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Bioclimatic Niche Model to predict Afghan Pika (*Ochotona rufescens*) distribution range in Iran

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ABSTRACT: Effective management and protection of wild life population depends to a large part on our ability to understand and predict species habitat and its relevant evolutions. Therefore, various methods of habitat modelling which have been increasingly used in wild life management since 1970 are able to provide useful information on the relationship between species and species habitat. We used a novel method known as maximum entropy distribution modelling or Maxent for predicting potential suitable habitat for Afghan Pika (*Ochotona rufescens*) in Iran Using climatic parameters in fact we predicted the area in which the climate is suitable for pika to succeed, the results of the present study indicated that some of the most important climatic factors in habitat suitability and limiting the distribution of Pikas include annual mean temperature (54.8%), temperature annual range (31.5%), Precipitation of Coldest Quarter (4.8%). In addition, the performance of the model by the area under receiver-operating characteristic curve (AUC), showed that the modelling approach used in this study is in excellent yield (average AUC = 0.846; SD = 0.103). Therefore, using Maxent method and presence dataset, it is possible to model the geographical location of species. The obtained suitability map significantly explains the dispersal of Pika in Iran and has a good consistency with other studies done. The method presented in this method is effectively able to predict suitable habitats of many species of wild life, especially the species subject to extinction by a limited number of sampling points.

Keywords: Afghan Pika (*Ochotona rufescens*), Bioclimatic niche, Habitat modelling, Maxent, climatic perspective, Iran

INTRODUCTION

Nowadays, the protection of the heritage of future generations is not possible without observing scientific principles and without careful management plans. The critical factor in protecting, identifying and acquiring valid knowledge, especially about the habitat requirements of species is importance that human attaches to a species. Many of the problems and bottlenecks of wildlife conservation root from lack of understanding of wildlife requirements, including the habitat requirements. Understanding distribution and ecological needs of habitats is essential to achieve species conservation. In fact, to determine the nature of distribution and determinants of species dispersion is the working foundation of an ecologist (Elith and Leathwick, 2009; Guisan and Thuiller, 2005). Probability distribution models can create a vision indicating the impact of different factors on the occurrence and continuation of species with time (Guisan and Zimmermann, 2000, Araujo and Williams, 2000). Nowadays, species distribution modelling is extensively used as a tool in the area of ecology and various environmental programs (Bunnell and Johnson 1974, MacArthur and Wang. 1974). These models show the relationship between species and the surrounding environment in the study area. In this regard, climatic models have a high status, and, in fact, understanding the impact of climate change on wildlife populations is highly important for the environmental experts and natural resource managers (Root and Schneider, 2006). Climatic changes can change existing resources and suitable habitats for animal species, which in turn it can significantly influence the survival percent of wild life (Hughes, 2000; Schwartz *et al.,* 2006). There are a myriad of methods for modelling and prediction of favorable species habitats (Gray, 1842, Guisan and Thuiller, 2005, Wei-Dong and Smith, 2005). In this study, we use the maximum entropy method Maxent to model Pika's favorable habitat in Iran by using climate parameters.

Pika is a species of Lagomorph family and is physically highly similar to big mouse, except that the tail of Pika is so small and is almost removed, Pika's ears are highly round and small, legs are not so high unlike rabbits and are somehow similar to arms, and their palms is covered with dense furs, its color is variable and akin to environment, and it converts from mixed gray and dark into bright red (Ziaei, 2008). Evidence suggests that contemporary Pikas within the family Ochotonidae originated in Asia in the early Oligocene and diversified into many different genera by the Miocene. At that time, Pikas were found throughout North America, Asia, and Africa (Grzimek 2004). Current distribution of Pika includes northern Holartic which covers North America, Europe and Asia (Elith *et al*., 2006); only one species of the family of Pikas entitled Afghan Pika or *O. rufescens* (*Ochotona rufescens*) have been reported by Gray in 1842 in the Middle East. Distribution of this species could be seen in mountainous regions including Afghanistan, Armenia, south west Turkey and Iran (Smith *et al.,* 1990; Hoffman *et al.,* 2005). Pika is one of most important member of their native ecosystem and play significant roles in the dispersal of vegetation species by collecting and feeding from various plant species (Nowak, 1999) and because of limited mobility caused by climatic changes, Pikas may become subject to extinction. Pikas are very sensitive to the ambience and they physiologically are not able to survive in a thermal degree higher than one threshold (Smith and Weston, 1990; Verts and Carraway, 1998). Due to such sensitivity to high temperature and habitat conditions (Mc Arthur, 1974, Smith and Wang, 1974), Pika can be regarded as a superior indicator for climatic changes (Beever *et al.,* 2003; Smith *et al.,* 2004). Therefore, environmental managers and protection groups must be equipped with innovative technology and research in order to protect Pikas with limited mobility against climatic crises in the contemporary world. One of such research requirements is to identify the climatic condition of species current habitats, sensitivities and climatic limitations in order to predict and study future variations. One of the most appropriate tools to achieve such objectives is to model habitats and, in the present study, to model species climatic niche.

