Predicting the potential distribution of striped hyena *Hyaena hyaena* in Iran

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Abstract. Predictive potential distribution modelling is crucial in outlining habitat usage and establishing conservation management priorities. Association among species occurrence and environmental and spatial characteristics has been calculated with species distribution models. Herein, we used maximum entropy distribution modelling (MaxEnt) for predicting the potential distribution of striped hyena *Hyaena hyaena* in the entire country of Iran, using a number of occurrence records (i.e., 118) and environmental variables derived from remote sensing. The MaxEnt model showed a high rate of success according to AUC test scores (0.97). Our results are roughly congruent with previous studies suggesting that mountainous regions in northern and western Iran, and the plains in central and eastern Iran are a suitable habitat for *H. hyaena*.

Introduction

The striped hyena, *Hyaena hyaena* (Linnaeus, 1758) is distributed in most parts of Africa (except for the southern parts), the Middle East including the Arabian Peninsula, the Levant, Turkey, Iraq, Iran, and the Caucasus, and extends further into Central Asia and the Indian subcontinent. The species occupies varied types of environments and ecosystems (AKAY *et al.* 2011; REICHMANN 2005), extending from arid deserts (SINGH *et al.* 2010; TICHON *et al.* 2016; WAGNER 2006) to dense Mediterranean shrubland (ABI-SAID & ABI-SAID 2007; ROSENBERG *et al.* 2016). It was reported that hyaenas prefer open semi-

arid habitats (ALAM *et al.* 2015; WAGNER 2006), and occur in low densities in true deserts and dense vegetation (ABISAID & DLONIAK 2015). Striped Hyaenas rely on large areas to support their resource requirements (ALAM *et al.* 2015; WAGNER 2006). The distribution of *H. hyaena* in the Middle East and the Caucasus in particular, is now patchy as the result of a decline which has occurred over the past decades (KASPAREK *et al.* 2004). Thus, this species has the largest range of distribution among hyaenids (KRUUK 1976). *Hyaena hyaena* has a wide range of distribution in Iran including mountainous, steppe and desert habitats throughout the country except north and northwestern provinces (ZIAIE 2008; KARAMI *et al.* 2016).

According to the IUCN criteria, the world status of striped hyenas has been called as "lower risk: near threatened" in the conservation action plan prepared by the IUCN/SSC Hyaena Specialist Group (MILLS & HOFER 1998). In Iran, it is mentioned in "Data Deficient" based on the latter reference and needs to be further investigated in the country.

According to ETEMAD (1985), the Iranian hyaenas belong to the subspecies *H. h. hyaena* (Linnaeus, 1758). The striped hyena occupies an extensive range of habitats and may settle wherever it gets sufficient food supply, adequate cover, and access to water (KRUUK 1976). It generally favors open or thorn bush areas in arid and semi-arid environments (ROSEVEAR, 1974; KRUUK 1976; RIEGER 1978; LEAKEY *et al.* 1999) to pine forests (AKAY *et al.* 2011) where water is available within 10 km (RIEGER 1979).

ZIAIE (2008) believed that the Iranian population of hyenas has severely declined. They live in steppes, semi-deserts, rocky fields and valleys with sparse trees (MILLS & HOFFER 1998; Fig. 1); they avoid deserts, high altitude areas, dense bushes and forests. Striped hyenas prefer living inside caves (MILLS & HOFER 1998; YILDIRIM 2010). These animals participate in the ecosystem by eating dead and decaying animal carcasses (MILLS & HOFER 1998; BUNAIAN *et al.* 2001; SINGH 2008; STEIN *et al.* 2013). The dietary preferences of this species include vertebrate (BON *et al.* 2012) and invertebrate animals, various fruits, vegetables and human-sourced organic wastes (WAGNER 2006). Being a dietary opportunist, hyenas are omnivorous carcass eaters. When starved, they can feed on melons, watermelons, grapes and some other vegetables (MILLS & HOFFER 1998; YILDIRIM 2010). Recently, factors have generally led to major habitat loss (Fig. 2). Therefore, it is very important to protect the hyenas' habitats. As such, habitat management based on evaluation is strongly recommended as a practical solution.

