion by nonnative plants and animals.

Conclusion

The partitioned Mahalanobis D2 modeling approach is a tool available to GAP projects to map suitable habitat for species and to predict community richness over large spatial areas. Niche models are powerful conservation tools, the uses of which are just in the early stages of development.

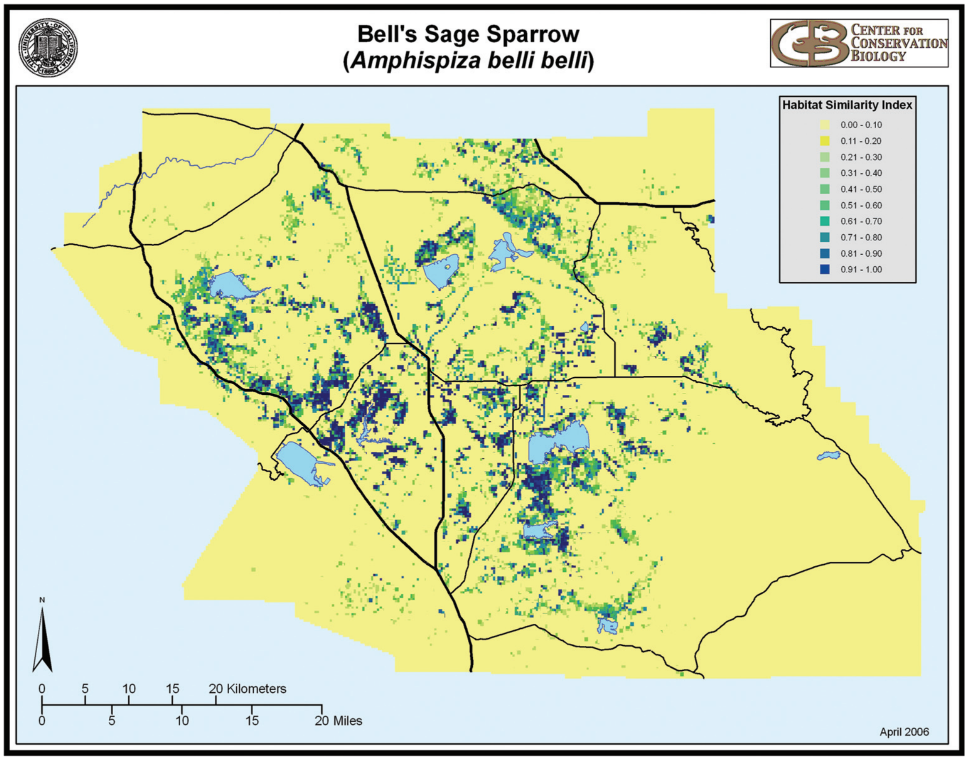

Figure 1. "HSIs" of habitat similarity for Bell's sage sparrow across the plan area: the higher the HSI, the greater the similarity between occupied habitat and other areas.

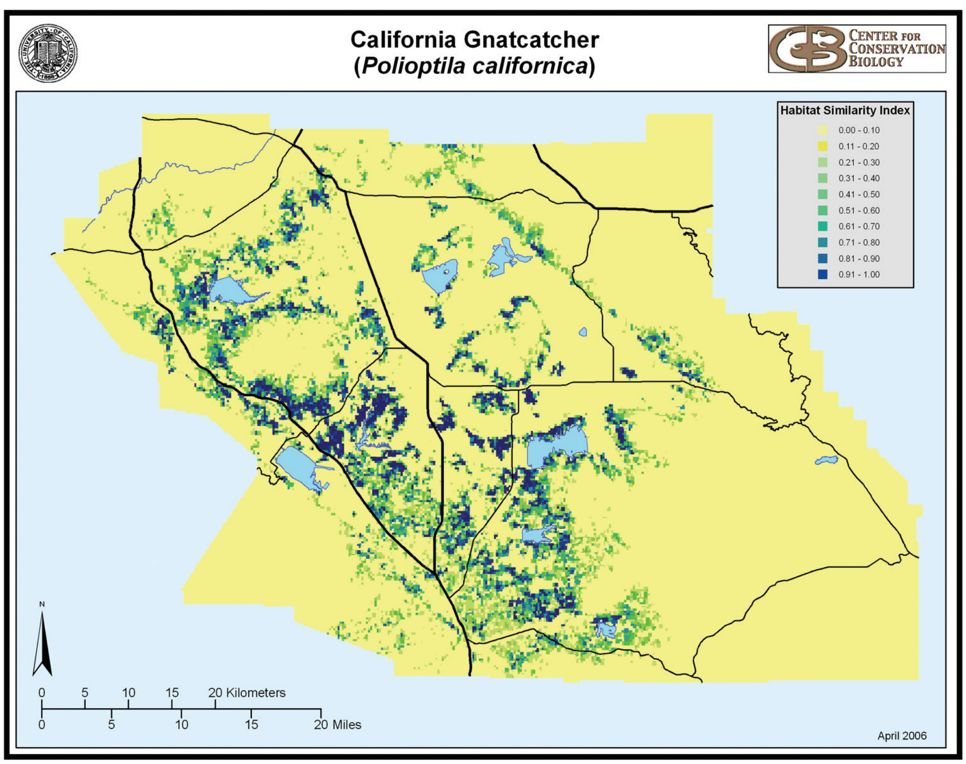

Figure 2. "HSIs" of habitat similarity for California gnatcatcher across the plan area: the higher the HSI, the greater the similarity between occupied habitat and other areas.

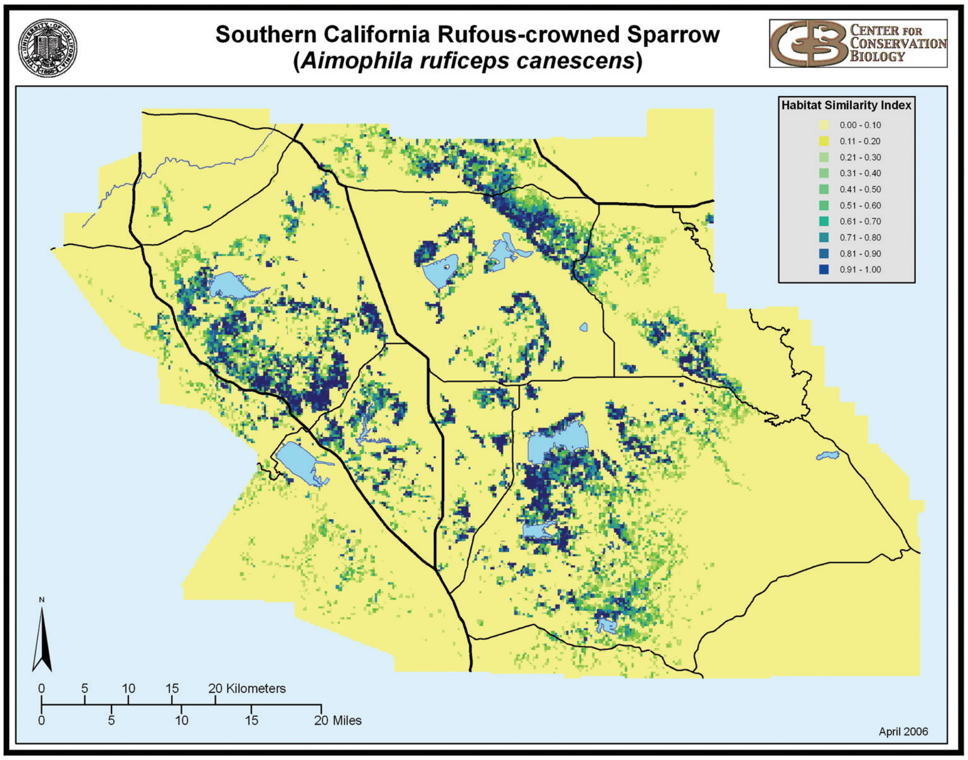

Figure 3. "HSIs" of habitat similarity for Southern California rufous-crowned sparrow across the plan area: the higher the HSI, the greater the similarity between occupied habitat and other areas.

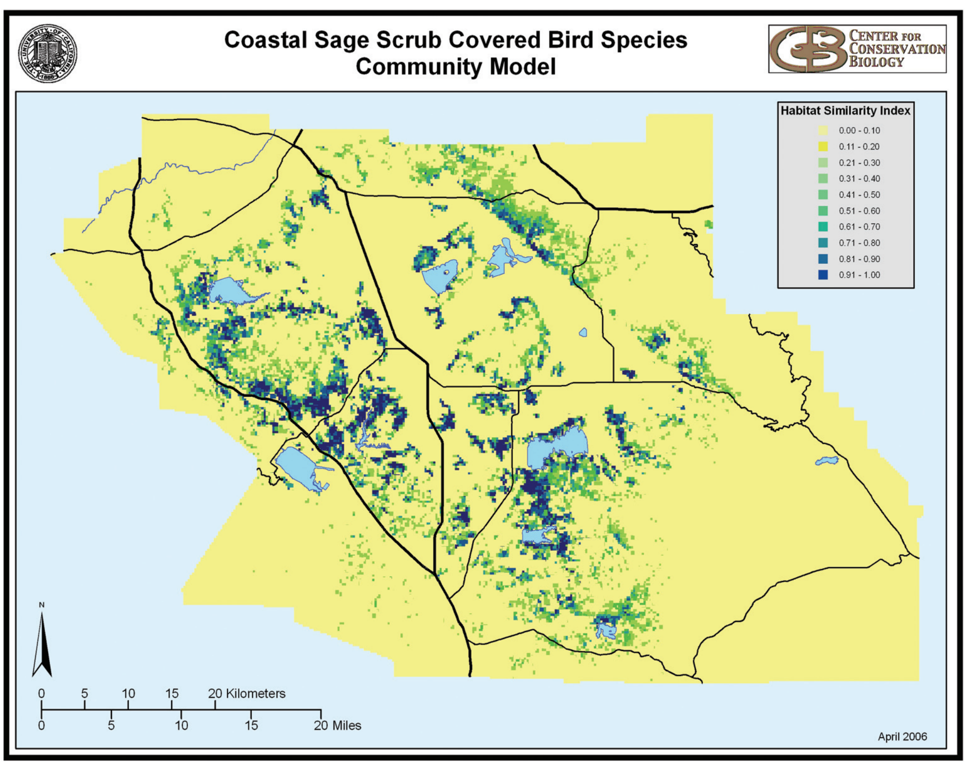

Figure 4. Cumulative habitat similarity index (HSI) values for four covered coastal sage scrub bird species across the plan area. The higher the cumulative HSI, the greater the predicted habitat suitability for multiple bird species. The map is from Allen et al. (2005).

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Application of Southwest Regional GAP Data to the Forest Stewardship Program's Spatial Analysis Project in Utah

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Background

Nearly 45 percent of the nation's forests (354 million acres) currently fall within nonindustrial private ownership, providing valuable timber resources, wildlife habitat, watershed protection, and recreational opportunities that benefit not only the landowner, but society as a whole (USDA Forest Service 2005). Authorized by the Cooperative Forestry Assistance Act of 1978, the Forest Stewardship Program (FSP) was created to promote sustainable forest practices among the nation's nonindustrial private forest sector (USDA Forest Service 2005). To encourage landowners to actively manage their forested lands, state forestry agency partners provide financial incentives and technical assistance through the development of individual forest stewardship plans.

An important challenge faced by the FSP, however, is the ability to assess the effectiveness of existing stewardship plans and determine where future efforts would have the greatest impact in terms of statewide objectives (WFLC 2004). A recent improvement to the FSP has been the development of the Spatial Analysis Project (SAP) and related decision-support tools (WFLC 2004). SAP involves a geospatial approach using a suite of common geographic information systems (GIS) data layers in a modeling environment that provides state foresters with a standardized, yet flexible tool to (1) monitor existing stewardship plans; (2) provide systematic statewide assessments of "priority" forests; and (3) account for the connectivity of FSP efforts in the context of the existing network of conservation lands (WFLC 2004).

The Utah Division of Forestry, Fire, and State Lands (UDFFS) has long been a partner of the FSP and as part of the second rollout of SAP, it was requested to develop a SAP for Utah. With the timely completion of the Southwest Regional Gap Analysis Project (SWReGAP) and a host of several newly created regional data sets for Utah, Arizona, Colorado, New Mexico, and Nevada, UDFFS decided to employ SWReGAP data in their SAP effort.

The Spatial Analysis Project for Utah

The primary objective of SAP is to identify specific locations of privately owned forested lands that are rich in natural resources (e.g., a water source, threatened or endangered species), that are associated with minimal threats (e.g., low fire risk, minimal development potential), and that adequately contribute to statewide conservation of forested areas (WFLC 2004). SAP functions as an FSP suitability analysis to locate the areas with the greatest potential to benefit from FSP practices. UDFFS contracted with the Remote Sensing (RS)/Geographic Information Systems (GIS) Laboratory at Utah State University to prepare the required data sets and develop the structure behind the SAP models. UDFFS will apply their expert opinion to adjust any parameters and decide on the final map output.

Data Needs and SWReGAP Data Applicability

Fourteen data layers are common to all SAPs (table 1). Other data layers may be added to improve the model where appropriate. GIS data used for this project were assembled from a variety of sources, including UDFFS, Utah's Automated Geographic Reference Center (AGRC), Utah Division of Wildlife Resources (UDWR), U.S. Census Bureau, U.S. Geological Survey National Hydrography Dataset (NHD), U.S. Geological Survey National Elevation Dataset (NED), and SWReGAP. SWReGAP provided several of the core data layers, including land cover, stewardship, and species richness (table 1).

The first data layer created was an analysis mask (i.e., the area of interest). The analysis mask was created by intersecting SWReGAP forest classes with the private ownership class extracted from SWReGAP stewardship data, and it was used to identify privately owned forested lands that could potentially benefit from FSP. All subsequent analyses were constrained by the analysis mask. From the land cover data, forest, riparian, and wetland classes were extracted to create three separate vegetation files: forested areas, riparian areas, and wetlands, respectively. Forest patches were created by removing buffered roads from the forest data and eliminating "patches" of forest smaller than a specified unit area, such as 1,000 acres (4.05 km^2). Proximity to public land was created by extracting all publicly owned lands and otherwise protected open space from SWReGAP stewardship data. A Euclidean distance function was used to generate a proximity index from public lands. It is assumed by FSP that private lands in closest proximity to public lands are of higher priority because they could augment existing open space and avoid piecemeal conservation strategies. Areas of high species diversity are not a common SAP data layer, but as an associated product of SWReGAP, species richness data were included in the SAP model because this provides additional information related to the resource richness of a given area.

Table 1. Spatial data layers and data sources used for the Spatial Analysis Project for Utah.

Spatial Analysis Project Common Data Layers:	Data Source:
Forested areas	SWReGAP Land Cover
Riparian areas	SWReGAP Land Cover
Wetlands	SWReGAP Land Cover
	SWReGAP Land Cover/Utah
Forest patches (roadless areas)	Automated Geographic Reference Center roads
Proximity to public land (protected open space)	SWReGAP Stewardship
Analysis mask (privately owned forests)	SWReGAP Land Cover/Stewardship
Areas of high species diversity (not a common SAP data layer)	SWReGAP Species Richness
Priority watersheds	USGS National Hydrological Dataset
Slope	USGS National Elevation Dataset
Forest pests Public water supplies Wildfire assessment Existing FSP plans	Utah Division of Forestry, Fire, and State Lands
Threatened or endangered species	Utah Division of Wildlife Resources
Change in households (developing areas)	U.S. Census Bureau

FSP Suitability Analysis: Model Building

The FSP suitability model was created using ArcGIS 9 Spatial Analyst Extension and Model Builder (ESRI 2005). The model was designed to be flexible so input variables could be added or removed and parameters within data layers could be rescaled (i.e., recoded) by UDFFS, depending on their specifications.

Figure 1 is an overview of the FSP suitability model, which, because of its graphical nature, allows the GIS analyst to see every initial data input (blue ovals) and intermediate calculation (yellow rectangles). The final column of intermediate output files (green ovals) shows the input predictor variables for the Weighted Overlay tool, which executes the suitability analysis. The Weighted Overlay tool requires all input data to be in raster format and to represent categorical data. The Weighted Overlay tool allows the analyst to (1) set the relative importance that every input data layer has on the suitability analysis by assigning weights (or "percent of influence"); and (2) to scale (or "rank") the categorical values within data layers (figure 2). Figure 2 shows the interface of the Weighted Overlay tool where weights (% Influence) and scaled values are adjusted between and within input data layers, respectively.

The RS/GIS Lab assigned equal influence to every data layer in the preliminary model. Values within the data layers were scaled so that areas with "no data" were given the lowest value (i.e., scaled value of 1), and the single true value was given the highest value (i.e., scaled value of 12) to reduce bias between or within data layers. Scaled values were based on the default evaluation scale of 1 to 12 by 1, which is determined by the number of input data layers to the Weighted Overlay. Finally, the "overlay" procedure multiplies across all given weights and scaled values to produce a map of suitability (figure 3). Figure 3 shows a preliminary map output of privately owned forested lands with potential to benefit from the FSP in Utah.

Map Products and Deliverables

All of the original data layers (table 1) and customized graphical models (figure 1) were provided to UDFFS in a geodatabase format (ESRI 2005). Graphical models provide an excellent record for tracking how alternative scenarios are derived. Additionally, the models are easily manipulated, enabling rapid data exploration and display capabilities.

UDFFS will generate several map products from SAP. The primary map product depicts areas with high, medium, and low potential to benefit from FSP planning efforts constrained to privately owned forested lands (figure 3). These types of maps provide valuable context for more intuitive decision making about where to apply additional conservation efforts. They also show to what degree the state's existing stewardship tracts overlap with "priority" lands (i.e., areas with high potential to benefit from FSP) and whether it is necessary to reevaluate the existing network of conservation plans. Other map outputs

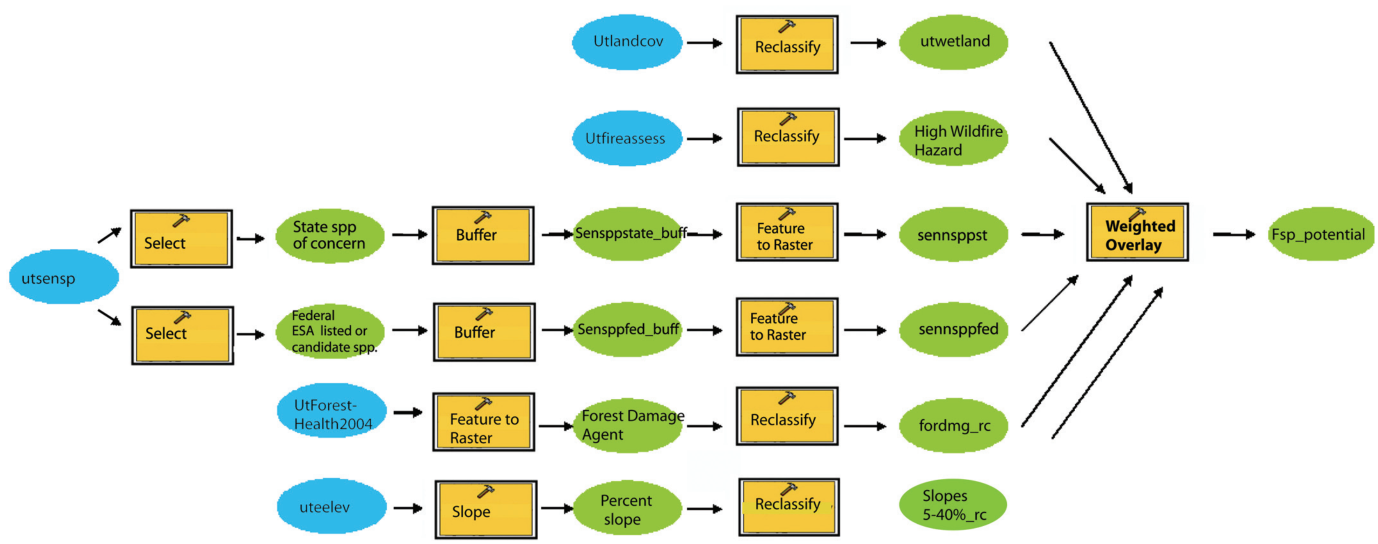

Figure 1. A schematic of a FSP suitability graphical model developed using Model Builder (ESRI 2005) for UDFFS. All input data are on the left (blue ovals), followed by a series of intermediate data manipulations and calculations (yellow rectangles) and temporary output files (green ovals) that converge into the Weighted Overlay tool to derive the map output for the suitability analysis (final green oval).

from SAP show areas of resource richness and resource threats constrained within privately owned forested lands. Models used to create these maps can be adjusted in the same manner as described for the FSP suitability model.

