# Case Study: **Generating a Prioritization Method for Informing Conservation Action Across the Five Ecoregions Overlapping Arizona, USA**

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[see also associated figures, tables and appendices]

## Purpose and region of analysis

The primary objective of this analysis was to facilitate the prioritization of conservation action within the Arizona Chapter. In doing so, we wanted to utilize a subset of aggregated ecoregional data archived in the Conservation Planning Tool (CPT) database as the basis of the prioritization process. We now plan to apply the method to an analysis of conservation areas based on habitat type so that we can begin to plan for and ultimately implement the Arizona Chapter's contribution to the new Conservancy-wide 10-year goal. The analysis occurred over multiple ecoregions including Apache Highlands, Arizona-New Mexico Mountains, Colorado Plateau, Mojave Desert, and Sonoran Desert.

## Criteria/Methods

We developed an index of *biological value* (BV) using rolled-up attribute data specific to the conservation targets selected for the five ecoregions. Data sets for the five ecoregions were previously archived in an aggregated version of CPT. A total of six standardized attributes were selected from an aggregated "Targets" table in CPT to use in the calculation of a BV: Grank, ESArank, TargetDistribution, TargetTaxonomicGroup, TargetHabitatType, and a combination of TargetScientificName and TargetCommonName (in order to conduct a count of targets). We also generated an index of *irreplaceability* (IRR) following the methodology outlined in the Apache Highlands Ecoregional Analysis (Marshall et al. 2003).

<u>Tabular Analyses</u>
We first tabulated the aggregated CPT data on linked "Targets" and "Target Occurrences" tables by conservation area using a series of queries in Microsoft Access. In this way, we generated a table of conservation areas with the following attributes:

- Total # targets
- Total # targets with G1/G2 ranks
- Total # targets with LE or LT ESA ranks

- Total # endemic targets (we defined "endemic" as those targets for which 90% of their range is found within one of five ecoregions analyzed)
- Total # Taxonomic groups represented
- Total # Aquatic/Riparian targets

We next generated a BV for each conservation area in two ways (excluding IRR score): (1) summed across raw, unweighted attribute total values and (2) summed across *weighted* and standardized variables (Appendix 1 describes the methodology used for determining weights placed on each conservation area attribute). Summations were conducted in Microsoft Excel.

Irreplaceability index scores for each conservation area were also generated using a series of Microsoft Access queries. Specifically, for each conservation target, we determined the number of conservation areas in which the target occurs, then calculated the inverse of that number to represent the importance of a particular area. Thus, for all targets at a given area, we computed the following:

*IRR = 1/(count of areas with target a) + 1/(count of areas with target b) + 1/(count of areas with target c)…+ 1/(count of areas with target z)*

For example, a target that occurs at 20 areas would have an index value of 1/20, since protecting any of those 20 areas would protect an occurrence of the target. Targets captured at fewer areas would have higher index values (e.g., 1/2 is larger than 1/20), giving them greater weight. We then summed across index values for all targets present in a given conservation area to arrive at a total IRR score.

<u>Spatial (GIS) Attribution</u>
Before the resultant BV and IRR scores were linked by conservation area to their corresponding spatial designations, all spatial portfolio files for each ecoregion were merged using an ArcView union operation. Those portfolio sites that contained adjacent and overlapping boundaries across ecoregional lines were then merged using an ArcView dissolve operation. The dissolve operation was guided by decision rules that took into account place names and biophysical characteristics. The average of biological values from the original conservation areas was attributed to the larger, dissolved cross-ecoregional conservation areas. However, in retrospect, it is suggested that one take the maximum value rather than the average. This process "distilled" 1130 original conservation areas into 589. This number was further reduced to 499 conservation areas to account for sites with no target data (expert polygons drawn for the Colorado Plateau plan) and non-standard data (conservation areas from the Mojave Desert plan that require a fair amount of additional work to link to CPT).