Fig. 1 – Images of *Hyaena hyaena* in natural habitat (Photo: Reza Aliasl).

The prediction of distribution patterns of organisms using species distribution models (SDMs) could represent more information about the effects of environmental factors on potential geographical distribution of organisms (ELITH & LEATHWICK 2009; COLLEVATTI *et al.* 2013; ESKILDSEN *et al.* 2013). SDMs are informative tools to map and monitor distribution of organisms, and have become increasingly important in the context of awareness of environmental change and its ecological consequences (MILLER 2010).

Prediction models can forecast changes in distribution and abundance of species. These changes could be the result of future climatic conditions coupled with increases in habitat fragmentation that may result in species extinction (BROWN *et al.* 1997; WALTHER *et al.* 2002; ROOT *et al.* 2003; WAKE 2007). According to the results of predictive models, if climate change continues unchecked, 37% of global species might be extinct by the end of 2050 (THOMAS *et al.* 2004). The effects of climate change such as increasing temperatures have been felt from species to community levels (POUNDS *et al.* 1999; WALTHER *et al.* 2002; THOMAS *et al.* 2004). This is a very serious issue for all species, and some regions may bear severe effects.

We used the maximum entropy (MaxEnt) modeling approach which is based on species presence data and environmental factors to predict potential distribution patterns. It is considered one of the most efficient techniques for predicting species distribution models based on presence only data (ELITH *et al.* 2006; PHILLIPS *et al.* 2006; ELITH *et al.* 2011). The aim of this study was to provide a comprehensive distribution map for striped hyena to recognize the environmental variables associated with the predicted distribution of this species using the MaxEnt distribution modeling approach.

Fig. 2– Images of *Hyaena hyaena*. **A**. Killing by farmers. **B**. Killing for using the genital female system. **C–D**. Road kill (Photo: Mohammadreza Abedi-Moghadam).

Material and methods

A total of 123 locality records for *H. hyaena* was gathered and after removing the duplicated records finally 118 points were used in the maximum entropy distribution modeling approach (Fig. 3). All records of *H. hyaena* were based on our own fieldwork as well as those obtained from the Department of Environment of Iran. Twenty environmental variables including temperature, precipitation, seasonality, and altitude, all with 30-arc-seconds resolution were obtained from the Worldclim data set (http://www.worldclim.org/; HIJMANS *et al.* 2005) and built in ArcMap version 10. First, correlations between all 21 environmental variables were measured using Pearson's correlation coefficient in SPSS 16. The variables with a correlation coefficient > 0.7 were excluded from the analysis (RISSLER *et al.* 2006). Then, 10 out of 21 environmental variables were selected and used in this study (Table 1).