Summary

The FSP's SAP provides states with a consistent methodology for conducting statewide assessments of privately owned forested lands that could benefit from FSP efforts. SWReGAP data provided several core data layers for these analyses. The RS/GIS Laboratory at Utah State University prepared the required data sets and developed the graphical spatial models to provide UDFFS with decision-making tools that promote the sustainable management of our nation's forests.

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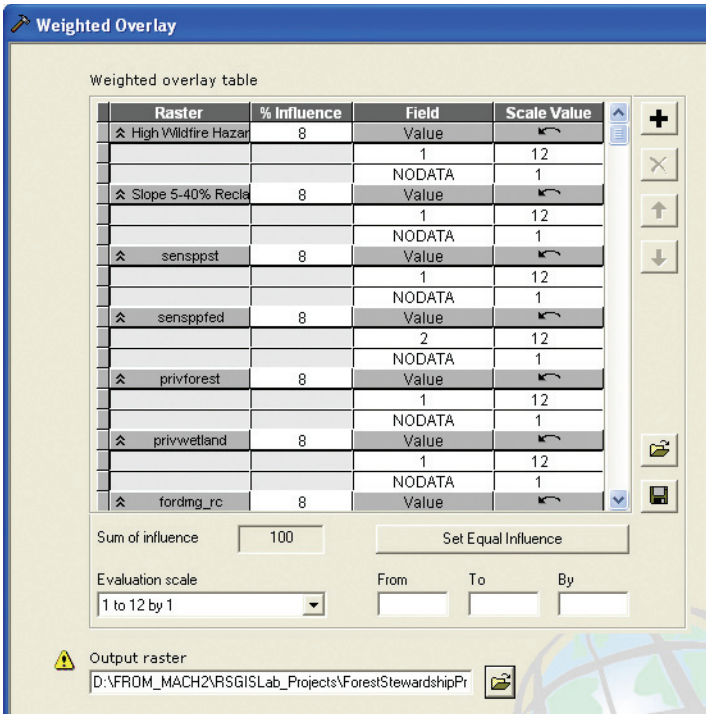

Figure 2. The interface for the Weighted Overlay tool is used to assign weights (% Influence) between each input raster data file and to scale (or rank) the values within the data files. All input raster files received an equal percent of influence in the model. Field values of 1 (or 2) were given the highest scaled value (i.e., scaled value of 12), while areas of “no data” were given the lowest scaled value (i.e., scaled value of 1) based on the evaluation scale of 1 to 12 by 1.

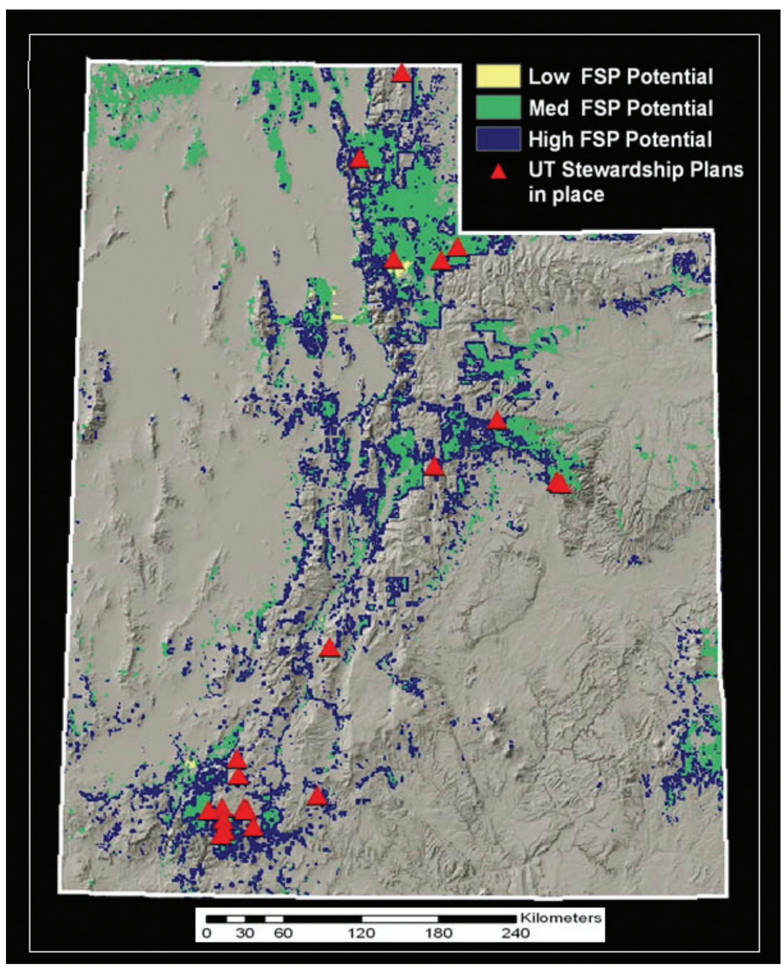

Figure 3. Sample map output of privately owned forested lands with potential to benefit from FSP in Utah (ranked as high, medium, or low potential). The red triangles represent locations where stewardship plans are currently in place. Note: this map was derived from a preliminary model prior to formal UDFFS analysis and is for illustrative purposes only.

Navajo Wind Energy Development Exclusions: An Analysis of Land Suitable for Wind Energy Development on the Navajo Nation

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Introduction

The Navajo Nation is located in the southwestern United States. Historically, energy development occurred on the reservation without much tribal involvement (Clow 2001). Decisions were made in Washington, D.C., and administered by the Bureau of Indian Affairs (BIA) (Wilkinson 1996). For the Navajo, a history of uranium, oil, gas, and coal extraction, each with its own important story, has set the stage for future energy decisions (McPherson and Wolf 1998). This changed during the decade following the passage of the Indian Self-Determination and Education Assistance Act of 1975 (Ashley and Secody 2003). The Navajo government and its people began to have more influence over the future of their nation.

Our work focuses on wind energy. Navajo land within Arizona was analyzed using a geographic information system (GIS) to determine areas suitable for wind energy development. Our work is modeled after a study performed by the National Renewable Energy Laboratory (NREL), but includes additional data and higher-resolution data. Importantly, it utilizes recently published Southwest Regional Gap Analysis Project (SWReGAP) land cover data. These land cover data (at 30-m resolution) provide the location of sensitive ecosystems and urban/developed areas.

The Energy Policy Act of 2005 (EPACT) has been a major motivator for our work. The bill incorporates provisions for wind energy development (USDOE 2005). It also includes, for the first time, a specific title dedicated to energy on tribal lands: Title V, Indian Energy.

Our work presents GIS analyses, techniques, and perspectives. The suitability of land is determined by land use, environmental considerations, and additional windy land factors, such as slopes greater than 20 percent. Those areas of land determined to be unsuitable were considered wind energy development exclusions (WEDEs). These exclusions and the reasons for unsuitability are often easy to understand, but some are arbitrary and not as clearly understood. Particular attention is given here to these exclusions.

The Navajo Wind Energy Development Exclusions study provides a tool for GIS professionals. This tool brings together a wide variety of GIS data, often high-resolution and computing-intensive data, and compares and contrasts these data to national wind-power models. Together, they provide a foundation for understanding the future of wind energy development on the Navajo Nation.

Background

<u>The Navajo Nation</u>

The size of the Navajo Nation gives the Navajo tribal government prominence in American Indian country. They govern and administer the largest reservation in the country: approximately 69,930 km^2 with nearly 300,000 members (see figure 1; Ahasteen 2005).

<u>The National Energy Policy Act of 2005 (EPACT)</u>

EPACT was the first major federal energy policy created in over

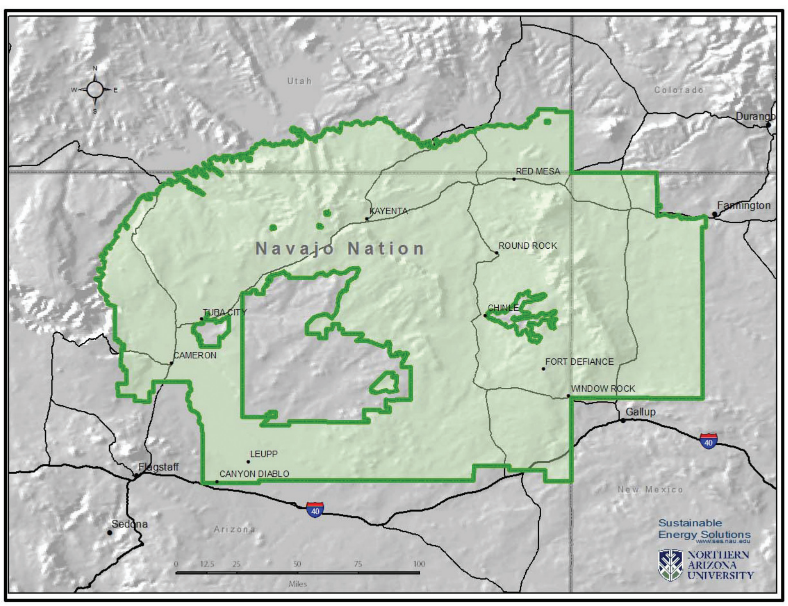

Figure 1. The Navajo Nation (shown in green) is 69,930 km^2, or approximately 24 percent of Arizona. The Navajo Nation surrounds the Hopi Nation. Canyon de Chelly National Park is the area in the eastern portion of the reservation and is shaped like a delta.

a decade. It attempted to address a broad array of energy issues in the United States, but importantly, it incorporated American Indian energy issues into an actual title (Title V, Indian Energy) for the first time in the history of federal energy legislation. EPACT describes a number of important policies that affect wind energy and specifically wind energy in American Indian country (USDOE 2005). EPACT provides the federal policy cement needed to spark the next great build-up of energy, especially in the West. It affects the Navajo Nation in ways that are unique, not only to the region, but to tribes in general. A full discussion of the tribal impacts of EPACT is beyond the scope of this work, but some provisions are worth noting:

- **The Production Tax Credit (PTC) was extended to the end of 2007.** The PTC is the major federal incentive driving the wind industry today. It provides a direct tax credit for every kilowatt hour of electricity produced from a wide range of renewable energy sources, including wind.
- **Tribal renewables will be double-credited toward the federal purchase requirement.** EPACT calls for the federal electricity load to be provided by a certain percentage of renewable energy, beginning in 2007 and ramping up to 7.5 percent by fiscal 2013. While the federal load may seem insignificant, remember that it is the largest load in the world. Renewable energy generated by tribes and delivered to satisfy the federal load will receive double the credits. In other words, 100 megawatts of tribal wind energy would be considered 200 megawatts of energy toward the 7.5 percent goal.
- **Section 368: West-wide Energy Corridor Programmatic Environmental Impact Statement.** This federal study has been in the pipeline for a number of years as a solution to the problem of extended uncertainty when planning energy on federal lands. The reason this study is so important in the West is that much of the land there is under federal ownership status. Energy planning in the West, especially planning for the transmission of that energy, means dealing with federal lands. This study will identify corridors across these federal lands and perform programmatic environmental impact statements on those areas, dramatically decreasing planning uncertainty. Because the Navajo are adjacent to many of these federal lands, the results of this study will be telling in terms of where they "sit" in the energy corridor future of the West.
- **Section 1813: Valuation of Tribal Energy Rights-of-Way.** This issue strikes a deep chord in American Indian country. As one might imagine, energy rights-of-way (ROW) on American Indian lands have been historically undervalued, dramatically so in some cases (USDOE 2006). Recently, following an era of American Indian self-determination that at times has tipped the power scales back in favor of tribes, some energy ROW on tribal lands are now overvalued (USDOE 2006). The study implies a move toward some standard form of valuation for tribal ROW; most tribes, however, view this language as a direct attack on their sovereignty. The Navajo Nation is crossed by many energy ROW, including gas pipelines and electric transmission lines. The results of this study will impact the energy future of the tribe.

High-Resolution Wind Resource Data

The *Wind Energy Resource Atlas of the United States,* published in 1986, was the first major effort to map wind energy potential (Elliott et al. 1986). Maps from the atlas were published in this form, as well as a "gridded" form, which classifies the data into approximately 32 km pixels (figure 2).

Following the publication of this work, the National Renewable Energy Laboratory (NREL) created higher-resolution wind resource models that estimate the wind power potential at 200-m resolution for many areas of the United States (figure 3). These maps were completed for 30 m, 50 m, 70 m, and 100 m, but only validated at 50 m (figure 3). The general pattern is similar to figure 2, but figure 3 presents the data in more detail. Where high-resolution data were unavailable or not validated by NREL, the older, "gridded" wind resource data from figure 2 were used. For Arizona, we used the higher resolution data for this study (figure 4).

Methods

For our analysis, windy land is defined as land with a wind resource greater than or equal to class 3 as predicted by the high-resolution wind resource data. That is, predicted average annual wind speeds are large enough that wind energy may be produced economically. However, not all windy land may be developed for wind power. There are many development exclusions that must be considered. For instance, land owned by the National Park Service must be excluded 100 percent from consideration for development. Developable windy land, therefore, is the windy land that remains after all development exclusions have been applied. Finally, excluded windy land is windy land (class 3 and above) that falls within a development exclusion.

A GIS was used to analyze wind energy development exclusions (WEDEs) on the Arizona portion of the Navajo Nation. We limited our analysis to Arizona data because WEDE data sets are generally available by state (figure 5). Limiting the analysis to only the Arizona portion of the Navajo Nation limited our data inputs and processing while still allowing us to assess the majority of the windy lands on the entire Navajo Nation.

Digital data sets were gathered that represented areas where wind energy projects should *not* be developed. Most data sets, once identified, were immediately ready for WEDE analysis. Other layers, like the non–ridge crest forest WEDE, required some processing.

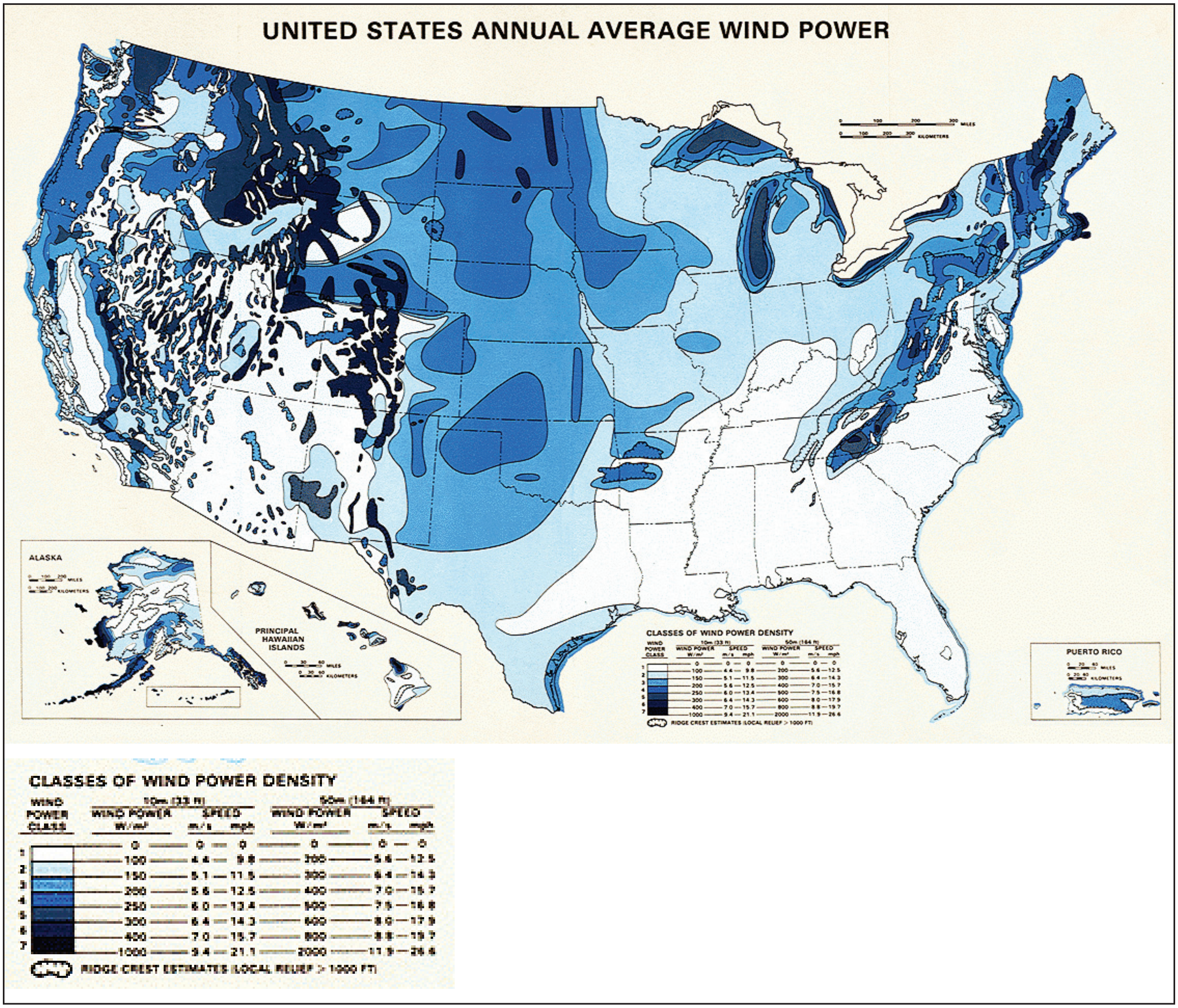

Figure 2. *Wind Energy Resource Atlas of the United States* (Elliot et. al. 1986).

This work includes a number of key higher-resolution data sets. Whereas past studies were limited to 1-km resolution at best, this work brought 30-m resolution data to important exclusion categories like wetlands, urban/developed lands, and open water. Buffers were added to some, but not all, WEDEs.

Consistent with the methodology applied by NREL, there are three general categories of WEDEs (Schwartz 2003): environmental exclusions, land use exclusions, and additional windy land factors (e.g., slopes greater than 20 percent).

Our work includes 11 WEDEs and their respective buffers (table 1).

Non-ridge crest forest exclusions were created by combining SWReGAP forest data with a layer derived from TPI (Topic Position Index) (Jenness 2005). TPI categorizes the landscape into 10 different categories (table 2) by comparing the results of a "small neighborhood" (1000-m radius) and "large neighborhood" (5000-m radius) analysis of a 90-m digital elevation model (DEM). Pinyon-Juniper (PJ) forests were not included as WEDEs.

