Case Study: Connecting priority conservation areas in the main island of Puerto Rico[1]

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Purpose and region of analysis

Identify areas that serve as the key connections between conservation priorities (protected areas, etc.) that are important for maintaining population dynamics of conservation targets and ensuring the persistence of the targets. These population dynamics include recruitment of species, genetic exchange of individuals between different populations, and long-distance rescue to supplement or replace populations that were weakened or eliminated as a result of natural or anthropogenic disturbances. The connectivity analysis was conducted for the main island of Puerto Rico, a total land area of ca. 8,500 km^2, including the Puerto Rican Moist Forests Ecoregion and Puerto Rican Dry Forests Ecoregion.

Criteria/Methods

We began our analysis of connectivity by mapping the coarse-scale conservation targets identified during the ecoregional planning process. The conservation targets were ecosystem-based targets (e,g, dry limestone forest, submontane wet evergreen forest). We mapped the distribution of ecosystem targets and used the centroid of each target to represent the occurrence. We then wanted to calculate the shortest distance an organism would have to cross in order to move between occurrences of a given conservation target. However, ecosystem-based conservation targets do not move as a unit; they are composed of many species that each has different dispersal distances. Two occurrences of a conservation target separated by 5 miles may be “connected” for a bird, but are completely isolated for a tree that relies on wind to disperse its seeds. Additionally, the type of intervening habitat between two conservation targets has a strong influence on dispersal patterns. In the example above, the seed could move across an agricultural field that is a mile long, but the bird may be reluctant to cross such habitat. Therefore, the shortest path between the two occurrences for the bird may be 8 miles, because the bird may skirt around the agricultural field to remain in some type of forest (see Bunn et al. 2000 for an empirical example).

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It is impossible to determine the threshold dispersal distance for every organism of every ecosystem target as well as the relative resistance that different land cover types pose to the movement of each organism. Therefore, we had to simplify our analyses by using individual or groupings of ecosystem targets and evaluating the dispersal ability of individual targets or group targets based on the following four categories: wet/rain/moist forest (group target), dry forest, mangroves, and wetlands (individual targets). For each target or group target, we had experts evaluate the target group's ability to cross the other three conservation targets. We also had the experts rate the ability of each target and group target to cross various land cover types, such as tillage agriculture, non-tillage agriculture, agroforestry, urban development, saltwater, and freshwater areas. The experts evaluated the relatively difficulty of each target and land cover type based on a 10-point scales (10 being a land cover type with the most resistance).

Based on a land cover map with a 30 x 30 m resolution (Helmer et al. 2002), we assigned a "cost" to each 30 x 30 m cell based on the experts' evaluations (Fig. 1). We then used Stepping Stone Connect. AML computer program (Tingey and Schill 2005) to calculate the shortest distance between occurrences of each conservation target based on the cost of the path (a least cost path distance), rather than measuring the absolute distance between occurrences. Many of the conservation targets had a large number of very small occurrences because of extensive fragmentation. In these cases, we grouped occurrences of the same target that were close together, and calculated the least cost path between grouped occurrences.

We then overlaid all the least cost paths in ArcView and calculated the density of paths in each 1.2 km x 1.2 km grid cell. Areas with a high density of the least cost paths were considered high priority areas for connectivity (Fig 2). We were particularly interested in identifying areas that connected protected areas across the main island of Puerto Rico (Fig. 3).

