Conservation Priorities in the Apache Highlands Ecoregion

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Abstract—*The Apache Highlands ecoregion incorporates the entire Madrean Archipelago/Sky Island region. We analyzed the current distribution of 223 target species and 26 terrestrial ecological systems there, and compared them with constraints on ecosystem integrity (e.g., road density) to determine the most efficient set of areas needed to maintain current biodiversity. The resulting portfolio of 90 areas includes 12.5 million acres (5 million ha) that should be priorities for protection. Conservation strategies include protection and restoration of grasslands, restoration or maintenance of natural fire regimes, and learning more of probable effects of climate change.*

Introduction

Any comprehensive effort to protect our rich biological heritage must answer two questions: "What are the most important places?" and "How much conservation is enough?"

In 1996, The Nature Conservancy began developing ecoregion-based conservation assessments to answer those questions for the entire United States and portions of the 31 other countries in which the Conservancy works (Groves et al. 2002). We report here the results for the Apache Highlands ecoregion. This project was conducted as a bi-national assessment in collaboration with colleagues from IMADES, the Sonora State Institute for Environment and Sustainable Development, in Mexico.

The Apache Highlands Ecoregion

The Apache Highlands ecoregion spans 30 million acres (12 million hectares) and portions of four States in two countries: Arizona and New Mexico in the United States, and Sonora and Chihuahua in Mexico. It is bounded on the north by the Mogollon Rim (the southern edge of the Colorado Plateau), to the west by the Sonoran and Mojave Deserts, to the south by the Sierra Madre Occidental, and to the east by the Chihuahuan Desert (figure 1).

The region is best known among the scientific community for its "archipelago" of "sky islands." Over 40 mountain ranges cloaked in pine-oak woodland and mixed conifer forests rise abruptly from surrounding basins composed of grassland and desert scrub to form forested islands in a "desert sea" (Marshall 1957; DeBano et al. 1995). The juxtaposition and change in major biotic communities as one moves across landscape gradients has played a critical role in the evolution of the biodiversity present today and, likely, will continue to play a role in shaping the biodiversity of tomorrow.

Methods

This ecoregional assessment involved:

- Identification of conservation targets, a group of organisms and ecological systems that comprehensively represent the ecoregion's biological diversity. Targets included ecological systems, typically characterized by a plant community (e.g., ponderosa pine forest) and supporting ecological processes, and a broad range of species representing major taxonomic groups (amphibians, birds, fish, insects, mammals, mollusks, plants, reptiles) and spanning all levels of rarity, from rare to common. We included 26 ecological systems and 223 species, with special emphasis given to imperiled, endemic, or keystone species, or those that are limited by area, dispersal, or particular ecological processes. We also emphasized aquatic systems and species, due to their rarity and imperiled status in this region.
- Identification of conservation goals for each target that serve as a hypothesis about the number and distribution of populations needed to maintain long-term species viability.
- Identification of conservation areas sufficient in size and distribution to capture ecological variation and meet conservation goals for targets.

Our target selection was based on the Coarse Filter/Fine Filter approach to conservation planning (Groves et al. 2002). We assume that protection for plant communities and ecological systems serves as a coarse filter to capture most of the biological diversity present, while the fine filter is the deliberate choice of species with distributions that might otherwise fall through the gaps or that have habitat needs that would not otherwise be protected.

We used a variety of data sets, including species' population locality data housed in the Arizona and New Mexico