In Iran, so far, Maxent metod has been applied to model distribution and dispersal of Asian Zebra Doneky in Touran Reservation Biosphere (Madani, 2008), to examine the factors influencing on the distribution and abundance of buck in Hirkani Khiroud Forests (Ibrahimi, 2011), and also to model wolf's attacks on man and livestock in Hamadan Province (Behdarvand, 2011). Although many studies have been done on ecology and habitat of different species of Pika in the world, there exist limited research on Afghan Pika in Iran; one example is a MA thesis entitled “a study of intra-species variations of Pika population” by Mansour Ali Abadian in 1992. In addition, Cermak *et al.,* (2006) in a study entitled “notes on Pika family in the Middle East”, specified some distribution points of Afghan Pika in Iran. Also, using Binary Logistic Regression Methods, HEP and Ecological Niche Factor Analysis (ENFA), Khaki *et al.,* evaluated the habitats of Afghan Pika in the Lashkar Protected Area (Khaki Sahneh *et al.,* 2011, Nouri, 2010). However, so far, no study has been conducted on Pika habitat using Maxent method.

Therefore, the present study mainly aims to model Afghan Pika habitats using the factor of climate in order to model Afghan Pika climatic niche in Iran. This study can pave the way for future studies on climatic variations on the distribution of this species. Therefore, while introducing such habitat modelling method, the present study attempts to achieve two main objectives including 1) the achievement of the suitability map of Pika bioclimatic niche, and 2) identification of the most important climate parameters relevant to the presence of this species and its climatic limitations in the study area. We used species occurrence records, GIS geographical information system, climate parameters, and the maximum entropy distribution modelling approach (Phillips *et al.,* 2006) to predict potential the area in which the climate is suitable for *O. rufescens* to succeed.

MATERIAL AND METHODS

A. Species distribution data

In the present study which was done from 2011 to 2012, considering studies on Pika natural history and the studies already conducted on its distribution in the Middle East and Iran, the distribution points of Afghan Pika in Iran were examined (Blanford, 1876; Murray, 1884; Misonne, 1956; Taghizadeh, 1964; Lay, 1967; Obuch & Kristín, 2004; Cermak *et al.,* 2006), and evidence and reports approved by practitioners and scholars (environment specialists and experts, biologist, taxidermists, nature photographers, environment protectors and experiences hunters) were collected. Finally, 50 points of the presence of Pika in Iran were recorded.

B. Environmental data

Considering the sensitivity of the stations to climatic factors which introduces this species as an excellent indicator for climatic variations (Beever *et al.,* 2003; Smith *et al.,* 2004), some studies have been done on other species of Pika which have the same habitat as Afghan Pika (Smith, 1974; Verts and Carraway 1998, Smith and Weston 1990; Bruggeman 2010). In addition, some other habitat modelling studies have been done by using Maxent method (Kumar *et al.,* 2006; Guisan *et al.,* 2007a-b).

We used as environmental predictors the climatic data provided by WorldClim (Hijmans *et al.,* 2005). Nineteen bioclimatic variables (Nix, 1986), biologically more meaningful to define eco-physiological tolerances of a species (Graham and Hijmans 2006; Murienne *et al.,* 2009), were obtained from WorldClim dataset (Hijmans *et al.,* 2005, http://www.worldclim.org/bioclim.htm. This climate parameters were 1 km spatial resolution (Table 1).

Table 1. Climatic variables used to elaborate the models.

Bio_1 = Annual Mean Temperature
Bio_2 = Mean Diurnal Range (Mean of monthly (max temp - min temp))
Bio_3 = Isothermality (P2/P7)*(100)
Bio_4 =Temperature Seasonality (standard deviation*100)
Bio_5 = Max Temperature of Warmest Month
Bio_6 =Min Temperature of Coldest Month
Bio_7 =temperature Annual Range (P5-P6)
Bio_8 =Mean Temperature of Wettest Quarter
Bio_9 =Mean Temperature of Driest Quarter
Bio_10 =Mean Temperature of Warmest Quarter
Bio_11 =Mean Temperature of Coldest Quarter
Bio_12 =Annual Precipitation
Bio_13 =Precipitation of Wettest Month
Bio_14 =Precipitation of Driest Month
Bio_15 =Precipitation of Seasonality (Coefficient of Variation)
Bio_16 =Precipitation of Wettest Quarter
Bio_17 =Precipitation of Driest Quarter
Bio_18 =Precipitation of Warmest Quarter
Bio_19 =Precipitation of Coldest Quarter

C. Modelling Procedure

We used the freely available Maxent software, version3.1 (http://www.cs.princeton.edu/~schapire/maxent/), which generates an estimate of probability of presence of the species that varies from 0 to 1, where 0 being the lowest and 1 the highest probability.

