Journal for Nature Conservation 39 (2017) 37–57

Contents lists available at ScienceDirect

Journal for Nature Conservation

journal homepage: www.elsevier.de/jnc

Biodiversity hotspots and conservation gaps in Iran

Azita Farashi[a,*], Mitra Shariati[b]

[a] Department of Environmental Sciences, Faculty of Natural Resource and Environment, Ferdowsi University of Mashhad, Iran
[b] Faculty of Geo-Information Science and Earth Observation (ITC), University of Twente, Enschede, The Netherlands

ARTICLE INFO

Article history:
Received 2 January 2017
Received in revised form 12 June 2017
Accepted 12 June 2017

Keywords:
Biodiversity hotspot
MaxEnt
Mammal
Bird
Reptile

ABSTRACT

Iran is one of the most important countries in the Middle East for biodiversity conservation. Because of the high habitat diversity in Iran, a wide range of animal species can live in the country. However, there is lack of knowledge about biodiversity hotspots in Iran. In this paper, the terrestrial mammal, bird, and reptile species listed as threatened (i.e. near threatened, vulnerable, endangered, critically endangered) at the global and national levels were studied. They included 18 mammal species, 26 bird species, and 7 reptile species. The biodiversity hotspots were identified using an ensemble forecasting framework based on MaxEnt model. The results indicated that 24% of Iran can be considered as the biodiversity hotspots out of which 10% are under protection. The results showed that large parts of Iran have potential to be considered as biodiversity hotspots. These areas were mostly located in northern Iran along the Alborz and Zagros mountain ranges; the latter stretches from northwestern Iran and spans the whole length of western and southwestern Iran. However, only a few of these hotspots are under protection. Therefore, it is essential to select new areas protected within biodiversity hotspots and to promote a network function of protected areas within these hotspots in Iran. Moreover, because of the few numbers of protected areas in Iran, it is important to conserve biodiversity outside the protected areas at least as buffers.
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1. Introduction

Since global biodiversity is subject to decline (Hoffmann et al., 2011; Tittensor et al., 2014), and has experienced a steeper decline over the last 60 years in comparison with any previous time in human history (Domisch, Jähnig, & Haase, 2011). Anthropogenic threats including pollution, habitat destruction, introduced species, and climate change are sources of current threats to biodiversity and that loss of animal or plant species have a dramatic effect on ecosystem services (Worm & Duffy, 2003).

Biodiversity in Iran is under serious threat; modern infrastructures such as road systems cutting across natural or semi-natural habitat have damaging effects on biodiversity via wildlife-vehicle collision. For instance, the main cause of cheetah deaths in Iran was road accidents (Jowkar, Ostrowski, Tahbaz, & Zahler, 2016). Over-grazing and over-cutting can turn rangelands to dessert by damaging vegetation and deteriorating soil; this poses a considerable threat to plant and animal communities thriving within these ecosystems. The fifth largest sheep population in the world in 2008 belonged to Iran with about 52 million animals (Jowkar et al., 2016; Valizadeh, 2010). Iran had the largest sheep population of all the arid rangeland countries in the world. The total livestock population in Iran is around 124 billion while the sheep and goat population doubled over the last 40 years. Evaluation of the livestock carrying capacity of the country's rangeland showed that livestock population was more than twice the sustainable carrying capacity and in some provinces it reached as much as five times the carrying capacity (Amiraslani & Dragovich, 2011). Large-scale livestock grazing in arid and sub-arid rangelands is a common conservation problem in the majority of the protected areas in Iran.

Illegal hunting and killing reduces the population of threatened species inside and outside the protected areas and has become a significant threat to wildlife (Makhdoum, 2008). One of the key pressures contributing to biodiversity loss in Iran is tremendous human population growth that has tripled from about 25 million in 1965 to 76–78 million in 2013 (Jowkar et al., 2016). Many other factors such as water and air pollution have also increased in proportion to population growth contributing to biodiversity loss outside the protected areas (Hassanvand, Nabizadeh, & Heidari, 2008).

Conservation of biodiversity can be achieved by identifying and protecting hotspots of biodiversity and critical habitats of the species (Dobson et al., 2006; Myers, Mittermeier, Mittermeier, Da Fonseca, & Kent, 2000; Schmitz, Hawlena, & Trussell, 2010).

* Corresponding author.
E-mail address: farashi@um.ac.ir (A. Farashi).

http://dx.doi.org/10.1016/j.jnc.2017.06.003
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Nowadays, there is serious concern about the effectiveness of the strategies existing for biodiversity protection. It is questionable whether the protected areas around the world provide effective protection for biodiversity since causes unrelated to conservation are involved in selecting many of them (Andelman & Willig, 2003; Rodrigues et al., 2004). These protected areas must be complemented by reserves principally established for biodiversity conservation (e Silva et al., 2014; Margules & Pressey, 2000). However, since there is limited resources of funds for conservation management, areas with the highest species diversity receive conservation priority (Myers et al., 2000). On the other hand, lacking data on species distribution and abundance poses a significant challenge to identifying critical habitats and hotspots (Clemens et al., 2010; Clemens et al., 2014). One way to solve this problem is species-level modeling. This method relates species occurrences at site level to environmental parameters using well-established modeling method such as Maximum Entropy (MaxEnt) for predicting species' distributions. This method can provide very large probability distribution values for environmental conditions outside the range present in the study area (called clamping) (Phillips, Anderson, & Schapire, 2006). The other way is the community-level modeling that predicts biodiversity distribution at community level, i.e. locations contain similar species composition and groups of species with similar distributions (Chapman & Purse, 2011; Ferrier & Guisan, 2006).