Finally, we wanted to assess the importance of each target occurrence in maintaining connectivity of conservation targets on the mainland of Puerto Rico. We calculated three metrics of connectivity for each occurrence: recruitment, flux, and traversability (Urban 2001). Recruitment relates to the ability of an occurrence to allow for the establishment of new individuals (immigration) and to produce individuals that leave to colonize new areas or supplement existing populations (emigration). Recruitment is related to the size and quality of a habitat patch, whereby larger patches of higher quality have higher recruitment values. Flux also is related to the quality and size of an occurrence, but it gives greater weight to occurrences that are near other high quality large occurrences – in other words, centrally located occurrences. Traversability measure how much each occurrence adds to extending the network of targets. If a centrally located occurrence was removed, then an otherwise extended network of occurrences may be broken into two (or more) isolated networks. The values of recruitment, flux, and traversability were evaluated over several different dispersal distances and then averaged to obtain a single set of values for each occurrence. See Urban (2001) and Keitt (1997) for more detail on the application of graph theory to conservation planning.

In order to calculate recruitment, flux, and traversability for each occurrence, we used the Landgraphs program developed by Urban (2003) to iteratively remove each occurrence from the network. The program then calculates the change in recruitment, flux, and traversability for the given occurrence. Occurrences whose removal results in a large change in these three metrics are considered important for maintaining connectivity. The nine most important occurrences of the dry limestone forest conservation target are shown in Figure 4.

Products and Outcomes

The connectivity analysis was incorporated into the Puerto Rico Ecoregional Assessment (Keel et al. 2005) and served as a case study as the Caribbean Ecoregional Assessment developed conservation plans for other islands in the Caribbean.

Tools

Marxan - assemble a portfolio of conservation targets
ArcView Spatial Analyst – build cost surfaces and overlay least cost path distances
Stepping Stone Connect. aml – calculate least cost path distances

Lessons learned (strength and weaknesses)

The final connectivity analysis produces a map that clearly communicates the high priority areas for maintaining connectivity between conservation targets in Puerto Rico. However, explaining how we conducted these analyses proved to be quite difficult, and there were many debates on how to group target occurrences and develop weights for the cost surface (see recommendations below). Overall, we believe this connectivity analysis substantially improved the ecoregional plan for Puerto Rico by placing each priority area in the context of its relationship to other priority areas, rather than solely focusing on the biodiversity within a given priority area.

Suggestions for others

1) Focus on finding a way to communicate the connectivity analysis to stakeholders early in the process. Because we were making adjustments as we continued the analyses, we had difficulty explaining the methods to others.

2) Although there are always paths connecting target occurrences, some of these paths may still cross significant barriers to movement in the landscape (such as highways). We suggest consulting local experts to refine the maps to eliminate these paths in identifying areas important for connectivity

3) Keep the analyses as simple as possible, even if detailed data about land cover are available. Because we know so little about the ways in which most organisms move when they are outside of their specific habitat, it is difficult to develop a detailed cost

surface. Overall, it might be better to develop a cost surface based on a few simple categories such as urban areas, agricultural areas, and natural vegetation cover. However, if an analysis focuses on a specific species with known dispersal limitations, it may be possible to develop a detailed cost surface.

References

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Figures

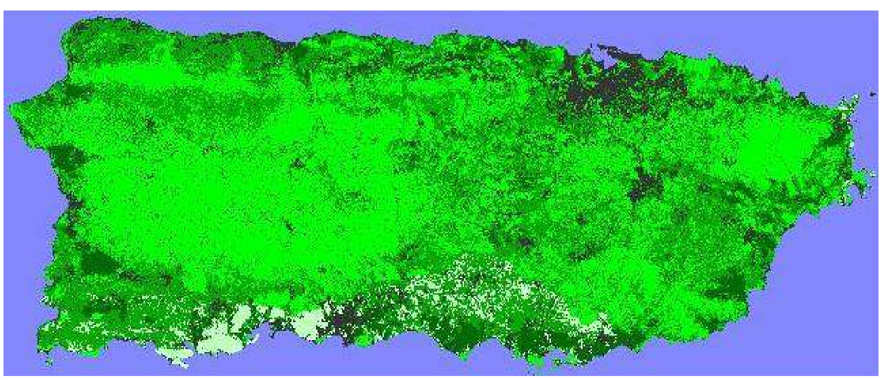

Figure 1: An example of a cost surface for conservation targets in Puerto Rico that were grouped into the dry forest classification. Darker areas represent areas less favorable for movement.