After removing WEDEs from the wind resource data for 50-m and 70-m heights, wind energy capacity (MW) was estimated using NREL's conservative standard of 5 MW per km^2. This factor was applied to all areas of land with a wind resource of class 3 or greater.

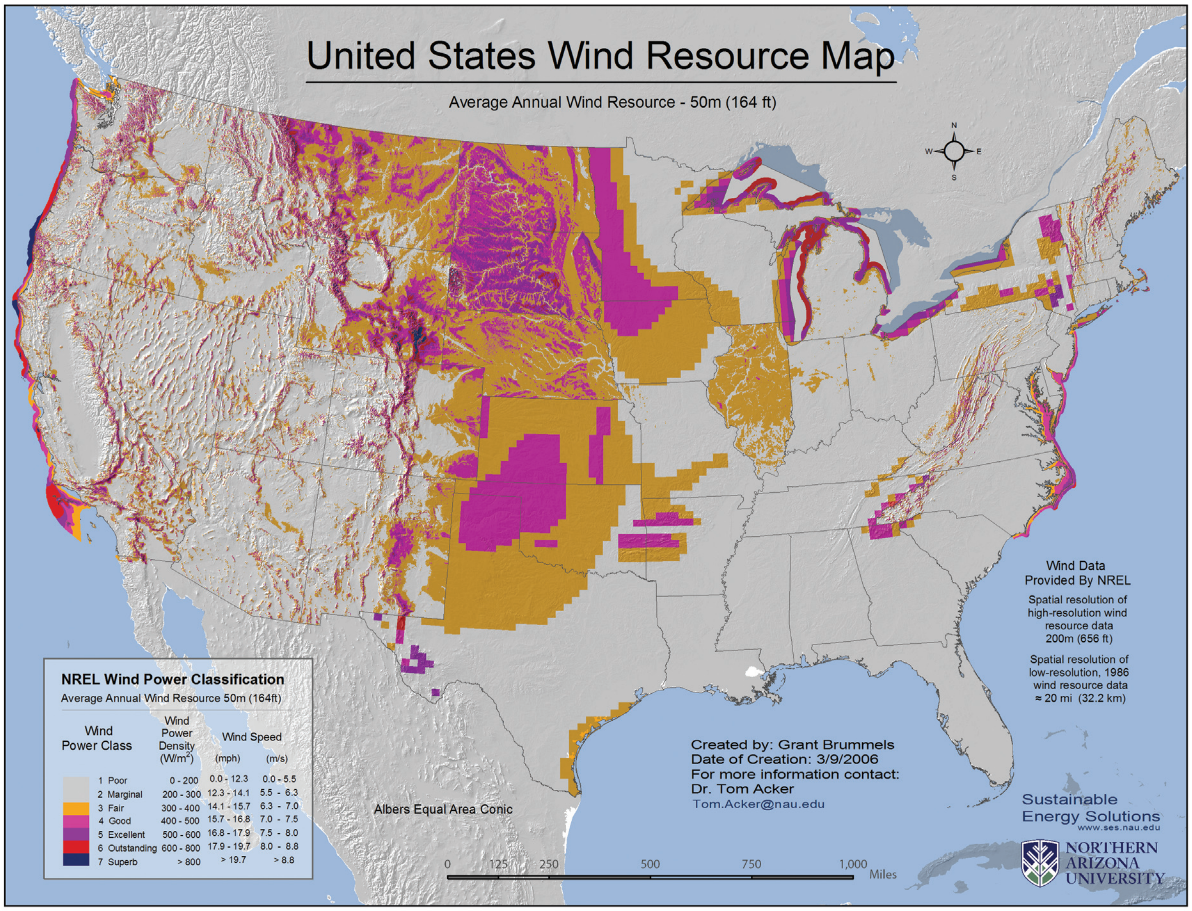

Figure 3. This map uses newer, high-resolution wind resource data where available. Wind resources in areas without high-resolution data are shown with the older, 1986 wind resource data.

Results

Our work found the total potential wind energy capacity at 50-m hub height, without applying WEDEs, to be 5,770 MW (table 3). After removing all WEDEs, the wind energy capacity was found to be 4,562 MW, or 79 percent of the total wind energy capacity at 50 m. At 70 m hub height, 14,046 MW of potential capacity was found. Of that, 11,806 MW, or 84 percent of the total capacity at 70 m, was available for development after all WEDEs were applied.

Most developable windy land is class 3 (table 3). However, windy land is a small percentage of total land on the Navajo Nation (table 4). WEDEs are distributed across the Navajo Nation land (figure 6).

Over 90 percent of areas considered "woodlands" by SWReGAP data were Pinyon-Juniper (PJ) woodlands (figure 7). PJ woodlands were not excluded for this study.

Wetlands in the southwestern portion of the Navajo Nation map are part of the Little Colorado River system (figures 8 and 9). Wetlands in the northeastern portion are part of the de Chelly River system.

Slopes were also an important WEDE category (figure 10).

The TPI analysis for the entire state of Arizona resulted in no category 6 landscapes, so the line for ridge crests was drawn between classifications 5 and 7 (figure 11). Classifications 7–10 were considered ridge crests for WEDEs.

A more detailed analysis using TPI was conducted for Gray Mountain (figure 12). The drainage to the north of Gray Mountain is the Little Colorado River, which drains into the Grand Canyon, the obvious feature in the northwest corner of the map.

For Gray Mountain most of the wind energy potential remains after all WEDEs are excluded (figure 13).

Discussion

Understanding where to locate wind turbines is important for the energy future of the Navajo Nation. Our study provided maps and data that help energy planners and policy makers understand how much wind energy can be developed on the reservation. High-resolution data for land cover and elevation provide a good understanding of ecosystems and ridge crests. Because we assessed the Navajo Nation, we uncovered interesting issues related to WEDE research on American Indian lands.

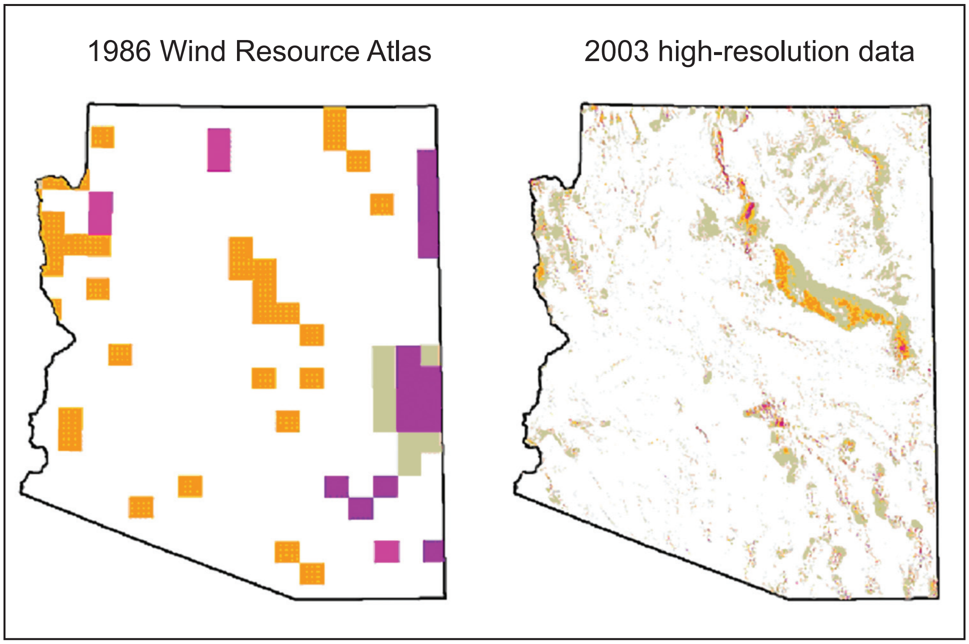

Figure 4. The map on the left shows data from the 1986 *Wind Energy Resource Atlas.* The map on the right shows the high-resolution results from NREL's 2003 mapping effort.

Figure 5. Navajo Wind Energy Development Exclusions study area. Only the Arizona portion of the reservation was analyzed.

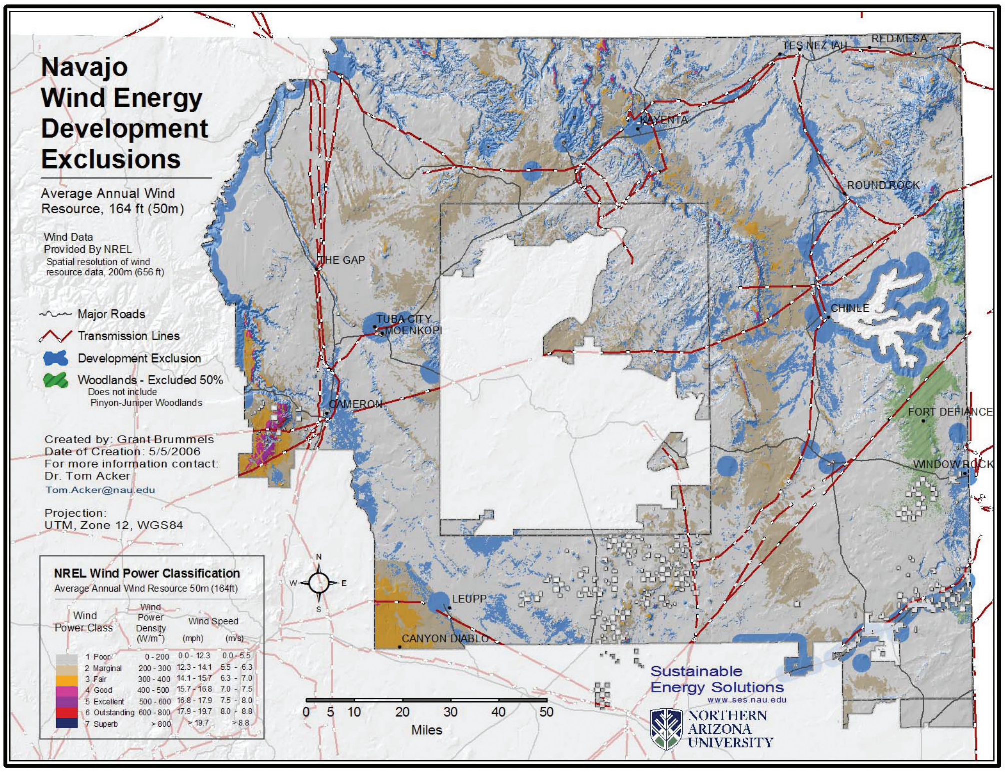

Figure 6. WEDEs are shown in blue; electric transmission lines are shown in red.

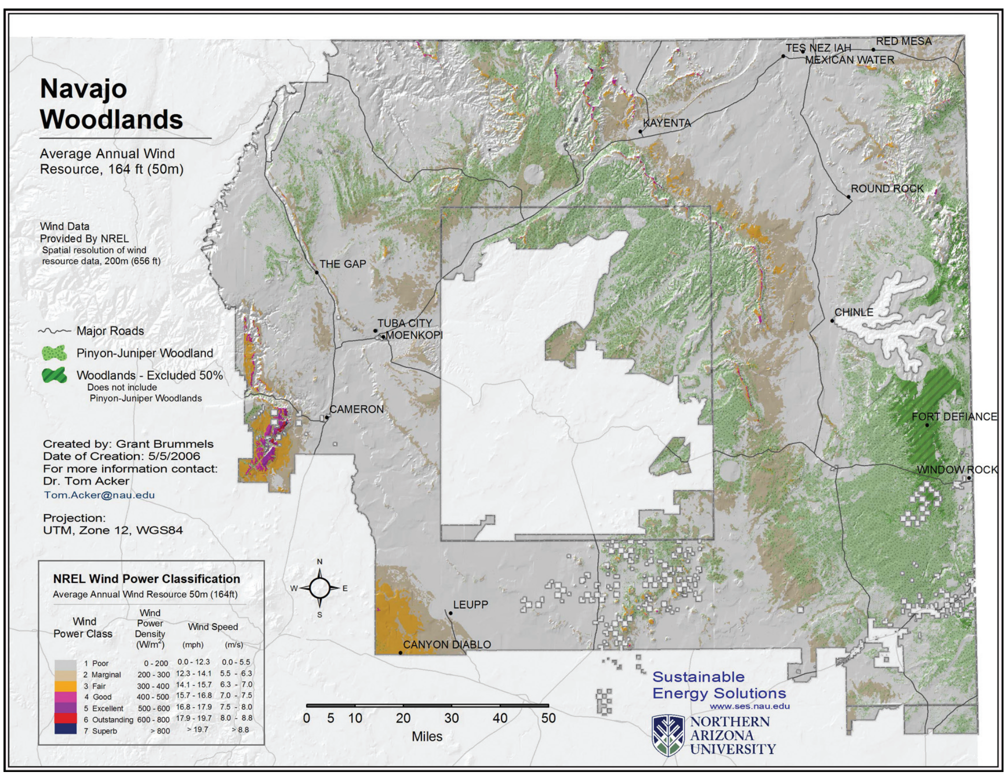

Figure 7. Pinyon-Juniper woodlands (not excluded in this work) are shown in light-green. Ponderosa pine woodlands (dark striped green), not on ridge crests, were excluded 50 percent.

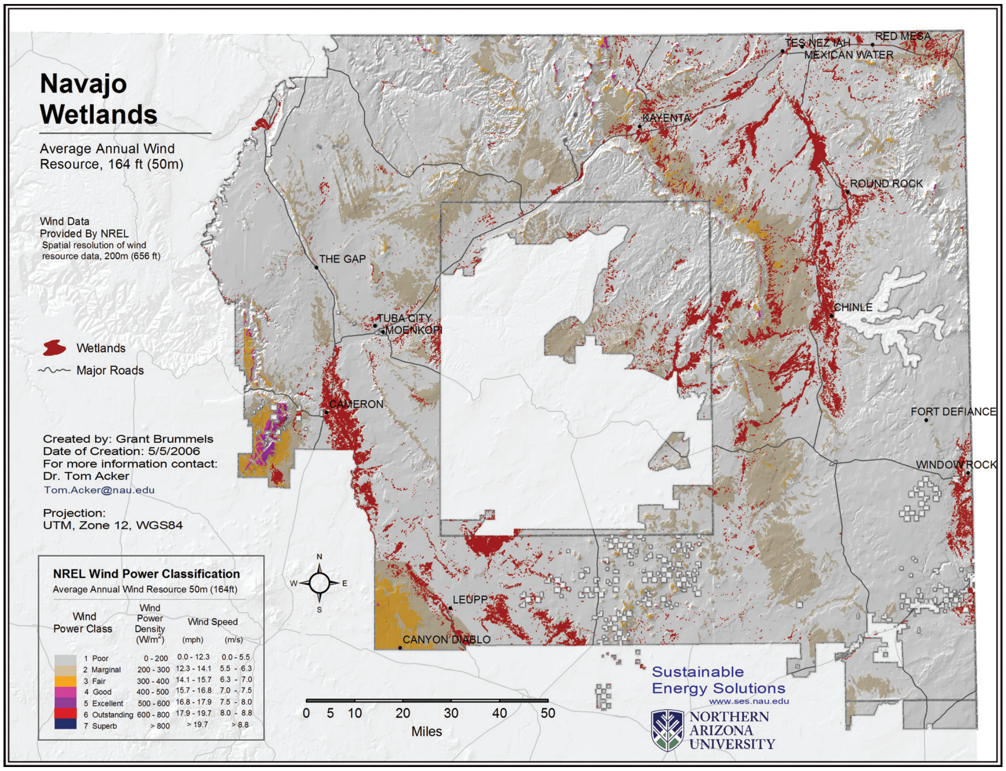

Figure 8. Navajo wetlands (shown in red).

Figure 9. Examples of wetlands from SWReGAP data. Photo on left shows wetlands along Colorado River near Page, AZ. Photo on right shows wetlands on the Little Colorado River near Cameron, AZ. The canyon walls are 2,000–3,000 feet tall.

Table 1. Wind Energy Development Exclusions.

Broad Exclusion Category	Exclusion	Exclusion Percentage	Exclusion Description	GIS Layer Source
Environmental Exclusions	National Park Service	100%	United States National Park Service land.	Arizona Land Resource Information System (ALRIS)
	Fish and Wildlife Service	100%	United States Fish and Wildlife Service land.	ALRIS
	Congressional Specially Designated Areas	100%	Special areas, like wilderness or wild and scenic rivers, congressionally designated as such.	U.S. Department of Agriculture Forest Service (FS)
	Inventoried Roadless Areas	100%	These are roadless areas of the country on federal land that have been congressionally designated as such.	FS
	State and Other Environmental Land	100%	State parks and other environmental lands designated as such by the state of Arizona.	ALRIS, U.S. Geological Survey (USGS) SWReGAP
	Other: Wildlife, wilderness and recreation areas on federal land of any designation (predominantly FS and Bureau of Land Management [BLM] lands)	100%	Land Stewardship Layer (includes Nature Conservancy Land).	ALRIS, USGS SWReGAP
Land Use Exclusions	Urban/Developed Areas	100%	Urban or developed land as described by USGS SWReGAP data.	USGS SWReGAP
	Airports	100%	Airports	National Atlas of the United States, USGS
	Wetlands	100%	Wetland ecosystems as described by USGS SWReGAP data.	USGS SWReGAP
	Water Bodies (includes seasonal and dry lakes)	100%	Areas covered by water all year or part of the year. Does not include rivers and streams.	USGS SWReGAP
	Non-Ridge Crest Forests	50%	Areas of forest cover that are not considered ridge crests by TPI analysis.	SWReGAP + TPI 8
	Ridge Crest Forests	0%	Areas of forest cover that are on ridge crests.	SWReGAP + TPI
Additional Windy Land Factors	Slopes > 20%	100%	Landscapes with slopes greater than 20%.	90m DEM, ALRIS

Table 2. List of 10 landscape categories derived by TPI (Jenness 2005).

1. Canyons, deeply incised streams
2. Mid-slope drainages, shallow valleys
3. Upland drainages, headwaters
4. U-shaped valleys
5. Plains
6. No areas reported this classification
7. Upper slopes, mesas
8. Local ridges/hills in valleys
9. Mid-slope ridges, small hills in plains
10. Mountain tops, high ridges

Table 3. Total and developable potential installed wind capacity for 50-m and 70-m hub heights by wind class.

	50 m			70 m		
Wind class	Navajo Nation potential installed capacity (MW) on windy land (no exclusions)	Navajo Nation 50-m potential installed capacity (MW) on developable windy land	Developable windy land (%)	Navajo Nation potential installed capacity (MW) on windy land (no exclusions)	Navajo Nation 70-m potential installed capacity (MW) on developable windy land	Developable windy land (%)
3	4,751	3,870	81%	12,405	10,591	85%
4	636	428	67%	1,282	990	77%
5	256	183	71%	276	184	66%
6	110	71	65%	73	38	52%
7	17	10	60%	10	4	43%
Total	5,770	4,562	79%	14,046	11,806	84%

Table 4. Windy land and developable windy land by wind class and as compared to the entire area of the Navajo Nation (50-m hub height).

