A GAP ANALYSIS OF TERRESTRIAL VERTEBRATE SPECIES OF THE COLORADO PLATEAU: ASSESSMENT FROM THE SOUTHWEST REGIONAL GAP ANALYSIS PROJECT

Kenneth G. Boykin, Charles Drost, and J. Judson Wynne

As part of the Southwest Regional Gap Analysis Project (GAP), we developed spatial habitat models of 819 vertebrate species for the region comprising Arizona, New Mexico, Colorado, Utah, and Nevada. Here we apply the results of the vertebrate habitat models to the Colorado Plateau region of northern Arizona, northwestern New Mexico, southwestern Colorado, and southern and eastern Utah. The Colorado Plateau boundaries encompass habitat for 581 vertebrate species from the original mapping effort. Total species richness is highest in areas of the Colorado and San Juan River drainages. We show, however, that patterns of richness vary among different vertebrate groups and subgroups (e.g. amphibians and bats). One important use of GAP data is to evaluate what proportion of the habitat of various species is managed for long-term conservation. These data can be expressed as "threshold" levels of species protection. We compare and contrast these GAP threshold species with lists developed by the state wildlife agencies of the southwestern states for "species of greatest conservation need" (SGCN). Our threshold lists differ from the SGCN lists because of their focus on longer-term protection of species that may still be quite common. In this way, the Southwest GAP data offer an alternative for land management and conservation planning in the region.

Conservation planning and assessments over large regions provide the ecological context necessary for landscape-scale management decisions. Previous conservation assessments have been conducted for the Colorado Plateau (Tuhy et al. 2002) and portions of the plateau in Arizona (Arizona Game and Fish Department 2005a, 2005b), Colorado (Colorado Division of Wildlife 2005), New Mexico (New Mexico Department of Game and Fish 2005), and Utah (Utah Division of Wildlife Resources 2005). In addition, previous gap analysis projects have provided conservation information for the same area (Edwards et al. 1995; Thompson et al. 1996; Schrupp et al. 2001; Halvorson et al. 2002).

Gap analysis involves creating digital data sets of land cover, habitat models for terrestrial vertebrate species, and land stewardship, and analyzing the co-occurrence of these features on the landscape (See Ernst and Prior-Magee, this volume). Geographic Information System (GIS) maps and tables of these data sets allow for a wide variety of analyses for use in conservation planning. Over broad landscape scales, gap analysis provides a "coarse filter" approach to natural resources data and conservation assessments.

Gap analysis initially used a state-based approach (Scott et al. 1993), and now states in some areas have begun to collaborate on regional efforts (e.g., the Upper Midwest Gap Analysis Project; http://www.umesc.usgs.gov/umgaphome.html). The Southwest Regional Gap Analysis Project was the first formal multi-state gap analysis project, and additional regional projects are now in

progress in the Southeast (www.basic.ncsu.edu/segap/) and Northwest (www.gap.uidaho.edu/Northwest/2007_factsheet.doc). This multi-state approach allows for gap analyses to be completed for large regions defined by natural biogeographic boundaries, rather than state or county boundaries.

Gap analysis relies on the concept of wildlife-habitat relationships to model species habitats. Boykin et al. (2006) defined a wildlife-habitat relationship as "a textual, mathematical, graphical, or combination statement that predicts abstractly or directly what conditions are considered necessary for a taxon's habitat to exist and where it likely exists on a landscape." To be used in a regional GIS-based model, habitat associations must be capable of being expressed as a GIS theme, and data for that GIS theme must be available for the region.

Drawing on data from the Southwest Regional Gap Analysis, we present preliminary gap analyses for terrestrial vertebrates of the Colorado Plateau. We also present sample analyses for individual species and two taxonomic groups (amphibians and bats) in the region.

METHODS

The Southwest Regional Gap Analysis Project used a deductive modeling approach to identify wildlife-habitat relationships for each species (Boykin et al. 2006). We developed models for all species known to use habitat in the five-state project area (Arizona, Colorado, Nevada, New Mexico, and Utah) for significant portions of their life cycles. Species were not included if they were accidental, vagrant, or extirpated in the project area, or were not considered to be distinct species (see Boykin et al. 2006 for a complete list of decision rules used in modeling). We developed habitat models from literature reviews for each species using specific associations of available GIS environmental variables. Variables used were land cover, elevation, slope, aspect, distance to hydrological features, landform (Manis et al. 2001), soils, and mountains (see Boykin et al. 2006). Models were constrained to the current known range of the species (or recent historic range, for species that have experienced recent declines) using state, regional, and national references. Range data were converted to sub-basin watershed units (8-digit hydrologic units, or "HUCs") using the National Hydrography Data Set (Boykin et al. 2006; see http://nhd.usgs.gov/). These HUCs provided smaller base units than currently described ecoregions for the five-state study area.

One of the main objectives of vertebrate species modeling within GAP is to intersect habitat models with land stewardship data to identify levels of long-term conservation management. The resultant maps and tables provide area and percent of area for species habitat in each of four management status categories (see Ernst and Prior-Magee, this volume). We used the Colorado Plateau Ecoregion as defined by Tuhy et al. (2002) to define the spatial extent of our analyses, and included habitat models for all species that we considered to have habitat within the boundaries of the Colorado Plateau.