The most common approach for testing the predictive performance is to divide data into 'training' and 'test' datasets. This approach creates relatively independent data for model testing (FIELDING & BELL 1997; GUISAN *et al.* 2006). Then, MaxEnt was carried out with default settings when separating records into training and test samples (75 and 25%, respectively) (PHILLIPS & DUDÍK 2008). Convergence threshold and maximum number of iterations were remained as default (0.00001 and 500, respectively) and auto feature. The cross-validation has been used to evaluate the predictive performance of the model. In addition, Jackknife testing was produced to estimate the average contribution and response of each variable to the model.
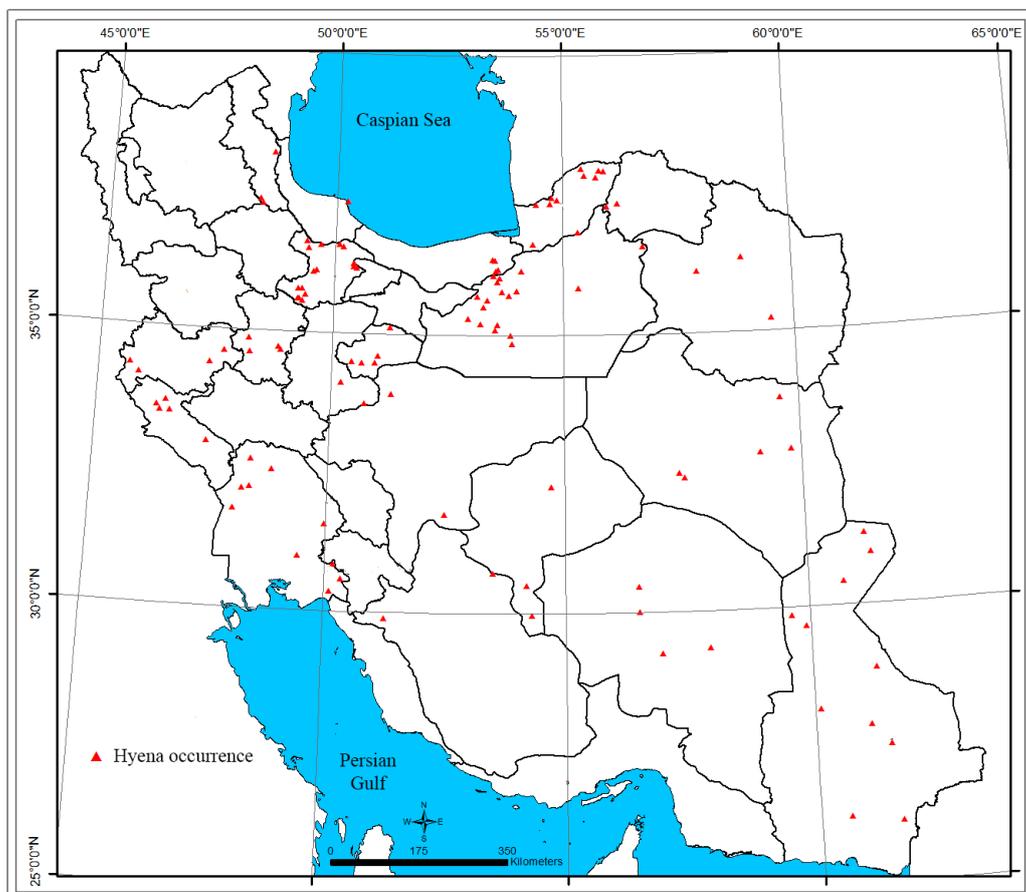
Fig. 3 – Distribution of hyena occurrence points applied in habitat suitability modelling.

TABLE 1

Percentages of contributions of variables included in the best-fitting distribution model for *Hyaena hyaena*.

Variable	Percent contribution	Permutation importance
bio8 (Mean Temperature of Wettest Quarter)	27.4	5.9
bio3 (Isothermality)	16	10.9
bio16 (Precipitation of Wettest Quarter)	14.1	44.1
bio4 (Temperature Seasonality (standard deviation *100)	14	10
bio5 (Max Temperature of Warmest Month)	11.1	11.6
Slope	7	11.5
bio6 (Min Temperature of Coldest Month)	5.1	1.1
bio15 (Precipitation Seasonality (Coefficient of Variation)	2.7	2.5
bio17 (Precipitation of Driest Quarter)	2.1	0.9
bio2 (Mean Diurnal Range (mean of monthly max temp – min temp)	0.3	1.4

Our model was tested with 'area' under the receiver-operating characteristic curve (AUC) used extensively in assaying species' distribution models, and measures the ability of a model to differentiate between sites where a species is 'present' versus 'absent' (PHILLIPS *et al.* 2006; ELITH *et al.* 2006). Models with AUC = 0.5 consider a performance equivalent to random; AUC > 0.7 as useful performance, AUC > 0.8 as good performance, and finally AUC ≥ 0.9 as excellent performance (MANEL *et al.* 2001).

