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Research Article

Habitat suitability modeling of Goitered Gazelle (*Gazella subgutturosa*) by Ecological Niche Factor Analysis in the Bidouyeh protected area, Iran

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Abstract

Species distribution models (SDMs) are a powerful tool in conservation. Predictive habitat models attempt to provide detailed predictions of distributions by relating the presence/absence of a species to a set of environmental predictors that are likely to influence the suitability of the environment for the focal species. For most of the available methods, accurate sampling of the presence/absence of the species is crucial. The lack of information about the areas where species are absent complicates the use of common ecological modeling tools, as they rely both on presence and absence data. For this reason, a modeling technique that does not require absence data was used. This modeling approach is extremely useful when absence data are not available, are unreliable, or are ecologically meaningless. So, one statistical technique that can be used to generate habitat maps based on the presence-only data is the Ecological Niche Factor Analysis (ENFA), using the modeling Biomapper software. The purpose of this study is to provide desirable habitats in Bidouyeh Protected Area in Kerman province based on the presence-only data and environmental conditions of the area by ENFA, to determine which parts according to the current conditions of the region are suitable habitat for Goitered Gazelle (*Gazella subgutturosa*). according to the Predicted areas, we will be able to better protect and manage the area. The results showed that variables the elevations 2000-2300 m, the western aspects, and the sealed road, respectively, are the most important factors influencing the selection of Goitered Gazelle habitat in Bidouyeh protected area. According to the modeling, approximately 15% of the Bidouyeh protected area is a suitable habitat for Goitered Gazelle.

Keywords: Biomapper, Bidouyeh Protected Area, ENFA, Goitered Gazelle, SDMs.

Introduction

Species distribution models (SDMs) estimate the relationship between the presence of species and environmental variables at sites (Franklin, 2010; Elith et al., 2011; Wunderlich et al., 2019). Currently, habitat suitability (HS) models have received much attention (Boyce and McDonald 1999; Guisan & Zimmermann, 2000; Manly et al., 2002; Pearce & Boyce, 2006; Barbosa et al., 2021; Sharma et al., 2018; Evcin et al., 2049; Cisneros-Araujo et al., 2021). Predictive geographical modeling has recently gained importance as a tool for estimating HS within a wide range of biodiversity and management (Phillips et al., 2006; Allouche et al., 2008; Skov et al., 2008; Song et al., 2013; Evcin et al., 2019). Conservation biology (Phillips & Dudík, 2008; Hu and Jiang, 2010; Elith et al. 2011), managing endangered species (Palma et al. 1999; Sanchez-Zapata & Calvo, 1999), ecosystem restoration (Mladenoff et al., 1997), species re-introductions (Breitenmoser et al., 1999; Cassinello et al., 2006), population viability analyses (Akcakaya et al., 1995; Akcakaya & Atwood, 1997) and human-wildlife conflicts (Le Lay et al., 2001) often rely on habitat-suitability modeling (Hirzel et al., 2001).

The HS modeling relates a species' occurrence to a set of environmental variables to model its ecological niche (Hirzel & Le Lay 2008) and predict its potential distribution (Soberón, 2007; Hirzel, 2008; Hirzel & Le Lay, 2008) Producing accurate predictions with available data is challenging due to the lack of information regarding the great majority of species. To solve the limitations in data, several statistical techniques and computer tools for data management have been combined to obtain information about the conservation status, geographic distribution, and habitat requirements of endangered species (Chefaoui & Lobo, 2007).

