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Short communication

The cost of postponing biodiversity conservation in Mexico

Trevon Fuller[a], *Víctor Sánchez-Cordero*[b], *Patricia Illoldi-Rangel*[b], *Miguel Linaje*[b], *Sahotra Sarkar*[a,*]

[a]*Biodiversity and Biocultural Conservation Laboratory, Section of Integrative Biology, University of Texas at Austin, 1 University Station, #C0390, Austin, TX 78712-1180, USA*

[b]*Departamento de Zoología, Instituto de Biología, Universidad Nacional Autónoma de México. Aptdo. Postal 70-153, México D.F. 04510, Mexico*

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ABSTRACT

Though Neotropical countries are the most species rich in the world, their biodiversity is threatened by the loss of native vegetation. Land conversion in Mexico during the last 30 years has been extensive and is representative of that of other developing countries. However, the effects of land use change on the required size and configuration of an adequate biological conservation area network are largely unknown. It is shown here that endemic mammals in Mexico could have been protected considerably more economically if a conservation plan had been implemented in 1970 than is possible today due to extensive conversion of primary habitats. Analysis of the distributions of 86 endemic mammal species in 1970, 1976, 1993, and 2000 indicates that the distributions of 90% of the species shrank during this 30-year period. At each time step, optimal conservation area networks were selected to represent all species. 90% more land must be protected after 2000 to protect adequate mammal habitat than would have been required in 1970. In addition, under a realistic conservation budget, 79% fewer species can be represented adequately in a conservation area network after 2000 compared to 1970. This provides an incentive for rapid conservation action in Mexico and other biodiversity hotspots with comparable deforestation rates, including Burma, Ecuador, Indonesia, the Philippines, and Sri Lanka. Due to ongoing habitat degradation, the efficiency of a conservation plan decreases with delays in its implementation.

1. Introduction

Planning problems that arise in the context of the design of conservation areas are often formulated as constrained optimization (minimization or maximization) problems (Csuti et al., 1997; Ando et al., 1998; Sarkar et al., 2006). The objective of the minimization is to pick as few sites as possible to serve as conservation areas subject to the constraint that the selected sites protect sufficient habitat for each species of conservation concern. The objective of the maximization is to protect as many species as possible subject to the constraint that the cost of the selected sites is less than a budgetary ceiling. The optimization problem may also include constraints to ensure that the conservation areas have a suitable spatial configuration (Onal and Briers, 2002).

* *Corresponding author:* Tel.: +1 512 232 7101/7122; fax: +1 512 471 4806.
E-mail address: sarkar@mail.utexas.edu (S. Sarkar).

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The selection of conservation areas via optimal or heuristic methods is just one stage of systematic conservation planning (Margules and Pressey, 2000; Sarkar, 2005). Systematic planning recognizes that species' ranges change dynamically in response to management policies or anthropogenic disturbance and stipulates that conservation areas be reassessed periodically after their establishment to quantify whether management goals are being satisfied within a suitable time frame (for examples, see Dirzo and Garcia, 1992; Bojórquez-Tapia et al., 2003; Bojórquez-Tapia et al., 2004). Species may disperse away from conservation areas due to climate change (Peters and Darling, 1985; Davis and Zabinski, 1992; Rutherford et al., 1999; Davis et al., 2000; Peterson et al., 2002; Burns et al., 2003), deforestation (Brooks et al., 1999; Fisher, 2000; Benning et al., 2002; Koh et al., 2006), or the spread of agriculture (Bomhard et al., 2005). If environmental changes destroy suitable habitat of a species or significantly reduce habitat quality inside the conservation areas, the conservation areas established before the environment changed will no longer be optimal (Halpin, 1997; Hannah et al., 2002; Midgley et al., 2003). Thus, rather than assuming that species' ranges are fixed, biodiversity management should be an adaptive and iterative process in which new sites are added to the conservation area network as deemed necessary by the monitoring plan.