Results

The most contributing environmental variables are following: bio8 (Mean Temperature of Wettest Quarter, 27.4), bio3 (16%), bio16 (Precipitation of Wettest Quarter, 14.1%), bio4 (Temperature Seasonality (standard deviation *100, 14%) (Table 1). The AUC value of our model was 0.970 ± 0.03 and then the performance is excellent (Fig. 4).
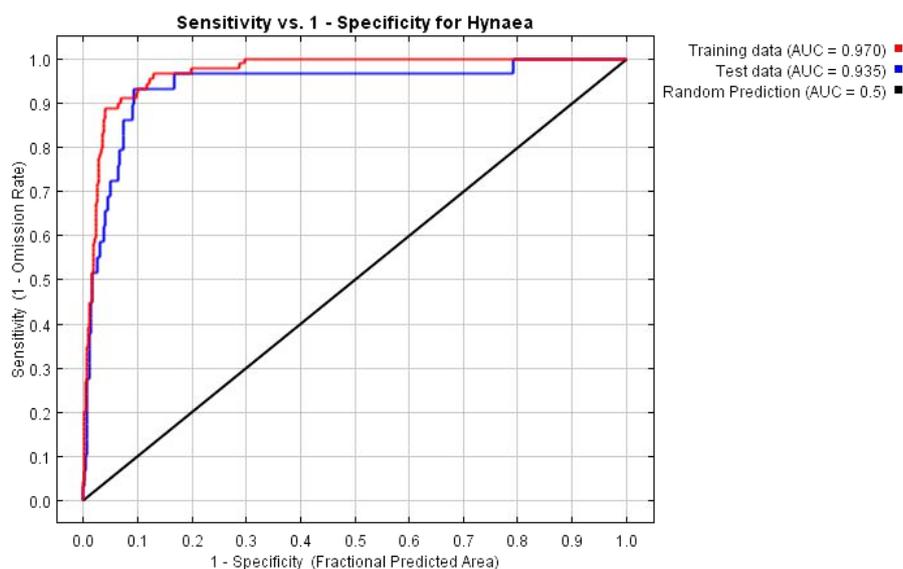

Fig. 4 – Receiver operating characteristic (ROC) curve for the data used in the study.

Modeling of the potential distribution of *H. hyaena* revealed that the most suitable habitats are mountainous regions in northern and western Iran, and plains regions in central and eastern Iran, as well (Fig. 5).
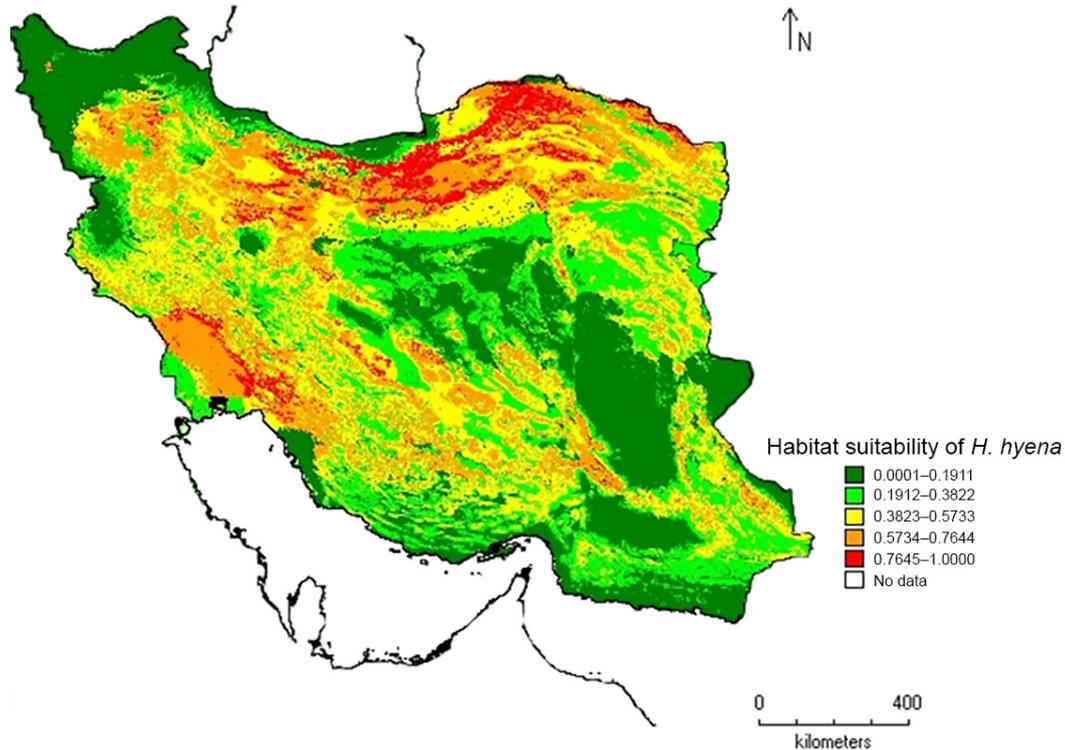

Fig. 5 – Potential distribution of *Hyaena hyaena* resulting from the best-fitting MaxEnt model. The high suitable habitat is shown in red and regions without any data in white.

