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Modeling of habitat suitability of Asiatic black bear (*Ursus thibetanus gedrosianus*) in Iran in future

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ABSTRACT

Future changes in climate are imminent and they threat endangered and rare species due to habitat destruction. The Asiatic black bear (*Ursus thibetanus gedrosianus*) is a rare and vulnerable species whose habitat fragmentation and habitat loss decreased the size of its population significantly. Climate change is another threat to this species that is investigated in this research work. Aiming at this goal, ten species distribution models (SDMs) were applied as helpful tools for evaluating the potential effectiveness of climate change in habitat suitability of Asiatic black bear in Iran. Potential dispersal of Asiatic black bear was modeled as a function of 32 environmental variables for the current time and 2070 for 44 climate change scenarios (CC scenario) of future climate. Our results showed that modeling result depended on type of model. Our results confirmed that one of the greatest threats in the near future for Asiatic black bear was the change of suitable habitat due to climate change. All the CC scenarios showed that migration of this species would be to the north and west areas with higher elevation and that an increase in area would be more than a decrease in area in all scenarios. Recognizing and protecting potential future habitats are of the important activities to conserve this species and identify areas with conservation priority.

1. Introduction

Future climate changes can be effective in fauna distribution worldwide leading to its habitat destruction [1]. Nowadays, many researchers have predicted potential impacts of climatic change on the distribution of plants [2,3] and animals [1,4,5]. Animals, as consumers at higher trophic levels are affected both by climate that has negative impact on physiological processes and land cover that provides habitat and other essential needs [1].

Asiatic black bear (*Ursus thibetanus gedrosianus*) is listed as a vulnerable species based on the red list of international union conservation natural resource (IUCN) since 1990 [6]. Asiatic black bear has been recently evaluated as nationally endangered by human – wildlife conflicts in some countries [7,8]. The most important parameter in local extinction of Asiatic black bear is habitat destruction and fragmentation because of human activities [9]. In recent thirty years, Asiatic black bear population has been reduced by 30–40% and it is predicted that the same rate will continue for the next thirty years unless effective conservation activities are implemented [6]. The Iranian black bear (*Ursus thibetanus gedrosianus*) has the most western distribution of the 7 subspecies of Asiatic black bear [47] and is different from other subspecies by nature [10]. Its natural habitats are increasingly becoming destructed and isolated from each other by human interventions and changes in land cover. Future climate changes can be the main threat to the species while considering their limited distribution in distribution areas. As reported, Asiatic black bears inhabit at higher elevations than normal in Nepal that it is possibly due to climate change [11]. The study performed by Almasieh et al. [12] also showed that climatic factors were important to identify Asiatic black bear habitat in Iran. Bioclimatic envelope models have been strongly implemented to predict species distribution model (SDM) in future [1,2,13,14], although the validity of these has recently been questioned [15–19]. Recently, many studies have predicted that species distribution in future will be highly variable [19,20]. Detection and quantification of variation sources are important for the purpose of improving the accuracy of prediction of species range shifts in future [19,20] Changes in the SDMs output might increase because of errors and uncertainties related to a) SDMs; b) features of species history; and c) changes in future climate scenarios (CC scenarios) [21]. Therefore, we modeled future potential distribution of Asiatic black bear under different CC scenarios and SDMs to obtain the best result.

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Table 1
Environmental predictors and their relative contributions to model potential distribution of Asiatic black bear.

Environmental predictors	Code	Present time	Future time
Climatic predictors			
Annual mean temperature	BIO1	13.2	10.1
Mean temperature of warmest quarter	BIO2	9.1	12.5
Mean temperature of coldest quarter	BIO3	13.5	16.3
Annual precipitation	BIO4	32.3	22.5
Precipitation of wettest quarter	BIO5	10.3	2.8
Precipitation of driest quarter	BIO6	7.3	3.7
Vegetation predictor			
Normalized difference vegetation index	NDVI	1.5	–
Anthropogenic impact predictor			
Human footprint index	HF	28.6	
Topographic predictors			
Altitude	T-A	5.4	18.4
Slope	T-S	8.8	7.8
Aspect	T-A	10.2	7.3
Topographic heterogeneity	T-TH	2.6	3.8
Land cover predictors			
Distance of stream	L-DS	7.7	–
Distance of river	L-DR	6.0	–
Distance of lake	L-DL	4.5	–
Distance of bare area	L-DBA	9.0	–
Distance of rocky area	L-DRA	11.1	–
Distance of protected area	L-DPA	16.4	–

2. Materials and methods

2.1. Study species and area

Asiatic black bears are generally rare in the world and in Iran as well. Recently, habitat fragmentation as the consequence of human activates as well as continuous and severe drought has worsened the situation for this species; therefore, it is clear that the number of bears has declined over the past several decades [7], and is still declining [6].