Gap analysis uses a variety of thresholds to provide conservation information to land managers (Scott et al. 1993). Such thresholds are useful in broad context, although specific needs of individual species vary based on their life history characteristics. For this assessment we used standard GAP reporting thresholds for the percentage of each species' predicted area of occurrence that is on lands managed for long-term protection (Status 1 and 2 lands). These thresholds provide a convenient reporting framework, with the option to further analyze single species, groups of species, or all species. In the remainder of this paper, we refer to the following thresholds of species habitat protection:

- Threshold 1: Less than 1% of predicted habitat is on Status 1 and 2 lands (least protected).
- Threshold 2: From 1% to less than 10% is on Status 1 and 2 lands.
- Threshold 3: Between 10% and 20% of predicted habitat on Status 1 and 2 lands.
- Threshold 4: Between 20% and 50% of predicted habitat on Status 1 and 2 lands.

- Threshold 5: More than 50% of predicted habitat is on Status 1 and 2 lands (most protected).

All of the states within the Southwest GAP area have recently identified "species of greatest conservation need" (SGCN) in accordance with their Comprehensive Wildlife Conservation Strategies (CWCS). The CWCS plans were submitted as a requirement for receiving State and Tribal Wildlife Grants from the U.S. Fish and Wildlife Service. State wildlife agencies identified these species based on criteria that were generally similar, but that differed from state to state. We reviewed these SGCN lists to provide a comparison and context for the Colorado Plateau species lists, based on perceived state concern for various species. Arizona identified 382 of the 819 species that Southwest GAP modeled as SGCN species (Table 1). Similarly, Colorado listed 114 species, New Mexico listed 85, and Utah listed 118.

We also evaluated species richness in the Colorado Plateau region using the GAP data. These species richness estimates were derived via two processes. We calculated the first species richness estimates using total species numbers (from the species habitat models) for each eight-digit hydrologic unit on the Colorado Plateau, to provide total richness of all species for the subregion. We also calculated species richness for all amphibians and for all bats using the predicted habitat models, to illustrate the application of smaller groupings of habitat models.

RESULTS

We identified 581 species that we predicted to have habitat within the Colorado Plateau Ecoregion (Tables 2 and 5). This was a majority (71%) of the species modeled in Southwest GAP for the entire five-state region (819 species). Analysis was conducted on 19 amphibians with predicted habitat on the Colorado Plateau (51% of all amphibians modeled in the region), 341 birds (78%), 143 mammals (67%), and 78 reptiles (60%). Full results for all models, including references, habitat data, modeling process, and textual and spatial models, can be found at http://fws-nmcfwru.nmsu.edu/swregap/.

The overall gap analysis (predicted habitat distribution by land management status) identified 43 species as "Threshold 1" species in the region, with less than 1 percent of the species' habitat on the Colorado Plateau managed for long-term conservation (Tables 2 and 3). There were 110 species in Threshold 2 (1–10% of habitat protected) with the majority of species in Thresholds 3 and 4. Only 20 species were Threshold 5 (Table 2). The following sections discuss patterns by major taxonomic group.

Amphibians

Of the four amphibian species identified in Threshold 1 (Table 3), two are closely associated with perennial aquatic systems—the Chiricahua leopard frog and lowland leopard frog. Within the Southwest, and specifically the Colorado Plateau, these aquatic and riparian systems are largely under private ownership. Couch's spadefoot has little or no association with permanent water sources. Two species (Great Plains toad and New Mexico spadefoot) were identified in Threshold 2 (see Table 5), and 13 species were placed in Thresholds 3 and 4. All but 3 of the 19 species in this analysis have been designated as SGCN by at least one state wildlife agency within Arizona, Colorado, New Mexico, and Utah.

Birds

Southwest GAP modeled 341 bird species on the Colorado Plateau. Of these, 286 were identified by one or more states as SGCN species. Of the 13 bird species identified within Threshold 1 (Table 3), 5 had less than 100 sq km of habitat identified on the Colorado Plateau (northern cardinal, gilded flicker, canvasback, Sprague's pipit, and bronzed cowbird). Those with more than 100 sq km of habitat were Mexican jay, curve-billed thrasher, dickcissel, white-throated sparrow, American pipit, brown thrasher, and whip-poor-will. All but three of these species (northern cardinal, gilded flicker, and brown thrasher) have been identified as SGCN.

There were 73 bird species identified in Threshold 2 (see Table 5). This covered a wide range of avian species, including 1

Table 1. Species of Greatest Conservation Need, by major taxonomic group, identified by the five states within the Southwest Regional Gap Analysis Project area.

Taxonomic Group	Arizona	Colorado	Nevada	New Mexico	Utah
Amphibians	11	4	2	7	8
Reptiles	32	8	13	8	32
Birds	268	81	60	48	42
Mammals	71	21	32	22	36
Total	382	114	107	85	118

Table 2. Total number of vertebrate species modeled by the Southwest Regional Gap Analysis Project on the Colorado Plateau, by gap analysis "threshold" levels. Thresholds represent proportion of habitat managed for long-term conservation, ranging from 1 (< 1% of habitat protected) to 5 (> 50% of habitat protected).