This note analyzes the implication for biodiversity conservation of distributional shifts of endemic mammals in Mexico in the recent past. It is shown that the accelerating pace of land conversion in Mexico since 1970 has reduced and fragmented mammal habitat in such a way that the amount of land that must be placed under protection to represent mammalian biodiversity today is significantly greater than the amount that would have been required to protect mammals at equivalent levels 30 years ago. Thus, because of these land cover changes, the cost of adequate conservation increases during this period. (This assumes a positive correlation between the total area of a conservation area network and the cost of implementing such a network.) Land conversion in Mexico during the last 30 years has been extensive and is representative of that of other developing countries. Tropical and temperate forests in Mexico are disappearing at high annual rates (Masera et al., 1997; Mendoza et al., 1999) accompanied by an increase in agricultural lands, shrubs, and pastures for cattle (Bocco et al., 2001). Some Mexican fauna such as butterflies can persist despite substantial reductions in forest cover, but these reductions extirpate many vertebrates such as mammals and birds (Sarukhán et al., 1996; Peterson et al., 2006). In addition, conversion to agricultural use creates habitat unsuitable for threatened mammals (Ceballos et al., 2005; Sánchez-Cordero et al., 2005; Stoleson et al., 2005). This is particularly critical because Mexico's mammal fauna ranks second worldwide and is 30% endemic (Fa and Morales, 1993). Moreover, Mexican endemic mammals are of special conservation concern because they are underrepresented in international treaties about threatened species (Ceballos et al., 2002).

Recently, a database with remote-sensed data were created for the extent and rate of land use/land cover change in Mexico since the 1970s (Sorani and Alvarez, 1996; Mas et al., 2004). The database includes nationwide land use and vegetation maps for 1976, 1993, and 2000; the last three dates correspond to the time slices in the land cover database for the Inventario Nacional Forestal (2000). However, such data do not indicate how land conversion affects strategies for the conservation of mammals (Kinnair et al., 2003). In particular, the effects of land use change on the required size of an adequate biological conservation area network are largely unknown.

To quantify these effects, the present analysis combined the database on land conversion with ecological niche modeling of 86 endemic mammals projected as species' distributions using the 1970, 1976, 1993, and 2000 land use and vegetation maps (see below). The ecological niche of endemic mammals was modeled using a computer genetic algorithm (GARP, genetic algorithm for rule set-prediction; Stockwell and Peters, 1999), a machine-learning algorithm that has provided accurate coarse-grained distributional predictions for Mexican mammals (Illoldi-Rangel et al., 2004; Sánchez-Cordero et al., 2005). The 1970 vegetation map was selected as a starting point because it pre-dates the most recent phase of extensive deforestation in Mexico (Rzedowski, 1986; Carabrias et al., 1994). This study analyzes distributional shifts of endemic mammals in Mexico in the recent past by quantifying the impact of land use patterns on species' distributions from 1970 to 2000 and assessing how distributional shifts affect optimal conservation area networks.

2. Methods

Mexico was divided into 71 248 rectangular sites at the 0.05° scale (hereafter "sites"). The mean area (±SD) of each site was 3091.1 (±2.1) ha. A multi-date database on land cover in Mexico (Sorani and Alvarez, 1996; Mas et al., 2004) with seven classes (primary temperate forest, secondary temperate forest, primary tropical forest, secondary tropical forest, scrubland, other vegetation covers, and human-made covers; scale 1:250,000) was generated by digitization of aerial photography (average date: 1976), and visual interpretation of Landsat TM color composites (1993), and Landsat ETM + (2000). Accuracy assessment of the database indicated digitization accuracy of 96% and accuracy of class identification of >90% (Mas et al., 2004).

2.1. Ecological niche modeling and species' distributions

Mammal distributions were modeled using point occurrence data from museum voucher specimens, environmental coverages and a GIS platform. The mammal database was compiled from national and international museum scientific collections (see Acknowledgements), following Villa and Cervantes (2003) for taxonomic nomenclature. The environmental coverages (raster GIS layers at $0.04° \times 0.04°$ pixel resolution) summarized potential vegetation types, elevation, slope, and aspect, according to the Hydro 1K data set (United States Geological Survey, 1998), and climatic parameters including mean annual precipitation, mean daily precipitation, maximum daily precipitation, minimum and maximum daily temperature, and mean annual temperature obtained from Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (hereafter "CONABIO") (CONABIO, 1998).