Journal for Nature Conservation 27 (2015) 26–36

Contents lists available at ScienceDirect

Journal for Nature Conservation

journal homepage: www.elsevier.de/jnc

Applying species distribution modelling to the conservation of an ecologically plastic species (*Papio papio*) across biogeographic regions in West Africa

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ARTICLE INFO

Article history:
Received 30 December 2014
Received in revised form 29 May 2015
Accepted 17 June 2015

Keywords:
Ecological niche models
Global models
Guinea baboon
Regional models
Spatial extent
Sahel

ABSTRACT

Ecological niche models are valuable tools to support conservation decision-making. Still, they are sensitive to the study area spatial extent. Ecologically plastic species ranging over different biogeographic regions often exhibit populations adapted to distinct environmental conditions. In such cases, regional models may be more accurate than global models in discriminating suitable areas in specific regions under such circumstances. We use the Guinea baboon as model system, to test the effects of restricting the range of environmental variables and study area extent, and explore geographic differences in the environmental conditions occupied by ecologically plastic species. Additionally, we explore conservation implications for this particular case study. We built global (West Africa) and regional models (Sahel, Savannah and Afrotropical) using a maximum entropy approach and explore geographic differences in environmental conditions occupied by regional populations using Principal Components Analyses. The most important variables identified differed between model types, distance to gueltas in global model and distances to gueltas, to croplands and to water bodies in regional models, as well as models' accuracy to define distribution and suitable areas, which are overestimated by global models. Environmental conditions overlapped slightly between regional populations, and the Sahel displayed the most divergent one. Areas of potential conflict between the species and humans were identified in the Savannah and Afrotropical region, but latter lack protected areas. We show for modelling the current distribution of ecologically plastic species, regional models are more accurate than global models in defining the species' environmental predictors and suitable areas. This will improve the definition of accurate local suitable areas for ecologically plastic species and improve the allocation of resources for local conservation actions.

1. Introduction

Defining priority areas for conservation is a major goal of biodiversity conservation (Jenkins, Pimm, & Joppa, 2013). Ecological niche models (ENMs) can greatly improve decision-making in conservation management, in particular, when the ecological knowledge is incomplete (Elith & Leathwick 2009a; Addison et al., 2013). In the last years, ENMs have become widely applied in several disciplines, including conservation assessments (Doko, Fukui, Kooiman, Toxopeus, & Ichinose, 2011; Addison et al., 2013; Bosso, Rebelo, Garonna, & Russo, 2013; Guisan et al., 2013; Virkkala, Heikkinen, Fronzek, & Leikola, 2013; Russo et al., 2014). However, ENMs are also subject to uncertainty, requiring numerous methodological and well-justified decisions. Among others, ENMs are sensitive to a number of scale-related issues (Guisan, Graham, Elith, & Huettmann, 2007), such as the spatial extent of the study area (Elith & Leathwick, 2009b; Franklin & Miller, 2009), which

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http://dx.doi.org/10.1016/j.jnc.2015.06.004
1617-1381/

is also a key factor affecting conservation planning (Hermoso & Kennard, 2012). In ENMs, the use of occurrence data from the complete species distribution range or at least from within complete biogeographical areas is recommended (Barbet- Massin, Thuiller, & Jiguet, 2010). The inclusion of the complete species' environmental range in ENMs is considered the best strategy to predict species-environment interactions for different regions or time periods from where the models were built (Thuiller, Brotons, Araújo, & Lavorel, 2004; Barbet-Massin et al., 2010; Russo et al., 2014).

Broad-scale and multi-country assessments outperform local-scale studies in terms of conservation efficiency (Hermoso & Kennard, 2012). However, practical conservation actions often unfold on a regional or local geographical scale, and more frequently, within political boundaries (Elith & Leathwick, 2009a; Hermoso & Kennard, 2012). At fine scales, abiotic or biotic factors rather than climate itself could shape the species distribution (Elith & Leathwick, 2009b; Wiens & Bachelet, 2009). At this level, ENMs applied to conservation planning are expected to discriminate not only the broad area of species' occurrence but also to distinguish areas more suitable than others (Elith & Leathwick, 2009a; Doko et al., 2011; Bosso et al., 2013). For ecologically plastic species, whose populations may be adapted to distinct local environmental conditions within the species-range, the discriminatory ability of ENMs could be limited (Peterson, 2003). Past studies showed specialist species or species with limited geographical extent yielded more accurate models than generalists or species with wide geographical ranges (Segurado & Araújo, 2004; Buisson, Thuiller, Casajus, Lek, & Grenouillet, 2010). A further scrutiny of these results showed they might be related to the spatial extent of the analysis (Elith et al., 2006), raising the questions if a constant extent of analysis is appropriate for all species in relation to the purpose of the predictions (Elith et al., 2006) and if models built with the entire species range are suitable to identify fine scale patterns of distribution. Furthermore, the ecological and biogeographic context may affect model performance (Osborne & Suárez-Seoane, 2002; Suárez-Seoane, Virgós, Terroba, Pardavila, & Barea-Azcón, 2014). Generally, species tend to be more abundant at the ecological core of their distribution and become rare and specialised as the availability of environmental conditions decreases and/or become more extreme (Brown, Mehlman, & Stevens, 1995). The performance of the models can be biased for species ranging over different biogeographical areas and for populations inhabiting the most distinct environments at the extremes of the range, which may deserve particular local conservation assessments considering their rarity.