Here, we used the site level approach to identify biodiversity hotspots in Iran. In classical terms, Iran is located in the Palearctic faunal realm and is assumed to be the origin of many genetic resources in the world (Makhdoum, 1993). Iran belongs to regions with high diversity that can be found in its geological structure, landform characteristics, soil types, and climate. Therefore, a variety of rich biological resources thrive in different parts of the country (Makhdoum, 2008). Iran can be considered as a bridge between four geographical regions including Central Asia, the Indian subcontinent, the Arabian Peninsula, and the lands bordering the Black Sea (Firouz, 2005). Although Iran is the twentieth global hotspot, the species richness of this country has not been comprehensively studied yet (Mittermeier et al., 2004). The present study aims to identify hotspots of species richness in Iran using the distribution map of endangered species. Therefore, the objectives of our study are: 1) identifying hotspots for mammal, bird, and reptile species; 2) identifying the hotspots of biodiversity in Iran; and, 3) examining the overlap between biodiversity hotspots and protected areas in Iran.

2. Material and methods

2.1. Study area and species

Iran is located in the Middle-East in a position like a bridge between Indian subcontinent, Arab peninsula, Middle Asia, and Europe (latitude 24°–40° N and longitude 44°–64° E). Because of high habitat diversity in Iran, a wide range of animal species can live in the country. Iran is one of the most important countries in the Middle East for biodiversity conservation. The ecosystems of Iran contain 8000 plant species, 197 mammal species, 535 bird species, 227 reptile species, 21 amphibian species, 160 freshwater fish species, and 710 marine fish species (Department of Environment of Iran, 2015).

We studied all the terrestrial mammal, bird and reptile species in Iran listed as threatened (i.e. near threatened, vulnerable, endangered, critically endangered) at the global (IUCN, 2016) and national scales (Kaboli, Aliabadian, Tohidifar, Hashemi, & Roselaar, 2015; Karami, Ghadirian, & Faizolahi, 2015; Mozaffari, Kamali, & Fahimi, 2014). Species with too few data points were excluded from the model. The final list included 18 mammal species, 26 bird species, and 7 reptile species (Table 1). Among all the species studied, only *Montivipera latifii* for reptile species and *Equus hemionus* and *Acinonyx jubatus* for mammal species are endemic in Iran and the distribution range of these species is confined to small parts of Iran. A wide variety of ecological preferences exist among the different species studied. This variety helped us to correctly identify biodiversity hotspots by taking all different ecosystems into account. For instance, *Capra aegagrus* lives in mountain areas and is widely distributed in Iran, while *Equus hemionus* prefers flat areas and only exists in central parts of Iran. A large number of raptor species inhabit the length of the mountain ranges, but water bird species such as *Grus leucogeranu* use wetland sites. Such different ecological preferences have also been observed among reptile species. For instance, *Crocodylus palustris* inhabits wetlands in south-east of Iran, while *Eremias pleskei* lives in semi-desert habitat in north-west of Iran. The distribution maps of these species have been obtained from atlas data with a 25 × 25 km resolution (Kaboli et al., 2015; Karami et al., 2015; Mozaffari et al., 2014) transformed in the grid format with a 1 × 1 km resolution. The atlas of the geographic distribution of these species was obtained from museum data, natural history collections, and occurrence records (camera-trap detections, telemetry, trappings, sightings, and specimens) (Table 1).

2.2. Species distribution models

We used Maximum Entropy (MaxEnt) to predict the expansion range of the species studied. MaxEnt is a widely used and effective tool for conservation management. Using this model, it is possible to identify the spatial distributions of endangered species (Elith et al., 2011; Meynard & Quinn, 2007; Merow, Smith, & Silander, 2013; Phillips & Dudík, 2008; Yackulic et al., 2013). To develop the SDM for the species studied, we used the Biomod2 package (Thuiller, Lafourcade, Engler, & Araújo, 2009; Thuiller, Georges, & Engler, 2013) for R version 3.1.25. MaxEnt uses presence-only data to define species distributions based on the environmental conditions of the sites of known occurrence. This is an accurate technique to select the most appropriate environmental variables to generate valid distribution models for species (Elith & Leathwick, 2009; Phillips & Dudík, 2008). Following the principle of maximum entropy, each variable needs a marginal suitability function that matches the empirical data with a mean equal to that obtained from empirical data. However, this can lead to models that over-fit the input data. Therefore, to avoid over-fitting, MaxEnt uses a process called β regularization. Using this procedure, the modeled distributions lie within a certain interval around the empirical mean rather than exactly matching it (Warren & Seifert, 2011). Testing different values of β is very important to run the model. Warren and Seifert (2011) generated ten models for each species studied using different levels of complexity by setting β at 1, 3, 5, 7, 9, 11, 13, 15, 17, and 19. The best model was selected by using the corrected Akaike Information Criterion (AICc) score. Using the same procedure, Porretta et al. (2013) found that with setting β equal to 1, the lowest score for the AICc was obtained. Therefore, they reconstructed the final models based on this setting. To classify the predicted model into 'absent' and 'present', the lowest presence threshold (LPT) was implemented; LPT is the lowest probability value found at any of the presence records (Hiestand, Nielsen, & Jiménez, 2014; Thorn, Nijman, Smith, & Nekaris, 2009). Here we used LPT that included only a certain percentage of the presence points and classified 95% of all known presence points as present (Waltari & Guralnick, 2009). In order to assess the average behavior of the models, 10 random partitions were used in the 10 models (Phillips et al., 2006; Tittensor et al., 2009). Each partition was generated by randomly choosing 75% species occurrence (logged from

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