Wind Class	Power (watts/m^2)	Total area (km^2)	Windy land as percent of total land area	Developable windy land (km^2)	Developable windy land as percent of total land area	Installed capacity (megawatts)
3	300–400	950	2.34%	774	1.906%	3,870
4	400–500	127	0.31%	86	0.211%	428
5	500–600	51	0.13%	37	0.090%	183
6	600–800	22	0.05%	14	0.035%	71
7	>800	3	0.01%	2	0.005%	10
Total			2.84%		2.246%	4,562

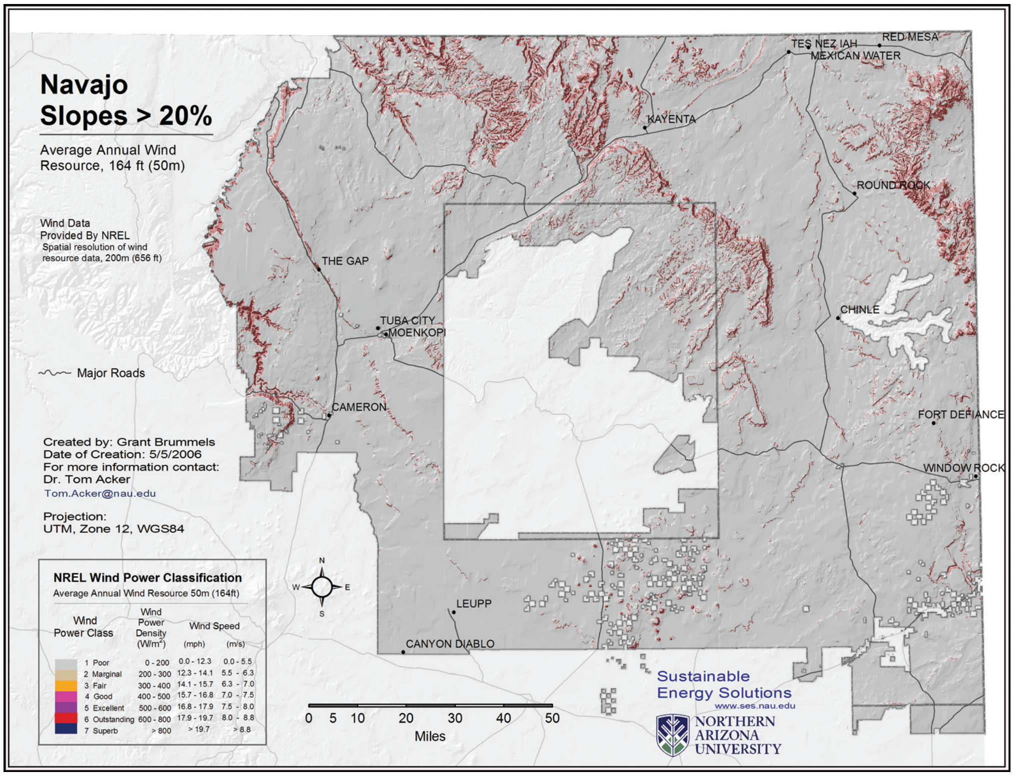

Figure 10. Sloped greater than 20 percent on Navajo Nation (outlined in red).

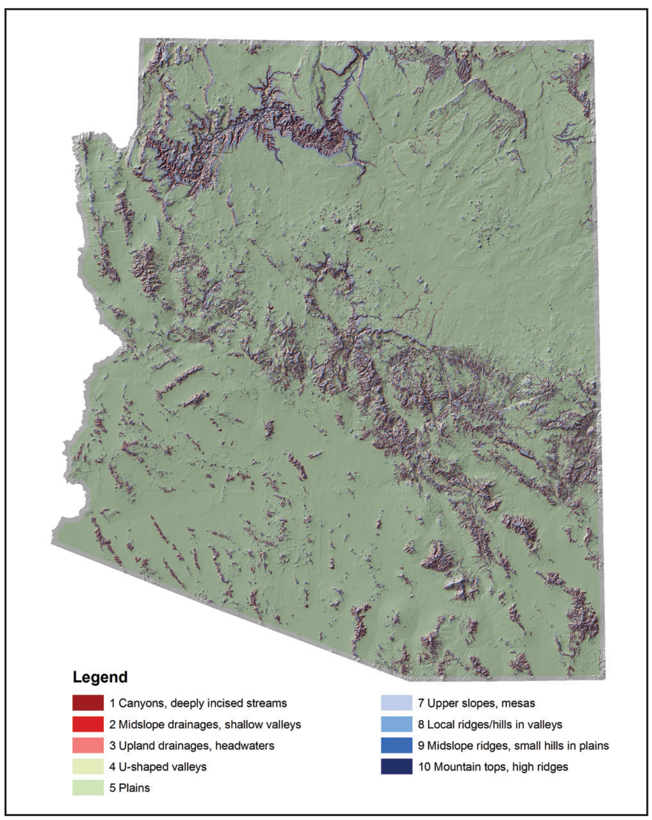

Figure 11. Topographic Position Index results for Arizona. Plains are shown in green. Areas shown in red and pink are drainages, valley, and canyons. Blue and gray areas are ridge crests and mountain tops.

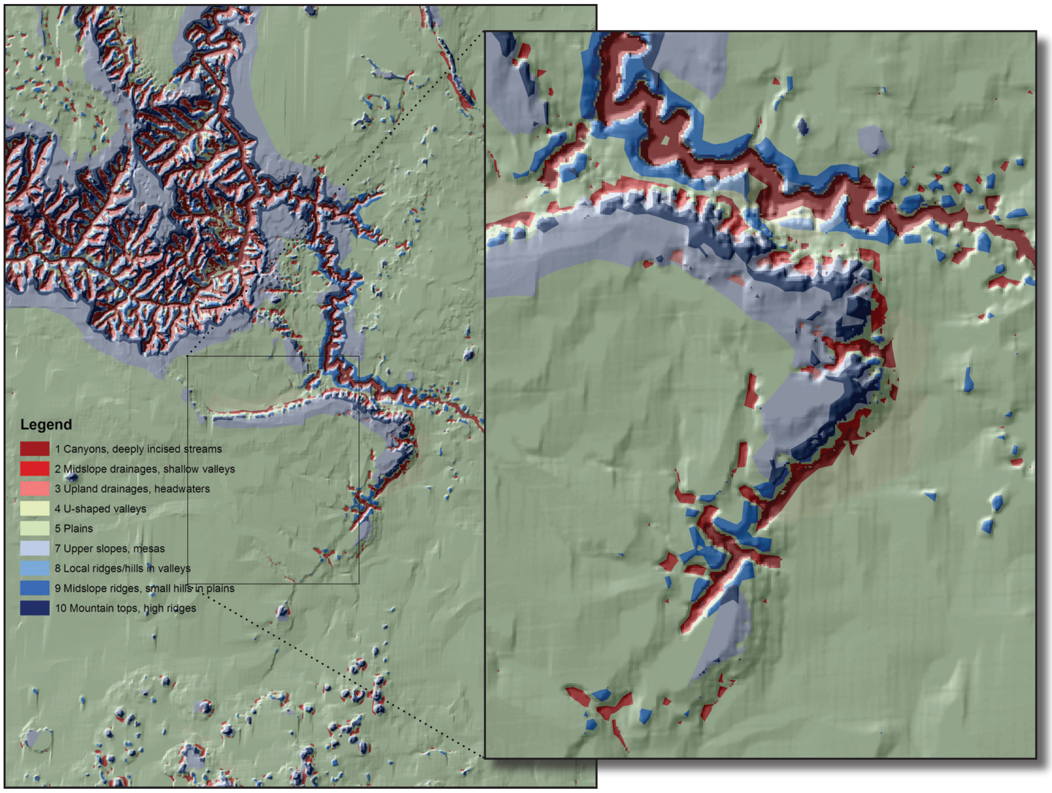

Figure 12. Topographic Position Index results for Gray Mountain at two different scales.

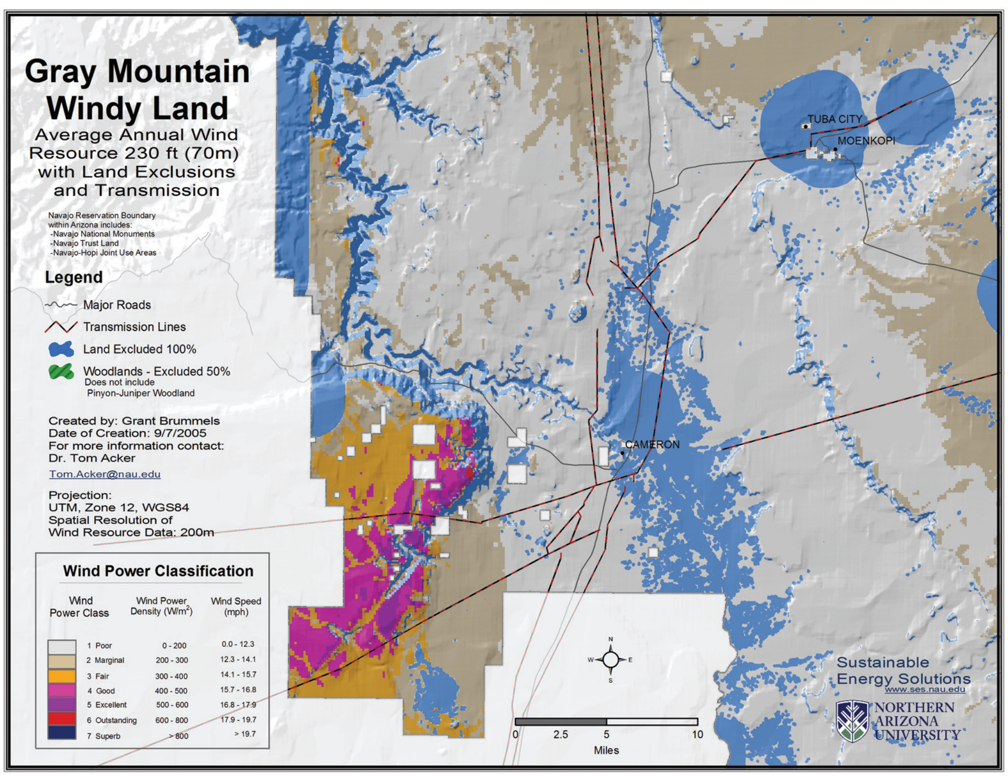

Figure 13. WEDEs (blue) and wind resources for Gray Mountain.

Federal lands are key qualifiers for WEDEs. In many cases, the reasons that federal lands are excluded relate to ecosystem qualities—they include protected land, wilderness area, or other valuable land because of the landscape and ecosystem supported. Indian lands, of course, do not have these types of federal lands, yet ecosystems rarely change according to political boundaries. As such, our study highlights the importance of looking at WEDEs from an ecosystem perspective when assessing WEDEs on American Indian lands. While our work did not incorporate specific Navajo data sets, like those that show cultural sites or sites of historical significance, future WEDE work in American Indian Country should utilize cultural information.

Incorporating 30-m SWReGAP data into the study provided a number of improvements over past studies and resulted in some key findings. Higher-resolution data were essential for identifying wetlands, especially in this region of the country. Wetlands were prominent on the Navajo nation.

Our work shows non–ridge crest forest exclusions as well. SWReGAP data proved useful in making this exclusion category clear by classifying forests into 53 different land cover classes. Different types of forests with their different forest structures were easily identified and assessed individually. Pinyon-Juniper forests were shown to be the dominant forest on the Navajo Nation.

While WEDEs on the Navajo Nation excluded 21 percent of the total windy land at 50 m, the large, contiguous areas of windy land in the western portion of the reservation were not excluded (table 3, figure 6). This is a positive sign for wind energy in the future of the Navajo Nation. Not only are these areas not excluded, but they are transected by existing electric transmission lines. Gray Mountain offers the most promising location for developing wind energy projects (figure 13).

Conclusions

The Navajo Nation is well positioned geographically to take advantage of wind energy. They have access to sites with quality wind resources, as well as access to regional transmission. Wind offers an alternative to typical fossil energy development, providing the energy without pollution and carbon emissions and without the use of water. Our results, however, indicate that wind is not suitable at all locations.

Wetlands were prominent on the Navajo Nation (figure 8), as were forests (figure 7). While most GIS analyses using satellite classification techniques would group Ponderosa pine forests with Pinyon-Juniper forests, by using the SWReGAP data we were able to separate the two and understand the forest structure that wind energy projects may encounter. Because Pinyon-Juniper forests are a large portion of the reservation and because they display different forest structure than Ponderosa forests, they were not included as a WEDE.

Planning for a wind energy project on the Navajo Nation can now proceed with at least a relatively broad understanding of where not to locate wind turbines. The public can be informed regarding wind energy and be assured that decisions are based on sound data. Wind developers can avoid problem areas and save money and time. Utility managers can estimate where wind energy projects could be sited within their control area. Finally, and perhaps most importantly, Tribal Council members can use our data and appreciate the future of wind energy on the Navajo Nation.

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Using Data from the Southwest Regional Gap Analysis Project to Formulate Conservation Objectives in the Lower Colorado River Watershed

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Introduction

The U.S. Fish and Wildlife Service (USFWS) is moving toward a strategic approach to habitat conservation. The agency is initiating efforts that use the best available scientific data and models in conservation planning to inform conservation actions, such as land acquisition and restoration projects. The goal of these efforts is to create an adaptive management loop (figure 1) that produces the most effective conservation actions.

A key piece of the adaptive management loop within the biological planning and conservation design elements is the formulation of conservation objectives based on biological information, such as species life history data. A team of biologists and natural resource managers from a variety of federal, state, and non-government organizations is currently developing conservation objectives for the Lower Colorado River (LCR) watershed (figure 2).

Applying GAP Data to Formulate Conservation Objectives

Developing meaningful conservation objectives requires high-quality biological data. A key source of such data for the LCR watershed is the Southwest Regional Gap Analysis Project (SWReGAP). Although the LCR watershed extends into California, beyond the southwestern edge of SWReGAP data, the land cover, species models, and stewardship data sets provide many inputs necessary to formulate conservation objectives and construct a watershed-scale plan. SWReGAP data, along with other data and information, are being used to set two types of objectives: (1) coarse-filter objectives based on prioritized ecological systems; and (2) objectives based on habitat requirements of priority species.

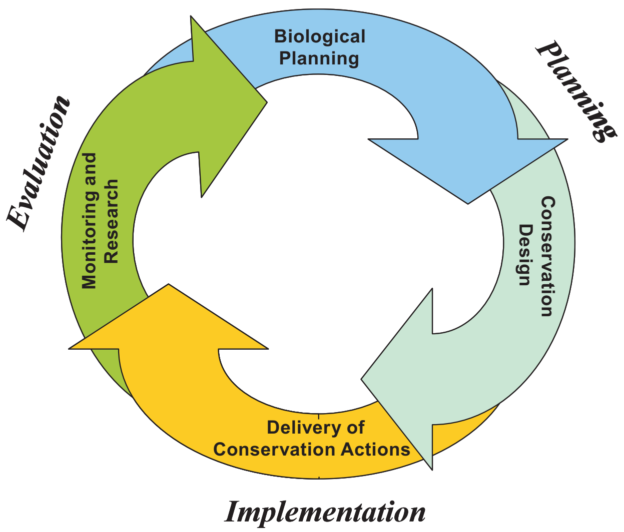

Figure 1. Adaptive management loop for planning, implementing, and evaluating conservation actions.

Conservation Objectives Based on Prioritized Ecological Systems

A map of ecological systems for the watershed based primarily on SWReGAP land cover was developed. The California portion of the LCR watershed was based on data obtained from the Lower Colorado Multi-Species Conservation Program (MSCP) and the National Land Cover Dataset (NLCD). A method for prioritizing ecological systems was developed using five analytical categories:

1. LCR biological responsibility for ecological systems,
2. representation of ecological systems in conservation lands,
3. decreasing area trends (estimated by expert opinion),
4. trend in ecological condition of ecological system (estimated by expert opinion), and
5. severity of threats facing ecological system (estimated by expert opinion).

Objectives were set to conserve representative samples of each ecological system based on its prioritization. Higher-priority ecological systems require more land area set aside in GAP status 1 and 2 lands.

Conservation Objectives Based on Habitat Requirements of Priority Species

Following the coarse-filter analysis, models are being used to determine conservation objectives for selected populations of species. To begin, a subset of 65 species was selected (subspecies in some cases) including 3 amphibians, 37 birds, 10 fish, 9 mammals, 3 reptiles, 1 insect, and 2 plants. These species were selected based on their status in various initiatives, including the MSCP and Partners in Flight. A biologically-based population

Figure 2. Lower Colorado River watershed, for which conservation objectives are being developed based on SWReGAP data.

objective was then determined, and habitat was modeled (including the quantity and location of the habitat necessary to support the population objective). Not enough data or knowledge were available to build models for all of these species; therefore, only a fraction will have spatially explicit habitat objectives.

Ecoregional Conservation Plan

The LCR watershed project will combine the objectives—those based on prioritized ecological systems and the objectives for each species—into a conservation plan. The plan will envision an efficient set of conservation areas that achieve the conservation objectives.

Potential for Future Work

After the initial LCR conservation plan is complete, implementation over the long term will be vital. Ideally, monitoring would be instituted to establish the response of species populations to achieving habitat objectives. The MSCP may provide partnership opportunities for monitoring within the floodplain of the Lower Colorado River. The conservation plan is considered to be iterative, requiring updates as additional data and information become available.

As the USFWS increases its capacity to undertake conservation planning at ecoregional scales, the agency will increase its demand for data and expert support. Habitat models can be improved with more information on structural and functional characteristics of land cover types. Collaborative projects with GAP and other U.S. Geological Survey programs can provide modeling efforts that focus on priority species and priority ecoregions.

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Stepping Down Regional Habitat and Population Objectives to Individual National Wildlife Refuges: A Pilot Project in the Roanoke-Tar-Neuse-Cape Fear (RTNCF) Ecosystem

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Introduction

Regional, national, and international conservation plans set broad-scale habitat and population objectives that can potentially impact local U.S. Fish and Wildlife Service (USFWS) wildlife refuge management practices. For example, Partners in Flight's South Atlantic Coastal Plain Bird Conservation Plan (Hunter et al. 2001) recommends that eastern North Carolina and southeastern Virginia support a minimum of 1,000 pairs of Henslow's sparrow and the plan sets associated regional grassland and longleaf pine habitat management recommendations. The South Atlantic Migratory Bird Initiative Implementation Plan (Watson and McWilliams 2005) sets a conservation target of 100 piping plover pairs in eastern North Carolina within the next 50 years. Yet how do these and other less specific, regional population objectives step down to provide measures of success within individual refuges? How many individuals or breeding pairs would represent a viable population within each refuge and how much variation should be expected from year to year? At an individual refuge, which habitat management strategies or land acquisitions would most benefit the targeted populations? Answering such questions requires models that move beyond species occurrence mapping to represent predicted gradients in species density or abundance (Guisan and Thuiller 2005).

The *Biological Review of National Wildlife Refuges of the Roanoke-Tar-Neuse-Cape Fear Ecosystem in Northeastern North Carolina and Southeastern Virginia* (USFWS 2002) considered national and international conservation plans when setting specific habitat management objectives designed to protect and enhance key management species within the ecosystem's 11 National Wildlife Refuges. The report stops short, however, of setting specific population objectives for each refuge. Our pilot project will use Southeast Regional GAP (SEReGAP) land cover data and species occurrence models as a foundation (1) to develop habitat-specific population objectives for the RTNCF ecosystem and for the individual refuges; and (2) to provide quantitative measures of success by which the refuges can monitor the effectiveness of their management actions and their contribution to broader-scale population objectives.