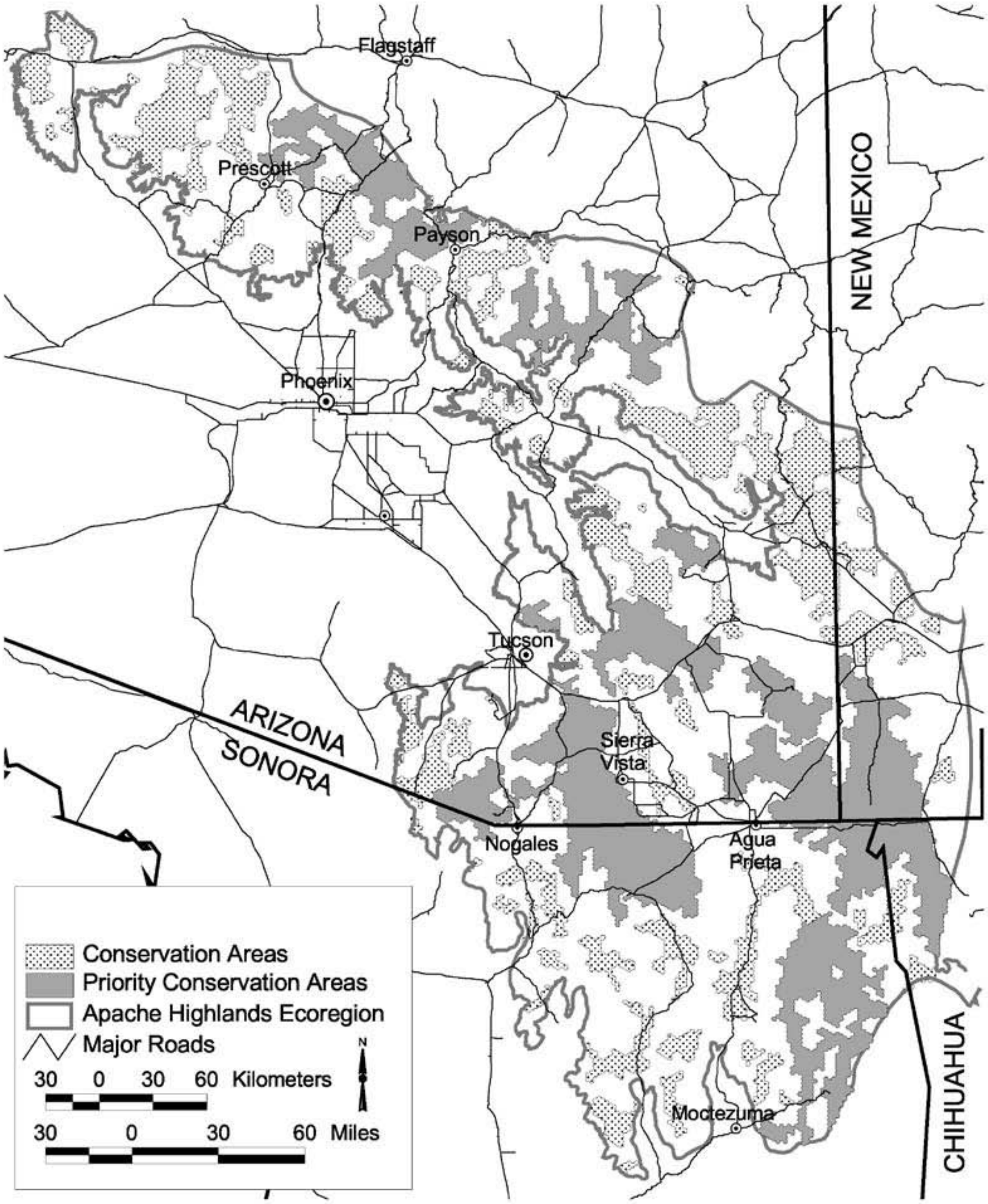

Figure 1—Apache Highlands Ecoregion with portfolio of conservation areas, emphasizing the eight areas of highest priority.

