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Brown Bear (*Ursus arctos*) habitat suitability modelling in the Alborz Mountains

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Abstract

Brown bear is the largest carnivore in Iran and is distributed the throughout the mountainous area of the country. The largest population of species inhabit the northern slopes of Alborz Mountains and the Hyrcanian mountainous forests part are the main species distribution area . Therefore, identifying the effective Biogeographical factors and selection of the suitable habitat by the species plays an important role in the describing species distribution. We collected the brown bear presence points in the three Northern Provinces of Iran Guilan, Mazandaran and Golestan. After testing the correlation of the parameters, the species habitat suitability map was prepared by using the Maximum Entropy Method. The results indicated that the model performed well in predicting suitable areas. The results of Jackknife analysis showed that the slope and after that vegetation index variables have the most effects on the suitability of the species habitat. Most parts of the study area are suitable for brown bear.

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INTRODUCTION

Wildlife habitat analysis, identification of the potential habitats and resources with priority to species survival of the species have great importance for habitats conservation and management for species survival (Nawaz, 2008). Habitat suitability modeling can be used to predict, identify and protect important and suitable habitats and, effective factors for suitability, the main means and the main objective of conservation in species management (Franklin, 2010). In this regard, species distribution models (SDMs) are one of the most important tools for achieving optimal species environment (Franklin, 2010; Guisan et al., 2013) and can provide fully documented information for decision making and conservation purposes (Rodriguez et al., 2007; Guisan et al., 2013).

The size of the population and habitat of large carnivores are extremely alarming, with the major causes of human development, habitat degradation and poaching. Brown bears as a large carnivore at the top of the food pyramid are in danger of disappearing from many habitats (Nellemannet al., 2007; Roelliget al., 2014; Støenet al., 2015; Fernández-Gilet al., 2016). The remaining populations of this species are small, isolated, threatened and often can not be dispersed to other sub-populations and larger populations. The distribution and selection of brown bear habitats in the world has been reported from sea level elevation up to 5000 meters above sea level (Sathyakumar, 2006). The species distribution in Iran is also in

the domain of global brown bear distribution (Gholamhosseini et al., 2010), especially forest and mountainous areas which are the most important habitat for the largest carnivore. The Alborz Mountains population has the higher importance both in terms of number and density (Etemad, 1985; Kiabi et al., 1994; Gutleb & Ziaie, 1999; Gutleb et al., 2002; Nezami & Farhadinia, 2011; Nezami et al., 2010). Since this species is known as an umbrella species and by the protecting it, other species of that ecosystem will be protected (Nezami, 2013; Carroll et al., 2001). Therefore, it can be used to formulate a more effective conservation strategy, particularly throughout the Alborz Mountains forest and semi-forest habitats , which have high species richness of endangered animal (Darvishsefat, 2006; Ziaie, 2008; Nezami et al., 2010).

Although, in general, the population of brown bears is large and is in the least concerned (Lc) category of the red list, the fact is that the existing populations of the species have low density and are isolated populations with serious threats to distribution to larger habitats (McLellanet al., 2017). Most brown bear are isolated in the mountainous areas (Swenson et al., 2000; Zedrosser et al., 2001). A large part of the current residential and human development areas has resulted in the destruction of suitable habitats and also disrupted the distribution of bears between habitats. Despite this, populations living in this situation or near residential areas are more under threat because they are more isolated and their interactions is limited due to many factors (Roelliget al., 2014; McLellanet al., 2017). Hence, it is necessary to develop programs to protect the potential and actual habitats of brown bears and habitat species. Distribution, biology, and biological requirements of the species are prioritized in these conservation and action plans. Modeling and mapping of the species habitats in proper planning should be the most important measures to consider (Pacificiet al., 2015).