We will develop examples of three quantitative species distribution modeling scenarios (inductive, deductive, and aquatic), with confidence intervals, for select USFWS Trust Species within the RTNCF ecosystem. Trust Species are those for which the USFWS has legislative mandate, and include federally listed threatened and endangered species, interjurisdictional fishes, and migratory birds (USFWS 1999). Inductive models will be developed for terrestrial vertebrate species represented by sufficient point count data within the RTNCF ecosystem region to quantify habitat-specific species density and to independently validate the models. This approach is being developed through another pilot project at SEReGAP (Williams and McKerrow 2005; Laurent et al. 2006), which is exploring the data requirements and limitations of various quantitative modeling techniques to define spatial gradients in habitat suitability for six forest bird species in North Carolina. Deductive models will be developed for selected terrestrial vertebrate species that are well-studied, yet for which there are limited point count data within the RTNCF region. The aquatic models will also follow a deductive approach, but will require different spatial data sets and different spatial analyses from the terrestrial deductive models. Expert opinion, literature review, and a Bayesian belief network will provide the foundation for these deductive models.

Once the three example modeling scenarios have been developed and reviewed, the pilot project will expand by (1) developing the models for additional species of interest according to available data and time; and (2) stepping down the models for each species to explore habitat and species objectives for the 10 individual USFWS refuges within the RTNCF ecosystem (figure 1). The models will be designed to guide future survey work to inform model refinement (e.g., by identifying and quantifying knowledge gaps and sources of model error and uncertainty) so that they may serve as useful, adaptive tools for setting and evaluating stepped-down, refuge-specific population and habitat conservation objectives. The models must also enable refuge managers to contrast the potential influence of alternative management scenarios, thereby facilitating the prioritization of candidate sites for various management actions, such as land acquisition and habitat manipulation.

For all modeling scenarios, significant challenges addressed by this pilot project arise from the USFWS's need for a product that will work across multiple spatial scales. We describe two of these challenges in this article: (1) how to effectively integrate habitat data compiled for regional applications with locally derived expert knowledge to provide quantitative population objectives at both the ecosystem and the refuge scale; and (2) how to effectively utilize expert opinion while distinguishing the uncertainty arising from natural variability from the uncertainty arising from applying experts' locally derived knowledge, information, and opinion over broader spatial scales.

Matching SEReGAP Data to USFWS Step-Down Objectives

Species respond to and impact the environment at multiple spatial scales. Therefore the abundance of a species at any given site reflects that species' environmental tolerances and preferences in relation to broad climatic gradients, land cover types, and microhabitat characteristics, as well as complex interactions across these scales (e.g., Poiani et al. 2000). The use of SEReGAP data for this project will focus attention on processes and patterns that occur, and can be resolved, at a scale of 30 m (the grain of GAP data) to 109,530 km^2 (the extent of the RTNCF ecosystem). Some features of ecological significance will not be mapped in GAP (e.g., snags required by some bird species nesting in bottomland hardwood), and although multiple refuges may offer similar acreage of desired habitat types (e.g., bottomland hardwood), not all refuges will have habitat of equal suitability (e.g., differing density of snags). While such variation may "average out" at the larger regional scale, as population goals are stepped down to the refuge scale, these fine-scale habitat features become increasingly important. Where USFWS defines a subclass of a mapped ecological system (Comer et al. 2003) from the GAP land cover map, or recognizes the importance of a particular microhabitat feature that varies greatly between refuges, we will have to call on expert opinion to estimate these characteristics and summarize the uncertainty associated with these estimates.

In addition to the inability to regionally map some very specific habitat features, differences between the general concepts applied to define habitat types become increasingly important when a study addresses applications at multiple spatial scales. A cross-walk between the list of habitat types used throughout the ecosystem *Biological Review* report (USFWS 2002) and the SEReEGAP land cover map is crucial for applying these data (table 1). The SE-ReGAP map legend was developed with regional habitat modeling as a primary objective. At the same time, the target classes reflect previous experience with mapping based on Landsat satellite imagery and the existing ancillary data sets. The cross-walk shows some of the inherent uncertainty that is introduced when attempting to apply a landscape-scale map to a habitat-type classification that has been independently derived based on local knowledge and management practices within a much smaller subregion. That uncertainty is reflected in the many-to-many relationships. For example, the refuge biologists recognize four types of fresh water pools, ponds, and lakes (interdune ponds, vernal pools, oxbow lakes, and Coastal Plain semipermanent impoundment), whereas the SEReGAP map legend currently has just a single class: open water fresh.

For two of the refuge classifications—interdunal ponds and vernal pools—these habitats will be found as inclusions in more general SEReGAP classes, similar to the snags needed by birds in bottomland hardwoods. With additional resources, oxbow lakes and Coastal Plain semipermanent impoundment habitats could be separated from the general open water cover class, but the question for the biologists will be, how much will that added detail change the predictions? In contrast, for bottomland hardwoods, the SEReGAP land cover map offers greater detail than the refuge biologists have included in their habitat classification (due to the relative rarity of this habitat within the existing refuge lands). The SEReGAP classifications account for variation in the stream/river size and blackwater versus brownwater subtypes. Habitat modelers have found these details important for regional and statewide applications, but it will be interesting to see if these distinctions, absent from the refuge documentation, will be applied locally.

Finally, because habitat types in the ecosystem *Biological Review* report (USFWS 2002) are specific to the USFWS refuge lands and those lands are concentrated along the coast (figure 1), the habitat types specific to the Outer Coastal Plain and

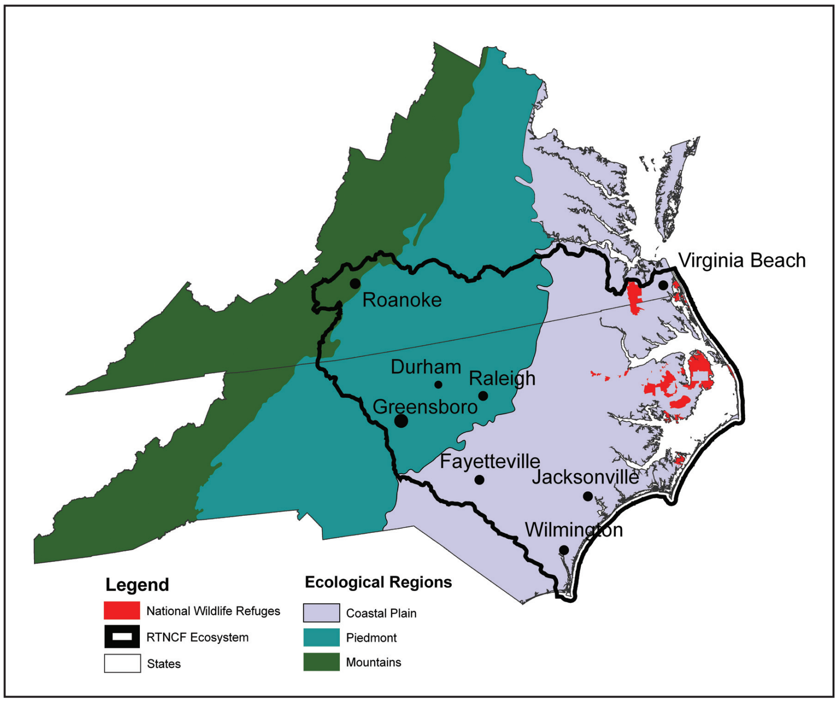

Figure 1. Distribution of National Wildlife Refuge lands within the Roanoke-Tar-Neuse-Cape Fear ecosystem in North Carolina and Virginia.

Piedmont region are not represented. Therefore, to scale down habitat objectives, we will have to develop an understanding of the habitats available outside the existing network of refuges. To do this, we will need to recruit additional experts in the development of habitat models. For those lesser-studied regions, the SEReGAP map legend can be used as the template for general habitat types, and the experts can help guide the development of any additional data needed to refine the models.

Predicting Species Abundance Despite Uncertainty

Conservation science is often described as a crisis science, where specific actions must be recommended despite uncertainty in the outcome (Soulé 1985). For management purposes, uncertainty has primarily been addressed indirectly, through the use of qualitative and comparative measures. For example, the use of habitat suitability index models to determine the relative suitability of different sites for a given species has a long history within the USFWS (Schamberger et al. 1982). There is increasing pressure, however, for managers to base their management practices on quantitative, rather than qualitative, predictions of habitat suitability (e.g., the 1997 National Wildlife Refuge System Improvement Act). In particular, management practices (and funding requests) must be justified by quantifying how the proposed actions will contribute to population objectives defined at broader scales.

While such quantitative estimates might seem unrealistic given current ecological knowledge, ecologists increasingly recognize the positive role that uncertainty can play when it is quantified and reported along with expert knowledge. Advances in the use of expert opinion allow experts' knowledge and experience to be elicited in ways that provide the necessary statistics to support quantitative, deductive habitat suitability modeling with confidence intervals (Johnson and Gillingham 2004). One such approach uses an interactive graphical computer program in which expert opinions are transformed to alternative prior distributions for use in Bayesian analyses (Al-Awadhi and Garthwaite 2006). This approach also allows the modeler to explore potential error introduced by any systematic bias in experts' opinions. Delphi surveys (e.g., Crance 1987), which use a series of questionnaires to build consensus among experts, can also be adapted to quantify uncertainty in expert opinion and thereby quantify uncertainty in model predictions. When uncertainty is explicitly considered, a manager predicts not just a population outcome, but also (1) the confidence intervals surrounding that prediction; (2) the potential consequences of over- or underestimating the outcome; and (3) the model components for which erroneous values would have the greatest influence on the model outcome (Johnson and Gillingham 2004).

In essence, this pilot project requires a model that can be applied at two spatial scales, yet both (1) the availability of species and habitat data, and (2) the applicability of experts' experience and knowledge will differ greatly between the ecosystem and the refuge scales. One component of this project will be to evaluate the sources and role of uncertainty in the species distribution models. For example, an expert's ability to precisely and accurately estimate species and habitat characteristics is expected to be highest within the spatial boundaries of their local work experience, and their uncertainty should increase as they are asked to apply locally derived knowledge over ever-broader regions (figure 2). Differences in experts' opinions between refuges at the refuge scale (figure 2, A versus B) might be more likely to reflect natural variability in species and habitat characteristics than experts' uncertainty or inexperience. Differences between their opinions at the ecosystem scale (figure 2, A and B), however, might reflect greater uncertainty, in addition to any natural variability. Again, using the example of snags in bottomland hardwoods, SEReGAP data document the location and extent of the bottomland hardwood habitat type, but would not provide the locations of suitable snags. Expert opinion and literature review would have to provide an estimate of expected snag density. At the refuge scale, individual experts (refuge biologists) may have quite precise and accurate knowledge of snag locations and density within their refuge, and snag density may vary between similar habitats at two refuges. As experts are asked to apply their knowledge to the broader, ecosystem area, however, the uncertainty of their estimates would be expected to increase.

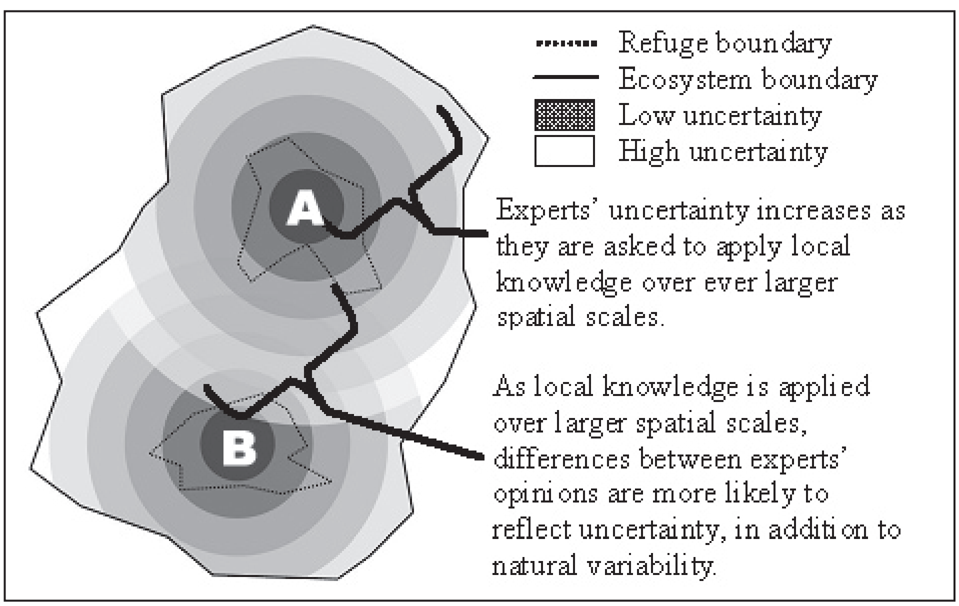

Figure 2. Sources and levels of uncertainty inherent in applying local expertise to regional objectives.

Table 1. A cross-walk between the habitat types used in the *Biological Review* for the RTNCF Ecosystem (USFWS 2002) and the SEReGAP land cover map units.

Habitat Types			
Level 1	**Level 2**	**Level 3**	**SEReGAP Map Unit Name**
Open Water			
	Marine, Sound, and Bay Waters	Open Water (Brackish/Salt)	
	Fresh Water, Pools, Ponds, and Lakes		
		Interdune Ponds	Open Water (Fresh)
		Vernal Pools	Open Water (Fresh); in part
		Oxbow Lakes	Open Water (Fresh)
		Coastal Plain Semipermanent Impoundment	Open Water (Fresh)
Unvegetated or Sparsely Vegetated Habitats Associated with Tidal Systems			
	Sand and Mud Bars		Bare Sand; in part
	Estuarine Flats		Unconsolidated Shore (Beach/Dune)
	Beach Front		
		Exposed Overwash Flats	Unconsolidated Shore (Beach/Dune)
		Lower Beach	Unconsolidated Shore (Beach/Dune)
		Upper Beach	Bare Sand
	Salt Flats		Bare Sand
Marshes and Grasslands			
	Salt Marsh		ACP Embayed Region Tidal Salt and Brackish Marsh
			ACP Central Salt and Brackish Tidal Marsh
	Brackish Marsh		ACP Embayed Region Tidal Salt and Brackish Marsh
			ACP Central Salt and Brackish Tidal Marsh
	Freshwater Marsh		
		Non-tidal Freshwater Marsh	ACP Large River Floodplain Forest - Herbaceous Modifier
			ACP Brownwater Stream Floodplain Forest; in part
			ACP Small Blackwater River Floodplain Forest; in part
			ACP Small Brownwater River Floodplain Forest; in part

Table 1, continued.

Habitat Types			
Level 1	**Level 2**	**Level 3**	**SEReGAP Map Unit Name**
		Tidal Freshwater Marsh	ACP Embayed Region Tidal Freshwater Marsh
			ACP Central Fresh-Oligohaline Tidal Marsh
	Natural Shoreline		Unconsolidated Shore (Lake/River/Pond)
			Unconsolidated Shore (Beach/Dune)
Managed Wetlands			
			Open Water (Fresh)
			Open Water (Brackish/Salt)
			Bare Sand
			Bare Soil
			Other Wetland
Farmland			
			Pasture/Hay
			Row Crop
Maritime Grasslands			
	Dune Grassland		ACP Northern Dune and Maritime Grassland
	Maritime Dry Grassland		ACP Northern Dune and Maritime Grassland
	Maritime Wet Grassland		ACP Northern Dune and Maritime Grassland
Managed Grasslands			
	Firebreaks and Rights-of-ways		Successional Shrub/Scrub (Utility Swath)
			Successional Shrub/Scrub (Other)
			Herbaceous Grassland (Other)
	Peatland Sites		Successional Shrub/Scrub (Other)
			Herbaceous Grassland
			Palustrine Scrub/Shrub Wetland (Other)
	Non-organic (Mineral Soil) Sites		Herbaceous Grassland (Other)
Pocosins and Related Habitats			
	Short Pocosins		
		Shrub (low) Pocosin	ACP Peatland Pocosin; in part
		Small Tree (high) Pocosin	ACP Peatland Pocosin; in part
		Small Depression Pocosin	ACP Peatland Pocosin; in part
	Pond Pine (Tall) Pocosin		
		Pond Pine Woodland	ACP Peatland Pocosin; in part

Table 1, continued.

Habitat Types			
Level 1	**Level 2**	**Level 3**	**SEReGAP Map Unit Name**
	Peatland Atlantic White Cedar	ACP Peatland Pocosin-Atlantic White Cedar	
	Bay Forests		ACP Peatland Pocosin; in part
			ACP Streamhead Seepage Swamp, Pocosin, and Baygall
Southern Pine–Dominated Forest Habitats			
	Longleaf Pine		
		Coastal Fringe Sandhill	ACP Longleaf Pine Woodland-Open Understory Modifier; in part
			ACP Longleaf Pine Woodland-Scrub/ Shrub Understory; in part
		Mesic Pine Flatwoods	ACP Longleaf Pine Woodland-Open Understory Modifier; in part
			ACP Longleaf Pine Woodland-Scrub/ Shrub Understory; in part
		Pine/Scrub Oak Sandhill	ACP Fall-line Sandhills Longleaf Pine Woodland - Open Understory Modifier
			ACP Fall-line Sandhills Longleaf Pine Woodland - Scrub/Shrub Understory Modifier
		Wet Pine Flatwoods	ACP Northern Wet Longleaf Pine Savanna and Flatwoods
		Pine Savanna	ACP Northern Wet Longleaf Pine Savanna and Flatwoods
	Loblolly (or Pond) Pine “Savannas” and Woodlands		
		Estuarine Fringe Loblolly Pine Forest	ACP Central Maritime Forest
			ACP Southern Maritime Forest
		Coastal Loblolly/Pond Pine Savanna (Maritime Pine Savannas)	ACP Central Maritime Forest
			ACP Southern Maritime Forest
Non-maritime Pine-Hardwood Mixed Forest Habitats			
	Coastal Fringe Evergreen Forest		ACP Central Maritime Forest
			ACP Southern Maritime Forest
	Loblolly Pine-Hardwood Mix		

Table 1, continued.

Habitat Types			
Level 1	**Level 2**	**Level 3**	**SEReGAP Map Unit Name**
		Bottomlands	ACP Large River Floodplain Forest—Oak Dominated
			ACP Nonriverine Swamp and Wet Hardwood Forest-Oak Dominated Modifier
			ACP Blackwater Stream Floodplain Forest-Forest Modifier
			ACP Brownwater Stream Floodplain Forest
			ACP Small Blackwater River Floodplain Forest
			ACP Small Brownwater River Floodplain Forest
			Evergreen Plantations
		Uplands	ACP Dry and Dry-Mesic Oak Forest
			ACP Mesic Hardwood and Mixed Forest
			ACP Fall-Line Sandhills Longleaf Pine Woodland-Loblolly Modifier
			ACP Fall-line Sandhills Longleaf Pine Woodland-Offsite Hardwood Modifier
			Deciduous Plantations
			Evergreen Plantations
			Successional Shrub/Scrub (Clear Cut)
			Successional Shrub/Scrub (Utility Swath)
			Successional Shrub/Scrub (Other)
			Evergreen Plantations
Maritime Shrub and Forest Habitats			
	Maritime Shrub		
		Salt Shrub	ACP Central Maritime Forest: in part
			ACP Southern Maritime Forest; in part
		Maritime Shrub	ACP Central Maritime Forest: in part
			ACP Southern Maritime Forest; in part
		Maritime Shrub Swamp	ACP Central Maritime Forest: in part
	Maritime Forest		ACP Southern Maritime Forest; in part
		Maritime Evergreen Forest	ACP Central Maritime Forest: in part
			ACP Southern Maritime Forest; in part
		Maritime Deciduous Forest	ACP Central Maritime Forest: in part
			ACP Southern Maritime Forest; in part
		Maritime Swamp Forest	ACP Central Maritime Forest: in part
			ACP Southern Maritime Forest; in part

Table 1, continued.