	Threshold					
	1 (< 1%)	2 (1–10%)	3 (10–20%)	4 (20–50%)	5 (> 50%)	Total
Amphibians	4	2	9	4	0	19
Birds	13	73	100	142	13	341
Mammals	15	22	63	38	5	143
Reptiles	11	13	23	29	2	78
Total	43	110	195	213	20	581

loon, 4 gallinaceous birds, 3 grebes, 1 egret, 4 owls, 38 passerines, 2 doves, 5 raptors, 7 shorebirds and gulls, 2 swifts, 1 hummingbird, 4 waterfowl, and 1 woodpecker. Of these, 15 species had less than 100 sq km of habitat mapped within the Colorado Plateau. Fifty-seven of the Threshold 2 species were identified as SGCN by one or more states within the region. There were 242 species of birds in Thresholds 3 and 4, and 13 species were in Threshold 5. Of these 255 species, 219 were identified as SGCN.

Mammals

Of the 143 mammal species modeled by the Southwest GAP project on the Colorado Plateau, 93 were identified as SGCN species. Fifteen species of mammals were in Threshold 1 (Table 3). Of these, eight species had less than 100 sq km of habitat mapped on the Colorado Plateau. Species with more than 100 sq km of mapped habitat and less than 1 percent of habitat in Status 1 and 2 lands included hooded skunk, southern plains woodrat, collared peccary, Osgood's mouse, cave myotis, southwestern myotis, and gray wolf (repatriated range). Eight of these 15 Threshold 1 mammals were identified as SGCN species.

There were a total of 22 mammal species in Threshold 2 (see Table 5). Three of these (desert kangaroo rat, Arizona gray squirrel, and hog-nosed skunk) had less than 100 sq km of habitat on the Colorado Plateau. The remaining 19 species included 3 carnivores (long-tailed weasel, the repatriated black-footed ferret, and wolverine), 3 hoofed mammals (white-tailed deer, the introduced Barbary sheep, and moose), and 13 rodents (spotted ground squirrel, house mouse, silky pocket mouse, Botta's pocket gopher, Gunnison's prairie dog, white-footed mouse, banner-tailed kangaroo rat, beaver, muskrat, thirteen-lined ground squirrel, Merriam's kangaroo rat, southern red-backed vole, and meadow vole). Sixteen of the 22 species

Table 3. Species with < 1 percent of predicted habitat on Status 1 and 2 lands on the Colorado Plateau. Status 1 and 2 lands are managed for long-term conservation purposes.

Taxa Group	Common Name	Scientific Name
Amphibian	Couch's spadefoot	*Scaphiopus couchii*
Amphibian	Colorado river toad	*Bufo alvarius*
Amphibian	Chiricahua leopard frog	*Rana chiricahuensis*
Amphibian	Lowland leopard frog	*Rana yavapaiensis*
Bird	Canvasback	*Aythya valisineria*
Bird	Whip-poor-will	*Caprimulgus vociferus*
Bird	Gilded flicker	*Colaptes chrysoides*
Bird	Black-billed cuckoo	*Coccyzus erythropthalmus*
Bird	Sprague's pipit	*Anthus spragueii*
Bird	Brown thrasher	*Toxostoma rufum*
Bird	Curve-billed thrasher	*Toxostoma curvirostre*
Bird	Bronzed cowbird	*Molothrus aeneus*
Bird	Northern cardinal	*Cardinalis cardinalis*
Bird	Dickcissel	*Spiza americana*
Bird	White-throated sparrow	*Zonotrichia albicollis*
Bird	Mexican jay	*Aphelocoma ultramarina*
Bird	American pipit	*Anthus rubescens*
Mammal	Preble's shrew	*Sorex preblei*
Mammal	Southwestern myotis	*Myotis auriculus*
Mammal	Cave myotis	*Myotis velifer*
Mammal	Pocketed free-tailed bat	*Nyctinomops femorosaccus*
Mammal	Snowshoe hare	*Lepus americanus*
Mammal	Hispid pocket mouse	*Chaetodipus hispidus*
Mammal	Southern plains woodrat	*Neotoma micropus*
Mammal	Mearns' grasshopper mouse	*Onychomys arenicola*
Mammal	Osgood's mouse	*Peromyscus gratus*
Mammal	Plains harvest mouse	*Reithrodontomys montanus*
Mammal	Hispid cotton rat	*Sigmodon hispidus*
Mammal	Hooded skunk	*Mephitis macroura*
Mammal	Lynx	*Lynx canadensis*
Mammal	Gray wolf	*Canis lupus*
Mammal	Collared peccary	*Pecari tajacu*
Reptile	Sonoran mud turtle	*Kinosternon sonoriense*
Reptile	Big Bend slider	*Trachemys gaigeae*
Reptile	Greater earless lizard	*Cophosaurus texanus*
Reptile	Regal horned lizard	*Phrynosoma solare*
Reptile	Crevice spiny lizard	*Sceloporus poinsettii*
Reptile	Checkered whiptail	*Cnemidophorus tesselatus*
Reptile	Rubber boa	*Charina bottae*
Reptile	Texas blind snake	*Leptotyphlops dulcis*
Reptile	Sonoran whipsnake	*Masticophis bilineatus*
Reptile	Checkered garter snake	*Thamnophis marcianus*
Reptile	Western coral snake	*Micruroides euryxanthus*

were identified as SGCN by at least one state (all of the above except house mouse, long-tailed weasel, white-footed mouse, Barbary sheep, moose, and meadow vole).