Discussion

According to the results of this study, the central parts of Iran which correspond to Dasht-e-Lut and Dasht-e-Kavir might not be suitable places to find the species. Moreover, north-western and central parts of Iran are not suitable habitat based on modeling. Generally, predicted distribution is approximately congruent with the known distribution pattern. According to SINGH *et al.* (2014), the striped hyena occurs in habitats with canopy forest and scrub vegetation, where they provide daytime resting sites. In addition, hyenas are mainly distributed in arid and semi-arid regions (RIEGER 1979). Hence, they cannot live in the great deserts of Iran, Dasht-e-Lut and Dasht-e-Kavir, or in cold high-altitude regions of north-western Iran. The species is rarely found across the southern Caucasus, including the neighboring Armenia (KHOROZYAN *et al.* 2011). Striped hyenas are known to avoid spatially occurring Persian leopard *(Panthera pardus saxicolor)* habitats in Iran (DAVIS *et al.* 2018), supporting our modeling results, which did not show a high spatial overlap with suitable landscapes for leopards, particularly north-western Iran (FARHADINIA *et al.* 2017).

Hyenas play an important role in removing pollution and cleaning the environment (TOURANI *et al.* 2012), although large parts of the species range are within the current network of protected areas. According to KARAMI *et al.* (2009), great numbers of hyenas can be observed in western and south-western of Khojir National Park, which is located 20 km east of Tehran, capital of Iran. The distribution of hyenas depends on climatic conditions, stressful factors, topography, habitat satiation and food availabilies. According

to ABADE *et al.* (2014), precipitation is one of the most important environmental factors that affects the distribution of spotted hyenas. The results of our study are congruent with the findings of these authors.

Various factors influencing the distributional pattern of hyenas, such as agricultural activities, livestock, mining, wild dogs, incursion and building of dams such as Mamlo dam located in the territory of the Khojir National Park. As a consequence, the most important cause of mortality of hyena in the country has been reported from Parchin road constructed in the middle of the Park. The model presented by REZAEI *et al.* (2017) concluded that *Hyaena hyaena* is successful in finding suitable nesting areas in the Haftad-Gholleh protected area in Iran.

Along with the threat of road strike, illegal hunting is also increasing. Striped hyenas are usually widely distributed among local communities (MOQANAKI *et al.* 2015; FARHADINIA *et al.* 2017), but they are rarely engaged in livestock's killing or damaging farm animals (FARHADINIA *et al.* 2017). Traditionally, the organs of hyenas are used as a medicine and in superstitious beliefs, which have originated from the myth that different parts of the hyena's body are an effective means to ward off evil and to ensure love and fertility (KARAMI *et al.* 2010; TOURANI *et al.* 2012; REZAEI *et al.* 2017). Habitat destruction and land modification stands as an important threat for the species and in some parts, farmers convert natural habitat into agricultural lands and start to kill hyenas to protect their crops. Land conversion reduces food access for hyenas, making predator-prey competition more disturbing. Unfortunately, there is no accurate data on the situation of *Hyaena hyaena* in neighboring countries, most data come from Iran.

Hence, identifying regions with high a suitability for hyenas can help to manage their conservation activities.

The International Union for the Conservation of Nature (IUCN) considers the striped hyenas to be Near-Threatened (ARUMUGAM *et al.* 2008). Although a high proportion of the species range is covered within the current network of protected areas in Iran (FARASHI *et al.* 2017), the species needs specific conservation programs, given that the majority of its suitable habitats lies near human settlements.

This study provides more information about suitable habitat and relevant environmental factors of the striped hyena. Certainly, more information about behavior and population size of the species could be obtained from ongoing research.

Acknowledgments

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