Habitat Types			
Level 1	**Level 2**	**Level 3**	**SEReGAP Map Unit Name**
Forested Wetland Habitats (Non-maritime)			
	Bottomland Hardwoods		
		Coastal Plain Levee Forest (Blackwater and Brownwater subtypes)	ACP Large River Floodplain Forest—Oak-dominated
		Coastal Plain Bottomland Hardwoods (Blackwater and Brownwater subtypes)	ACP Large River Floodplain Forest—Oak-dominated
			ACP Small Blackwater River Floodplain Forest
			ACP Small Brownwater River Floodplain Forest
		Coastal Plain Small Stream Swamp	ACP Blackwater Stream Floodplain Forest
			ACP Brownwater Stream Floodplain Forest
		Coastal Plain Wet Hardwood Forest	ACP Nonriverine Swamp and Wet Hardwood Forest—Oak-dominated Modifier
		Nonriverine Swamp Forest	ACP Nonriverine Swamp and Wet Hardwood Forest—Taxodium/Nyssa Modifier
	Cypress-Gum		
		Cypress-Gum Swamp (Blackwater and Brownwater subtypes)	ACP Large River Floodplain Forest—Cypress-dominated
		Tidal Cypress-Gum Swamp	ACP Southern Tidal Wooded Swamp
Administrative Areas			
	Buildings, Maintenance Areas	Developed Open Space	
			Low-Intensity Developed
			Medium-Intensity Developed
			High-Intensity Developed
	Roads		Developed Open Space
			Low-Intensity Developed
			Medium-Intensity Developed
			High-Intensity Developed
	Firebreaks		Successional Shrub/Scrub (Utility Swath)
			Successional Shrub/Scrub (Other)
			Herbaceous Grassland (Other)

Conclusion

At this point, we have compiled a list of the key management species with their associated habitats, as identified in the RTNCF ecosystem *Biological Review* report (USFWS 2002). This list has been compared to the species and habitat data presented for the same region by (1) the North Carolina Wildlife Action Plan (North Carolina Wildlife Resources Commission 2005); and (2) the North Carolina Gap Analysis Project (NC-GAP) (McKerrow et al. 2006). For several of the key management species, the USFWS has already developed habitat suitability indices, which offer graphical representations of species-habitat associations that could serve as a starting point for a graphical analysis of uncertainty. An initial cross-walk to match the USFWS and SEReGAP habitat classifications has also been completed (table 1) and will need to be reviewed by the refuge biologists. Therefore, the next step will be to meet with wildlife biologists to identify a short list of candidate species for modeling and to confirm the classification cross-walk. Short-listed species will be selected based on (1) species data availability (including expert knowledge); (2) habitat data availability (including expert knowledge); (3) suitability of NC-GAP data (habitat classes, resolution) to model species-habitat associations; and (4) species management potential based on presumed threats.

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STEWARDSHIP

Developing the Land Stewardship Database for the Southeastern United States

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Introduction

One of the most important and often misunderstood data sets developed by the Gap Analysis Program (GAP) is the Land Stewardship layer. It is commonly recognized that to accurately assess the conservation network, a current detailed land stewardship data set is required; but the level of effort and the sources of error are often underestimated.

For many states, the first-generation GAP land stewardship data was the first statewide data set with a specific focus on land management. Similar to our experiences with land cover mapping and vertebrate modeling, developing stewardship data on a state-by-state basis for first-generation GAP projects led to inconsistencies in data sets across state boundaries. Some of the potential inconsistencies were reduced by the adoption of national standards (Crist 2000; Edwards et al. 1994), including a common coding scheme and the use of a dichotomous key for assigning status codes central to the gap analysis process.

In addition to the consistent assignment of ownership, other important issues that need to be addressed for second-generation GAP efforts are management and status codes, currency, completeness, and the transparency of the process. For those reasons, the National Gap Program has adopted a regional approach to updating the land stewardship data for both the Southwest Regional Gap Project (SWReGAP) (USGS National GAP 2005) and the soon-to-be completed Southeast Regional Gap Project (SEReGAP).

Approach

Work toward a regionally consistent land stewardship database for SEReGAP was initiated in spring 2006. For this effort we are building on the experience and expertise of SWReGAP; specifically, Andrea Ernst from SWReGAP is coordinating the development of the Southeast database. In Alabama, where state-level GAP efforts are being conducted in parallel with regional work, Amy Silvano is working with her state cooperators to ensure maximum utility of the database for their applications. The initial phase of work has involved compiling a detailed list of federal and state management entities throughout the Southeast region. Once the list is complete, management plans are acquired for each land unit. If management plans are not available, an interview is conducted to determine management practices and the appropriate management status code for attribution in the database. Spatial data for the land stewardship layer will be compiled in a Geodatabase model within ESRI's ArcGIS 9.1 platform.

During the design phase of the Southeast prototype, several technical issues were identified. To increase the functionality of the database, we have decided to include a "parent parcel" attribute that will allow end users to identify which parcel each managed area belongs to. For example, in many of the national forests there are multiple management units, so without maintaining a specific link or relationship to the broader forest unit, queries become more complicated. A second technical issue is the inclusion of an owner code in addition to the traditional list of manager/owner codes. In this case we are proposing including an attribute that identifies a global owner ID (state FIPS, federal, private, regional, local), a state specific agency name, and a sequential parcel ID. This added attribute enables the structure of the management code to be explicit at the regional and national levels, while allowing for independent information detailing the true owner within each state.

In the Southeast, a general list of state agencies (coastal management, state parks, state wildlife) has been identified. This agency list was the basis for developing categories used in the management coding scheme at the state level (table 1). The list of ownership and management detail within each state is commonly a complicated array of associated relationships. For state-level GAP efforts, those relationships were simply accounted for in state-specific management codes. At a regional level, however, where multiple states are being accounted for, there is an inherent disparity with owner and management responsibility. This disparity is due to the simple fact that each state within the region organizes its agencies and their responsibilities differently. SEReGAP encompasses a nine-state area, which, in terms of coding, could lead to the creation of a large, complex, and reticulate management coding scheme. To address this issue, we decided that including a thematically based state management category and an information-rich owner code would allow for

Table 1. Proposed management codes for the state-level stewardship for the Southeast Regional GAP Stewardship database.

3000	**State Land**		
	3100	**State Park and Recreation Areas**	
		3101	State Park
		3102	State Recreation Area
		3103	State Historical Park
		3104	State Historic Site
		3105	State Resort Park
		3106	State Wild or Scenic River
		3107	State Rustic Park
		3108	Interstate Park
		3109	State Lake or Reservoir
	3200	**State Land Board and State School Land**	
		3201	State Trust Land
		3202	State Stewardship Trust Land
		3203	University Research and Demonstration Land
		3204	Ecological Preserve or Natural Area
		3205	Arboretum or Botanical Area
	3300	**State Wildlife Reserve**	
		3301	State Wildlife Reserve
		3302	State Habitat Area
		3303	State Fishing Unit or State Hatchery
		3304	State Wildlife Recreation Area
		3305	State Wildlife Administration Building
	3400	**Other State Land**	
		3401	Other State Land
		3402	State Sovereign Land
		3403	State Offshore and Other Submerged Land
	3500	**State Forest**	
		3501	State Forest
		3502	State Educational Forest
	3600	**State Coastal Reserve**	
		3601	State Coastal Reserve
		3602	State Aquatic Preserve
		3603	State Buffer Preserve
	3700	**State Natural or Cultural Preserve**	
		3701	State Natural Area
		3702	State Nature Preserve
		3703	State Heritage Preserve
		3704	Forever Wild Tracts

Table 1, continued.

	3800	**State Department of Transportation**	
		3801	State Mitigation Site
		3802	State Right of Way
	3900	**State Department of Agriculture**	

more detailed information to be organized in a concise manner, as well as for more meaningful and less complex queries of data across state lines.

A draft of the SEReGAP Land Stewardship layer, complete with federal and state lands, will be ready for review in September 2006. After completing the federal and state lands, we will identify additional regional, local, and private management categories and focus our efforts on gathering additional data.

Future Directions

The ultimate goal will be to have a national database of land stewardship data maintained through cooperation with the long list of agencies that actively manage land ownership and management data. Land ownership changes daily and it would be impossible for any one program to maintain a current database until a consortium of agencies is formed to work on integrating data from a large network of partners. It is realistic to believe that the framework could be constructed that would allow the exchange of data in a timely and efficient manner, thereby allowing the partners to focus on improving the data they provide, as opposed to having to acquire and code other agencies' stewardship information. The introduction of our thematic-based coding scheme with a relation-based structured geodatabase model will give agencies the functionality to relate coding schemes or add data specific to their organizations needs or both. This approach could be viewed as one of many possible precursory steps toward a unified national stewardship framework.

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AQUATIC GAP

Development of an Aquatic GAP for the Lower Colorado River Basin

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Introduction

The Lower Colorado River Basin (LCRB) (see figure 1), is a highly altered system in terms of flow and temperature modifications, irrigation, land use, and nonnative fish invasions (Mueller 2005). The lower main stem has "the dubious distinction of being among the few major rivers of the world with an entirely introduced fish fauna" (Mueller and Marsh 2002). The LCRB has one of the most unique but imperiled fish fauna in the nation (Mueller and Marsh 2002; Olden and Poff 2005). Of 31 native fish species, 75 percent are endemic, and 25 percent are extinct, extirpated, or listed as endangered or threatened under the Endangered Species Act (USFWS 1999).

Figure 1. Lower Colorado River Basin.

Although researchers have suggested that the full recovery of native fish communities in the LCRB is not feasible for political, societal, and economic reasons (Minkley and Deacon 1991; Mueller 2005), the development of conservation areas will be helpful for future considerations to protect aquatic species. Previous Aquatic GAP efforts for inland streams have been conducted in relatively mesic areas of the United States. The Lower Colorado River Basin Aquatic GAP project (LCRBGAP) will provide an opportunity to compare and contrast the role of environmental and biological variables in predicting fish distributions in the arid Southwest and in more mesic regions in the Midwest and East.

Phase one of the LCRBGAP project was initiated in 2004 as a one-year feasibility study to gather existing data sets and to evaluate stakeholder interest in participating in development and in using LCRBGAP products. We are now in phase two, developing species distributions and predictive models for the Verde River watershed within the LCRB (figure 2). Using methods refined in phase two, phase three will expand the process to the entire LCRB and define conservation areas for the basin based on native biodiversity and threats to the system, with the intention of combining aquatic models with terrestrial models produced through the Southwest Regional Gap Analysis Project (SWReGAP). We report here on the methods that will be used for this project and on our progress to date.

Methods

Conservation areas for the LCRB will be based on three primary factors: predicted distributions of native versus nonnative fishes, ecosystem traits (e.g., stream hierarchy, land cover type, stream density, etc.), and threats. Each fish collection site is being attributed with habitat parameters in a geographical information system (GIS). Habitat parameters were selected based on the relationships documented between specific variables and fish communities, such as elevation, the distance to and presence of barriers, and land use practices (Mandrak 1995; Wang et al. 1997; Matthews 1998; Marchetti and Moyle 2001; Lamouroux, Poff, and Angermeier 2002; Zorn, Seelbach, and Wiley 2002).

Two methods that performed well in other systems (artificial neural networks and classification and regression trees) will be used to model fish distributions (Olden and Jackson 2002; McKenna 2005; Oakes et al. 2005). The predictive performance of our models will be evaluated using a jackknife validation procedure (Olden and Jackson 2000; Oakes et al. 2005) and Cohen's Kappa (Titus, Mosher, and Williams 1984). These models will be developed for both native and nonnative fish, with the more robust method (based on the proportion of correctly classified occurrences across species) being used in the process to define conservation areas.

A hierarchical classification framework to conserve biodiversity will be created for the LCRB following guidelines created by Sowa et al. (2004) and Higgins et al. (2005). The upper levels will be derived from existing sources, such as Maxwell et al. (1995) and Abell et al. (2000). Each ecological drainage unit (EDU) and aquatic ecological system (AES) will be derived using biotic and abiotic data (e.g., geology, gradient). The number of EDUs and AESs will be determined through multivariate techniques such as clustering, principal components analysis, and nonmetric multidimensional scaling (Sowa et al. 2004). Expert reviewers will evaluate our hierarchical classification framework.

An anthropogenic threats classification will be created at the AES level and will include variables such as road density, dam locations, impaired streams, and/or other data deemed to be threatening to aquatic resources. Once all metrics are identified, correlation analysis will be used to determine redundant metrics that can be eliminated from future analysis (Sowa et al. 2004). The remaining metrics will be combined to create one human stressor index for each AES.

After the hierarchical stream classification and threats classification systems are developed and approved, conservation areas within each EDU will be determined. These conservation areas will be the EDUs (and possibly AESs) that have the highest need (or most potential) for conservation. Priority areas will be selected to protect native biodiversity and underrepresented species/communities using factors such as native species richness, highest predicted target species richness (e.g., state or federally listed species), limited or no presence of nonnative fishes, low human stresses, high proportion of public land, and overlap of existing conservation initiatives (Sowa et al. 2004). Resource professionals within the region will review our analyses and the selected priority area. This methodology will incorporate a broad array of information (threats, land use, species and habitat data, expert opinion) in the decision-making process for selecting conservation areas (Wilson et al. 2005).

Progress to Date

Species Data

Fish location data have been gathered from several state and federal agencies, universities, online fish databases, and museums. Fish records with complete collection information (point location, species name, site description, and date collected) are being checked for accuracy and then entered into a database. Currently we have over 1,500,000 individual records in the database, encompassing 160 species. The distribution of records between native and nonnative species is nearly even. Although the data range from the early 1900s to the present, about half the records were obtained from 1980 to the present.

Habitat and Supplementary Data

Numerous habitat data have been collected based on documented relationships between fish occurrence and habitat variables. We are in the process of deriving specific parameters (e.g., the number of dams per watershed, the percentage of land upstream that is used for agricultural purposes, etc.) for the basin. These parameters are being linked to a stream layer and associated with species occurrence records.

Verde Basin Pilot Project

The Verde Basin (figure 2) was selected for a pilot study because it is one of the few remaining perennial rivers within the LCRB (Averitt et al. 1994) and it may serve as refugia for native fishes. The upper 60 percent of the Verde River is unimpounded and located within National Forest Service lands, though scattered allotments of private lands occur throughout. Approximately 65 kilometers of this unimpounded stretch have been designated as a Wild and Scenic River (USDA Forest Service 2004). In addition, the Verde River has been identified by the Arizona Game and Fish Department as a focus area for future fisheries planning (Young et al. 2001; Larry Riley, Arizona Fisheries Branch Chief, personal communication).

The Verde Basin currently contains 13 native fishes typically found outside the main stem of the Lower Colorado. Of the native species, more than 50 percent are listed by the state of Arizona or the U.S. Fish and Wildlife Service (USFWS) as of concern, endangered, or threatened. Threats to the system include 41 dams, numerous stock ponds, more than 15 nonnative fishes (outside the reservoirs), and surface and groundwater diversions for public supply, agriculture, and livestock uses.

Public Outreach

Literature Collection

At the request of several stakeholders (e.g., the Arizona Game and Fish Department, USFWS, U.S. Environmental Protection Agency), we developed an online literature database for products related to the LCRB that is searchable by author, title, year, and keyword. This database currently contains nearly 4,000 records, of which approximately 1,300 are available to download. The database is accessible through the LCRBGAP Web site <http://www.lcrgap.org/search.htm>.

Web Page Development
A Web page was developed to disseminate project updates and products, <www.lcrgap.org>. When the Web site went online, 135 cooperators and interested parties were notified of the Web address. The Web page is our primary method of communication with our stakeholders (e.g., regional, state, and federal government branches; university researchers; and local interest groups).

Future Tasks and Challenges
The ultimate goal is to predict the distributions of fishes throughout the basin so that conservation areas can be developed. We continue to build the species database by acquiring and correcting additional data sets, and we update those already acquired. We are coordinating with several organizations to obtain additional fish occurrence records. The entire stream of network data are being corrected and attributed for use in predictive species modeling. A challenge will be to identify ephemeral drainages to minimize the overestimation of species distributions. Additional documents are being collected for the literature database from Web sites and through contacts with the cooperating agencies and organizations.

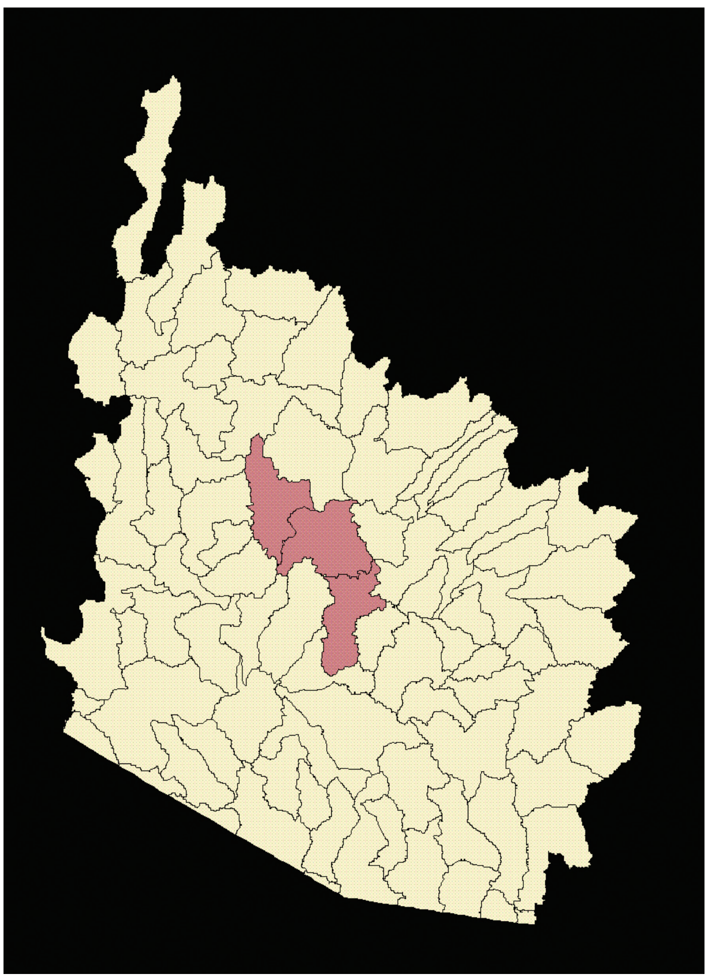

Figure 2. Shading signifies the Verde Basin within the Lower Colorado River Basin.

In the short term, our focus is on the Verde Basin. We posted an Internet map server to display species records compiled to date so that reviewers could examine these data and provide feedback. This attribution of environmental and anthropogenic data will be completed soon so that species models can be developed by the end of summer 2006. They will also be posted online through our Web site.

Potential Outcomes
Products from this project may prove useful for a variety of conservation objectives. Examples from other Aquatic GAPs include using habitat models to locate an existing population of fish that was presumed extirpated, and utilizing distribution models and threat indices in State Wildlife Action Plans (SWAPs). Although SWAPs have been completed for the states encompassing the Lower Colorado River, GAP products can be used to address specified information needs in those SWAPs, such as:

- habitat use models for species of conservation priority;
- characteristics that drive whether a species will be invasive, an important keystone species, or more sensitive to stressors; and
- determining threats to vulnerable species.