The Maximum Entropy Algorithm (MaxEnt) is known as one of the best and most appropriate methods in the wildlife habitat selection studies (Suel, 2019). It is based on the of presence points technique, which is of the great use in studying species distribution patterns (Robertson et al., 2001; Hirzel et al., 2002). Currently, it is one of the best and most widely used methods to predict the geographical distribution of animal and plant species (Phillips et al., 2004; 2005; 2006; 2009). This method provides one of the most accurate results using the presence points (Suel, 2019). The MaxEnt algorithm yields a better result, from the use of digital environmental variables, than the other models that only act on the present data, when the size of the samples is small (Robertson et al., 2001; Hirzel et al., 2002). This approach, using multivariate statistical analysis and GIS, estimates the probability of the presence or absence of a species in a set of habitat conditions (Guissan & Zimmerman, 2000).

The purpose of this study is to provide a map of distribution of suitable brown bears habitats in the Alborz Mountains. It is also important to determine the environmental variables affecting habitat suitability in the study area. Finally, the valuation of optimal spots based on landscape ecology principles with respect to features such as size, environment-to-area ratio, distance and proximity of stains is important.

MATERIAL AND METHOD

Study area

Based on Darvishsefat (2006), Iran is rich in more than 8000 species in terms of plant diversity due to its specific geographical location, soil, high altitudes and climatic diversity. The present study was carried out in Hirkanian forests in the northern Iran and the southern coast of the Caspian Sea. The area forms a green belt with an area of about 43,600 Km^2, in the south of the Caspian Sea, from the Golidaghi valley in the northeast to the east of Astara in the northwest of Iran. This habitat covers the plainlands of the south of the Caspian Sea and the northern slopes of the Alborz Mountains which ranges from -25 to 3000 meters above sea level. There is a great variety of species in this habitat with 80 species of trees and shrubbery has led to the formation of various forest communities (Darvishsefat, 2006). Mammals that are still living in the area, but are dropping dramatically, include Persian leopard *Panthera pardus*, Lynx *Lynx lynx*, brown bear *Ursus arctos*, wolve *Canis lupus*, Golden Jackal *Canis aureus*, Jungle cat *Felis chaus* and Otter *Lutra lutra* (Caspian Hyrcanian Forests Project, 2018).

Data collection

Data collection was started in winter 2015 to winter of 2016. During the study, 265 species' observation points were

collected and entered into Excel 2010 software. The observation data was categorized according to the province and validation in the software. In the data validation section, the data was categorized into three levels. Level one data is based on verified direct observations and signs and tracks; level two data was collected on the basis of observation confirmed by DoE; and level three data is georeferenced observations. Finally, we could collect 15 points in the first category, 190 in the second and 60 in the third. Based on Ambarli et al., (2016), the home rang of the Syrian brown bear was in Turkey, we considered a buffer size of 7 km^2 for the points. Creating this buffer will help in reducing the multiple counting of the observations and moreover, it helps to make pseudo-presence points in the modeling of the suitable habitats. Finally, after applying the buffer on the species distribution points, 91 points out of 265 collected points were used in the modeling.

Environmental Variables

After collecting species' presence points, the habitat suitability model was studied by using the three categories of environmental variables; vegetation, topography and climatic variables, along with human variables, (Peknet et al., 1395). By using the literature review, similar studies were performed on brown bears or other carnivores and moreover, eight layers were selected according to the correlation between layers and of the species ecology, (Ataei et al., 2012; Kaboli et al., 2012; Nawaz, 2008; Nezami et al., 2018; Komaii, 2013). We used NDVI instead of vegetation cover which was downloaded using the Modis satellite in the period of 16 to 29 May. The climate variables were prepared from the WorldClim data center (Kermani et al., 2017). Based on the species ecological studies on the and the use of correlation on the layers by ENM Tools 4.4.1 software, annual precipitation and annual average temperature were also used for the modeling. Two of the layers, slope and aspect, were prepared from dem with the 85 accuracy. Human Footprint index was used to showing the human activities. Considering that water resources are vital and play a significant role in distribution of the species presence, and some species are fed from some other aquatic species, such as fish (Gholamhosseini et al., 2010), therefore, we used the distance from the rivers in the modeling after converting to the KML format and checking the error rate and data bias in the Google Earth software. Due to the conflict between brown bear and local communities, the distance from the villages was also selected as a layer. Environmental layers were arranged and processed in ArcMap 10.2 software. Finally, the same cell size and boundary were assigned to the variables, and in order to verifying the correlation, they introduced to the IDRISI Selva 17.0 software. Since the correlation between the variables may lead to the statistical errors and inaccurate predictions (Franklin, 2010), before using the information layers in the modeling process, their correlation was tested and the variables with a correlation greater than 0.7 were removed from the modeling. Although the MaxEnt model has less susceptible to the correlation between environmental variables than other similar models (Phillips et al., 2009), it is recommended that only one of the variables be used in modeling if the correlation coefficient between two variables is more than 0.7 (Trisurat et al., 2012).