There were 63 species in Threshold 3 and 38 species in Threshold 4. Five species (i.e. round-tailed ground squirrel, desert pocket mouse, rock pocket mouse, marten, and western mastiff bat) were identified within Threshold 5.

Reptiles

Nine of 11 Colorado Plateau reptile species in Threshold 1 are on the periphery of their range, with less than 30 sq km of habitat mapped on the Colorado Plateau (Table 3). The two other species (greater earless lizard and crevice spiny lizard) have approximately 500 sq km of habitat, with less than 1 percent of that habitat in Status 1 and 2 lands. The crevice spiny lizard is not currently known to occur on the Colorado Plateau but its range extends near the southeast margin of the region, and suitable habitat was mapped on the plateau. Neither of the latter two species were identified by state agencies as SGCN.

Of the 13 reptile species in Threshold 2 (see Table 5), 7 are lizards and 6 are snakes. The six lizards with more than 100 sq km of habitat are the round-tailed horned lizard, Clark's spiny lizard, Great Plains skink, little striped whiptail, desert grassland whiptail, and lesser earless lizard. The Madrean alligator lizard (with < 100 sq km of habitat on the Colorado Plateau), round-tailed horned lizard, and a subspecies of the lesser earless lizard have been identified as SGCN. The six snake species we documented are the western diamondback rattlesnake, western hog-nosed snake, plains black-headed snake, Mojave rattlesnake, milk snake, and mountain patch-nosed snake. All but the western hog-nosed snake have been identified by at least one state as SGCN.

Fifty-two species fell within Thresholds 3 and 4 and only two species were identified in Threshold 5. Of the 78 reptile species mapped on the Colorado Plateau, 52 have been identified as SGCN species by one or more state agencies.

Species of Greatest Conservation Need

We compared the "threshold" habitat protection levels from the Southwest GAP data for the Colorado Plateau with the state SGCN lists (Table 4). In this comparison we omitted non-native species (e.g. European starling, house mouse), which are of little interest in a comparison of conservation priorities. As a predictor of conservation need, the GAP data diverge from the SGCN data. Of 43 species identified as Threshold 1 (little or no habitat managed for long-term protection) by the gap analysis, 28 (65%) were identified by one or more states as SGCN. As the threshold and level of protection increases, proportionately more species are identified by the states as SGCN. The proportion of species identified as SGCN reaches a maximum of 85 percent for Threshold 5, in which more than half of identified habitat is managed for long-term protection.

Table 4. Number of Colorado Plateau species in GAP habitat protection categories (thresholds), compared to numbers of those species identified as Species of Greatest Conservation Need (SGCN) by state wildlife agencies in the Southwest. Threshold 1 is least protected (< 1 % of modeled species range is managed for long-term conservation) and Threshold 5 is most protected (> 50 % of range is managed for long-term conservation).

	Threshold					
	1	2	3	4	5	Total
No. of species	43	106	194	213	20	576
No. of SGCN species	28	82	150	171	17	448
Percent SGCN	65.1	77.4	77.3	80.3	85.0	

Species Richness

Total species richness calculated from the Southwest GAP data for the Colorado Plateau averaged between 354 and 390 species per drainage subbasin (Figure 1). Species richness was higher in the eastern portion of the plateau, associated with the San Juan Mountains and the San Juan River, and on the western side of the plateau along the Colorado and Virgin Rivers. Compared to the entire Southwest GAP region, species richness on the Colorado Plateau was intermediate, with higher richness than more northern areas but lower richness than southern Arizona, much of New Mexico, and the Rocky Mountain front range in Colorado.

In addition to total richness of all vertebrate species, we also calculated species richness for two subgroups of vertebrates—amphibians and bats. Amphibian richness on the Colorado Plateau was highest in the northern and western areas of the plateau, associated with tributaries of the Colorado River (Figure 1). The southern and eastern extent of the plateau was relatively depauperate by comparison. The highest amphibian richness for the entire Southwest occurs in a broad band from southeastern Arizona across southern and central New Mexico to southeastern Colorado. High species richness in this area is a result of the convergence of several ecoregions, including the Great Plains, Rocky Mountains, Madrean, and Chihuahuan Desert. Most of Nevada and the northern deserts of Utah have relatively few amphibians, and most of the Rocky Mountain region is also poor in amphibian species.