Other organizations (the Arizona Game and Fish Department, and two multi-agency species planning efforts) intend to use products from the LCRBGAP to develop species-specific and regional conservation plans. Additional uses identified through discussions with regional management organizations have included identifying areas with appropriate habitat conditions for use as nursery areas, prioritizing research efforts, identifying potential reintroduction sites, and focusing sampling efforts to areas with a high probability of occurrence for a target species or community.

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FINAL REPORT SUMMARIES

Nebraska Gap Analysis Project

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Introduction

The Nebraska Gap Analysis Project (NE-GAP) was undertaken to assess the distribution and conservation status of biodiversity in the state under existing land ownership and management regimes. Our objectives were as follows: (1) to map actual land cover as closely as possible to the alliance level; (2) to map the predicted distribution of those terrestrial vertebrates and selected other taxa that spend any important part of their life history in the project area and for which adequate distributional habitats, associations, and mapped habitat variables are available; (3) to document the representation of natural vegetative communities and animal species in areas managed for the long-term maintenance of biodiversity; (4) to make all GAP information available to the public and those charged with land-use research, policy, planning, and management; and (5) to build institutional cooperation in applying this information to state and regional management activities.

Land Cover

A map of the land cover of Nebraska was prepared using primarily Landsat Thematic Mapper (TM) imagery from the period 1991–93. When possible, early spring and late summer dates were selected within the same year. The minimum mapping unit (MMU) for the land cover map is 30 meters, which is the spatial resolution (pixel) of Landsat 5 TM data.

The final thematic map identifies 20 different land cover classes. Agricultural fields and grasslands dominate the landscape of Nebraska, covering almost 40 percent of the state. The second most identifiable feature is the Sandhills Upland Prairie class (23 percent), which is found throughout the Nebraska Sandhills. Five woody vegetation classes cover 3 percent of the state, and they are usually found along riparian corridors and canyons. Ponderosa Pine Forests and Woodlands are found along the Pine Ridge in northwest Nebraska and along the Niobrara River. Juniper woodlands (mainly cedar), which are increasing across the state due to the suppression of wildfires, are concentrated in valleys, canyons, and other protected lowlands and are usually mixed with deciduous woody vegetation.

Open water and wetland classes cover only 2 percent of the state, but these features figure prominently into vertebrate species distribution. Of note are the Platte River, which cuts across the middle of the state, and the various reservoirs found across the state. Wetlands fed by groundwater are found in the Sandhills and are important for waterfowl breeding. Other wetlands are found in the Rainwater Basin of south-central Nebraska. These wetlands are fed by runoff and are used by birds and waterfowl during migration along the central corridor. Only the largest of the state's wetlands are filled year-round.

Accuracy Assessment

An accuracy assessment was conducted to evaluate the results of the land cover classification using two separate sets of ground reference data collections. Producer accuracies for the different land cover classes ranged from 0–81 percent, while user accuracies ranged from 7–83 percent. The delineation of shrublands appears to be a weak spot in the land cover map. The shrubland category, however, covered only 1,824 km^2, or 0.9 percent of the land area in Nebraska. The dynamic nature of agriculture also poses significant problems for land cover mapping and accuracy assessment. Many of the misclassifications evident in this class may have arisen from temporal decorrelation. Field data were gathered in the late 1990s and early 2000s, but the imagery is from the early 1990s. In many agricultural areas of the state, land use has changed during this time period.

Terrestrial Vertebrate Distributions

Potential distribution maps were developed for 332 terrestrial vertebrate species, comprising 193 species of breeding birds, 78 species of mammals, 14 species of amphibians, and 47 species of reptiles. The NE-GAP wildlife habitat relationships were modeled and species range maps were generated on a grid of 40km^2 hexagons. To develop models of the relationships between the wildlife species and their habitats, a database of geospatial data was developed that included a broad range of surrogate variables for habitat suitability and quality, such as land cover composition, aspects of climate, surficial soil texture, hydrology, and terrain. This geodatabase was linked using advanced statistical modeling (a recursive partitioning algorithm) to species occurrence data obtained from biological surveys and museum voucher specimens. In the absence of a sufficient number of observations, wildlife-habitat relationship models were developed from the literature and implemented in the geodatabase.

Accuracy assessment of the models was conducted using occurrence data not previously used and a focus was placed on the omission error rate (i.e., an estimate of the frequency of incorrectly designating an area as "not habitat"). Higher omission rates indicated poorer model performance. Considered across taxa (birds versus reptiles and amphibians versus mammals), the median values are almost always zero, while the average omission rates range from 2.6–27.5 percent. This discrepancy between the average and the median indicates a highly skewed distribution of model performance, which indicates that omission rates are generally quite low, but a few species have poorly performing models, which affect the average, but not the median.

Land Stewardship

The NE-GAP project revealed profound gaps in the network of stewardship needed to cover a representative selection of Nebraska's biodiversity. Privately owned lands compose the majority of Nebraska's land area (approximately 97.4 percent) and more than 98 percent of land in Nebraska can be classified as belonging to land management status class 4. Only 0.61 percent of Nebraska's land area can be designated as status 1 or status 2 lands. The largest property owners of these lands are The Nature Conservancy, which manages a number of preserves, and the U.S. Fish and Wildlife Service (USFWS), which manages three national wildlife refuges in the state.

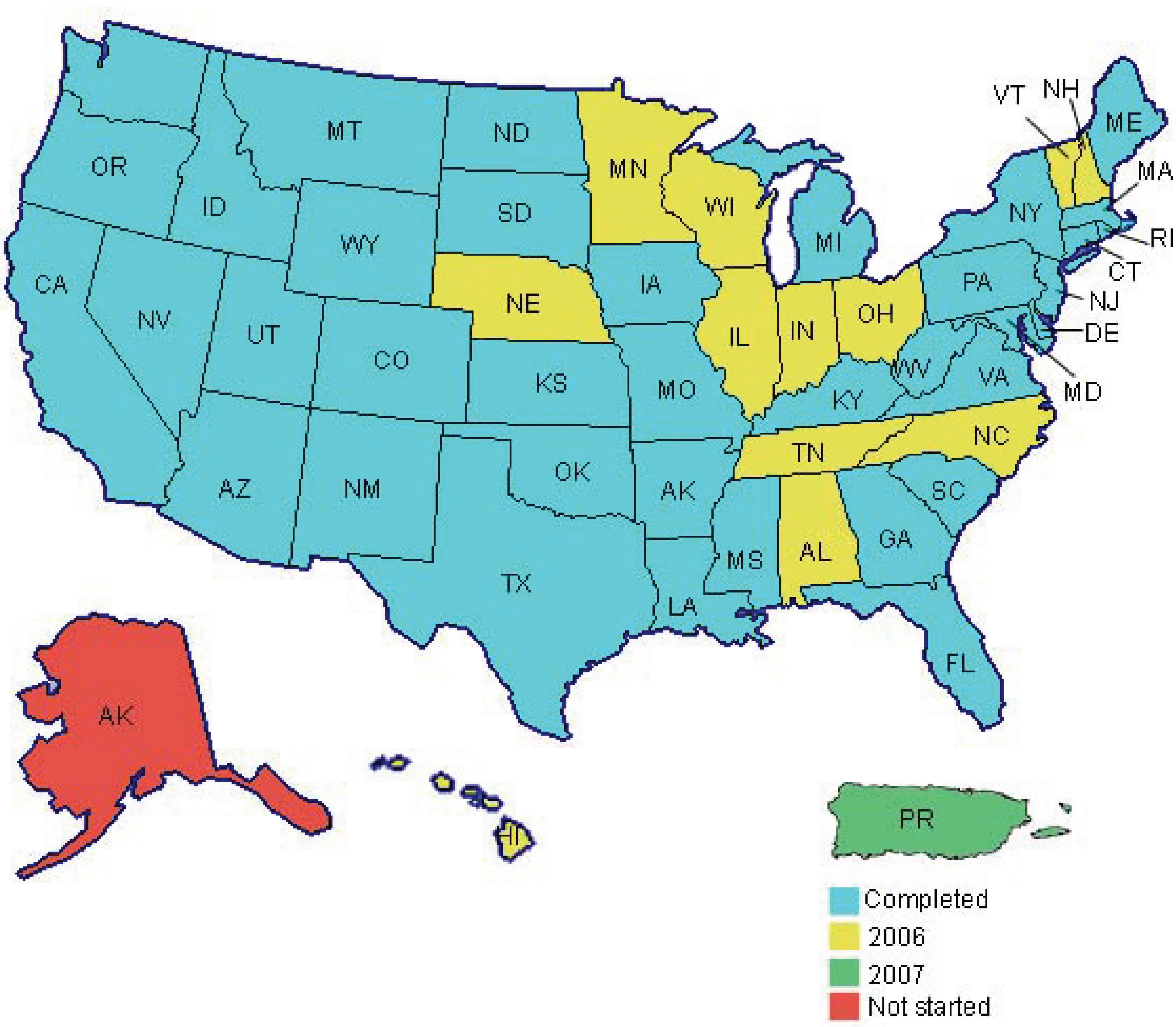
Gap Analysis

The protection status for each land cover classification was derived from a digital overlay of the land cover map with the stewardship map in a geographic information system (GIS). This process created an intersection between each land cover type and its representation in a management status. The largest amount of land area for the state is in active or fallow agricultural fields (39.38 percent), followed by Sandhills upland prairie (22.74 percent), then Little Bluestem-Gramma Mixedgrass Prairie cover type (15.13 percent). Land ownership in Nebraska is predominately private (97.2 percent) and most lands are classified as status 4. The distribution of protected areas (status 1 and 2) includes 4 University of Nebraska prairie sites, 1 U.S. Department of Agriculture Forest Service wilderness area, 64 USFWS waterfowl protection areas, 6 USFWS wildlife refuges, 49 units owned by non-government organizations, 7 state Natural Resource District–managed areas, and three national monument sites managed by the National Park Service.

Only six of the 332 modeled terrestrial vertebrate species in Nebraska had more than 1 percent of their predicted habitat in status 1 and 2 lands. No species had more than 10 percent of their predicted habitat on these protected status lands.

STATE PROJECT REPORTS

Status of GAP State Projects as of June 2006



All completed products and reports are available through the GAP Web site at <http://gapanalysis.nbii.gov>. Draft data and other products may be obtained from the state project principal investigator (PI). Contact information for completed states can be found on the Web site. Updates on incomplete projects are included below. Many completed projects are currently being remapped as part of regional projects. For information on regional projects, check the Regional Project Reports section (p. 76) of this Bulletin.

Alabama

Project under way.
Anticipated completion date: December 2006

Contact:
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Land cover:
As part of our ongoing partnership with the Southeast Regional Gap Analysis Project (SEReGAP), the Alabama Gap Analysis Project (AL-GAP) is responsible for all land cover mapping within the East Gulf Coastal Plain (EGCP). In February 2006, we expanded this mapping effort to include the Mississippi Alluvial Plain (MAP) within the states of Mississippi and Tennessee. Overall, land cover mapping has been continual in these regions throughout 2005 and 2006. In June 2006, our initial draft maps, based on the Terrestrial Ecological Systems and described by NatureServe (Comer et al. 2003), hereafter referred to as Systems, for both the EGCP and MAP were sent out for a regional review among our cooperating SEReGAP partners. Final revisions, as well as report writing and accuracy assessments for the Systems maps, will be compiled throughout fall 2006, with our final products anticipated in December 2006.

Animal modeling:
All spatial parameters and habitat relationship models for each vertebrate species were finalized in winter 2005–06. Development of the predicted habitat distribution maps for all vertebrate species is anticipated to be completed in August 2006. Additionally, as part of our ongoing partnership with SEReGAP, a regional reviewing committee is being developed to evaluate the vertebrate habitat models and predicted habitat distribution maps. Regional reviews are expected to take place in fall 2006, with report writing and accuracy assessments of habitat maps to be completed by December 2006.

Land stewardship mapping:
Stewardship mapping is ongoing. Digital boundary files and ownership data have been compiled from various public and private agencies through cooperative arrangements. We began working collaboratively with SEReGAP in February 2006 on database design structure and federal land allocation to ensure consistency of products at the national level. We will continue updating this layer for the duration of the project and will complete the final map in September 2006.

Analysis:
The gap analysis will be initiated upon completion of the final vertebrate distribution models and land stewardship layer.

Reporting and data distribution:
Report writing will be ongoing through the duration of the project. Project updates and current information can be found on our Web site at <http://www.auburn.edu/gap>.

Papers and posters presented in 2005:
Hogland, J. S., and M. D. MacKenzie. 2005. Creating spatial probability distributions for longleaf pine ecosystem across east Mississippi, Alabama, the panhandle of Florida, and west Georgia. Paper presented at the Joint Ecological Society of America (ESA) Ninetieth Annual Meeting and Ninth International Congress of Ecology (INTECOL), Montreal, Canada, August 9.

Kleiner, K. J. 2005. Alabama GAP: Priority model to target restoration hotspots by determining probabilities of existing longleaf pine stands found by remote sensing. Paper presented at the Second Mountain Longleaf Pine Workshop, Mount Berry, GA, November 18.

Kleiner, K. J., and M. D. MacKenzie. 2005. Spectral separability of ecological systems in the East Gulf coastal plain. Paper presented at the Joint Ecological Society of America (ESA) Ninetieth Annual Meeting and Ninth International Congress of Ecology (INTECOL), Montreal, Canada, August 9.

MacKenzie, M. D., J. S. Hogland, and K. J. Kleiner. 2005. Creating and using spatial probability distributions for longleaf pine ecosystems across east Mississippi, Alabama, the panhandle of Florida, and west Georgia. Paper presented at the National Gap Analysis Conference and Interagency Symposium, Reno, NV, December 8.

MacKenzie, M. D., K. J. Kleiner, J. S. Hogland, A. L. Silvano, B. Taylor, and J. B. Grand. 2005. Alabama GAP: Land cover mapping to produce predicted distribution maps for native vertebrate species. Poster presented at the Joint Ecological Society of America (ESA) Ninetieth Annual Meeting and Ninth International Congress of Ecology (INTECOL), Montreal, Canada, August 9.

Literature Cited:
Comer, P., D. Faber-Langendoen, R. Evans, S. Gawler, C. Josse, G. Kittel, S. Menard, M. Pyne, M. Reid, K. Schulz, K. Snow, and J. Teague. 2003. *Ecological systems of the United States: A working classification of U.S. terrestrial systems*. Arlington, VA: NatureServe.

Alaska

Not started.

Hawaii

Project under way.
Anticipated completion date: August 2006

Contact:
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Land cover:
Under review.

Animal modeling:
Under review.

Land stewardship mapping:
Under review.

Analysis:
Under review.

Reporting and data distribution:
First drafts of all the major project data layers have been completed and are currently being reviewed by the national GAP office. Project completion and data distribution are anticipated in summer 2006.

Illinois

Draft data available from state at:
<http://www.inhs.uiuc.edu/cwe/gap/>.
Anticipated completion date: Summer 2006

Review under way.

Contact:
Tari Tweddale
GAP Coordinator
Illinois Natural History Survey, Champaign
tweicher@uiuc.edu, 217-265-0583

Land cover:
Complete.

Animal modeling:
Complete.

Land stewardship mapping:
Complete.

Analysis:
Complete.

Reporting and data distribution:
The IL-GAP team is now in the process of compiling the final report and completing the necessary revisions to the data deliverables. The final report will be submitted in August 2006. Anticipated project completion date is October 2006.

Indiana

Near completion.
Anticipated completion date: July 2006

Contact:
Forest Clark
U.S. Fish and Wildlife Service, Bloomington
forest_clark@fws.gov, 812-334-4261 x206

Land cover:
The Indiana land cover data are complete.

Animal modeling:
The Indiana project completed the modeling of 300 vertebrate species.

Land stewardship mapping:
The land stewardship map of Indiana, developed primarily under the aegis of the Indiana Department of Natural Resources, Division of Fish and Wildlife, is complete.

Analysis:
A gap analysis of Indiana has been run.

Reporting and data distribution:
The final report has been completed and final revisions are being made. Project completion is expected in summer 2006.

Minnesota

Project under way.
Anticipated completion date: December 2006

Contact:
Gary Drotts
Minnesota Department of Natural Resources, Brainerd
gary.drotts@dnr.state.mn.us, 218-828-2314

Land cover:
Land cover mapping followed the Upper Midwest GAP protocol <http://www.umesc.usgs.gov/documents/misc/umgap/98-g001.pdf>.The state Department of Natural Resources (DNR) completed classification of the entire state and, with the assistance of NatureServe, cross-walked the classification to the National Vegetation Classification Standard (NVCS). Land cover mapping is complete.

Animal modeling:
Hexagon species range maps have been developed for Minnesota and delivered to the U.S. Geological Survey's Upper Midwest Environmental Sciences Center (UMESC). Final revisions are being made to the vertebrate distribution models. Completion is anticipated in summer 2006.

Land stewardship mapping:
Final revisions are being made to the land stewardship layer. Completion is anticipated in summer 2006.

Analysis:
Gap analysis will be completed in 2006.

Reporting and data distribution:
Project completion is anticipated by December 2006.

Nebraska

Draft data available from state contact:
<http://www.calmit.unl.edu/gap/>.
Anticipated completion date: June 30, 2006

Contacts:
James W. Merchant, PI
Center for Advanced Land Management Information Technologies (CALMIT)
University of Nebraska-Lincoln
jmerchant1@unl.edu, 402-472-7531

Land cover:
The land cover map has been completed.

Animal modeling:
Animal models have been completed.

Land stewardship mapping:
Land stewardship mapping has been completed.

Analysis:
Gap analyses have been completed.

Reporting and data distribution:
The final report has been completed and CDs are being compiled.

North Carolina

Near completion.
Draft data available from state contact.
Review under way.

Anticipated completion date: August 2006

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

Land cover:
Complete.

Animal modeling:
Complete.

Land stewardship mapping:
Complete.

Analysis:
Complete.

Reporting and data distribution:
The final report is in review and project completion is anticipated in June 2006.

Ohio

Project under way.
Anticipated completion date: September 2006

Contacts:
Land cover, Dr. J. Raul Ramirez
The Ohio State University Center for Mapping, Columbus
raul@cfm.ohio-state.edu, 614-292-6557

Animal modeling, Troy Wilson
U.S. Fish and Wildlife Service, Reynoldsburg
614-469-6923

Land cover:
The land cover map is complete.

Animal modeling:
Vertebrate species modeling is nearing completion. Draft products are in review.

Land stewardship mapping:
The land stewardship map is complete.

Reporting and data distribution:
The Ohio terrestrial gap analysis and final report will be completed by December 2006.

Puerto Rico

Project under way.
Anticipated completion date: February 2007

Contacts:
William Gould, Principal Investigator
Geographic Information Systems and Remote Sensing Laboratory
USDA Forest Service
International Institute of Tropical Forestry, San Juan
wgould@fs.fed.us, 787-766-5335 x302

Land cover:
Land cover mapping for Puerto Rico is complete.

Animal modeling:
Draft vertebrate distributions have been completed and reviewed by the national GAP office; the models are currently being reviewed by expert biologists. Final products are anticipated in summer 2006.

Land stewardship mapping:
The land stewardship map has been completed.

Analysis:
Gap analyses will begin in summer 2006 following expert review of our vertebrate distribution models.

Reporting and data distribution:
The final report is anticipated in December 2006, with project completion anticipated in February 2007.