Natural Heritage programs, Sonora's Centro de Datos para la Conservación, and museums throughout North America, along with spatially referenced data on vegetation, land use, land management, hydrography, topography, infrastructure, and protection status. For target species, we incorporated 4,565 point localities into the analysis. For ecological systems, we obtained Gap Analysis Program (GAP) vegetation coverages for Arizona and New Mexico, and the Forest Inventory 2000 for Sonora and Chihuahua. Those systems' data were developed from imagery dating from the early 1990s (Halvorson et al. 2002; Palacio Prieto et al. 2000; Thompson et al. 1996; Velázquez et al. 2001). We supplemented data for riparian ecological systems with results from the Arizona Statewide Riparian Inventory and Mapping Project and the USGS National Land Cover Data (AGFD 1993; USGS 2000). Differences in the cover classifications between States were reconciled, particularly along borders, to form a consistent coverage for the ecoregion.

In addition, we developed three new spatial data sets: a complete coverage depicting the location of the ecoregion's ciénegas, the distribution and status of the ecoregion's remaining grasslands (see Enquist and Gori, this proceedings), and native fish distributions.

We considered the representative "cost" of conserving an area through a suitability index, which integrated major land use factors, such as road class density, mines/industrial development, agricultural/urban development, and minimum land area. This was a unit-less index, not directly associated with property values. We assigned each index factor a different weight depending on the assumed impact the factor might have on conservation targets (e.g., four-lane paved roads have greater influence than one-lane dirt roads, and are thus assigned higher values). We also assigned base land "cost" to the whole ecoregion in recognition that all land has some inherent costs associated with protecting it.

Table 1—GAP protected status for the Apache Highlands Ecoregion. All values are in percentages, except where noted. Unknown GAP status indicates Native American lands where we have inadequate information. See text for descriptions of GAP ranks.

	GAP 1	GAP 2	GAP 3	GAP 4	Unknown	Total area (ha)
Percent of ecoregion	1	4	27	59	8	12,154,707
Percent of combined portfolio conservation areas	2	5	30	61	2	5,061,500

We divided the ecoregion into 500-ha hexagons, which we attributed by intersecting them with point and polygon information for targeted species, ecological systems, and the suitability index.

We set conservation goals that are proportions of current known distributions of the conservation targets. Ideally, our goals would be stated in terms of historical extent to better inform recovery efforts for those targets that have declined, but we lacked adequate data for most targets to approximate their historic distributions across the ecoregion.

We tried to ensure that conservation targets were captured in a distribution that approximates their current distribution, and to avoid bias that might stem from the greater availability of locality data on the United States side of the international border. To do this we divided the input data and conservation goals according to a stratification scheme, breaking the ecoregion into nearly equal thirds.

We used the computer algorithm, SITES, to identify the portfolio of conservation areas. SITES selects areas to meet conservation target goals while balancing objectives of efficiency, defined as the greatest number of goals met for the lowest "cost" or least amount of suitable land (Andelman et al. 1999). We developed and evaluated 27 different scenarios before settling on a draft conservation area portfolio that met our goals for both number and distribution of target occurrences "captured" within conservation areas. The draft portfolio was reviewed by regional experts to identify omitted areas that are important to conservation targets as well as included areas where conservation is no longer feasible. We incorporated expert input, analysis of species distribution maps, comparison to land parcel boundary maps, and restoration potential in considering the boundaries of each area. The draft portfolio was reviewed by biologists with Arizona Game and Fish Department and IMADES, along with several taxonomic group experts from Mexico, and revisions made based on review comments.

Results

Nearly 3.7 million acres (1.4 million ha) were identified as priorities for conservation in the Mexico portion of the ecoregion, while the remaining 8.8 million acres (3.6 million ha) of the conservation portfolio was identified in the United States (Marshall et al. 2004). This distribution closely matches the proportions of the ecoregion, with 31% of the ecoregion and 28% of the portfolio in Mexico. The final portfolio consists of 90 conservation areas encompassing just over 12.5 million acres (5 million ha), about 40% of the ecoregion (figure 1). Conservation areas range in size from 1,235 to 1.9 million acres (500 to 757,500 ha), with an average of 138,967 acres (56,239 ha). The portfolio captured 2,118 miles (3,408 km) of perennial streams, 86% of the perennial stream length in the ecoregion. Aquatic or riparian targets occur in 77% (n = 69) of the conservation areas. Some conservation areas incorporate continuous landscapes from valley bottoms to mountain tops which, if fully protected, should buffer conservation targets against the impacts of climate-induced changes in habitat. Other areas form continuous mountain-to-mountain spans that are needed to maintain habitat connectivity for wide-ranging, forest-dwelling species such as black bear.