While working with Maxent software, user is faced by a number of inputs, outputs and parameters. The inputs are the same information relevant to the presence of species and environmental layers. Environmental layers format (habitat parameters) is ASC. In the present study, to prepare data layers to enter software Maxent, Arc GIS 9.3, Conversation Tools were used and the presence points of the species include 50 points in the separate Excel file with CSV format were prepared. In addition, to examine the correlation between the variables, Multivariant tape wire in Spatial Analysis Tools, software Arc GIS 9.3 was used. After performing correlation analysis, out of the variables with a correlation higher than 0.8, one was selected. 50 occurrence records and 7 climate parameters were used in Maxent to model potential habitat distribution for *O. rufescens.*

D. Modelling with maximum entropy method

Maxent is one of the most common algorithms in machine learning. The principle of Maxent is related to the maximum entropy or prximity to reality.

Shannon in 1984 described entropy as a criterion out of the options involved in the occurrence of an event. The application of maximum entropy rule for species distribution is supported by thermodynamic law of ecological processes. According to the second thermodynamic rule, in the close systems, the process goes along the maximum entropy. Therefore, in the absence of the impact of other confining factors compared to the limitations imposed on the model, species geographical distribution tends to the maximum entropy. Maxent Modelling program was scripted by Philips *et al.,* (2006). Maxent is regarded as one presence method for species distribution modelling. The model is obtained as a species by a number of environmental layers along with some points relevant to the presence of species, and the suitability of each cell in habitat is explained as a function of environmental variables. The high value of each cell indicates that the cell has a good condition for that species. The calculated model expresses the possibility of population distribution within all cells. The selected distribution is the part which is closer to reality (maximum entropy) and it must have the same condition for each variable.

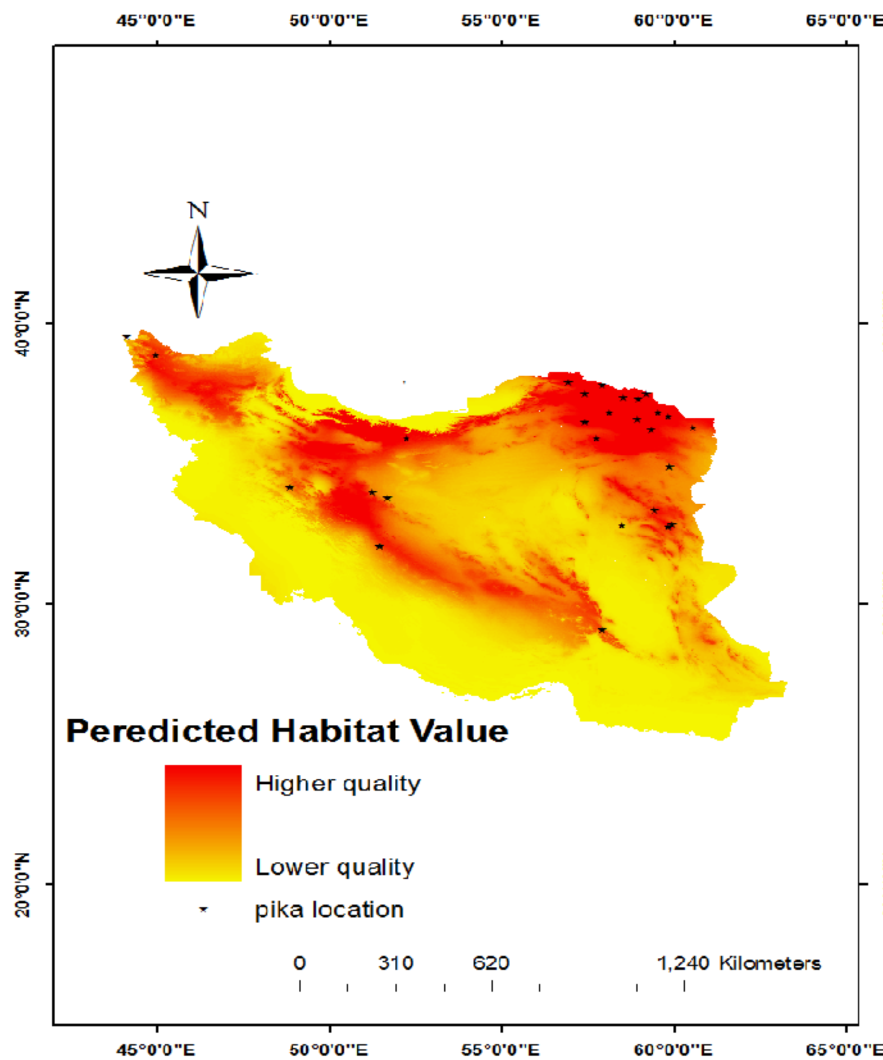
Based on the study by Ausin, the statistical modelling of species distribution is composed of three parts: 1) ecological model regarding the used ecological theory 2) the data model regarding data collection 3) the statistical model regarding statistical theory.