Analysis of bat species richness on the Colorado Plateau identified areas of relatively high richness throughout much of the plateau (Figure 1). Areas of highest richness were identified around Zion National Park and the Music Mountains–Grand Wash Cliffs area. The relatively high numbers of bat species in the Zion area have been corroborated by other researchers conducting surveys at the park (M. Bogan, personal communication). Further analysis of bat species richness provides additional information on conservation opportunities on the Colorado Plateau. Analysis of potential gaps in bat habitat protection indicates that the most species-rich areas, where 18–19 species potentially occur, have 1 percent or less of the area effectively protected (Figure 2). Other areas that are relatively species-rich, supporting up to 11–17 species, range from 5 to 25 percent of the area effectively protected (Status 1 and 2 lands).

DISCUSSION

The goal of gap analysis is to provide data for conservation planning. It is one of many tools available and is intended to provide background information and ecological context for land managers. It provides broad landscape perspectives as well as providing data for land managers on conservation opportunities available to them. Analyses of GAP data often focus on Status 1 and 2 lands (lands managed for long-term conservation), but it is important to note that there are also many conservation opportunities on multiple-use lands (Status 3) and private lands (Status 4).

There are several caveats for the Southwest GAP models and the analyses presented here. The Southwest GAP vertebrate models are models of species habitat with no inferences as to differing levels of habitat quality or species abundance. The resulting maps show predicted distribution of habitat for each species, but do not necessarily indicate that the species occurs in all areas mapped as habitat. Further, model accuracy depends on available knowledge (literature sources and available regional data sets) and the resolution of the spatial data used in model development (Boykin et al. 2006). Mapped areas of predicted habitat for a species may or may not be occupied by that species, particularly at the periphery of the species' range. Hence, these habitat models tend to overestimate the extent of occupied range for a species on the landscape.

In reviewing these analyses it is important to recognize that species identified as

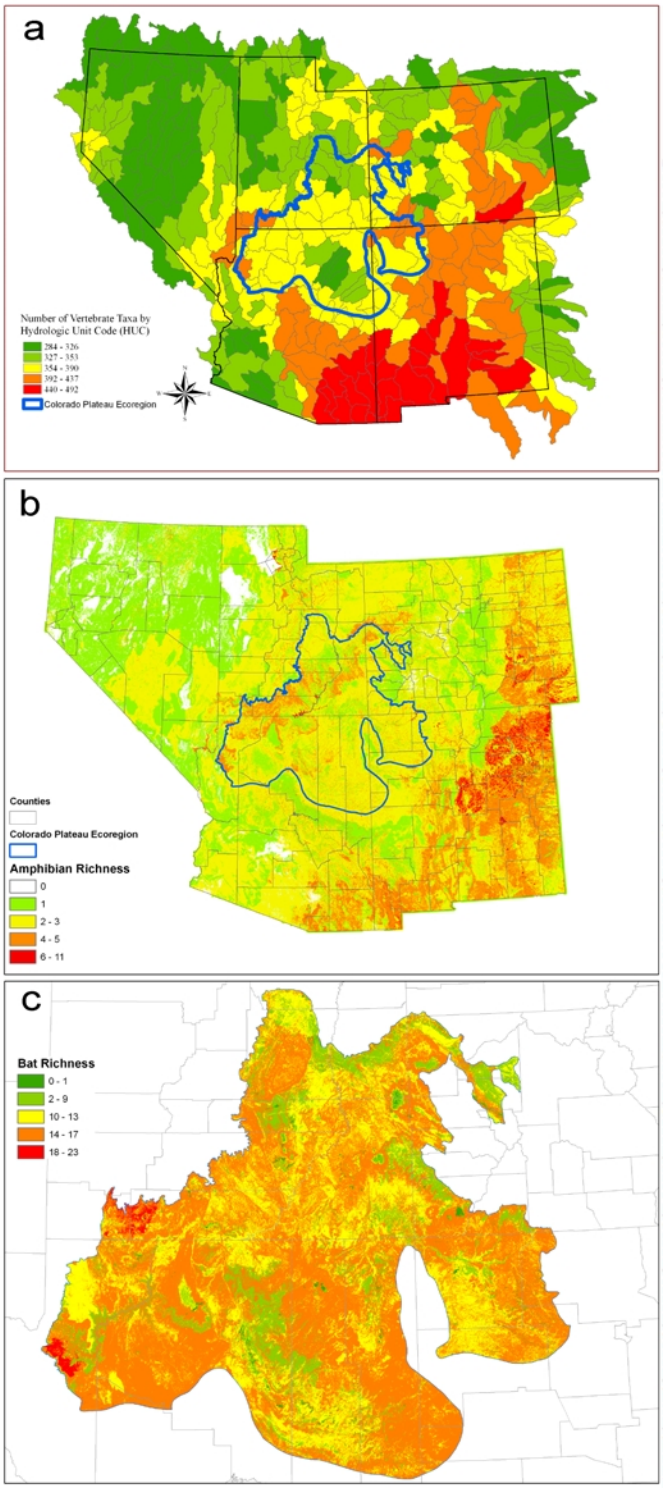

Figure 1. (a) Terrestrial vertebrate species richness by 8-digit hydrologic unit (HUC) in the southwestern United States, as modeled by SReGAP, showing boundary of the Colorado Plateau. (b) Species richness of 37 amphibian species. (c) Bat species richness.