The portfolio of conservation areas met the conservation goals for 83% of the targets, including 189 species and 12 ecological system targets. Individual conservation areas captured from 1 to 119 conservation targets, with an average of 17 targets.

An analysis of protected status using a modified GAP classification (Weinstein 2002) revealed that only 5% of the ecoregion is in GAP categories 1 and 2, the highest levels of biodiversity protection afforded (table 1; figure 2; GAP 1 is managed for biodiversity with <5% of land cover converted by human uses, GAP 2 is managed for selected species and may have low-level human disturbances such as grazing and recreation). Twenty-seven percent of the ecoregion is in GAP category 3, where protection of natural land cover is balanced with extractive uses (e.g., Federal multiple-use lands in the United States). Nearly 60% of the ecoregion, however, permits intensive land uses and lacks mandates preventing the conversion of native vegetation cover by anthropogenic uses (GAP category 4). The conservation areas we identified are only slightly better protected, with 7% in GAP 1 and 2; thus, creating lasting protection for biodiversity in this ecoregion will require significant further efforts.

The portfolio captured 95-100% of Critical Habitat for 10 of the 11 species in this region with that designation under the Endangered Species Act. It only captured 64% of Critical Habitat for the Mexican spotted owl, missing portions of Saguaro National Park, but also capturing large areas of occupied spotted owl habitat that was not designated.

We used two analyses to rank the biodiversity value of the 90 conservation areas: target richness, or the number of targets found in each conservation area, and "irreplaceability," the difficulty of protecting the conservation targets in that area by substituting another area if the first is compromised. Of the 10 highest ranking conservation areas identified in each of the two analyses, 8 areas were shared between analyses (figure 1). In both the richness and irreplaceability measures the Huachuca Mountains Grassland Valley Complex and Sierra