The recent development of Geographic Information Systems (GIS) has made it easier the study of habitat selection, by taking into account more explicitly the spatial dimension of the data in the analyses (Manly et al., 2002), which is highly developed in the field of Ecology (Guisan & Zimmermann, 2000; Calenge, 2006; Traill & Bigalke, 2006; Guilbault et al., 2019). The predictive habitat models attempt to provide detailed predictions of distributions by relating presence or absence of a species to a set of environmental predictors that are likely to influence the suitability of the environment for the focal species (Guisan & Zimmerman, 2000; Araújo & New, 2007; Elith et al., 2006; Franklin, 2010; Naimi et al., 2014). For most of the available methods, accurate sampling of the presence/absence of the species is crucial (Hirzel et al., 2002). Methods that predict species distribution based on presence-only data for the area focus more on the presence area (Guisan & Zimmerman, 2000; Dormann et al., 2007). One statistical method that can be used to generate habitat suitability maps, is the Ecological Niche Factor Analysis (ENFA) by using the Biomapper software (Hirzel, 2001). ENFA generates HS maps by relating species presence data with background environmental variables to determine the species' niche (Hirzel et al., 2002; Jiménez-Valverde et al., 2008; Rouhi et al., 2018; Hoseinnejad et al., 2019). This program also incorporates descriptive statistics, as well as a GIS, for generating HS maps (Traill & Bigalke, 2006; Estrada-Pena & Venzal, 2007). The ENFA has been utilized to generate HS maps for terrestrial flora and fauna (Hirzel, 2001; Zaniewski et al., 2002; Hirzel & Arlettaz, 2003a; Reutter et al., 2003). This modeling approach is extremely useful when absent data are not available (Cassinello et al., 2006), unreliable, and ecologically meaningless (Reutter et al., 2003; Bryan & Metaxas, 2007). The ENFA compares the geographical distribution of species for presence data (Hirzel et al., 2001) which species presence has been recorded with the whole area (Cassinello et al., 2006; Skov et al., 2008). The ENFA summarizes all predictors into a few uncorrelated factors retaining most of the information Therefore, the factors have an ecological meaning: the first factor is the ‘Marginality’ and reflects the direction in which the species niche mostly differs from the available conditions in the global area. Subsequent factors represent ‘Specialization’ (Hirzel & Le Lay, 2008). They are extracted successively by computing the direction that maximizes the ratio of the variance of the global distribution to that of the species distribution. The species distribution on these factors is used to compute an HS index for any set of descriptor values (Hirzel et al., 2001). The purpose of this study was to determine the optimal habitat for Goitered Gazelles in Bidouyeh Protected Area and to investigate the effective variables in determining the optimal habitat to find a reasonable relationship between management and conservation of this species in the area.

Material and methods

Target species

Goitered Gazelle (*Gazella subgutturosa*) is one of the species of the Bovidae family and has been classified as Vulnerable (IUCN Red List, 2017), but evaluated as Endangered at the regional level (Yusefi et al., 2019). Human activities have increasingly threatened the populations of Large-body ungulates (Olson et al., 2010), because of ongoing declines due to poaching, habitat degradation from overgrazing, competition with livestock, and industrial and commercial development. The decline is estimated to have exceeded 30% in the last 14 years (three generations), (IUCN Red List, 2017).

Study Area

Bidouyeh Protected Area with an area of 1680.33 Km^2 is located in Kerman province, Iran. this area is in the geographical range of 56˚19′ to 56˚59′ eastern longitude and 29˚53′ to 30˚17′ northern latitudes (Fig. 1).