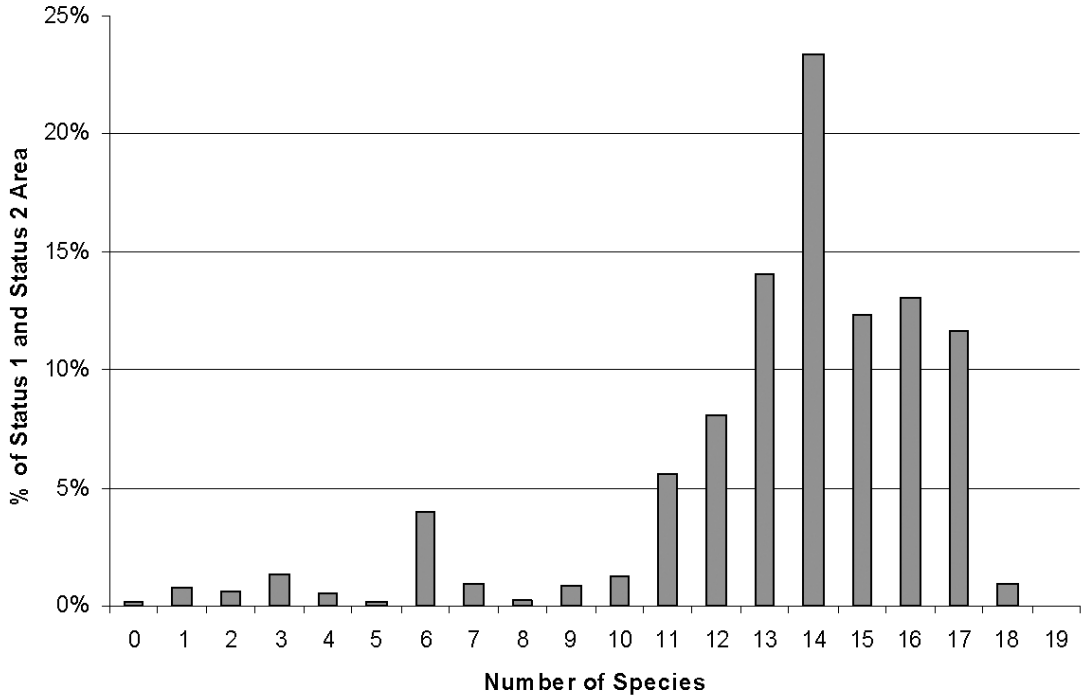

Figure 2. Level of long-term habitat protection, relative to species richness of bats on the Colorado Plateau. For each category of richness (number of bat species within an area), the vertical axis shows the proportion of that area that is within Status 1 and 2 lands (well protected over the long term).

GAP species may or may not need conservation attention; the species that are identified by the GAP filters should be evaluated case by case. For example, species that occur largely in "settled" habitats (e.g. the house finch, which is identified as a Threshold 2 species) will often be identified because such areas are not under conservation mandates. Wide-ranging species (e.g. the coyote) may also be identified as Threshold 1 or 2 in these analyses because such species are ubiquitous across the landscape and most of the landscape is within Status 3 or Status 4 lands. The threshold categories discussed here are somewhat arbitrary and different species doubtless need differing levels of habitat protection. The threshold level of 10 percent is simply a starting point for analysis. The analyses presented herein allow for preliminary generalizations, but further research is needed regarding the validity and specificity of these thresholds.

Species of Greatest Conservation Need

Our comparison of "Species of Greatest Conservation Need" and species identified as Threshold 1 and Threshold 2 by gap analysis highlights differences between the two lists. This is not surprising, because the two lists were prepared using very different approaches. The state SGCN lists take a bottom-up, species-centered approach, identifying species that are known or suspected to be threatened, or that are known to have experienced population declines. Species whose status is not well known, or that appear to be secure at the present time, do not typically receive attention. Gap analysis provides an alternative top-down approach, looking across the entire community of vertebrate species in the region and comparing them with a single currency—the percentage of each species' habitat that is considered well protected.

The GAP lists represent just a single filter; the species identified in this manner need to be examined further. The process produces some results that are clearly not of conservation concern (e.g. introduced species such as the house sparrow, identified as Threshold 2), and these can be easily eliminated. On the other hand, species identified by gap analysis as relatively well protected (e.g. Threshold 4) may still be threatened from causes other than habitat loss. One of the values of the GAP lists lies in this kind of careful examination, to identify species that may be at risk of decline or loss in the future.

This highlights another difference between the two approaches. Federal and state lists of threatened or at-risk species typically focus (as well they should) on those known to be declining or facing other apparent problems. Gap analysis provides the ability to identify species that may face declines in the future, because their habitat is subject to degradation or loss. These species may be common and widespread now, but with gradual loss of habitat they may experience significant declines in the future.

Both approaches have value for conservation planning, and they are best used in a complementary manner. Species that are currently threatened or in decline may need immediate attention. Over the longer term, however, conservation planning would benefit from efforts, like gap analysis, to protect overall diversity and to identify species that may become the threatened species concerns of the future.