Maxent is a statistical model and to obtain the species distribution, a relation must be established between this model and two other components of modelling (data model and ecological model). The important step to formulate the ecological model of Maxent method is to use a set of appropriate characteristics which are regarded as environmental factors limiting species geographical distribution. The environmental layers are applied to produce characteristics which limit the possibility of species distribution. In the model Maxent, using the points of the presence of species (x1 to xm) and limited geographical space X (a set of the pixel of the relevant area) the possibility of unknown distribution is calculated. The entropy is defined as follows: $H(\hat{\pi}) = -\sum_{x \epsilon X} \hat{\pi}(X) \ln \hat{\pi}(x)$

ln: natural logarithm
X: the set of the area pixels
x: the points of the presence of the species

It is worth mentioning that Maxent is the most capable modelling method in producing useful results with sample sizes of less occurrences (Hernandez *et al.*, 2006; Pearson *et al.*, 2007).

Considering that the number of the presence points of Pikas in the study is 50, to make better use of the small sample size of Pika present in Iran, we used the cross-validation method in Maxent (Behdarvand *et al.*, 2014). Instead of extracting a training-test dataset from the data, all of the pika locations were used to build Maxent model. Pika location were randomly split into 10 folds containing equal number of occurrences, and training models were created by eliminating each fold in turn. The removed fold was then used for testing the model derived from the remaining training folds. We used the area under receiver-operating characteristic curve (AUC), calculated for test folds, to evaluate models derived from training folds.



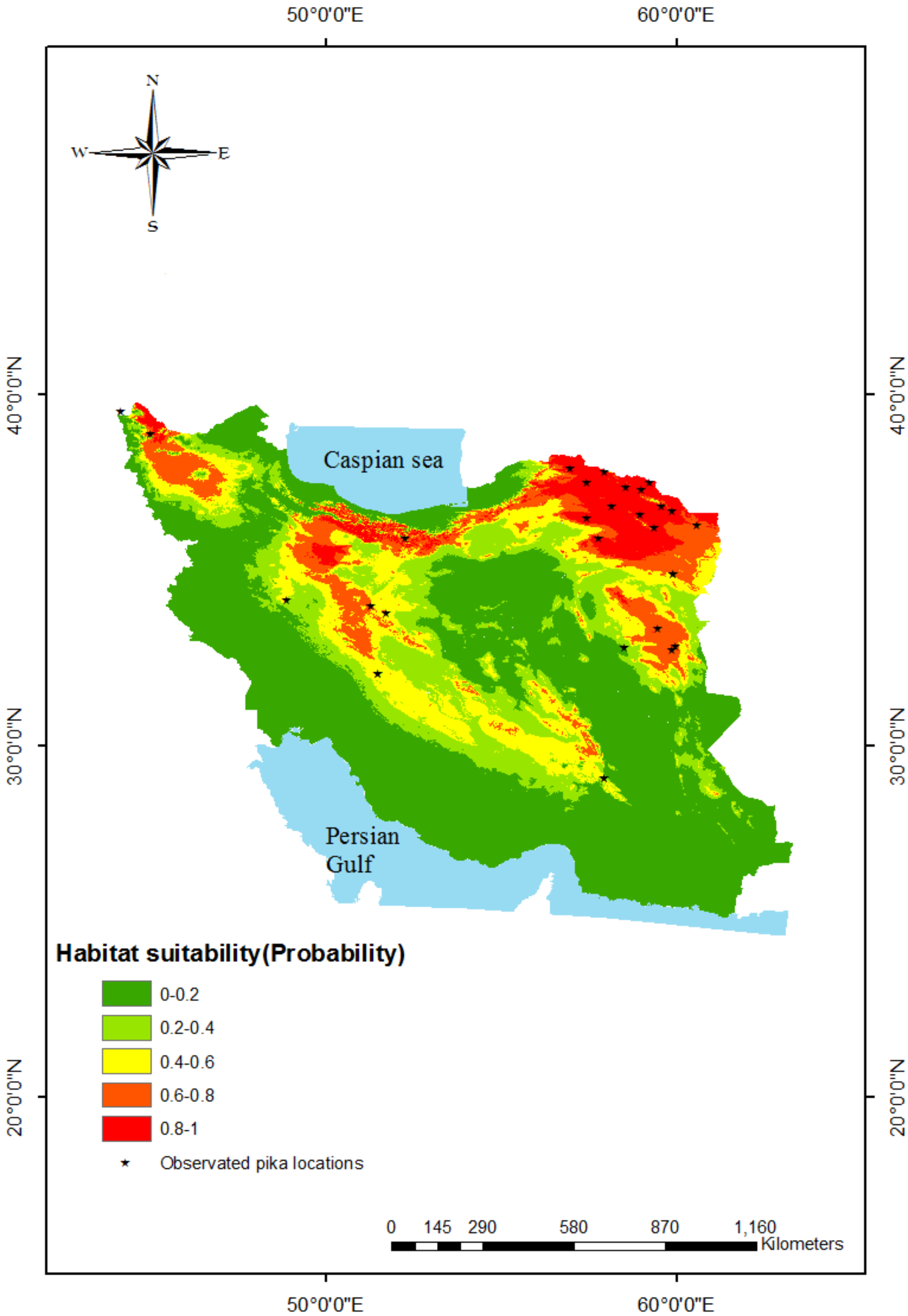


Fig. 1. Predicted map of bioclimatic niche for *O. rufescens* in Iran : Maps depicting areas in which the climate is suitable for *O. rufescens* to succeed and present in Iran from the cross-validated Maxent models a: continuous And b: reclassified into 5 equal-sized probability classes.