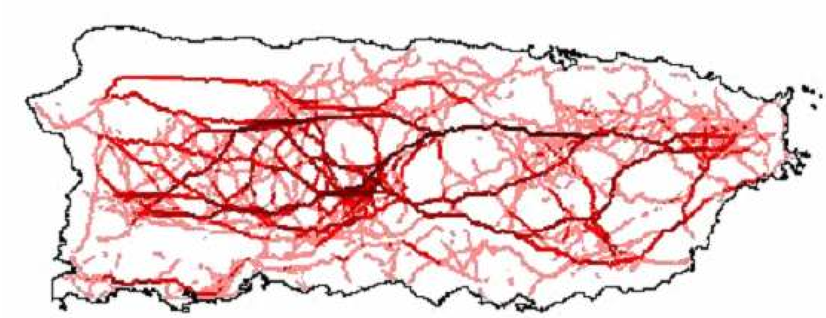

Figure 2: Density of least cost paths between all occurrences (or grouping of occurrences) for all conservation targets.   Areas with a higher density of least cost path (the darker areas) are high priority areas for maintaining connectivity.

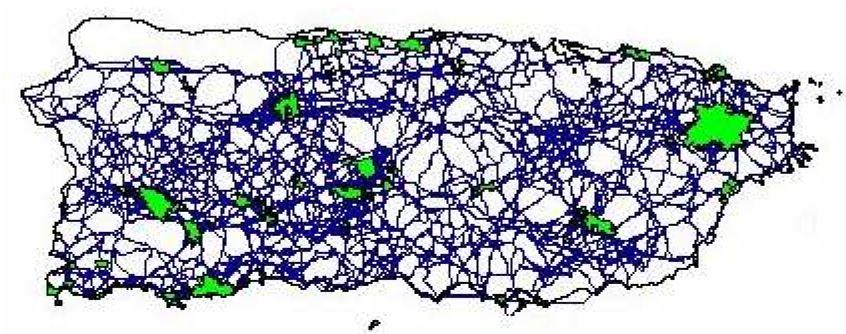

Figure 3: Overlay of the current protected area system in Puerto Rico and all the least cost paths (note that this figure displays all least cost paths, not the density, which makes it appear that there are more paths in this figure than in Figure 2). The current protected area system is shown in green, and each least cost path is shown in blue.

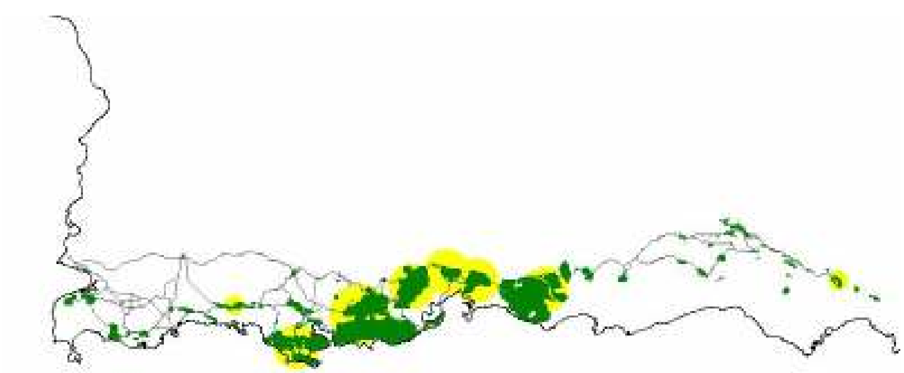

Figure 4: Detail of Figure 1 (southwestern section of Puerto Rico). The highlighted areas represent the nine most important occurrences of dry limestone forest for maintaining connectivity. This conservation target is only found in the southwest corner of Puerto Rico. The light grey lines show the least cost paths between each occurrence of the target.