Case Study: **Selecting terrestrial conservation targets in Puerto Rico and it's archipelago**

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Purpose and region of analysis

Using a coarse and fine filter approach, the ecoregional assessment team identified ecosystem conservation targets with the help of the geoclimatic model and selected species targets by consulting a variety of species databases. The distribution map of ecosystem targets was obtained by the GIS overlays of geoclimatic regions and the recent land cover map. The Natural Heritage Division of the Department of Natural and Environmental Resources of Puerto Rico provided species occurrences maps. Both coarse and fine filter conservation targets were subsequently reviewed and the ecological integrity of their occurrences verified in a series of experts' workshops.

The Commonwealth of Puerto Rico, including the main island and it's archipelago—Vieques, Culebra, Mona, Monita, Desecho, Culebrita, Caja de Muerto et al.—with a total land area of ca. 8,900 km^2 was the study area. The area consists of two terrestrial ecoregions: Puerto Rico Moist Forest Ecoregion and Puerto Rico Dry Forest Ecoregion.

Criteria/Methods

Identification of Ecosystem Targets

The coarse filter terrestrial ecosystem targets were assembled and their locations identified, with the following GIS overlays: (1) geoclimatic regions and (2) a recent land cover map.

Geoclimatic Model

Geoclimatic regions were determined with a model based on the combination of the Holdridge Life Zones map (Ewel & Wetmore 1973) that provides biotemperature, precipitation and potential evapotranspiration ratio and a simplified geological map (Figueroa-Colón 1996). The Holdridge Life Zones, a classification system widely applied throughout the Tropics, is a bioclimatic model with logarithmic increments of mean values of biotemperature and total annual precipitation (Holdridge 1967). Biotemperature is the range of temperatures within which vegetative growth occurs, with 0°C as the minimum and 30°C as the maximum. A day's biotemperature is the sum of the positive hourly temperatures (temperature <0°C and >30°C count as 0°C), divided by 24. The annual mean biotemperature is the sum of daily biotemperatures divided by 365. This information is then combined with mean annual precipitation to determine the potential evapotranspiration ratio (PET) with the following formula: PET = mean annual biotemperature x 58.92 / mean annual precipitation (mm). PET is then converted to a moisture regime according to the following table:

PET	**Moisture Regime**
0.125-0.250	Rain
0.250-0.500	Wet
0.500-1.00	Moist
1.00-2.00	Dry
2.00-4.00	Very Dry

Holdridge Life Zones include information relating to biotemperature and precipitation and therefore, can be used to determine the climatic regime of a target occurrence.

A simplified geological map of Puerto Rico was created by grouping different generic geological parent rocks by virtue of their soil-producing characteristics. This classification resulted in six distinct geological parent material types: (1) all extrusive volcaniclastic rocks were consolidated into one unique class based on their generally producing shallow-to-deep clayey soils; (2) granodioritic intrusive igneous rocks were grouped as producers of sandy edaphic substrates; (3) sedimentary deposits were divided into two generic groups, based on origin, calcareous and non-calcareous sedimentary, calcareous sedimentary rocks (3a) producing relatively basic soils, and non-calcareous sedimentary rocks (3b) producing relatively acidic soils; (4) ultramafic rocks of mantle origin, producing nutrient deficient, weathered soils and (5) Quaternary alluvial deposits producing relatively nutrient-rich, loamy soils (Figueroa-Colón, 2003). The overlays of the Holdridge Life Zones map and the simplified geological map resulted in 28 geoclimatic regions. The WWF Ecoregions (Dinerstein et al. 1995) are aggregates of Holdridge Life Zones (Table 1).

Table 1. The nesting relationship between ecoregions, Holdridge Life Zones, and geoclimatic regions.