**Products/Outcomes**

We produced three prioritization, or ranking, schemes for the 499 conservation areas in both tabular (available upon request) and spatial format: (1) biological value using unweighted scores (Figure 1), (2) biological value using weighted scores (Figure 2), and

(3) irreplaceability index score (Figure 3). We found that while each prioritization scheme was unique, they were all strongly correlated. Not surprisingly, the weighted and unweighted ranks were most strongly related, while IRR and the weighted ranks exhibited the least strong relationship (Table 1).

| Priority Method | Unweighted BV | Weighted BV | IRR |
|---|---|---|---|
| Unweighted BV | ************************* | $r=0.978$, $r^2=0.956$ $p<0.0001$ | $r=0.89$ , $r^2= 0.79$ $p<0.0001$ |
| Weighted BV | $r=0.978$, $r^2=0.956$ $p<0.0001$ | ******************* | $r=0.853$ , $r^2=0.728$ $p<0.0001$ |
| IRR | $r=0.89$ , $r^2= 0.79$ $p<0.0001$ | $r=0.853$ , $r^2=0.728$ $p<0.0001$ | ******************* |

Table 1. Correlation statistics for priority ranking schemes.

Based on our evaluation of the three methods presented here, we believe that the *weighted* BV ranking scheme provides the most comprehensive approach to prioritizing conservation areas in the five ecoregional area. The ranking scheme is based on standardized data across six important biological variables, each weighted by expert input. In addition the BV minimizes bias caused by differences in the way ecoregional assessments were completed. While IRR characterizes an important attribute, it is more sensitive to sampling bias because the occurrence data used may not represent the actual distribution of the target. This reduces the robustness of using this single attribute to derive priorities.

**Strengths and weaknesses**

We were successful in utilizing standardized data aggregated from five southwestern ecoregions to inform our conservation prioritization process. Furthermore, instead of using a single variable to drive priority selection, we used a multiple criteria approach derived from Decision Theory (Voogd 1983, Eastman 2001). Others have also used multiple criteria to generate a systematic conservation prioritization assessment (Noss et al. 2002, Groves 2003). In our study, we incorporated an attribute weighting method based first on expert knowledge and then a straightforward pairwise comparison algorithm (Saaty 1977) used widely in the GIS/natural resource planning community (Rao et al. 1991, Campbell et al. 1992, ESI 2003). These steps not only served to enhance the application of the biological value index, but also lent credence to an otherwise wholly subjective process.

Our first concern was data reliability when using the conservation target attribute data in the rolled-up CPT database. These ecoregional data sets were derived from a number of sources, some over five years in age. We attempted to standardize each attribute to the best of our ability, given limited time, resources, and inability to contact original ecoregional team members. Another problem arose when we linked the tables of targets, target occurrences, and conservation areas to the merged GIS layer of portfolio sites. In total, 158 portfolio sites appeared to not contain targets. Most of these sites (133) occurred within the Mojave Desert Ecoregion, while 25 occurred within the Colorado

Plateau Ecoregion. These sites are indicated in gray on the corresponding GIS maps (Figures 1-3). We are in the process of attempting to resolve these issues.

Second, we recognized that the biological attributes associated with each target are not independent variables. We confirmed this using the non-parametric correlation statistic, Spearman's rho (statistics available upon request). Nevertheless, because we were not developing a statistical model as the basis for our BV index, we concluded that we were not at risk of violating specific assumptions associated with many statistical tests. We discussed the possibility of artificially inflating index scores as result of this lack of independence, yet felt that using each variable still provided sufficiently important biological information such that no variable was eliminated. Moreover, we felt that this cumulative scoring method provided us with a valuable reflection of the ecological properties of the targets within a particular conservation area.

Third, based on the Theory of Island Biogeography, we were aware that the area or size of a given conservation area could influence the overall count of targets. We tested this hypothesis by conducting a series of linear regression analyses using area as the predictive value and each target attribute as the response. The resulting $r^2$ values ranged between 0.15 and 0.45 ($p<0.0001$). Although weak, relationships with area evidently exist. However, because species-area curves are not linear we felt that defining and implementing an appropriate area adjustment could be problematic. We therefore decided to forego adjusting attribute values by area at this point in our prioritization process.