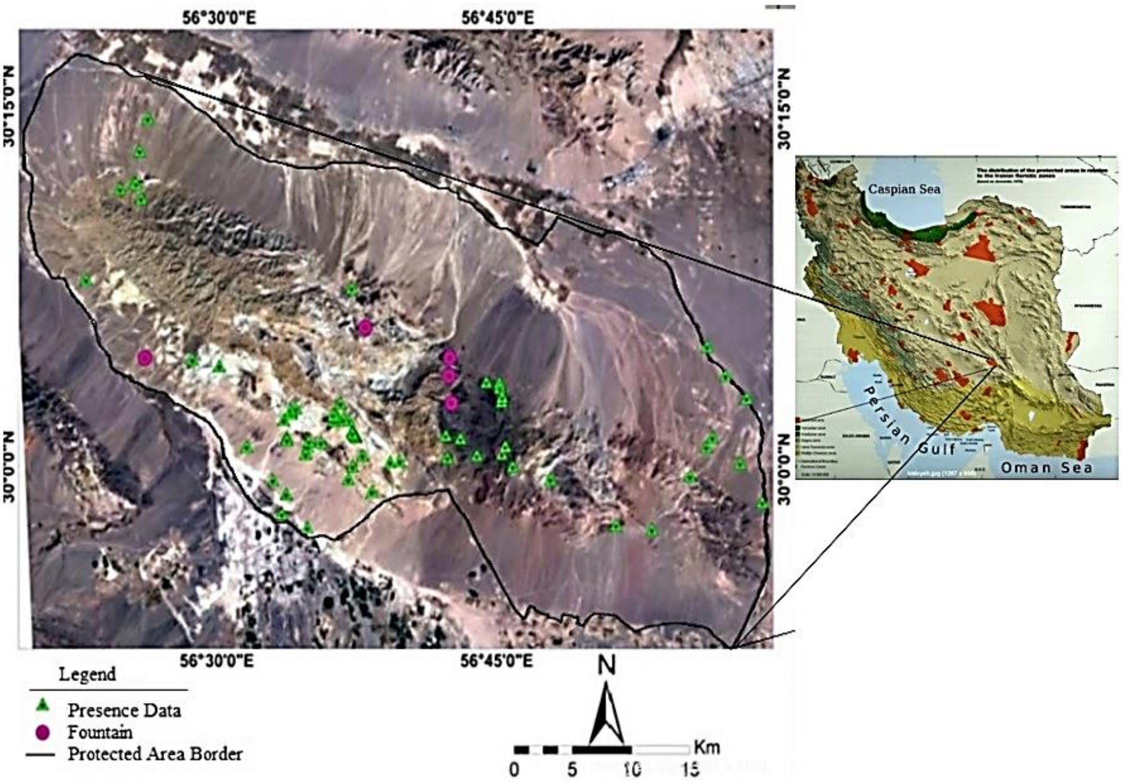

Figure 1. Location map of the study area and presence data

Occurrence and Environmental Data

Lack of information about areas where species are not present complicates the use of conventional environmental modeling tools (Guisan & Zimmermann, 2000) Because some of these models rely on presence and absence data (Segurado & Araujo, 2004). For this reason, a modeling technique that does not require absence data was used to identify the environmental factors that explain both the distribution of *Gazella subgutturosa* in Bidouyeh as well as areas of HS: Ecological Niche Factor Analysis (Hirzel et al., 2002; Santos et al., 2006). We used the Ecological Niche Factor Analysis (Hirzel et al., 2002) to elaborate on the presence-only models. This model was generated from the presence-data and independent environmental variables selected and surveyed in this study include; topographic and geomorphological, vegetation, water resources, and human development variables such as villages and roads. Also, by using the DEM map, slope percentages and slope directions were prepared, elevation sea level and slope percentage maps were classified based on the distribution of recorded points of presence in the area in GIS software. Data layers of all variables were converted to raster maps after digitization with 30×30 m cell size. All variables (including domain classes, vegetation classes) were transformed into spatial variables. Biomapper software was used to perform ecological niche factor analysis, which was a combination of statistical software and geographic information system format. Idrisi software is compatible. All layers were uniformly separated and normalized by Box-Cox transformation to be usable by software. The Correlation of environmental variables was examined to include only variables with less than 85% correlation. Because the presence of variables with a correlation of more than 85% in the analyzes can lead to large eigenvalues in the results. If there were variables with a correlation of more than 85%, one of the variables was removed by expert opinion. The ENFA was performed using BIOMAPPER 3.1 software (Hirzel et al., 2004). The ENFA modeling technique computes a group of uncorrelated factors with ecological meaning (marginality and specialization), summarizing the main environmental gradients in the region considered. The HS is modeled using the selected factors to estimate the ecogeographic degree of similarity between each grid square and the environmental preferences of the species. This method estimates the probability that a given cell belongs to the environmental domain of the presence-only observations. The resulting HS map has scores (HS values) that vary from 0 (minimum HS) to 100 (maximum), (Chefaoui & Lobo, 2007). The occurrence locations of Goitered Gazelle were collected during a 2-years field survey and by using the Global Positioning System (GPS). The X and Y coordinates of the presence data received by GPS collars were used to build the model, and a portion of occurrence records was used to validate the model accuracy. To collect occurrence records, the distance sampling method (Waltert et al., 2008; Thomas et al., 2010; Wu et al., 2016), direct observations, footprints, repose imprints, feces, and tracks were used.

Results

The ENFA principle is to compare the distributions of the predictor variables between the species distribution and the whole area (Chefaoui & Lobo, 2007). Several methods developed on these principles show the increase in computer powerful allowing ecologists to include more and more details (Hirzel & Arlettaz, 2003b; Wisdom et al., 2020). As a result of the increased availability of Geographic Information Systems (GIS) and powerful statistical tools, it is now possible to quantify species-environment relationships and use these to predict the geographical distribution of species from known occurrences (Guisan & Zimmermann, 2000; Lehmann et al., 2002; Rushton et al., 2004; Gür, 2013; Fattahi er al., 2014; Kurnaz & Şahin, 2021). The resultant HS maps produced by Biomapper are a spatial representation of HS values (0-100%) calculated for every 30 m cell in the study area (n=65), we used all available presence data to produce a final HS model as recommended by Fielding and Bell (1997).