Table 1. Variables used for the MaxEnt analyses

Variable	Variable defining	Variable type
Bio 1	Average annual temperature	continuoues
Bio 12	Average annual precipitation	continuoues
Slope	Slope	continuoues
Aspect	Aspect	catergorical
NDVI	NDVI	continuoues
Footprint	Footprint	continuoues
Village Distance	Village Distance	continuoues
River Distance	River Distance	continuoues

In order to prevent disturbance in habitat suitability model results, the correlation of the habitat variables was measured and

variables with a correlation over 0.7 were identified. From each pair of variables with a high correlation, only one variable according to the ecological aspects selected.

Model Validation:

Just like any other sampling method, model accuracy should be evaluated. The prepared model by the MaxEnt method can be evaluated by calculating the Area Under the Curve (AUC) for the ROC curve. AUC is one of the most common methods for determining the accuracy of the model. The Area Under the Curve which is equal to the probability of a randomly chosen presence point, is considered more suitable by the model than a randomly chosen background point (Pierce and Ferrier, 2000). The number is typically between 0.5 – 1. Those values close to 0.5 indicate that the model performance is not better than the random model and score 1 indicates a complete performance. AUC is used to evaluate the performance of the model and is equal to a probability that a randomly chosen presence point obtains a higher degree of suitability than a randomly chosen background point, other parts of an area where the presence of species is not registered. These random background points are used as Pseudo-absence in all analyses in MaxEnt (Phillipes and Dudik, 2008). In this research, 70% of the present points were used to create the model (train data), and the remaining 30% were used for testing the model (test data). The area under the curve was calculated for both sets of data.

In this method presence data randomly divided into some categories with the same sample size which is shown as K. Then the modeling repeats K times and in each time one category left out for testing the sample and K-1 extant category use for training the model. The iteration can be used to calculate the average and standard deviation for results of the model. Lower standard deviation indicates the power of prediction and more stability of the model. In this research data is divided into 4 categories.

Making the Habitat Suitable Modeling

To predict the brown bear distribution, we used the MaxEnt v.3.3.3a (Phillips et al., 2006; Phillips and Dudik, 2008). The MaxEnt method only requires the presence points of the species, as well as determining which environmental variables are the most important factors explaining the distribution of the species, is one of the most important strengths of this method (Warren and Seifert, 2011; Mandle et al., 2010). Therefore, the choice of this model for carrying out this research is due to higher efficiency of this method than other available methods (Elith et al., 2006).

Based on this, modeling was conducted by selecting 10,000 random points as background points (Hemami et al., 2015; Obyadavi et al., 2016; Nezami et al., 2018). The prepared habitat suitability map was classified into ArcMap 10.2 software for analysis.

RESULTS

The surface under the curve was equal to 0.849, indicates that the model could separate very suitable areas for brown bear from undesirable areas.