Species Richness

Species richness is often used for conservation assessments and we present examples of such analyses here. Our analyses using all vertebrate species (by drainage subbasin) and two taxonomic groups (amphibians and bats, by habitat) demonstrate the utility of the overall data set. For most purposes, broad analyses (such as total vertebrate species richness) provide less insight than finer-scale explorations. Comparing areas based on total mammal richness, for example, can obscure areas of particular importance to specific groups of mammals. Areas of high total mammal richness may have low richness of bats, or no bats in the genus *Myotis*, or no nectar-feeding bats (this latter category includes two threatened species). In addition to analyses based on taxonomic groupings, a wide variety of other analyses are possible,

using habitat or life history groupings, for example, depending on management or research interest. We encourage users of these data to more fully explore these possibilities.

Conservation and Management Considerations

Most of the Threshold 1 species identified within the boundaries of the Colorado Plateau are marginal species that are at or near the edge of their ranges. They have very limited mapped habitat (most < 100 sq km; see Table 5) and many are not currently known to occur on the plateau. In some cases, such species may be of particular interest precisely because they are present in limited habitat near the edge of their ranges. Some examples in this respect are the American pipit, which breeds in scattered alpine habitats on the Colorado Plateau, and the mountain plover, found in limited grassland habitats on the Colorado Plateau in Arizona and New Mexico. The southwestern myotis has a relatively limited total range, and occurs marginally along the southern edge of the Colorado Plateau.

Species identified as Threshold 2 (1–10% of mapped habitat managed for long-term protection) may be more instructive for understanding general patterns for conservation planning on the Colorado Plateau. Many of these species are grassland inhabitants. Examples in Threshold 2 include the Great Plains toad among amphibians, the Great Plains skink, little striped whiptail, lesser earless lizard, and milk snake among reptiles, the mountain plover, short-eared owl, savannah sparrow, prairie falcon, and others among birds, and the silky pocket mouse, spotted ground squirrel, Gunnison's prairie dog, and banner-tailed kangaroo rat among mammals. This pattern among vertebrate species adds further weight to other sources that have expressed concern over the decline of Southwest grasslands and the species they support (e.g. McClaran and Van Devender 1995).

CONCLUSIONS

The results presented here represent very preliminary analyses of the wealth of data produced by the Southwest GAP project. Even at a preliminary level, these analyses highlight some individual species and groups of species (e.g. those in grassland habitats) that may warrant additional consideration. Full data for all aspects of the Southwest GAP project (vegetation/land cover, animal habitat models, stewardship maps) are available at http://fws-nmcfwru.nmsu.edu/swregap/. The Southwest GAP project provides these data for use, review, and revision. The data provide baseline information for conservation on the Colorado Plateau. Particularly when combined with other current efforts these data provide researchers and managers with another tool for understanding the distribution of vertebrates on the Colorado Plateau, within the context of these species' habitats in the Southwest. An important objective of the Southwest GAP project has been to create models and processes that can be modified and updated using new data (or different perspectives on current data), such that the models remain current and continue to reflect an increased understanding of vertebrate species in the Southwest.

ACKNOWLEDGMENTS

The Southwest Regional Gap Analysis Project was the focus of more than 100 professionals during the life of the project. Nineteen habitat modelers spent long hours synthesizing data and creating the models. Without their efforts, this manuscript would not have been possible. Funding for the project was provided by the USGS Biological Resources Division. Senior author funding was provided by the New Mexico Cooperative Fish and Wildlife Research Unit during part of manuscript preparation.

Table 5. Colorado Plateau species in GAP Thresholds 1 (< 1% of habitat protected), 2 (1–10 %), and 3 (10–20 %), modeled as part of the Southwest Regional Gap Analysis Project. "Species of Greatest Conservation Need" are from draft lists available from the respective state natural resources agencies in Arizona, Colorado, New Mexico, and Utah, as of August 2005. In SGCN columns 1 = species, 2 = subspecies. Status columns list the modeled area of each species' habitat within lands of varying conservation status, from Status 1 lands (most protected) to Status 4 lands (least protected). Areas are in square km and percent of total predicted habitat for each species. Species are listed by major taxonomic groups, and within groups, by percent of habitat in Status 1 or 2 lands.