Iran lies between latitude 24° and 40° N and longitude 44° and 64° E. Variation in habitat conditions leads to a rich diversity of fauna and flora in Iran making it one of the most important countries in the Middle East and Western Asia for biodiversity conservation [22]. Asiatic black Bear also called Baluchistan bear lives only in the mountains of Kerman, Hormozgan, and Sistan and Baluchistan Provinces in the southeast of Iran [23]. This bear is omnivorous and occupies a very dry and sparsely-forested landscape [24].

2.2. Environmental variables

We initially compiled 32 environmental predictors, for modeling the potential distribution range of Asiatic black bear under current condition. 19 bioclimatic predictors were obtained from the World Clim database at a resolution of 30″ × 30″ [25]. Normalized Difference Vegetation Index (NDVI, as the average of values for 12 months over a 16-year period from 2000 to 2016) was used as vegetation variable and extracted from 30m Landsat TM imagery. We used the human footprint index to assess anthropogenic impacts on Asiatic black bear, which is an estimate of human disturbance based on human settlements, land transformation, accessibility and infrastructure data [26]. We quantified heterogeneity in topographic relief for each 1 × 1 km grid cell as elevational range (maximum minus minimum elevation) from a Digital Elevation Model (DEM) generated by the National Cartographic Center of Iran (NCC) at 1:25,000 scale.

We based model projections into the future on predicted average climate data for 2070 for the four 44 CC scenarios that were obtained from the World Clim 1.4 database at a resolution of 30″ × 30″.

Autocorrelation analysis was done to select proper environmental variables, but variables with cross-correlation coefficient value greater than ±0.8 were excluded (Table 1).

2.3. Data collection and climate change scenarios

We obtained the presence records of the species in Iran from the literature (e.g., [10,12,23,27]), atlases [48] and IUCN data set [6]. These presence points were modeled for current potential distribution. We also identified suitable areas outside the present range of the species by projecting the best SDM under the present condition as presence points to model future potential distribution [28] under 44 CC scenarios (by 11 global climate models (GCMs) under four Representative Concentration Pathways (RCPs) (Table 2).

RCPs are the greenhouse gas concentration trajectories were admitted by the IPCC for its fifth Assessment Report in 2014 [29]. The CO_2-equivalent concentrations are 490, 650, 850, and >1370 ppm for RCP 26, 45, 60, and 85, respectively [30]. GCMs are different types of climate model. Mathematical models of the general circulation of a planetary atmosphere or ocean are performed them. The Navier–Stokes equations

Table 2
Parameters of CC scenarios (Global Climate Models and Representative Concentration Pathway).

Type	Full name	ID	Institute
Global Climate Models (GCMs)	BCC-CSM1-1	GCM 1	Beijing Climate Center, China Meteorological Administration
	CCSM4	GCM 2	National Center for Atmospheric Research
	GISS-E2-R	GCM 3	NASA Goddard Institute for Space Studies
	HadGEM2-AO	GCM 4	National Institute of Meteorological Research/Korea Meteorological Administration
	HadGEM2-ES	GCM 5	Met Office Hadley Centre (additional HadGEM2-ES realizations contributed by Instituto Nacional de Pesquisas Espaciais)
	IPSL-CM5A-LR	GCM 6	Institute Pierre-Simon Laplace
	MIROC-ESM-CHEM	GCM 7	Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies
	MIROC-ESM	GCM 8	Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies
	MIROC5	GCM 9	Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology
	MRI-CGCM3	GCM 10	Meteorological Research Institute
	NorESM1-M	GCM 11	Norwegian Climate Centre
Representative Concentration Pathways (RCPs)	Representative Concentration Pathway 26	RCP 26	Intergovernmental Panel on Climate Change (IPCC)
	Representative Concentration Pathway 45	RCP 45	Intergovernmental Panel on Climate Change (IPCC)
	Representative Concentration Pathway 60	RCP 60	Intergovernmental Panel on Climate Change (IPCC)
	Representative Concentration Pathway 85	RCP 85	Intergovernmental Panel on Climate Change (IPCC)