Maxent calculates some thresholds to categorize continuous probability maps into suitable/unsuitable classes. This is more important when identifying suitable habitats and applying management activity is inevitable (Phillips *et al.,* 2006).

By using cross-validation method for resampling, Maxent provides a number of thresholds for each cross-validated fold which will cause ambiguity to choose a single threshold to categorize the concluding probability map (Behdarvand *et al,* 2014).

RESULTS

There are various files in Maxent outlet. The Plots folder contains all the pictures of graphs, maps, and charts that Maxent creates from the run. Ochotona rufescens.asc incudes a prediction map by asc format which could be converted into raster file and then classified, and Ochotona rufescens.png which is regarded as the image of distribution prediction.

The prediction map designed by Maxent is a continuous possibility map which it was categorized into 5 classes in Arc GIS environment, and we assume that at the classes with higher ranks, the possibility of the presence of Pikas is higher. The prediction map shows that the highest habitat suitability exists in north-eastern Iran, and this location takes privilege of the maximum points relevant to the presence of Pikas.

A. Analysis of variable contributions

In this part you will see a table that shows the Analysis of variable contributions (Table 2). This table shows the climatic variables used in the model and their percent predictive contribution of each variable. The higher the contribution, the more impact that particular variable has on predicting the occurrence of that species (Phillips *et al*., 2006). In this study Annual Mean Temperature (. bio_1) had the highest predictive contribution of 54.8% (Table 2).

Table 2: Selected climate parameters and their percent contribution in Maxent model for *O. rufescenc* species in Iran.

No.	Environmental variable	Percent contribution	Source/Reference
1	Annual Mean Temperature (Bio1, degree C)	54.8	WorldClim; Hijmans *et al.* 2005
2	Precipitation of Coldest Quarter (Bio19, degree C)	31.5	WorldClim; Hijmans *et al.* 2005
3	Temperature Annual Range (Bio7, degree C)	4.8	WorldClim; Hijmans *et al.* 2005
4	Precipitation of Seasonality (Coefficient of Variation (Bio15, degree C)	4.4	WorldClim; Hijmans *et al.* 2005
5	Mean Diurnal Range (Mean of monthly (max temp – min temp)) (Bio2 degree C)	2.8	WorldClim; Hijmans *et al.* 2005
6	Precipitation of Driest Month (Bio14, degree C)	1.8	WorldClim; Hijmans *et al.* 2005
7	Isothermality (P2/P7)*(100) (Bio3, degree C)	0	WorldClim; Hijmans *et al.* 2005

B. Graph of the Jackknife of Regularized Training Gain

The Jackknifing shows the training gain of each variable if the model was run in isolation, and compares it to the training gain with all the variables. This is useful to identify which variables contribute the most individually (Phillips *et al.,* 2006). In the jackknife procedure, we calculated the loss in regularized training gain of models when each variable was sequentially omitted. We also estimated obtained gain for each variable when used alone in the model. Subsequently, by considering the regularized training gains, the most important variables were determined.

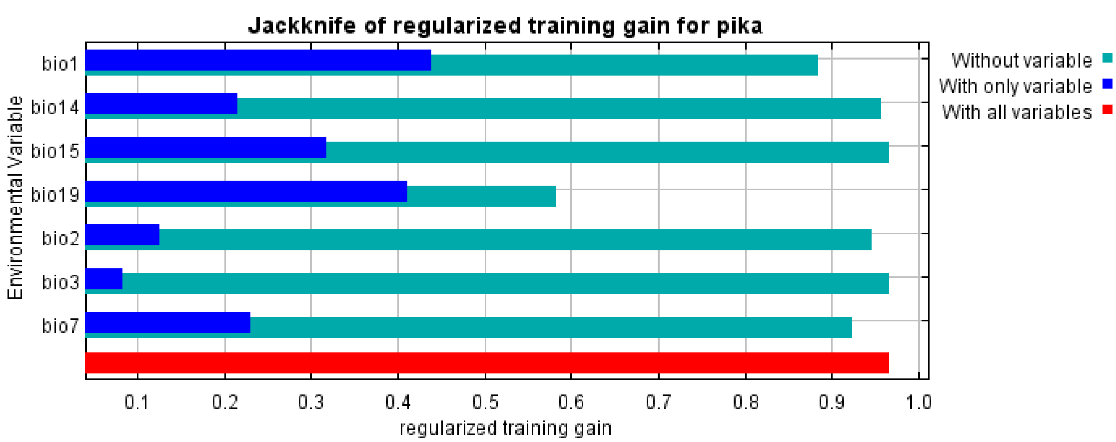


Fig. 2. Results of jackknife evaluations of relative importance of predictor variables for 0. rufescens Maxent model.