	SGCN				Total	Status 1		Status 2		Status 3		Status 4		Status 1 & 2		
	AZ	CO	NM	UT	Area	Area	%	Area	%	Area	%	Area	%	Area	%	Threshold
AMPHIBIANS																
Couch's spadefoot (*Scaphiopus couchii*)	1	1	–	–	27	0	0	0	0	3	11.6	24	88.4	0	0.0	<1
Colorado River toad (*Bufo alvarius*)	–	–	1	–	61	0	0	0	0	1	1.1	60	98.9	0	0.0	<1
Lowland leopard frog (*Rana yavapaiensis*)	1	–	1	–	260	0	0.0	0	0.0	31	11.9	229	88.1	0	0.0	<1
Chiricahua leopard frog (*Rana chiricahuensis*)	1	–	1	–	93	0	0	1	0.8	31	32.8	62	66.4	1	0.8	<1
Great plains toad (*Bufo cognatus*)	–	–	–	1	12231	201	1.6	504	4.1	10194	83.3	1332	10.9	705	5.8	1-10
New Mexico spadefoot (*Spea multiplicata*)	–	–	–	1	9994	225	2.3	577	5.8	6195	62.0	2996	30.0	802	8.0	1-10
Mountain treefrog (*Hyla eximia*)	–	–	1	–	62	7	10.5	0	0	43	68.8	13	20.7	7	10.5	10-20
Boreal chorus frog (*Pseudacris maculata*)	–	–	–	–	48	1	2.3	5	9.9	16	32.6	27	55.2	6	12.2	10-20
Bullfrog (*Rana catesbeiana*)	–	–	–	–	644	37	5.8	54	8.3	153	23.7	400	62.1	91	14.1	10-20
Northern leopard frog (*Rana pipiens*)	1	1	–	1	351	26	7.4	28	7.9	143	40.8	154	43.8	54	15.3	10-20
Western toad (*Bufo boreas*)	–	1	2	1	4247	134	3.1	553	13.0	1576	37.1	1984	46.7	687	16.2	10-20
Tiger salamander (*Ambystoma tigrinum*)	2	–	1	–	194117	8416	4.3	23400	12.1	118055	60.8	44246	22.8	31816	16.4	10-20
Woodhouse's toad (*Bufo woodhousii*)	–	–	–	–	128924	4361	3.4	18412	14.3	78180	60.6	27971	21.7	22773	17.7	10-20
Canyon treefrog (*Hyla arenicolor*)	1	1	–	1	12675	786	6.2	1536	12.1	7481	59.0	2871	22.7	2322	18.3	10-20
Red-spotted toad (*Bufo punctatus*)	1	–	–	–	93920	4887	5.2	12991	13.8	54605	58.1	21437	22.8	17878	19.0	10-20

Table 5 (continued)

	SGCN				Total	Status 1		Status 2		Status 3		Status 4		Status 1 & 2		
	AZ	CO	NM	UT	Area	Area	%	Area	%	Area	%	Area	%	Area	%	Threshold
REPTILES																
Rubber boa (*Charina bottae*)	–	–	–	1	6	0	0	0	0	5	77.9	1	22.1	0	0	<1
Checkered whiptail (*Cnemidophorus tesselatus*)	–	–	–	–	13	0	0	0	0	11	84.7	2	15.3	0	0	<1
Greater earless lizard (*Cophosaurus texanus*)	–	–	–	–	501	0	0.0	0	0.0	7	1.4	494	98.6	0	0.0	<1
Sonoran mud turtle (*Kinosternon sonoriense*)	2	–	–	–	0	0	0	0	0	0	0	0	100	0	0	<1
Texas blind snake (*Leptotyphlops dulcis*)	–	1	–	–	2	0	0	0	0	1	60	1	40	0	0	<1
Sonoran whipsnake (*Masticophis bilineatus*)	2	–	–	–	25	0	0	0	0	1	2.8	24	97.2	0	0	<1
Western coral snake (*Micruroides euryxanthus*)	2	–	–	–	19	0	0	0	0	0	0	19	100	0	0	<1
Regal horned lizard (*Phrynosoma solare*)	–	–	1	–	1	0	0	0	0	0	0	1	100	0	0	<1
Crevice spiny lizard (*Sceloporus poinsettii*)	–	–	–	–	598	0	0.0	0	0.0	135	22.6	463	77.4	0	0.0	<1
Checkered garter snake (*Thamnophis marcianus*)	–	–	–	0	0	0	0	0	0	91.7	0	8.3	0	0	<1	
Big Bend slider (*Trachemys gaigeae*)	–	–	–	–	0	0	0	0	0	0	83.8	0	16.2	0	0	<1
Madrean alligator lizard (*Elgaria kingii*)	–	–	2	–	1	0	0	0	1	0	9.1	1	90	0	1	1-10
Round-tailed horned lizard (*Phrynosoma modestum*)	–	1	–	–	821	1	0.1	10	1.2	568	69.2	242	29.5	11	1.3	1-10
Clark's spiny lizard (*Sceloporus clarkii*)	–	–	–	–	14944	20	0.1	219	1.5	3823	25.6	10883	72.8	239	1.6	1-10
Western diamondback rattlesnake (*Crotalus atrox*)	1	–	1	–	11606	1	0.0	197	1.7	4591	39.6	6816	58.7	199	1.7	1-10
Great Plains skink (*Eumeces obsoletus*)	–	–	–	–	29163	381	1.3	215	0.7	10543	36.2	18024	61.8	596	2.0	1-10
Little striped whiptail (*Cnemidophorus inornatus*)	–	–	–	–	13002	428	3.3	421	3.2	8285	63.7	3868	29.7	849	6.5	1-10
Western hog-nosed snake (*Heterodon nasicus*)	–	–	–	–	25759	97	0.4	1756	6.8	20332	78.9	3574	13.9	1853	7.2	1-10