**Suggestions for others**

First and foremost, teams should have a strong degree of confidence regarding the data used in analyses that may have profound implications for conservation action, such as priority setting. Generally speaking, recent ecoregional analyses were conducted using the best available scientific knowledge and thus this point may not be of particular concern. However, when taking a multi-ecoregional approach, data reliability increasingly becomes a factor, especially if a substantial amount of time has passed since an ecoregional assessment was conducted.

We believe that we could have increased the value of our prioritization process if we could have used a two-pronged approach similar to that described by Margules & Pressey (2000). The first approach follows the approach described in this paper (biological value and/or irreplaceability). The second involves the development of a vulnerability or threats index using an approach similar to a suitability index. Noss et al. (2002) demonstrated the use of this two-pronged approach in the prioritization of conservation sites within the Greater Yellowstone Ecosystem. Theobald (2003) provides a method of conducting vulnerability or threats analyses using publicly available socioeconomic data (land ownership, protection status, roaded areas, and housing density). Once vulnerability/ threats scores and biological value/irreplaceability scores area generated for each conservation area, a two-dimensional graphical depiction of scores (should be on similar scale) can easily be generated, with vulnerability/threats on the x-axis and biological value/irreplaceability on the y-axis. The resulting plot can then be divided into 4 quadrants representing the following priorities: Quadrant I: Highest Priority, Quadrant II: 2nd Highest (biological value assumed as having greater importance than threats), Quadrant III: 3rd Highest, Quadrant IV: Lowest Priority. By using this simple yet elegant approach, a conservation planning team can readily prioritize conservation sites while taking into account a broad spectrum of important biological and socioeconomic variables.

**Tools**

Conservation Planning Tool (CPT)
Microsoft Access
ArcView GIS

**Bibliography**

Campbell, J.C., J. Radke, J.T. Gless, and R.M. Wirtshafter. An application of linear programmingand geographic information systems: cropland allocation in Antigua. *Environment and Planning A*. 24: 535-549.

Eastman, J.R. 2001. *Guide to GIS and Image Processing Volume 2*. Clark Labs, Clark University. Worcester, MA.

ESI Corporation. 2003. Pima County Economic Analysis Section 10 Permit. Phoenix, AZ.

Groves, C.R. 2003. Safeguarding nature's investments: setting priorities for action among conservation areas. In C. Grove's *Drafting a Conservation Blueprint: A Practitioner's Guide to Planning for Biodiversity.* Island Press, Washington, D.C. pp.260-287.

Margules, C.R. and R.L. Pressey. 2000. Systematic conservation planning. *Nature*. 405: 243-253.

Marshall, R.M., D. Turner, A. Gondor, D. Gori, C. Enquist, G. Luna, R. Paredes Aguilar, S. Anderson, S. Schwartz, C. Watts, E. Lopez, P. Comer. 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 pp.

Noss, R.F., C. Carroll, K. Vance-Borland, and G. Wuerthner. (2002). A multicriteria assessment of the irreplaceability and vulnerability of sites in the Greater Yellowstone Ecosystem. *Conservation Biology*. 16: 895-908.

Rao, M., S.V.C. Sastry, P.D. Yadar, . Kharod, S.K. Pathan, P.S. Dhiniwa, K.L. Majumdar, D. Sampat Kumar, V.N. Patkar, V.K. Phatak. 1991. *A Weighted Index Model for Urban Suitability Assessment-A GIS Approach*. Bombay Metropolitan Regional Development Authority, Bombay, India.

Saaty, T.L. 1977. A scaling method for priorities in hierarchical structures. *J. Math. Psychology*. 15: 234-281.

Theobald, D.M. 2003. Targeting conservation action through assessment of protection and exurban threats. *Conservation Biology*. 17: 1624-1637.

Voogd, H. 1983. *Multicriteria Evaluation for Urban and Regional Planning*. Pion, Ltd., London.