The Maxent model's internal jackknife test of variable importance and Analysis of variable contributions showed that 'Annual Mean Temperature (Bio1, degree C)', Precipitation of Coldest Quarter (Bio19, degree C)'and Mean Diurnal Range (Mean of monthly (max temp - min temp)) (Bio7, degree C) were the three most important predictors of *O. rufescens* distribution (Fig. 2, Table 2).

C. Response curves

These curves show how each environmental variable affects the Maxent prediction. The curves show how the logistic prediction changes as each environmental variable is varied, keeping all other environmental variables at their average sample value (Phillips *et al.*, 2006).

Results derived from curves showed that the probability of the presence of *O. rufescens* decrease with the increase in Annual Mean Temperature; but with increase in Precipitation of Coldest Quarter, Precipitation of Seasonality, Precipitation of Driest Month, Temperature Annual Range, Mean Diurnal Range, it somehow increases.

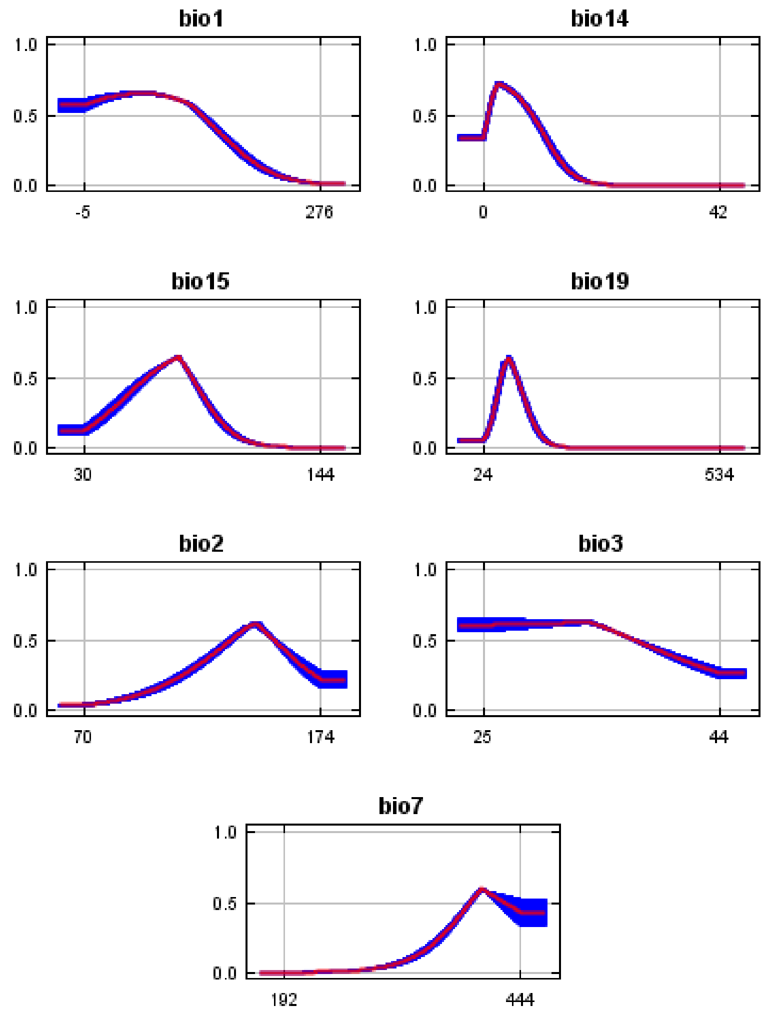


Fig. 3. Response curves affect the Maxent prediction of 0. rufescens These curves are generated for the most important variables and show the mean response of the cross-validated models with 10 replicate runs (red) and the mean±one standard deviation (blue).

D. Area under (ROC) Curve

This is a graph of the area under the Receiver Operating Characteristic (ROC) Curve or AUC. The AUC values allow you to easily compare performance of one model with another, and are useful in evaluating multiple Maxent models. An AUC value of 0.5 indicates that the performance of the model is no better than random, while values closer to 1.0 indicate better model performance (Phillips et al., 2006). The average test AUC for the replicate runs is 0.846, and the standard deviation is 0.103.

