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Original research article

Should I stay or should I go? Climate change effects on the future of Neotropical savannah bats

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HIGHLIGHTS

- Climate change will impact 36 Cerrado's bat species if displacement is not considered.
- Important areas for bat species occurrence in 2050 are located more than 281 km away from current ones.
- Future competition for space between agriculture and biodiversity may enhance the impacts of climate change.
- Corridors to facilitate bat's movement must be implemented to mitigate such expected impacts.

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ABSTRACT

Most extant species are survivors of the last climate change event 20,000 years ago. While past events took place over thousands of years, current climate change is occurring much faster, over a few decades. We modelled the potential distribution area of bat species in the Brazilian Cerrado, a Neotropical savannah, and assessed the potential impacts of climate change up to 2050 in two scenarios. First we evaluated what the impact on the distributions of bat species would be if they were unable to move to areas where climate conditions might be similar to current ones. The novelty of our paper is that, based on least-cost-path analyses, we identified potential corridors that could be managed now to mitigate potential impacts of climate change. Our results indicate that on average, in the future bat species would find similar climate conditions 281 km southeast from current regions. If bat species were not able to move to new suitable areas and were unable to adapt, then 36 species (31.6%) could lose $\geq$80% of their current distribution area, and five species will lose more than 98% of their distribution area in the Brazilian Cerrado. In contrast, if bat species are able to reach such areas, then the number of highly impacted species will be reduced to nine, with none of them likely to disappear from the Cerrado. We present measures that could be implemented immediately to mitigate future climate change impacts.

1. Introduction

Climate change is a frequent event in the Earth's history and at least four major events have occurred in the last 420,000 years (Petit et al., 1999). The speed of current climate change is likely to pose a serious threat to a large number of

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species (Bradshaw and Holzapfel, 2006). Despite the uncertainties of climate-change models, it is necessary to implement measures now to prevent the negative effects of this process (Ekins and Speck, 2013). Currently, there are 40 (0.7%) mammal species, 814 (7.8%), birds 76 (1.2%) amphibians, 69 (1.6%) reptiles and 175 (4.4%) fish assessed by IUCN that might be experiencing habitat shifts and modification due to climate change (IUCN, 2015).

The impacts of a number of climate change scenarios on the geographic distribution of fauna and flora have been assessed by using ecological niche modelling over a wide range of taxa and locations (Chapman et al., 2014). The vulnerability of each species will depend on a combination of degree of exposure, sensitivity and adaptive capacity. Although accurate predictions on impacts are needed, they are difficult to formulate (Dawson et al., 2011). Three fundamental aspects of animal and plant shifts are among the most discussed. The first is about the methods to generate accurate models of future distribution (Araújo et al., 2005; Diniz-Filho et al., 2009). The second aspect concerns the adaptive capacity of organisms to move to newly suitable areas (Bradshaw and Holzapfel, 2006; Rebelo et al., 2010). Third, the localisation of the suitable niches in the future has received considerable attention (Schloss et al., 2012).

The Brazilian Cerrado is an area of considerable conservation importance that is at risk from climate change. The region consists of savannah-like vegetation that was shaped by past climatic oscillations of the Tertiary and Quaternary. The biodiversity of the Cerrado may have increased because of earlier interchanges with neighbouring forested biomes (da Silva and Bates, 2002). Because of a heterogeneous geology and geomorphology, and high diversity in soil types and climate (Eiten, 1972; Furley and Ratter, 1988), the Cerrado is a mosaic continuum of different phytophysiognomies ranging from grasslands to closed canopy forests (Eiten, 1972).

Recent research has shown that climate change is likely to drastically alter the potential distribution of Cerrado plant species, with many species potentially experiencing a reduction of 50%–90% in their geographical range (Siqueira and Peterson, 2003). These changes in distribution are particularly important when plant species with economic and cultural importance are involved. Endemic species such as *Lychnophora ericoides* (Brazilian arnica) and *Caryocar brasiliense* (souari nut) are used in medicine and as food, and may lose >90% of their geographic distribution across the Cerrado (Simon et al., 2013). Such species may no longer be economically viable for many rural communities in the future (Nabout et al., 2011). Besides the range reduction, plant species will be restricted to suitable places located in the most degraded area of Brazil (southern and eastern regions of Cerrado) (Collevatti et al., 2011; Simon et al., 2013). For Cerrado birds, the same suitable areas in the future have been predicted (Marini et al., 2009). However, climate change may affect savannah-dependent bird species less harshly than forest and grassland-dependent species (Marini et al., 2009).

Agricultural expansion is the primary cause of the reduction of the Cerrado (Klink and Machado, 2005) and current estimates indicate an annual rate of loss of 0.7%, i.e. 700,000 ha/year (Brasil, 2011). Due to the short time frame (last 40 years) and high rate of continuous deforestation, the Cerrado is nowadays considered to be the most threatened savannah in the world and one of the most threatened biomes in Brazil (da Silva and Bates, 2002). Even though the Cerrado is a hotspot for biodiversity (Myers et al., 2000), top-down decision-making does not reflect its urgent conservation needs. This is reflected by the small amount of protected areas (<3% of the original area) in the Cerrado (Klink and Machado, 2005).

Although few bat surveys have been conducted in the Cerrado (Bernard et al., 2011), bats play important social and economic roles in the local people's lives. Bats pollinate and disperse seeds of locally used plants (including the aforementioned *C. brasiliensis*). Bats also eat large numbers of insect pests in the Cerrado (Aguiar and Antonini, 2008; Bobrowiec and Oliveira, 2012). Understanding how climate change may affect the future distribution of bats in the Cerrado is therefore important from conservation and sustainability perspectives.

Few climate change models have incorporated present land use in their evaluation of potential barriers for biodiversity niche shifts (Faleiro et al., 2013). Whether species will be able to establish populations in areas that match the current set of environmental conditions will depend largely on the current fragmentation status of suitable habitat (Lawler et al., 2013). Thus, here we used the ecological niche model approach to map current distribution patterns of bat species distributed in the Brazilian Cerrado. We compared such scenarios with maps reflecting future environmental conditions. To highlight our primary objective, the effect of climate change on bats was verified and actions that might mitigate potential impacts identified and proposed. Our basic assumption is that climate change will decrease current environmental suitability for bats in the Cerrado by modifying the temperature, precipitation regime and occurrence of extreme climate events. These abiotic parameters are those previewed to be changed in the near future (IPCC, 2003; van Vuuren et al., 2011). Under such scenario, the bats of the Cerrado would have only two options: (a) move to new suitable areas or (b) try to adapt to new climate conditions in the Cerrado region.

In this paper, our predictions are that if bats are not able to disperse to new suitable areas, then their habitats will shrink causing significant impacts on species persistence. On the other hand, bats that are able to disperse to new suitable areas may have problems reaching such areas depending on current landscape connectivity and habitat health.

To evaluate those predictions, we defined two scenarios to assess the bats' response to climate. The first scenario is based on the assumption that species will not be able to disperse, that is to say they will not reach the future suitable areas outside of their current range. The second scenario considers that species will use the future suitable areas, but to that they will have to face a very fragmented and human-dominated landscape. We identify routes that would facilitate the movement of bats into areas that may become more suitable for them in the future, and highlight these routes as priorities for conservation.