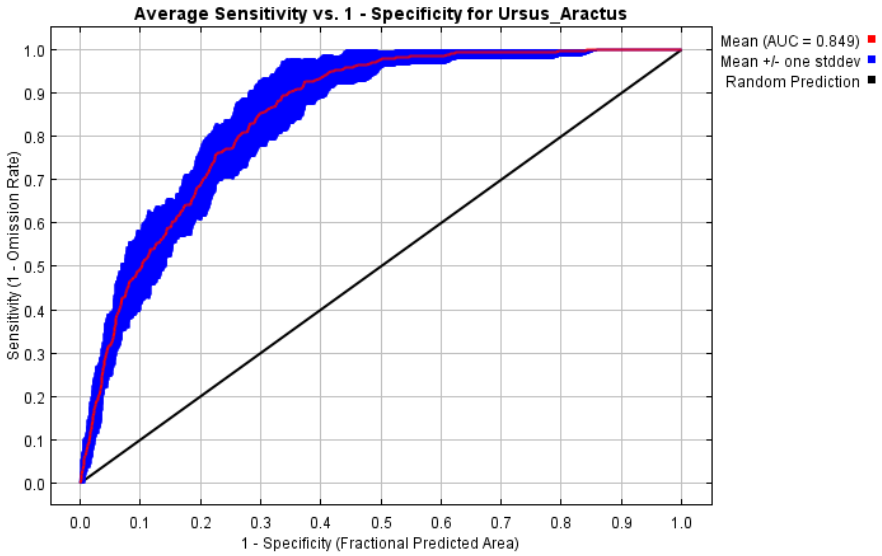

Figure 1. Validity of the model by calculating the Area Under the Curve (AUC) for the ROC curve

According to Jackknife test, slope and vegetation index have the most effect on the suitability of brown bear habitat. The slope variable is the most important variable in the habitat suitability (Figure 2).

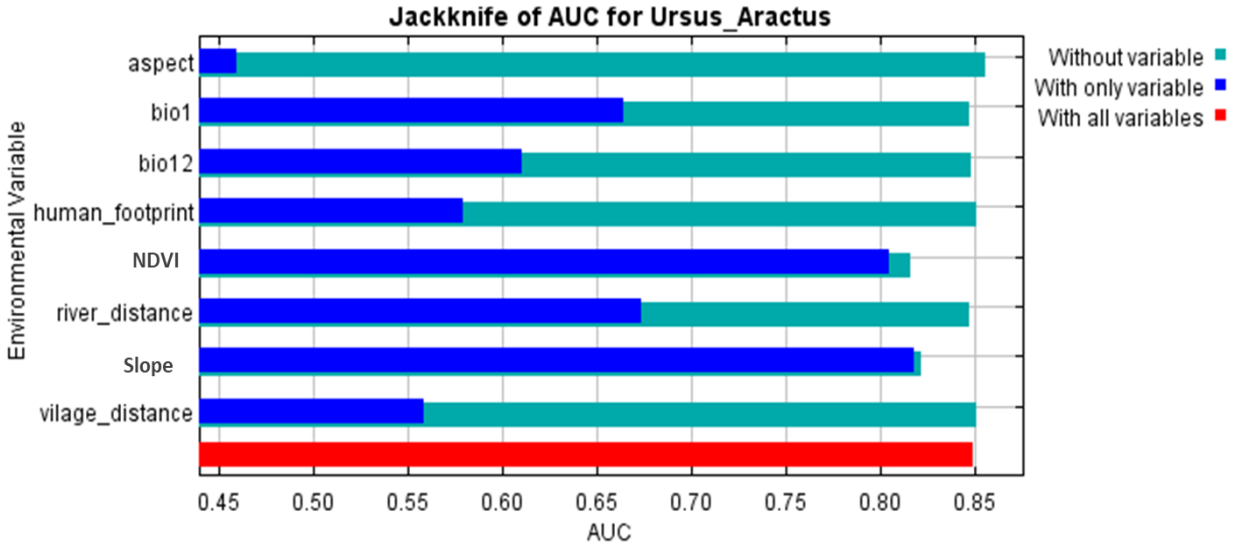

Figure 2. Jackknife's test results to examine the role of the importance of each variable in the model

Based on the Jackknife's test, the slope is the most effective variable on the suitability of the habitat of the brown bear. The second most effective variable is the vegetation index. The third most effective parameter in determining the suitability of the habitat is the distance from the river. According to the response curves, brown bears prefer the northern slopes of the Alborz Mountains with higher slopes which have a lower temperature. In fact, they are highly dependent on water resources , vegetation density, the habitat's suitability decreases sharply. as the distance from the water resources increases or vegetation density decreases.

