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Formulating conservation targets for a gap analysis of endemic lizards in a biodiversity hotspot

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ABSTRACT

Species gap analyses that adopt conservation targets based on individual species attributes recognize that some biodiversity features need more protection than others and should lead to better outcomes than uniform conservation targets. In the Brazilian Cerrado hotspot, 4 of the 30 endemic lizard species are included in the IUCN or Brazilian red lists of threatened species. For 18 species with more than 5 occurrence records, we produced distribution models using Maxent and for 12 species with less than 5 occurrence records we used a 5 km radius around the records to indicate distributions. For all species, we estimated habitat loss after discounting cleared areas from indicated distributions. Non-modeled species were considered as truly restricted-range endemics and had conservation targets set a priori as 100%. We formulated conservation targets for 18 modeled species based on three characteristics: natural rarity, vulnerability, and life-history. We estimated vulnerability from a model of future habitat loss across the Cerrado, derived with Maxent. We then performed a gap analysis considering strictly protected conservation areas. We applied percentage targets (between 12% and 23%) to estimated species distributions prior to habitat loss and evaluated the targets against the presence of the species within strictly protected conservation areas. Disturbingly, only one species is adequately protected by the current system of protected areas. We also found that one species is a minor conservation gap, whereas the remaining 28 species are either major (13) or total (5) conservation gaps. Habitat loss has erased a significant fraction of the original distribution of Cerrado endemic lizards and the existent network of protected areas is wholly inadequate to ensure their conservation. The use of conservation targets based on natural rarity, vulnerability, and life-story will support more defensible conservation guidelines than commonly used uniform targets for this threatened Neotropical savanna biome.

1. Introduction

The protection of natural areas is a historical concern of humankind. However, the effectiveness of many protected areas (PAs) around the world is questionable, because they have often been established for reasons unrelated to biodiversity conservation, such as their scenic value or lack of competing interests (Andelman and Willig, 2003; Pressey and Tully, 1994; Rodrigues et al., 2004b; Rouget et al., 2003a; Scott et al., 2001). To be effective, a PA system should be composed of reserves that complement each other in their biodiversity attributes, minimizing redundancy across space (Margules and Pressey, 2000; Pressey and Nicholls, 1989). They should also be representative, containing samples of these attributes at adequate levels to ensure their long-term permanence and viability (Pressey and Nicholls, 1989); otherwise, gaps in regional biodiversity conservation will occur (Jennings, 2000; Scott et al., 1993). Among the several tools to make PA systems more representative (Margules and Pressey, 2000), gap analysis has been successfully used in conservation planning (Catullo et al., 2008; De Klerka et al., 2004; Oldfield et al., 2004; Paglia et al., 2004).

To detect whether a PA system adequately protects a given species or taxonomic group of interest, a gap analysis requires: (1) an estimate of its distribution in the region, (2) the identification of protected sites (Scott et al., 1993), and (3) the definition of explicit

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conservation targets necessary to ensure acceptably small extinction risks (Pressey et al., 2003). Conservation targets represent "the minimum amount of a particular biodiversity feature that we would like to conserve through one or several conservation actions" (Carwardine et al., 2009). Targets lend accountability and defensibility to the process of conservation planning (Pressey et al., 2003), even recognizing the inevitable uncertainty inherent to the process of target definition, since most species are insufficiently studied. We are usually not sure about species distributions, population sizes, metapopulation dynamics, gene flow, and other important biological and ecological factors that could accurately indicate the area requirements for species conservation. Nevertheless, it is important to use the best available information and, in the absence of an adequate knowledge of the species full distribution, species distribution models (SDMs) can be useful, especially when sampling bias can be controlled (Costa et al., 2010; Elith et al., 2006; Phillips et al., 2006).

Integrating vulnerability estimates is also valuable in systematic conservation planning (Pressey et al., 2003), as indications of how much and how urgently protection is needed. Populations in more threatened regions have less chance of persisting outside PAs (Pressey and Taffs, 2001) and vulnerability can be estimated by modeling threats across species distributions. For example, Rouget et al. (2003b) used rule-based and statistical models to identify areas likely to be transformed in the future by agriculture, urbanization, and alien species, and also to formulate conservation targets for different habitat types in the Cape Floristic Region of South Africa. The most commonly-used targets in biodiversity conservation planning exercises are uniform targets for all species considered (Urbina-Cardona and Flores-Villela, 2010) or for groups of species with equivalent distributions (Catullo et al., 2008; Marini et al., 2009). Problems with uniform targets include potentially favoring widespread species (Vimal et al., 2011) and failing to acknowledge that some species need more extensive protection than others for a variety of reasons (Pressey et al., 2003).