WWF Ecoregion	**Bedrock classe- Life Zone**	Alluvial	Limestone	Sedimentary	Volcanic-Extrusive	Volcanic-Intrusive	Ultramafic
Puerto Rican Dry Forests	Dry	X	X	X	X	X	X
PuertoRican Moist Forests	Moist	X	X	X	X	X	X
	Wet	X	X	X	X	X	X
	Rain	X	N/A	N/A	X	X	N/A
	Lower Montane/ Wet	X	X	N/A	X	X	X
	Lower Montane / Rain	N/A	N/A	N/A	X	X	N/A

Mapping the Distribution of Ecosystem Targets

The occurrences of the ecosystem targets were identified by overlaying the map of geoclimatic regions on a recent land cover map illustrating 25 vegetation formations in Puerto Rico (Helmer et al. 2002), Vieques and Culebra (International Institute of Tropical Forestry IITF, 2004) with simplified vegetation classes—natural vegetation, non-natural vegetation, and non-vegetated areas (Table 2).

Table 2. Twenty-five terrestrial vegetation formations in Puerto Rico (Source: IITF Forest and Land Cover Map of Puerto Rico 2000)

Vegetation – Formation (active or past land use are highlighted**)**	**Total Area (Ha.)**
Lowland dry semideciduous forest	16273.88
Lowland dry semideciduous woodland/shrubland	22745.04
Lowland dry mixed evergreen drought-deciduous shrubland with succulents	984.36
Lowland dry and moist, mixed seasonal evergreen sclerophyllous forest	3568.68
Lowland moist evergreen hemisclerophylous shrubland	90.38
Lowland moist seasonal evergreen forest	54497.11
Lowland moist seasonal evergreen forest/shrub	68026.1
Lowland moist semi-deciduous forest	5188.56
Lowland moist semi-deciduous forest/shrub	1946.19
Lowland moist seasonal evergreen and semi-deciduous forest	25924.74
Lowland moist seasonal evergreen and semi-deciduous forest/shrub	26046.77
Submontane and lower montane wet evergreen sclerophyllous forest	3102.84
Submontane and lower montane wet evergreen sclerophyllous forest/shrub	1927.7
Submontane wet evergreen forest	49716.92
Active sun/shade coffee, submontane and lower montane wet forest/shrub	26638.6
Submontane and lower montane wet evergreen forest/shrub and active/abandoned shade coffee	52073.23
Lower montane wet evergreen forest - tall cloud forest	21638.67
Lower montane wet evergreen forest - mixed palm and elfin cloud forest	2954.12
Lower montane wet evergreen forest – elfin cloud forest	1071.57
Tidally and semi-permanently flooded evergreen sclerophyllous forest	6856.45
Seasonally flooded rainforest	313.95
Tidally flooded evergreen dwarf-shrubland and forb vegetation	51.77
Other emergent wetlands (including seasonally flooded pasture)	5742.15
Salt and mud flats	536.61
Pasture (including abandoned agricultural land)	324406.42

The overlay of the natural vegetation class of the land cover map on Puerto Rico's 28 geoclimatic regions produced a map showing the distribution of the currently remaining occurrences of terrestrial vegetation formations in each geoclimatic region (Figure 1). Areas that were non-natural and non-vegetated were eliminated from the target list.