Because of connectivity and unity of jungles, Hyrcanian Forests are a suitable area for the species . According to map 2, by increasing distance to the Hyrcanian mountainous forests the suitability of the habitats reduces and the habitats lose their unity. The average annual temperature is the fourth variable affecting the suitability of brown bear habitat, that increases the suitability of the species habitat as it decreases.

Based on table 2, the contribution rate of the variables in the model, the slope variable has the highest participation in the implementation of the model. Based on the sensitivity and specificity results the habitat suitability map classified into three categories, , high (more than 0.8), medium (the area between 0.5 – 0.8) and low (the area between 0.295 – 0.5) suitability for the brown bear (Figure 3).

Table 2. The contribution rate of the variables to producing the model

Variable	Percent Contribution
Slope	55.4
NDVI	31.2
River Distance	4.9
Bio 12	3.2
Human Footprint	1.9
Aspect	1.8
Bio 1	1.7
Village Distance	0

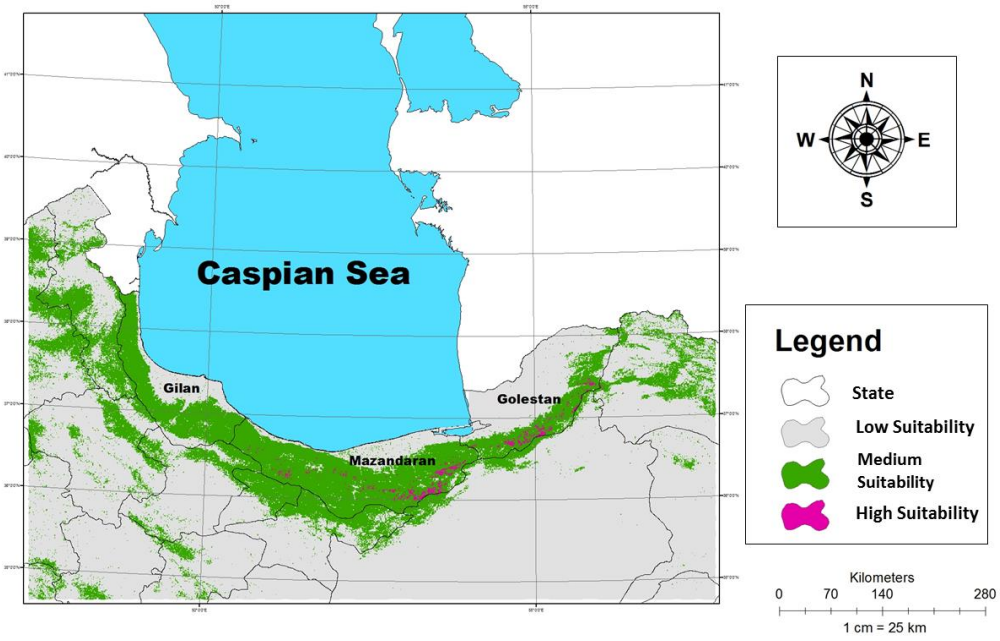

Figure 3. Suitability map of brown bear in the north of Iran

Considering the range with high suitability for brown bears, it can be concluded that this habitat area is very important for the conservation of the brown bears in the country.

Generally, about 3450672 hectares of the three northern provinces including Golestan, Guilan and Mazandaran are suitable for the species. Compared to the total area of the three provinces, lots of the parts of the northern provinces have suitable for brown bear. Among three provinces, respectively, Mazandaran, Guilan and finally Golestan have the most suitability for the species. Although Golestan Province has the least suitability area among the other ones, the level of high suitability (red area in the map 2) in this province is more than the other twoones. Moreover, the high suitability area in Mazandaran Province is adjacent to Golestan province.

