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Surrogate species protection in Bolivia under climate and land cover change scenarios

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ABSTRACT

The Amazon rainforest covers more than 60% of Bolivia's lowlands, providing habitat for many endemic and threatened species. Bolivia has the highest rates of deforestation of the Amazon biome, which degrades and fragments species habitat. Anthropogenic habitat changes could be exacerbated by climate change, and therefore, developing relevant strategies for biodiversity protection under global change scenarios is a necessary step in conservation planning.

In this research we used multi-species umbrella concept to evaluate the degree of habitat impacts due to climate and land cover change in Bolivia. We used species distribution modeling to map three focal species (Jaguar, Lowland Tapir and Lesser Anteater) and assessed current protected area network effectiveness under future climate and land cover change scenarios for 2050.

The studied focal species will lose between 70% and 83% of their ranges under future climate and land-cover change scenarios, decreasing the level of protection to 10% of their original ranges. Existing protected area network should be reconsidered to maintain current and future biodiversity habitats.

1. Introduction

Climate change is one of the major factors leading to global species extinction (Opdam & Wascher, 2004; Root et al., 2003). Plants and animals will experience significant shifts in species ranges and habitat loss under future climate change scenarios (e.g. Jetz, Wilcove, & Dobson, 2007; Davies, Buckley, Grenyer, & Gittleman, 2011), and about 18% of the global biodiversity could be lost by 2050 under moderate climate change scenarios (Thomas et al., 2004).

Anthropogenic deforestation is the major threat that leads to species relaxation and extinction (e.g. Brooks, Pimm, & Oyugi, 1999; Malcolm, Liu, Neilson, Hansen, & Hannah, 2006). Tropical areas include large forested habitats and are the epicenter of current and future species extinctions (Brooks et al., 1999). The Amazon forests provide habitat for a large number of endemic and threatened species and belong to one of the three major tropical wilderness areas (Mittermeier, Myers, Thomsen, Da Fonseca, & Olivieri, 1998). High deforestation rates in the Amazon forest are caused by clearings, cattle ranching, and agriculture, and their effects on biodiversity are exacerbated by climate change (Brooks et al., 1999; Malhi et al., 2008). Current trends in agricultural expansion in the Amazon forests estimate that one-quarter of the 382 mammal species will lose about 40% of their habitat ranges due forest losses (Soares-Filho et al., 2006). Despite the remarkable policy-driven reduction in deforestation rates in Brazil during the last ten years, half of the global tropical rainforest loss is still happening in South America (Hansen et al., 2013). Bolivia includes a large part of the Amazon moist broadleaf forest and Chaco dry forests; both of which experience high pressure from intensive agriculture expansion, clearance and road development, resulting in one of the highest rates of tropical forest loss in South America (Steininger et al., 2001; Sangermano, Toledano, & Eastman, 2012; Hansen et al., 2013). For instance, in the historical period between 1991 and 2000, 92% of all land cover change occurring in Bolivia corresponded to the transition of moist broadleaf forest to agriculture, and 0.85% to the transition from Chaco dry broadleaf forest to agriculture (Sangermano et al., 2012). These land cover changes are expected to be exacerbated by climate change, and therefore there is a need for relevant management strategies that would target biodiversity threated by both changing landscapes and climate.

In spite of evidence of the negative influences of climate and land cover change on biodiversity preservation, few studies integrated these threats into policy and conservation network design

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(e.g. Davies et al., 2011; Lemes & Loyola, 2013). Several studies demonstrate different adaptive strategies to incorporate climate change threat in conservation planning. Within these strategies are climate-envelope models, population models or direct observations of climate influences on species persistence (Dawson, Jackson, House, Prentice, & Mace, 2011; Lemes & Loyola, 2013; Ramírez-Villegas et al., 2014). The inclusion of adaptive strategies in conservation planning increases the effectiveness of protected areas, when compared to traditional static methods (Margules & Pressey, 2000; Hagerman, Dowlatabadi, Satterfield, & McDaniels, 2010). According to the concept of systematic conservation planning proposed by Margules & Pressey (2000), successful natural reserves should meet two main criteria: representativeness; and, long-term persistence. Representativeness can be reached by choosing an adequate surrogate species for biodiversity, whereas persistence is feasible only with effective management of the conservation network under the dynamics of climate and land cover change. Therefore, conservation planning should include natural and anthropogenic dynamics that influence biodiversity distribution in order to be successful (Pearson & Dawson, 2003; Pressey, Cabeza, Watts, Cowling, & Wilson, 2007; Dawson et al., 2011).