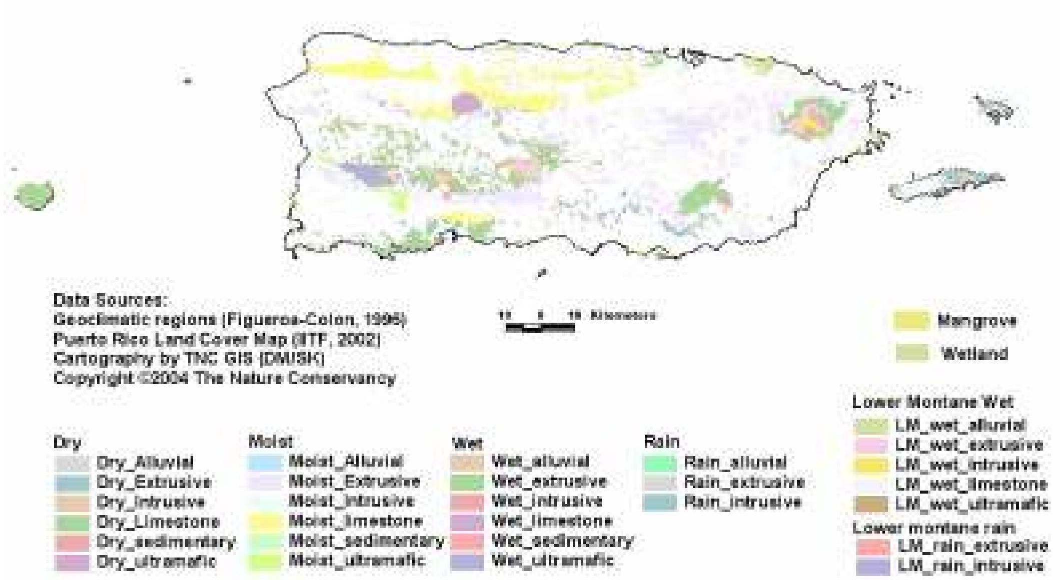

Figure 1. Map of 28 Puerto Rican ecosystem target occurrences. (Areas where there are no target occurrences appear in white. These are agricultural areas, urban areas, non-native vegetation such as plantations, or non-vegetated areas. Each color corresponds to a target.)

These vegetation remnants represent successions in each geoclimatic region (Figure 2) and will eventually develop into climax vegetation adapting to specific environmental conditions of individual geoclimatic regions. The preservation of the best vegetation remnants of each geoclimatic region should be a priority in order to allow successions to return to their original state. Thus vegetation remnants in each geoclimatic region can be treated collectively as one coarse filter ecosystem-level conservation target. We, therefore, gave the ecosystem level target the name of the geoclimatic region, and the ecosystem level target is the collective vegetation remnant in a given geoclimatic region (Keel et al, 2005). See Appendix 2 of the full report for the distribution of vegetation patches of each coarse filter target and photos of current vegetation.

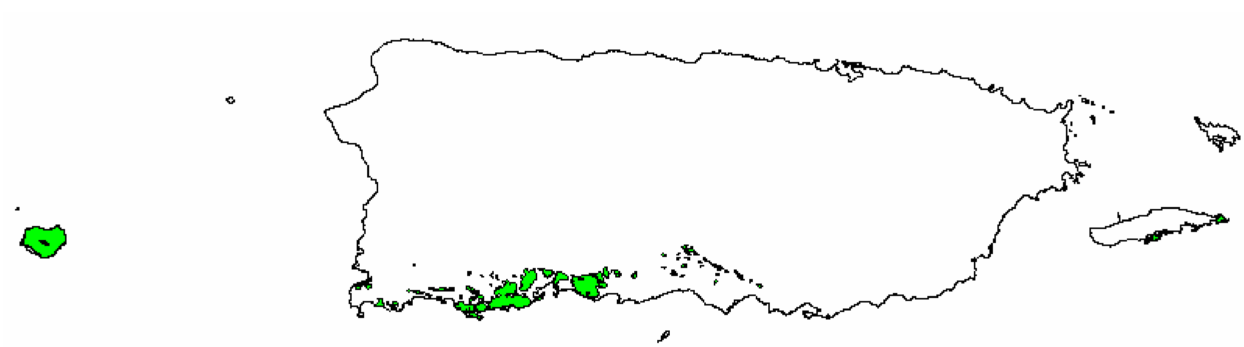

Figure 2. Map of vegetation patches in Dry-Limestone ecosystem

Identification of species Targets

Puerto Rico and its archipelago harbor a large number of endemic species. Table 3 gives an idea of the islands' biodiversity and endemism of vascular plants and vertebrates.