Vermont and New Hampshire

Draft data available from state contact. Review under way.
Anticipated completion date: September 2006

Contact:
Ernie Buford
University of Vermont, Burlington
ebuford@uvm.edu, 802-656-3007

Land cover:
Final revisions are being completed.

Animal modeling:
The vertebrate distribution models are nearing completion.

Land stewardship mapping:
Final revisions are being completed.

Reporting and data distribution:
Completion is anticipated by December 2006.

Wisconsin

Project under way.
Anticipated completion date: December 2006

Contact:
Kirk Lohman
U.S. Geological Survey
Upper Midwest Environmental Sciences Center (UMESC), La Crosse
klohman@usgs.gov, 608-781-6341

Land cover:
Land cover mapping is completed, and a draft version is available from UMESC.

Land stewardship mapping:
The land stewardship data is complete and in final review; a draft version is available from UMESC.

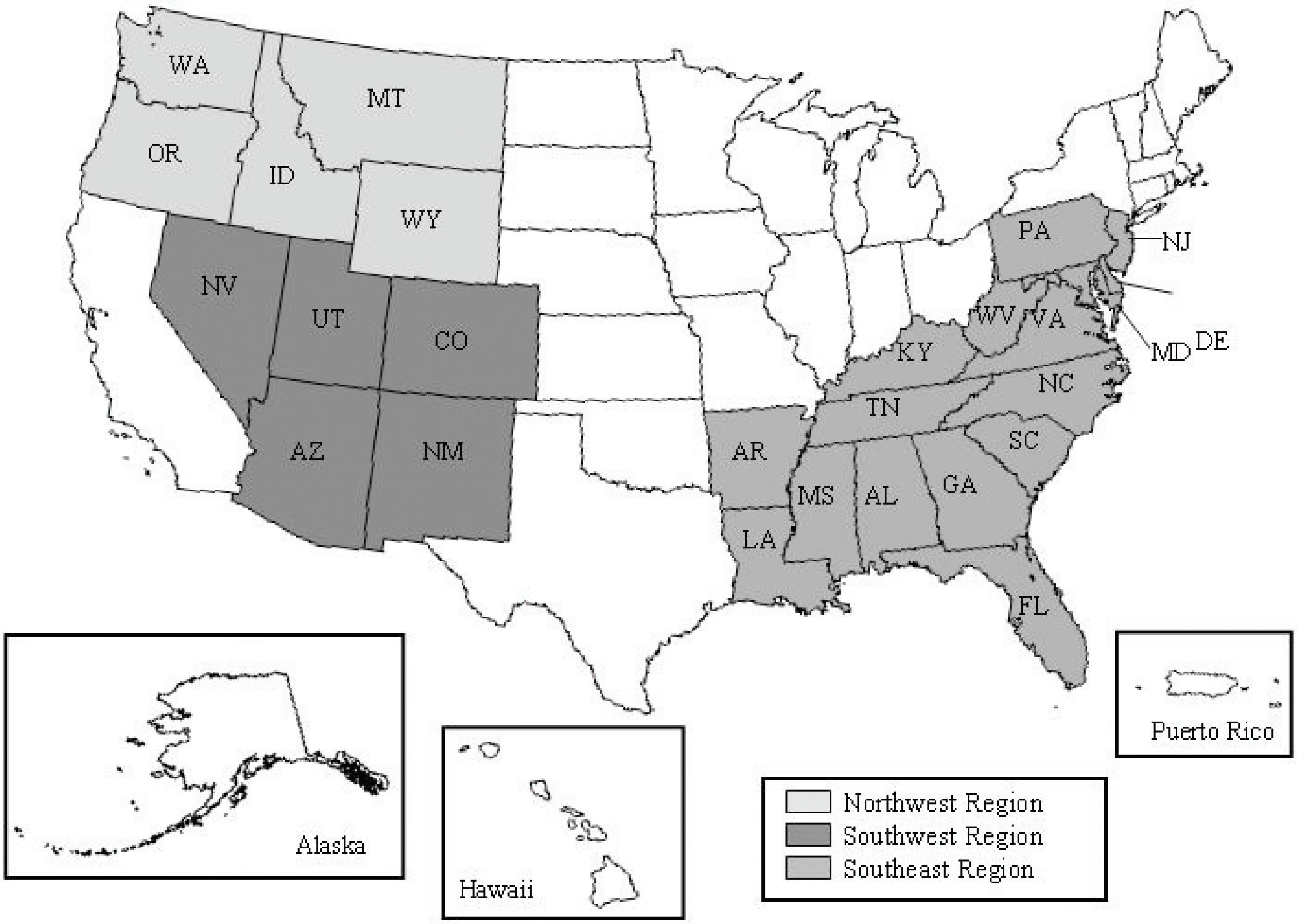
Animal modeling:
The vertebrate models are nearing completion.

Gap analysis:
Once the vertebrate models are complete and reviewed, the gap analysis can be conducted. Completion is anticipated in August 2006.

Reporting and data distribution:
Report writing is under way and a draft report is expected in October 2006. Final project completion is anticipated by December 2006.

REGIONAL PROJECT REPORTS

Status as of June 2006



Northwest Regional GAP (NWReGAP)

Update under way for five-state region encompassing Washington, Oregon, Idaho, Montana, and Wyoming.

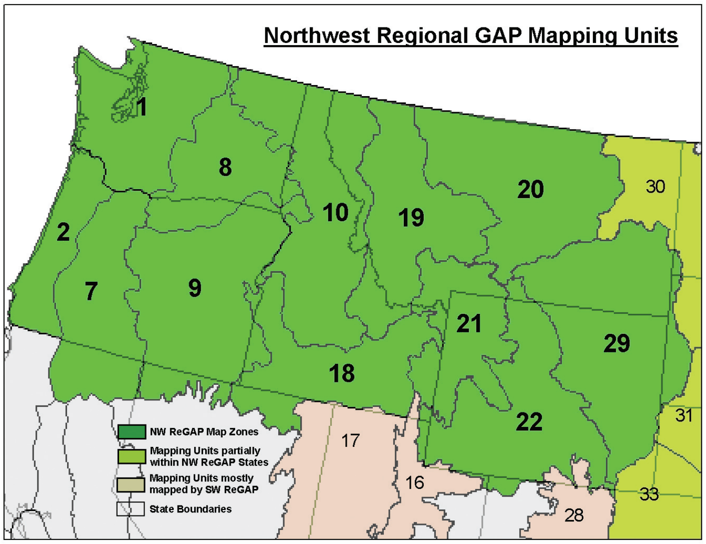
Contact:
Jocelyn Aycrigg
National Gap Analysis Program
Moscow, ID
aycrigg@uidaho.edu, 208-885-3901

NWReGAP started in August 2004 and is currently mapping the land cover, species distributions, and land stewardship data for Washington, Oregon, Idaho, Montana, and Wyoming. These data will help with conservation efforts throughout the Northwest.

Land cover

Map zone 1: Complete and available in draft form from the National Gap Analysis Program at <http://gapanalysis.nbii.gov>.

Map zones 2 and 7: Mapping began in May 2006 in partnership with the U.S. Department of Agriculture Forest Service and Oregon State University. Both zones are scheduled to be complete by December 2007.



Map zones 8 and 9: Nonforested areas were completed by the Sagebrush and Grassland Ecosystem Map Assessment Project (SAGEMAP). We partnered with the U.S. Department of Agriculture Forest Service and Oregon State University to complete the forested areas. They delivered a draft map in April 2006 that we are currently reviewing. These data will be available as soon as our review is complete.

Map zones 10 and 21: The mapping for these zones is being conducted by personnel in our Moscow, ID, office. From May through September 2006, we are collecting field vegetation plot data.

Map zone 18: Completed by SAGEMAP.

Map zone 19: We are conducting the mapping of this zone in our Moscow, ID, office. We started this zone in May 2005 and it is scheduled to be complete by the end of 2006.

Map zone 20: We have contracted with Sanborn Solutions to conduct the mapping for this zone. Sanborn started their work in October 2005 and they plan to complete it by the end of 2006.

Map zone 22+: This includes portions of zones 16 and 28 that extend into Wyoming. The mapping of this zone is scheduled to begin in 2006.

Map zone 29+: This includes portions of zones 30 and 33 that extend into Montana and Wyoming, respectively. The mapping of this zone is scheduled to begin in 2006.

Vertebrate modeling:
We are partnering with the Wyoming Natural Diversity Database (WYNDD) to conduct the vertebrate modeling for the Northwest. The Natural Heritage programs in each the five states are responsible for collecting the species' records of occurrence for their state. All these data are projected to be delivered to WYNDD in early 2007 so the models can be developed. Both deductive and inductive modeling approaches will be used to develop the best possible model for each species. We intend to map the range, distribution, and habitat of each species in the Northwest.

For more information, please see the Northwest Regional Gap Analysis Project Web site: <http://www.gap.uidaho.edu/Northwest/home.htm>.

Southeast Regional GAP (SEReGAP)

Update under way.
Anticipated completion date: November 2006

Contacts:

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steve_williams@ncsu.edu, 919-513-7413

Elizabeth R. Kramer
Natural Resource and Spatial Analysis Laboratory
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Athens, GA
lkramer@arches.uga.edu, 706-542-3577

Amy L. Silvano
Alabama Cooperative Fish and Wildlife Research Unit
Auburn University
Auburn, AL
silvaal@auburn.edu, 334-844-9294

Land cover:
As one component of the regional land cover mapping effort, seven mapping zones of the National Land Cover Dataset (NLCD) 2001 have been completed. Those data are currently available for viewing and download using the Multi-Resolution Landscape Characteristics Consortium's Dynamic Download Tool (<http://gisdata.usgs.net/website/MRLC/>). In addition to the NLCD land cover, impervious surface estimates are complete and canopy closure estimates will be finalized by June 2006 for those same seven mapping zones. Each of these data sets was developed using the NLCD 2001 mapping protocols (Homer et al. 2004), with some modifications to address local land cover patterns. For example, to accurately map large acreages of evergreen wetlands that occur in the Atlantic Coastal Plain (zones 58 and 55), we found it necessary to incorporate wetland masks into the decision-tree process (McKerrow and Earnhardt 2004). The NLCD 2001 land cover is available for nine of the 10 southeastern mapping

zones. Two of those mapping zones were completed by the Kentucky Landscapes Snapshot project and the U.S. Geological Survey is taking the lead on Southern Florida (zone 56) mapping.

GAP-level mapping is ongoing, with a scheduled completion date of August 2006 for the 10 mapping zones. Mosaicking and edge matching into a regional land cover map will be done as adjacent mapping zones are finalized. The target map legend includes 135 vegetated cover classes, with NatureServe's Ecological Systems as the basis for the natural vegetation map units. In the Southeast, we defined a series of modifiers to the Ecological Systems where we expected the variability within a system to be important to habitat modeling. For example, the Southern Piedmont Dry Oak–(Pine) Forest is a matrix forest community of the Piedmont. Historically the forests of the Piedmont were hardwood dominated, with clearing followed by abandonment; much of the forest is now dominated by loblolly pine. For the Southeastern GAP map legend, we have added three modifiers to that system (hardwood, mixed forest, and pine dominated). A large proportion of the acreage in the Piedmont is being mapped as the pine-dominated expression of this system. In addition to the modifications to the Ecological Systems classification, we have split some of the NLCD 2001 cover classes into categories that are informative for habitat modeling. For example, shrub/scrub habitats are being mapped as clearcut shrub/scrub, power line corridors, with the remaining scattered shrub/scrub areas being left as the general shrub/scrub class. Our vertebrate modelers felt these distinctions were important to accommodate the different patterns in the shape and succession within that land cover class.

The approach to mapping ecological systems in the Southeast is a hybrid approach, combining expert and decision-tree modeling, pattern recognition, and for a few systems, manual delineation. For each matrix, large patch, and linear system, a range map has been developed. Those ranges were delineated using primarily ecoregional boundaries, with additional information such as species range maps being used to indicate turnover from one Ecological System to another. For example, the range maps of shortleaf pine (*Pinus echinata*) and longleaf pine (*Pinus palustris*) were used to identify the boundary between the East Gulf Coastal Plain Interior Upland Longleaf Pine Woodland and the East Gulf Coastal Plain Interior Shortleaf Pine-Oak Forest Systems. In addition to the Systems ranges, ancillary data, including the three seasons of Landsat TM imagery, the general land cover classes of the NLCD 2001, landform models, blackwater/brownwater rivers, geology, National Wetland Inventory data, and State Soil Geographic (STATSGO) and Soil Survey Geographic (SSURGO) data, are being used in mapping the Ecological Systems and the additional general land cover classes.

Draft maps of ecological systems for the East Gulf Coast (zone 46), Southern Piedmont (zone 54), and Interior Low Plateau portion of Tennessee and Alabama (zone 48) have been reviewed internally and minor edits are being made. The Southern Blue Ridge (zone 57), the Northern Piedmont (zone 59), the Mississippi Alluvial Valley portion of Mississippi and Tennessee (zone 45 in part), and the Northern and Southern Atlantic Coastal Plain (zones 58 and 55) are under way. Upon completion of the regional mosaic, reference data previously set aside will be used to assess the regional land cover map, with statistics provided on a mapping zone and ecoregional basis.

Animal modeling:
The habitat affinity database and species range maps are complete for the 614 species being modeled. The ancillary data sets will be finalized in summer 2006. To take advantage of the fact that the National Hydrologic Dataset was being continuously updated with higher resolution stream data, the bulk of the work was put off until spring 2006, when the majority of the region had high-resolution data made available. Upon completion of the GAP-level land cover maps, the land cover derivative layers (forest interior, edge habitats) will be generated and the models run and internally reviewed. Workshops and one-on-one meetings will be held to solicit reviewer comments on three components of the vertebrate models, the ranges, the habitat affinities, and finally the modeling parameters. A database to track reviewer comments has been designed based on experiences from previous GAP projects in both the Southeast and the Southwest, and on discussions with biologists. Running of the animal models will be initiated in late summer 2006 and the final models, with reviews, will be available in fall 2006.

Other accomplishments and innovations:
The SEReGAP and the U.S. Fish and Wildlife Service project continues (see Laurent, Williams, and McKerrow, this volume). We are actively involved in the Onslow Bight Landfire Pilot project, using GAP land cover and vertebrate models to help identify areas where partnering on prescribed burning can benefit wildlife in addition to meeting the broader goals of ecosystem maintenance, restoration, and fuels reduction. We are representing GAP on the Federal Geographic Data Committee Vegetation Subcommittee in their efforts to update the National Vegetation Classification Standard (NVCS). Our work with modeling peak fire season throughout the Southeast for use in modeling presettlement fire frequencies at the fire block level will be presented at the Ecological Society of America in August 2006.

Literature Cited

Comer, P., D. Faber-Langendoen, R. Evans, S. Gawler, C. Josse, G. Kittel, S. Menard, M. Pyne, M. Read, K. Schulz, K. Snow, and J. Teague. 2003. *Ecological systems of the United States: A working classification of U.S. terrestrial systems*. Arlington, VA: NatureServe.

Homer, C., C. Huang, L. Yang, B. Wylie, and M. Coan. 2004. Development of a 2001 national land-cover database for the United States. *Photogrammetric Engineering and Remote Sensing* 70, no. 7:829–40.

McKerrow, A. J., and T. S. Earnhardt. 2004. Southeast Gap Analysis Project: A regional approach to land cover mapping. Proceedings of the American Society of Photogrammetry and Remote Sensing Annual Conference, Denver, CO, May 2004.

Southwest Regional GAP (SWReGAP)

An update is under way for the five-state region encompassing Arizona, Colorado, Nevada, New Mexico, and Utah. State coordination for the project is facilitated through the SWReGAP web site, <http://fws-nmcfwru.nmsu.edu/swregap/>.

Nearly complete: Review under way.

Contacts:

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Nevada: William G. Kepner, Co-PI
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New Mexico: Ken Boykin, Co-PI
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kboykin@nmsu.edu
505-646-6303

Utah: John Lowry, Co-PI
Remote Sensing/Geographic Information Systems Laboratory
College of Natural Resources
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Logan, UT
jlowry@gis.usu.edu, 435-797-0653

Land cover:
Complete.

The SWReGAP land cover data set is currently available to the public with “provisional” status from <http://earth.gis.usu.edu/swgap>. The Web site allows users to download specific geographic segments of the region, such as individual states, counties, or ecoregions. Additionally, the Web site offers an Internet map server from which users can interactively clip a specified rectangle in the region. The clipped data set is subsequently bundled with metadata and made available for downloading.

Animal habitat modeling:
Complete.

SWReGAP animal habitat modeling data is currently available to the public with “provisional” status from <http://fws-nmcfwru.nmsu.edu/swregap/>.

Land stewardship mapping:
Complete.

SWReGAP land stewardship data is currently available to the public with “provisional” status from <http://fws-nmcfwru.nmsu.edu/swregap/>.

Analysis:
Complete.

Reporting and data distribution:
All products derived from SWReGAP are complete and undergoing review.

NOTES AND ANNOUNCEMENTS

GAP Welcomes Anne Davidson as New GIS Technician

In December 2005, Anne Davidson joined the National GAP office in Moscow, ID, as a remote sensing geographic information systems (GIS) analyst, working part-time before moving to full-time in July. Her time is split between working on the land cover mapping for the Northwest Regional Gap Project and providing support and review for states that are finishing up their Gap Analysis projects.

Anne grew up in Boulder, CO. She earned a B.A. in environmental biology from the University of Colorado and an M.S. degree in environmental science from Washington State University. She is most interested in using GIS and remote sensing technology to map and characterize habitat for wildlife and fish. Her master's thesis documented the creation of a habitat suitability model for lynx in the Clearwater region of central Idaho.

Anne's professional experiences include working as a wildlife biologist in a study of mountain plover nest site selection and breeding biology on the Pawnee National Grasslands of northern Colorado, conducting surveys for rare plants and noxious weeds in central Idaho, and doing spatial modeling of watershed sedimentation risks in northern Oregon. Most recently, Anne performed the GIS analysis and wrote the terrestrial habitat characterizations and wildlife biology sections for five subbasin plans produced as part of the Northwest Power and Conservation Council's subbasin planning process. You can contact Anne at 208-885-3907 or e-mail her at <adavidson@uidaho.edu>.

2007 National Gap Analysis Conference

The 2007 National Gap Analysis Conference will be held September 11-13, 2007, at the Renaissance Asheville Hotel in Asheville, NC. The conference will feature data and projects from the Southeast Regional Gap Analysis Project (SEReGAP).

This meeting is sponsored by the U.S. Geological Survey, the Biodiversity and Spatial Information Center at North Carolina State University, Alabama Gap at Auburn University, the Institute of Ecology at the University of Georgia, and the University of Idaho. Attendees will learn about the most important environmental issues in the country, particularly in the Southeast, and discuss how GAP data sets can be used for resource management and decision-making. A special symposium will focus on conservation issues in the Southeastern United States and on the use of SEReGAP data for addressing these issues. This symposium is intended to bring together all interested individuals and agencies to explore the highest priority management needs in this region and to discuss how data resources can be used to assist managers.

The focus on applications of GAP data will be especially relevant to federal and state natural resource management agency personnel, nonprofit conservation groups, and academic researchers. Those with special interests in the Southeast should plan on attending the SEReGAP data sessions. Individuals using GAP data for planning and research are encouraged to submit presentation and special session proposals in response to the forthcoming call for presentations.

For more information, please visit the GAP Web site at <http://gapanalysis.nbii.gov> or contact Nicole Coffey-Nell at the National GAP Operations Office. She can be reached by e-mail at <nnell@uidaho.edu> or by phone at 208-885-3555.

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