The success of conservation planning depends on the selection of appropriate biodiversity surrogates to define the network design (Margules & Pressey, 2000). One of the most widely used concepts for biodiversity surrogates is the 'umbrella' species concept, which is generally used for defining the size and configuration of conservation networks (Branton & Richardson, 2011). An umbrella species distribution range should cover a large number of co-occurring species in order to become a successful surrogate for conservation planning (Roberge & Angelstam, 2004). The main difference between umbrella species and other surrogates is that the umbrella species concept helps to protect all biodiversity occupying the same range area and vulnerable habitats (Caro & O'Doherty, 1999). Mammals with large body size usually have larger home ranges, so they are most commonly used as umbrella species (Berger, 1997; Caro & O'Doherty, 1999).

In some cases the selection of single-species as a surrogate for biodiversity preservation do not successfully protect all co-occurring species. It is unlikely that only one species would define the variety of spatial and ecological factors crucial for biodiversity conservation (Chase, Kristan, Lynam, Price, & Rotenberry, 2000; Roberge & Angelstam, 2004). In order to refine the umbrella species method, Lambeck (1997) introduced a multi-species umbrella concept which combines a number of species with different ecological traits for thorough representation of the biodiversity and habitat characteristics at the conservation area. Several chosen species are assigned to four major categories: area-limited; resource-limited; dispersal-limited and, process-limited species.

Area-limited species occupy relatively small and fragmented habitat ranges and it is assumed that the minimum patch size provide enough resources for preserving biodiversity of the study area. Dispersal-limited species have small habitat patches that are isolated by distance so the animals' movements between the patches are restricted. Resource-limited species are sensitive to a shortage of critical resources in the habitat patches. Process-limited species are the species that could successfully persist in the landscape even when they were managed differently (e.g. altered fire regimes, introducing new competitive species, innovative land planning practices, etc.) (Lambeck, 1997; Maes & Dyck, 2005). Therefore, area-limited species are related to the spatial configuration of the habitat patches in multi-species umbrella; dispersal-limited species relate to habitat connectivity; resource-limited species are related to resource availability; and, process-limited species are related to management regimes that have to be implemented (Lambeck, 1997).

In this research we focused on Bolivia's current conservation network and its usefulness in maintaining biodiversity under changing environment. We paid special attention to Amazonian deforestation within Bolivia, as this ecoregion is under high deforestation threat and is a home to a variety of rare and endangered species (Mittermeier et al., 1998). Using the multi-species umbrella concept, the objective of this study was to estimate potential species habitat losses caused by climate and land cover change scenarios, and to assess current biodiversity protection network effectiveness in the light of climate and land cover change.

2. Methods

2.1. Study area

Bolivia occupies a territory of 1 098 000 km^2 in central South America and encloses 13 ecological regions (Figure A.1). Bolivia's main land cover types include lowland tropical forest and woodlands (Steininger et al., 2001). Bolivian lowlands preserve a high degree of biodiversity and they are among the top 25 world biodiversity hotspots (Myers, Mittermeier, Mittermeier, da Fonseca, & Kent, 2000). The country has developed a vast network of protected areas covering 237 817 km^2, including 36 national parks, 27 departmental protected areas, 22 municipal protected areas and 5 regional protected areas (Figure A.1).

2.2. Umbrella species as a biodiversity surrogate

Following the concept of systematic conservation planning (Margules & Pressey, 2000), for this study we used umbrella species as biodiversity surrogates (Caro & O'Doherty, 1999; Roberge & Angelstam, 2004). We chose three large mammals: the Jaguar (*Pantehra onca*); the Lowland Tapir (*Tapirus terrestris*); and, the Lesser Anteater (*Tamandua tetradactyla*) which are highly representative of the Amazonian forest. These umbrella species were selected based on their conservation status and ecological traits. The review of the basic features for potential umbrella species is shown in Table A.1 (Caro & O'Doherty, 1999; Favreau et al., 2006).

Panthera onca (Jaguar) is a predator with habitats ranging from rainforest to dry deciduous forest. Population size of the species is declining and *P.onca* currently has a status of near threatened species (Caso et al., 2008). Gradually declining population size and restricted habitat specialization makes this species a relevant candidate for dispersal-limited species group (Lambeck, 1997). *T.terrestris* has a status of vulnerable species and its population size is currently declining due to deforestation of the Amazon forest (Naveda et al., 2012). *T.tetradactyla* is distributed within similar ecological regions, but this species is a strict specialist and feeds on ants and termites (Miranda et al., 2014). Thus, *T.terrestris* represents an area-limited group of a focal species, whereas *T.tetradactyla* is a resource-limited species (Table A.1).

The three described species have a well-known biology, large home ranges and population size which allow for successful future species monitoring. The biological and ecological traits indicate that the species habitat ranges can be used as a multi-species umbrella for representing the biodiversity of the area (Lambeck, 1997). Since all three species are large charismatic mammals and attractive to the public, they all can also be used as flagship species (Leader-Williams & Dublin, 2000).

2.3. Species distribution modeling

We used species distribution modeling to predict species habitat ranges for past (circa 2000) and future (2050) climate and land cover conditions. MaxEnt distribution modeling detects the probability distribution of maximum entropy subject to a set of