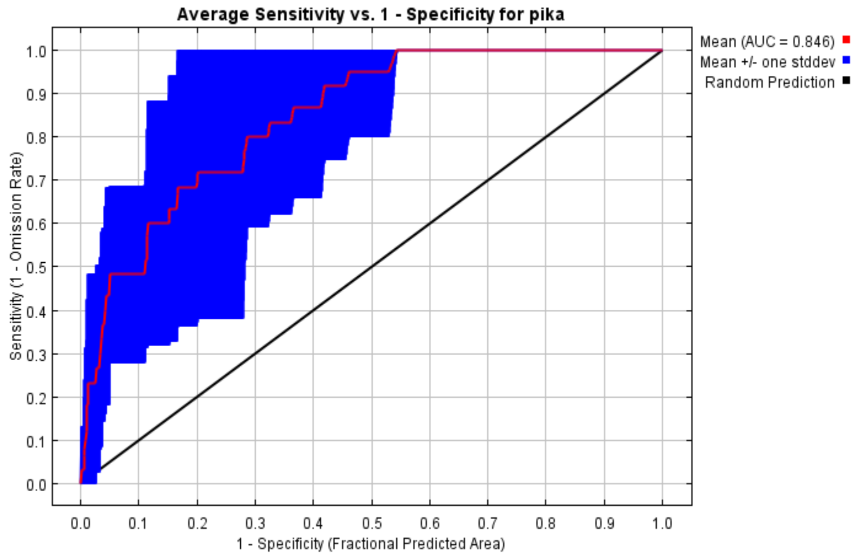


Fig. 4. Area under the (ROC) Curve.

DISCUSSION

As climate can directly influence plant populations, increased temperature in the current age can change the distribution of plant species toward higher geographical latitudes, and in turn, this can lead to the mobilization and emigration of animal species, especially herbivorous mammals to supply their required food (Root *et al.*, 2003). Notably, the population of the species with limited mobility and habitat range becomes limited to a special location due to the presence of geographical and physical hurdles; also it can hinder any genetic exchange with other populations and so they become more exposed to extinction risks (Parmesan, 2006). Pikas as small mammals are more susceptible to extinction due to their limited mobility potential caused by climatic variations. In fact, the results of different studies indicate that the climate is the most significant factor in shrinking the distribution rate of Pikas throughout the world. Therefore, using Maxent modelling method, the present study mainly aims to determine the optimal bioclimatic niche for Pikas in Iran and also to specify the climatic limitations of this species. Notably, the obtained suitability map in the present study was in a good from consistency with the distribution of Pika in Iran reported in other studies, which this shows the significance of climatic parameters on Pika distribution.

The model obtained from Maxent successfully shows the climatic characteristics of Pika environment and climatic factors limiting the species distribution. There is a direct relationship between some climatic factors and the presence of the species. The model results underline the significance of temperature and precipitation on distribution and selection of Pika habitat. In fact, considering the results from the present study, it could be said that the most significant climatic factor influencing the distribution or paucity of Pikas is annual mean temperature, which by an increase in this parameter, habitat suitability will be reduced (Fig. 2, Table 2).

Smith (1974) believes that when Pikas get exposed to the temperature over 77°F (25°C) for a couple of hours, they experience a severe stress due to their fur and it is even possible to die. Also, the studies done on American Pika shows that increased temperature has reduced the agility, increased the sensitivity and decreased the reproduction rate of this species (Beever *et al.*, 2003; MacDonald and Brown, 1992). These results are in a good consistency with the results from the present study, and the model obtained from the present study underlines the significant impact of temperature (Fig. 2, Table 2).

MacArthur and Wang (1974) argued that in temperature range of 37 to 81°F, there is a negative correlation between the time that Pikas spend outdoor and temperature degree. The response curve resulted from the current study indicate that by an increase in Mean Diurnal Range and Temperature Annual Range, habitat suitability first increases and then reduces.

Both very elevated and very low temperatures can influence reproduction rate of Pika. This is because this species reproduces mostly in hot months of year (Smith *et al.*, 1990; Nowak, 1999). Therefore, there is low possibility of the presence of Pika in the regions with very low diurnal temperature and hot days, and such places are not a good habitat for the species.

Recent studies indicate that climatic change can significantly influence the population of Pikas in the world (Wei-Dong and Smith, 2005; Beever *et al*. 2003). Increase in temperature influences Pikas' different living aspects such as the abundance or paucity of vegetation, change in the time of forage collection and change of behavior due to Pika's body varying thermal regulation.

As Pikas do not experience winter sleeps, they must store their required food for winter. So they spend a lot of time in summer and autumn to collect plants. The main challenge faced by Pikas for collecting plants in these seasons is high temperature. Therefore, by an increase in temperature annual range, mean diurnal range (mean of monthly (max temp-min temp)), the behavior of plant collection is influenced. During summer, Pikas have two feeding states; one is direct feeding from fresh plants (Dearing, 1996). The second state of feeding is related to plants collection for the use in winter. By an increase in plants age, their biomass will be increased, and they produce secondary intoxicating compositions. However, these can preserve plant in winter and when plants are dried, they will be removed (Dearing 1996). So Pikas collect plants at the peak of their growth and biomass (Huntly, 1987). Increase in temperature and precipitation can positively influence the growth of plants and plants achieve their growth peak sooner, in turn, Pikas can sooner collect their required plants (Parmesan, 2006). Therefore, other roles of the factors influencing Pika habitat suitability include precipitation of coldest quarter, precipitation of seasonality and precipitation of driest month. It is expected that by an increase in precipitation rate, vegetation and food for Pika will be enhanced. However, excessive precipitation rate also makes plants achieve sooner their growth peak and so Pikas are not able to directly use it.