Table 3. Current diversity of Puerto Rican native terrestrial biota

Group	Total # of species	Rare or threatened species (DNER database, 2003)	# of Caribbean endemic species	% of PR endemic species	Source
Vascular Plant	2891	409	236	**8**	Davis, S.D., et al. 1997
Mammal	36	7	0	0	Rodríguez-Duran, A. & T.H. Kunz, 2001; NatureServe database, 2004
Amphibian	18	11	14	**78**	NatureServe database, 2004
Reptile	43	14	37	**86**	Schwartz, A. & R. W. Henderson 1991
Birds	299	30	12	**4**	NatureServe database, 2004

Much species-level biodiversity, especially plant-species diversity, is captured by coarse filter ecosystem targets. After reviewing various species databases, the team decided to use species that are rare or threatened, that is, species assigned by The Natural Heritage Division of the Department of Natural and Environmental Resources (DNER) with national conservation status—N1, N2 and N3 for species and T1, T2and T3 for subspecies/varieties. N1 and T1 stand for critically imperiled, typically 5 or fewer occurrences or 1,000 or fewer individuals; N2 and T2, imperiled, typically 6 to 20 occurrences or 1,000 to 3,000 individuals; N3 and T3, vulnerable, rare, typically 21 to 100 occurrences or 3,000 to 10,000 individuals. The occurrence maps of rare and threatened species were generously provided by DNER.

Products/Outcomes

The target selection for Puerto Rico and its archipelago considered two ecologically significant scales—ecosystem and species. With the help of the geoclimatic model, 28 ecosystem level coarse filter targets were identified. The overlay of the natural vegetation class of the land cover map on Puerto Rico's 28 geoclimatic regions produced a map with 28 ecosystem targets, and 3978 occurrences. For the portfolio design, rare or threatened species (N1, N2, and N3) and subspecies/varieries (T1, T2, and T3) with occurrences outside of the official protected areas—86 plant species (including 3 varieties) and 28 faunal species were selected as fine filter targets. The ecological integrity of targets' occurrences, including ecosystems and species, were examined in experts' workshops.

The use of a systematic classification of vegetation formations for Puerto Rico based on geoclimatic regions is justified with the results of tests against ecological life zones and generalized geological parent material types as alternate classification units. Life zones, geological parent material, and geoclimatic regions were tested using the native tree species. The distribution patterns of 506 native tree species in Puerto Rico show a statistically significant affinity toward geoclimatic regions. Working with geoclimatic regions—the combined life zones and geological parent material types—is more effective in identifying local ecosystems or vegetation types than relying on either life zones or generalized geological parent material types alone (Figueroa-Colon, 2003).

Tools

- Arc/View 3.3
- Geoclimatic Model
- Experts' workshops

Strengths/Weaknesses

In the Caribbean, climate and geology are the dominant environmental variables controlling the distribution of vegetation and its associated biodiversity (Lugo et al. 2000). The geoclimatic model was built on the key environmental factors that determine vegetation types and the biodiversity they contain. The Model has provided a solid framework for capturing biodiversity occurrences across environmental gradients. This systematic approach to identify features of biodiversity was well-received and widely used in Puerto Rico. By adding other environmental drivers to the geoclimatic model, the ecosystems can be classified into smaller, ecological meaningful units. Similarly, the ecosystems can be aggregated into coarser ecological units. The geoclimatic model facilitates multi-scale assessments of biodiversity. Unlike species or natural communities, geology and climate data are readily available. The model using physical drivers is a useful tool to organize biodiversity information and facilitate analysis.

Climate and geology are highly useful parameters to select conservation areas but relying on them exclusively may prevent conservationists from considering places that are dictated by topography, e.g. peaks, canyons, and caverns, which may have higher conservation priority. Experts' consultation, literature survey or additional data layers of environmental drivers may help to bridge the gaps inherent in the geoclimatic model.

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