The Guinea baboon (*Papio papio*, Desmarest 1820) displays high ecological plasticity and occupies different biogeographical areas throughout its range. The species' range follows a latitudinal gradient in precipitation: from arid conditions in the Sahel to secondary forest in the Afrotropical biogeographic area. Considering the Near Threatened status (Oates, Gippoliti, & Groves, 2008), Guinea baboons are in need of specific conservation measures in distinct locations. In both West Sudanian Savanna and Afrotropical biogeographic areas, range contraction and population fragmentation have been related to agricultural expansion and hunting for meat and pet trade (Oates et al., 2008; Ferreira da Silva, 2012; Ferreira da Silva, Godinho, Casanova, Minhós, Sá, & Bruford, 2014). While in the Sahel there are no evidences of range contraction, particularly associated with human activities. Yet populations were mainly observed in mountain rock-pools (locally known as gueltas, Cooper, Shine, McCanna, & Tidane, 2006; Brito, Alvares, Martínez-Freiría, Sierra, Sillero, & Tarroso, 2010), suggesting a tight association between species occurrence and water availability. Distinct environmental and human-related pressures could shape Guinea baboon distribution in different biogeographical areas but the relative contribution of each factor across areas is unknown. For this highly plastic species, global models can be less accurate than regional models in defining suitable areas. High accuracy mapping of suitable areas is needed for the identification of potential areas of conflict with humans, and for estimating range fragmentation levels and the number and location of subpopulations. Such knowledge is basal to identify potential conservation units and define priorities for species conservation at the local level.

In this work, we aim to assess how the performance of global and regional models affects predictions of the distribution of ecological plastic species. We used as model system the Guinea baboon and we addressed three specific questions: (1) Does the importance of variables for the species occurrence differ across biogeographic areas? (2) Does the performance of models for identifying suitable areas for the species occurrence differ in distinct biogeographic areas? (3) Is there niche overlap between suitable areas predicted by regional models? According to the above-referred evidences, we expected: the most important environmental variables related with the species' distributions to differ between biogeographic areas; regional models to perform more accurately in defining suitable areas and; discordance between predicted suitable areas in each ecoregion. Additionally, we identified isolated subpopulations, potential areas of conflict with human activities and degree of formal protection of predicted suitable areas to inform local conservation planning of Guinea baboons. We expect to demonstrate that when working with ecologically plastic species, local-scale studies could be more accurate to define local suitable areas and that local models may outperform broad-scale assessments in terms of conservation efficiency.

2. Materials and methods

2.1. Training areas

We selected four areas for model training: West Africa and three restricted areas (Sahel, Savannah and Afrotropical), which match with the global and regional scales, respectively (Fig. 1). West Africa was delimitated with both a buffer of 150 km bounding the IUCN polygon of the species distribution (Oates et al., 2008) and the observation data (Fig. 1). Regional areas correspond to three major biogeographic areas and were accessed by WWF terrestrial ecoregions (Olson et al., 2001): Sahelian Acacia Savanna (Sahel) and West Sudanian Savanna (Savanna) ecoregions, and the Afrotropical, comprising the Guinean forest-savannah mosaics, Guinean mangrove, Guinean montane forest and the Western Guinean lowland forest ecoregions, all included in the Afrotropical biogeographic realm (Fig. 1).

2.2. Presence data

As model system, we used the Guinea baboon. We assembled 141 geo-referenced observations of the species and they were used for modelling purposes (Fig. 1): 75 were collect by the authors using a Global Positioning System (GPS) (Torres 2007; Brito et al., 2010; Ferreira da Silva et al., 2014), and 66 bibliographic observations (see Supplementary material Appendix A.1), including geo-referenced localities or clear toponomies from which coordinates were collected with 1 km precision. For West Africa dataset, we randomly selected a total 79 non-clustered observations from clusters of species occurrence according to the Nearest Neighbour Index (NNI) estimated using ArcGIS 10.0 (ESRI, 2011) and two datasets were built: 50 observations for training and testing and 29 observations for the validation dataset (see Supplementary material Appendix Table A.1). We divided the initial dataset according to each regional training area and repeated the previous procedure (Sahel: $N = 35$; savannah: $N = 41$; afrotropical: $N = 46$; see Supplementary material