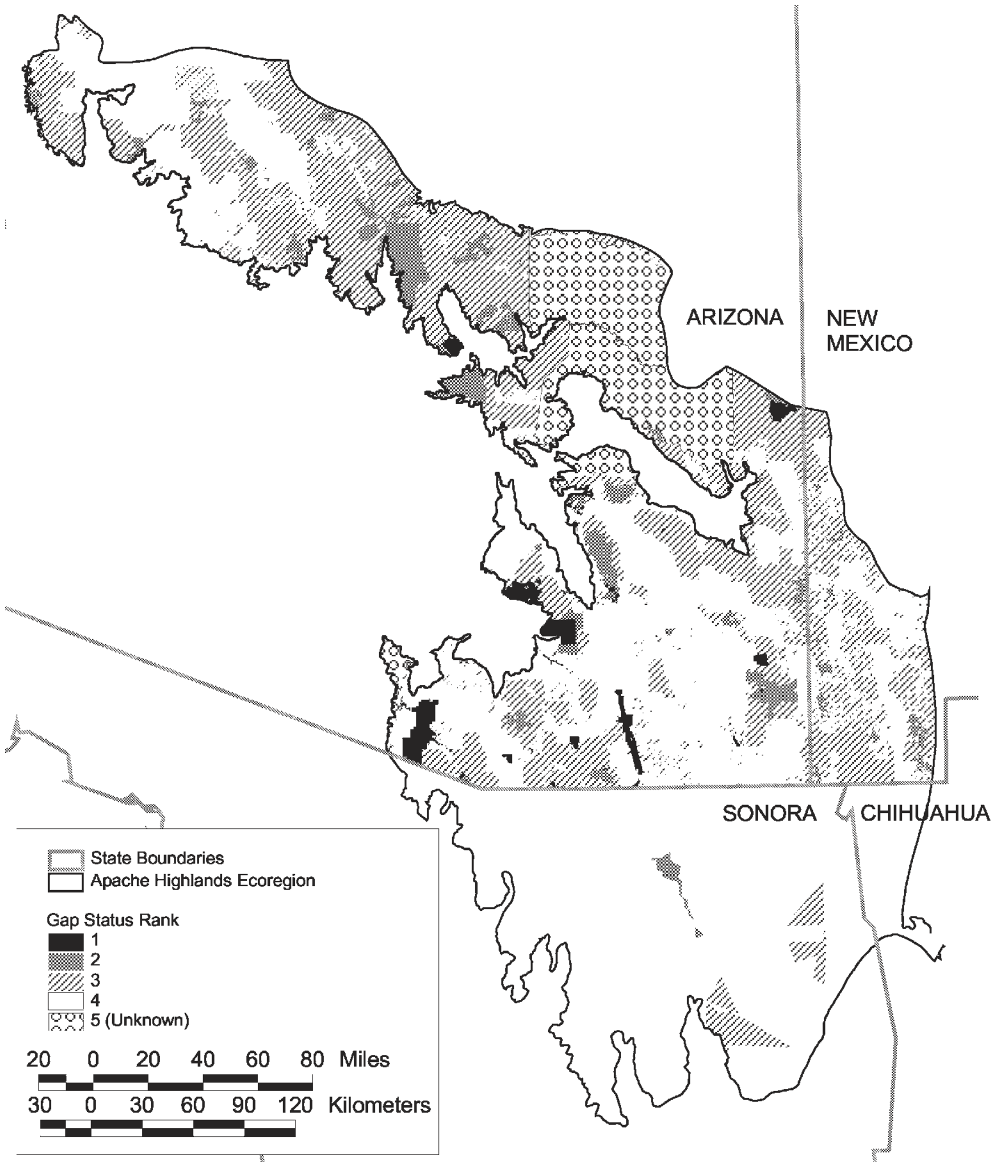

Figure 2—Gap status of land stewardship in the Apache Highlands Ecoregion. See text for descriptions of ranks.

San Luis/Peloncillo Mountains were the first- and second-ranked areas, respectively.

Discussion

The portfolio of conservation areas that we identified represents a hypothetical minimum area which, if managed well, would maintain the native biodiversity of the ecoregion through the next century.

This ecoregional analysis was meant primarily to identify those areas most important for maintaining biodiversity. During the process, we also identified strategies that address conservation issues across multiple areas. These include the need to increase protection and restoration of grasslands, maintain or restore natural fire regimes, improve conservation management in identified conservation areas, strengthen binational conservation efforts, and plan for climate-induced effects on native species and communities.

We also noted some important gaps in the information needed to move forward with protection or restoration of the region's biodiversity. These include: (1) Better mapping and analysis of the distribution of rare and declining species in aquatic and riparian communities, and the threats to those communities; (2) Field inventories on the distribution of rare species in northeastern Sonora and northwestern Chihuahua; (3) Better knowledge of needs for and distribution of large mammal movement corridors between mountain ranges; (4) Field surveys on the status and condition of ciénegas; (5) Predictions about the effects of climate change on species or vegetation communities in this region; and (6) A comprehensive survey of invasive plant and animal species in the ecoregion, and a coordinated strategy for their control.

Proactive conservation efforts, such as Pima County's Sonoran Desert Conservation Plan, need to be replicated throughout the ecoregion before conservation issues reach crisis levels, at which time it will be far more costly to develop effective solutions. Such efforts will not only require the best available scientific information, as presented here, but also commitments by community leaders to engage the public in a focused dialogue about balancing future growth with conservation of our natural heritage. The results of this analysis and the data developed for this study, collectively, provide a scientific basis for decision-making by Federal, State, county, and municipal agencies in planning for land and water conservation.