DISCUSSIONS

According to the Yusufi et al., (1395); Goodwin, (1940); Blanford, (1876); De Fillippi, (1862); Gutleb and Ziaei, (1999); Lay, (1967) and Missone, (1954) the northern population of brown bears (the northern slopes of Alborz Mountains) is the main bear population in Iran with highest aboundance and number.

Based on the response curve of the vegetation index, increasing the density of the cover increases the suitability of the species habitat (Mattson and Merrill, 2002: Gholamhosseini et al., 2010; Zarei et al., 2015). Therefore, vegetation density seems to be one of the criteria for selecting habitats for the brown bears (Nawaz et al., 2014). Very high altitude rangelands of habitats are used only by the species in the short period (late spring to mid-summer) (Nezami, 2008), because during this period, the production of pasture plants, especially the family of Gramineae, is very high (Nezami ,2014) and, moreover, it is also a rodent activity season that is a good source of protein for bears (Nawaz, 2008). The Alborz Mountains and Hyrcanian forests are one of the highest rates of the brown bear breeding areas in Iran compared to other areas of the country (Nezami and Farhadinia, 2011). There seems to be a positive correlation between diet and reproductive performance among brown bears (Hilderbrand et al., 1999). Therefore, it can be mentioned that vegetation and availability of food sources have increased the density of brown bears in Alborz compared to other habitats of the country such as Zagross Mountains in the west and Caucasian part in the northwest of Iran (Nezami ,2014). Based on the results, habitats close to water resources increase the habitat suitability although studies conducted in southern Iran (Zarei et al., 2015) suggest that the effects of this factor in the winter, when bears are in the winter torpor, are ineffective.

Although in the southern Alborz, the slope variable did not play a key role in predicting the suitability of the summer habitat of brown bears (Ataie et al., 2009), the results of this study indicate that increasing slope plays the great important role in the habitat suitability of brown bears. Studies in Fars province and south of Iran showed that rocky slopes and rocky areas at high altitudes have great suitability in brown bears habitats, which is probably due to its higher security (Zarei, 2013; Zarei et al., 2015). Because in another study in Fars province (Gholamhosseini et al., 2010) the presence of the brown bears in low-altitude areas is considered only for security reasons. The preferred slope for brown bears in the Alborz Mountain is the northern slope with dense vegetation cover over other slopes. After the northern slopes, the southern directions are also selected by brown bears. The reason is probably higher vegetation cover in the north than other directions. As the altitude increases, the air temperature drops, and the suitable habitat will be added (Gholamhosseini et al., 2010). Species distribution in Fars province is mainly related to cold regions (Gholamhosseini et al., 2010). They also state that bears choose the most suitable habitats with appropriate rainfall. In fact, most of the distribution indexes in this study related to the areas with rainfall ranging from 600 to 700 ml/year. Regarding the annual rainfall response curve in this study, despite the different curves, the maximum habitat suitability in the distances of 500 to 900 millimeter has been shown. The results show that the habitat suitability decreases with distance from villages and roads, indicating a high level of conflict between brown bears and local communities. Therefore, increasing public awareness of the values and status of the species can be effective in protecting species in the study area (Madadi ,2018).

CONCLUSION

The results of the study showed that out of 5824200 hectares, the area of the three southern provinces of the Caspian Sea, about 59 percent have high suitability and about 41 percent have low suitability for brown bears. Considering the wide range of suitable area and the high suitability rates for species, it can be concluded that the area is a source habitat for the bears in the country (Nielsen et al., 2006). The proposed habitat suitability map can be a decision-making tool for the conservation managers, to have an appropriate strategy against the future development plans in brown bear priority habitats. Using this method, in addition to long-term conservation of the species within the study area, conserving of the other species of wildlife and other natural resources will be guaranteed (Nawaz et al., 2014). The most important treatment to protect the species and habitats in the future can be to prevent habitat loss, fragmentation and degradation. Conservation of this range can protect Sink Habitats of the species especially in southern provinces (Delibes et al., 2001).

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