The results of the observation by Ricankova on Alpine Pika and the study results of Wei-Dong and Smith (2005) on Ili Pika indicate that precipitation rate can somehow influence Pika habitat suitability and higher than that rate can have a negative impact. Considering the current distribution points of Afghan Pika and obtained suitability map in Iran (Fig. 1), the lack of Afghan Pikas on the Caspian Sea, Persian Gulf and Gulf of Oman and the low suitability of these regions for Pikas can justify the results from Response Curves on Precipitation of Driest Month, Precipitation of Coldest Quarter, and Precipitation of Seasonality.

In fact, excessive precipitation can reduce the possibility of the presence of Pikas. It must be noted that it is possible that two parameters annual mean temperature and precipitation of coldest quarter in a macro-level and other parameters in regional level influence Pikas habitat suitability and this issue requires doing more research.

Overall, it could be concluded that temperature play significant roles in the distribution of Pika, and this species is highly sensitive to climatic variations due to its limited mobility and unique habitats; as climatic variations, especially increase in temperature is a potential threat to Pikas, different studies recently have been done on the condition of Pikas as a species subject to extinction (Federal Register, 2009). In addition, a study of exposition of Afghan Pikas to varying temperatures as the only species of Pikas which are used as in laboratory (Smith *et al.,* 1990) can be more significant.

The obtained suitability map (Fig. 1) is able to significantly justify the distribution of Afghan Pikas in Iran.

Based on the recordings, the main distribution points of Afghan Pikas could be categorized into five areas including 1) Northeast and East Iran including Hezar Masjed Mountains and Kopet Dag and Binaloud 2) Southeastern Iran including Taftan and Deh Baraki Mountains in Kerman 3) central Iran including the central Alborz and Zagros mountain ranges and northern part of Kouhroud 4) the length of Alborz from south eastern Kerman to Iran and Turkey border located in Bastam in Western Azarbaijan, and 5) central and eastern part of Alborz (Fig. 1). In fact, the distribution of Afghan Pikas starts from Southeastern Iran from Taftan Mountain ranges in Sistan and Balouchestan and extends from the extreme point of Zagros Mountain ranges including Kerman and Bastam in the border of Iran and Turkey.

Another part of the distribution of Afghan Pika which accounts for main population of Pika in Iran starts from Eastern Iran and Kopet Dag and Binaloud Mountains and extends along Alborz to Qazvin province. Considering the obtained suitability map, these regions have a high climatic suitability.

Along with the above explanations on the valid depiction of the Afghan Pika distribution in Iran by the model, this model has a higher accuracy as well, for example in some parts of Iran such as Semnan, Tandoureh in Khorasan and different parts of Southern Khorasan as the main habitats of Afghan Pikas(Fig. 1).

Considering the resultant climatic suitability map, the possibility of the presence of the species is higher than other assumptions and predictions, and such regions have a better suitability class (1-0.8). This indicates the higher accuracy of this model in determining the distribution of Afghan Pika based on the climate parameter in Iran. Given the model, it is possible to obtain the relative climatic suitability percent of each point for Afghan Pikas in Iran, and so to measure the intensity and weakness of other factors on the distribution of Pika. The model also shows that Pikas often live in Iran mountainous areas with cold and Semiarid weather and this confirms the results of Lay (1974).

Using this model as an appropriate living climate for Afghan Pika and considering its elevation displacements, it is possible to examine the role of climatic changes on the displacement and mobility of Pikas and to use it as an indicator for climatic conditions. The results from some studies indicate that due to climatic changes in some areas, Pikas have changed their elevation up to 190 m (Beever *et al.,* in review).

A review of different resources shows that Pikas basically live in elevated regions and are severely dependent upon low temperatures and are not physiologically able to reproduce under the other conditions (Smith and Weston, 1990; Verts and Carraway, 1998). In fact, the elevation plays a modifying role for climatic parameters of Pikas' life. Species like Pikas with obligate temperature thresholds will shift their distribution either poleward or upward. On average, species have been predicted to respond to a 3o C increase in temperature by moving 250 km north or 500 meters upward in elevation (MacArthur 1972).

Considering the above, it is suggested that, in case of increase in temperature, the new habitat of Pika in Iran achieve a better and new modelling and suitability map, compared to the current suitability map obtained in the present study. This could be done for other species, especially the species subject to extinction risks.

It is noteworthy that Areas of a bioclimatic niche can be empty of the

expected species because:

-It can't get there

-The substrate is wrong

-It can't compete with other species

In addition, as the obtained suitability map comrhensively covers a large part of Iran, it is possible that Iran Pikas have different species or sub-species with a different climatic niche, and the obtained model is an estimation and mean of this different climatic niches. Therefore, succeeding studies assume that Iran Pikas have two or more sub-species with a different climatic niche.

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