The South American Cerrado, the largest and richest savanna on Earth (Eiten, 1971; Ribeiro and Walter, 1998), has a large core distribution in central Brazil with isolated patches in Amazonia and the Atlantic Forest (Fig. 1a). It is characterized by a highly heterogeneous landscape, with vegetation patches ranging from grasslands to forests (Eiten, 1971; Ribeiro and Walter, 1998) and a marked wet–dry seasonality. The Cerrado supports a rich and unique biota (Diniz et al., 2010; Oliveira and Marquis, 2002; Werneck, 2011), but has been extensively transformed by agriculture, livestock, and other anthropogenic activities (Klink and Machado, 2005); thus, it is considered a global biodiversity hotspot (Mittermeier et al., 2000; Myers et al., 2000). Integral protection areas in Brazil, which correspond to Category Ia of IUCN Protected Areas Categories System, currently occupy only 3% of the Cerrado (Fig. 1a). To date, conservation gaps in the Cerrado PA system have been identified only for odonates (Nóbrega and De Marco, 2011) and birds (Marini et al., 2009).

Lizards are often considered model organisms for ecological and evolutionary studies (Camargo et al., 2010; Pianka and Vitt, 2003). Nevertheless, lizards are at risk of global and regional extinction (Gibbons et al., 2000; Sinervo et al., 2010), with about one in every five species being threatened (Böhm et al., 2013). There is critical need for a rigorous evaluation of their conservation status, accounting for life-history characteristics, differential area requirements, vulnerability, and natural rarity. At least 30 endemic species of lizards occur in the Brazilian Cerrado (Nogueira et al., 2011), most of which are associated with specific habitat features (Mesquita et al., 2006; Nogueira et al., 2009). Herein we formulate conservation targets based in three different characteristics likely to influence the conservation needs of lizard species: natural rarity, vulnerability, and life-history, and report on a gap analysis for the endemic lizards of the Brazilian Cerrado.

2. Materials and methods

2.1. Study area

We adopted boundaries of the Cerrado following Instituto Brasileiro de Geografia e Estatística (IBGE, 1993; Silva, 1995; Silva and Bates, 2002). We obtained data on federal, state, and municipal PAs from Ministério do Meio Ambiente – MMA (available from http://mapas.mma.gov.br/i3geo/datadownload.htm) and Instituto Brasileiro do Meio Ambiente – IBAMA (available from http://siscom.ibama.gov.br/). We included only integral protected areas in analyses, considering the unpredictable consequences of permitted activities in sustainable use areas for Cerrado biodiversity. The latter chiefly correspond to large areas (6% of the Cerrado) with very little regulation on permitted uses, potentially reducing their contribution to biodiversity conservation. We also used information on Cerrado remnants, habitat loss (available from http://siscom.ibama.gov.br/monitorabiomas/cerrado/index.htm), and first-order rivers (available from http://www.ana.gov.br/bibliotecavirtual/solicitacaoBaseDados.asp) to model the probability of future habitat loss and to assess the vulnerability of species to further habitat loss.

2.2. Species distributions

We obtained distribution records for 30 endemic species of Brazilian Cerrado lizards (Nogueira et al., 2011) from the Global Biodiversity Information Facility (GBIF), the literature, and specimens deposited at Coleção Herpetológica da Universidade de Brasília (CHUNB), the largest scientific collection with emphasis on the Cerrado herpetofauna (Table 1). We are confident this represents the best available data on the distribution of the species of Cerrado lizards.

2.3. Spatial analyses

For 18 species with five or more distribution records (Table 1), we produced SDMs with Maxent 3.3.2 (Elith et al., 2006; Phillips et al., 2006, 2004). Maxent is a presence-only SDM algorithm that can produce robust distribution estimates even with small sample sizes (Hernandez et al., 2006; Wisz et al., 2008). We used the bioclimatic variables of mean annual temperature (BIO1), standard deviation in annual temperature (BIO4), and annual and wettest quarter precipitation (BIO12 and BIO17, respectively) from Worldclim (Hijmans et al., 2005). We also included two non-climate environmental correlates that are likely to influence the species: the Normalized Difference Vegetation Index – NDVI (mean, from Terra MODIS, MOD13 product) and slope. We chose this small set of variables to avoid a reduction in model accuracy due to overparameterization (Warren and Seifert, 2011), to minimize collinearity, because they represent different aspects of the climate, and because they are relevant to the life-histories of ectothermic animals in general and Cerrado lizards in particular (e.g., Colli, 1991; Colli et al., 2002b, 2003b, 1997; Garda et al., 2012; Meiri et al., 2013; Mesquita and Colli 2003a,b; Wiederhecker et al., 2002). All environmental layers had a spatial resolution of 1 km^2 and were continuous for our study region with a 1-degree ($\sim$100 km) buffer. We ran Maxent with the default settings and randomly selected background (10,000 locations) across the study area. To assess SDM performance, we used AUC, the area under the receiver-operating-characteristic (ROC) curve (Fawcett, 2006;