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References

AGFD (Arizona Game and Fish Department). 1993. Arizona riparian inventory and mapping project: a report to the Governor, President of the Senate, and Speaker of the House. Phoenix, AZ: Arizona Game and Fish Department.

Andelman, S.; Ball, I.; Davis, F.; Stoms, D. 1999. SITES v. 1.0: an analytical toolbox for designing ecoregional conservation portfolios. Manual prepared for The Nature Conservancy. http://www.biogeog.ucsb.edu/projects/tnc/toolbox.html

DeBano, L. F.; Ffolliott, P. F.; Ortega-Rubio, A.; Gottfried, G. J.; Hamre, R. H.; Edminster, C. B. 1995. Biodiversity and management of the Madrean Archipelago: the sky islands of Southwestern United States and Northwestern Mexico; 1994 September 19-23; Tucson, AZ. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station.

Groves, C. R.; Jensen, D. B.; Valutis, L. L.; Redford, K. H.; Shaffer, M. L.; Scott, J. M.; Baumgartner, J. V.; Higgins, J. V.; Beck, M. W.; Anderson, M. G. 2002. Planning for biodiversity conservation: putting conservation science into practice. Bioscience 52: 499-512.

Halvorson, W. L.; Thomas, K.; Graham, L.; Kunzmann, M. R.; Bennett, P. S.; Van Riper, C.; C. Drost, C. 2002. The Arizona Gap Analysis Project final report. Tucson, AZ: U.S. Geological Survey, Biological Resources Division, Western Ecological Research Center.

Marshall, J. T. 1957. Birds of pine-oak woodland in southern Arizona and adjacent Mexico. Berkeley, CA: Cooper Ornithological Society, Pacific Coast Avifauna.

Marshall, R. M.; Turner, D.; Gondor, A.; Gori, D.; Enquist, C.; Luna, G.; Paredes Aguilar, R.; Anderson, S.; Schwartz, S.; Watts, C.; Lopez, E.; Comer, P. 2004. An ecological analysis of conservation priorities in the Apache Highlands Ecoregion. Prepared by The Nature Conservancy of Arizona, Instituto del Medio Ambiente y el Desarrollo Sustentable del Estado de Sonora, agency and institutional partners. 152 p.

Palacio Prieto, J. L.; Bocco, G.; Velazquez, A.; Mas, J. F.; Takaki, F.; Victoria, A.; Luna Gonzales, L.; Gomez Rodriguez, G.; Lopez Garcia, J.; Palma, M.; Trejo Vazquez, I.; Peralta, A.; Prado Molina, J.; Rodriquez Aguilar, A.; Mayorga Saucedo, R.; Gonzalez Medrano, E. 2000. La condicion actual de los recursos forestales en Mexico: resultados del inventario forestal nacional 2000. Investigaciones Geograficas, Boletin del Instituto de Geografia, UNAM 43: 183-203.

Thompson, B. C.; Crist, P. J.; Prior-Magee, J. S.; Deitner, R. A.; Garber, D. L.; Hughes, M. A. 1996. Gap analysis of biological diversity conservation in New Mexico using geographic information systems. Final GapAnalysis Report. Las Cruces, NM: U.S. Department of the Interior, New Mexico Cooperative Fish and Wildlife Research Unit.

USGS (U.S. Geological Survey). 2000. NLCD regional land cover, "Arizona and New Mexico." U.S. Geological Survey, EROS Data Center.

Velázquez, A.; François Mas, J.; Saucedo, M.; Palacio, J. L.; Bocco, G.; Gómez Rodríguez, G.; Luna González, L.; Trejo, I.; López García, J.; Palma, M.; Peralta, A.; Prado Molina, J.; Gónzalez Medrano, F. 2001. El Inventario Forestal Nacional 2000. Ciencias No. 64: 12-19

Weinstein, S. 2002. Gap analysis of land stewardship in the Apache Highlands ecoregion. Tucson, AZ: The Nature Conservancy. 263 p.