Specialization indicates the extent to which species are specialized in the use of area resources (Hirzel et al., 2001). Various combinations of environmental variables were used to produce the habitat utility model to select the best set of variables. The criterion for selecting the best variables is the contribution of the model created with them (the final model) to the justification of species specialization and model validity. The obtained value for more than one indicates that the species prefers the set of environmental conditions above the mean of the region. A degree of specialization greater than one also indicates that the species is dependent on a limited range of environmental conditions in the region and is specialized in the use of habitat resources. Using the results obtained from ecological niche factor analysis, the HS map can be calculated. The HS threshold, the value above which habitat supports Goitered Gazelle, then allowed us to consider only the area of habitat predicted to be more suitable than the threshold (Long et al., 2008). The first factor, called Marginality, described the distance of the species from the mean habitat in the study area (Hirzel et al., 2002; Santos et al., 2006). Goitered Gazelle specialization rates (more than 2.383) indicate that the species is semi-specialized in the use of habitat resources (Table 1).

Table 1. Specialization and Marginality results for Goitered Gazelle

Number of variables used	Number of factors selected	The specialization explained by Factors	The rate of tolerance	The rate of Specialization	The rate of Marginality
20	4	67	0.42	2.383	0.752

An appropriate algorithm must be selected to calculate HS. In the software Biomapper, algorithms of middle, geometric mean, and harmonic mean are presented to calculate HS (Hirzel & Arlettaz, 2003a; Hirzel et al., 2004). To evaluate the accuracy of the predictions of the model produced Boyce index and level-adjusted frequency chart are used. the Boyce index can improve the interpretation and utilization of HS models (Hirzel et al., 2006). Based on this index, the best algorithm can be selected to determine the classification threshold. Thus, the higher the algorithm and the lower the standard deviation, the more appropriate the index. The HS output map consists of a continuous map of values between the interval 0 to 100, which increases as the closer to 100 (Fig. 2), resulting in higher suitability class numbers. By interpreting the frequency diagram adjusted by surface, one can determine the threshold of suitability and divide the habitat into desirable and undesirable classes (Hirzel et al., 2006). In this study, by comparing the numbers obtained from different algorithms (Table 2) and adjusted frequency diagram. The harmonic algorithm was used to classify habitat (Fig. 3).

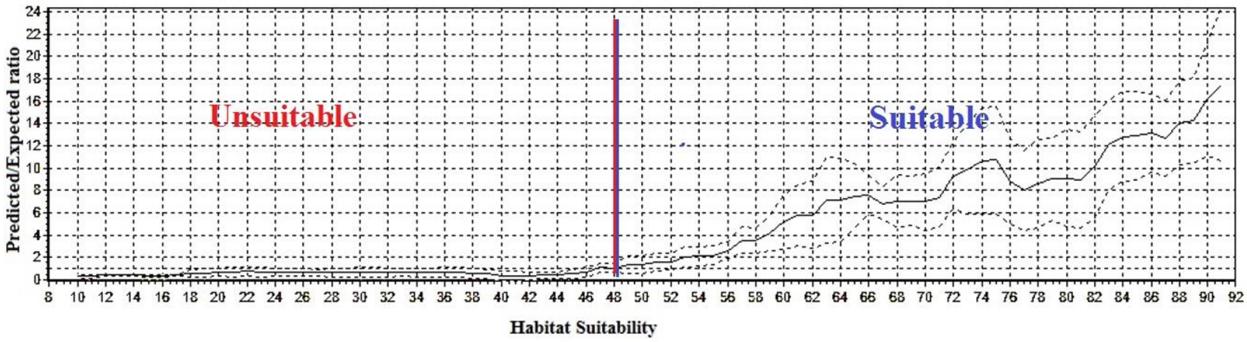

Figure 2. level-adjusted frequency diagram based on the harmonic algorithm

Table 2. Boyce index calculated from different algorithms

standard deviation ± Boyce index		
Harmonic mean	geometric-mean	Medians
0.92±0.03	0.44±0.019	0.12±0.39

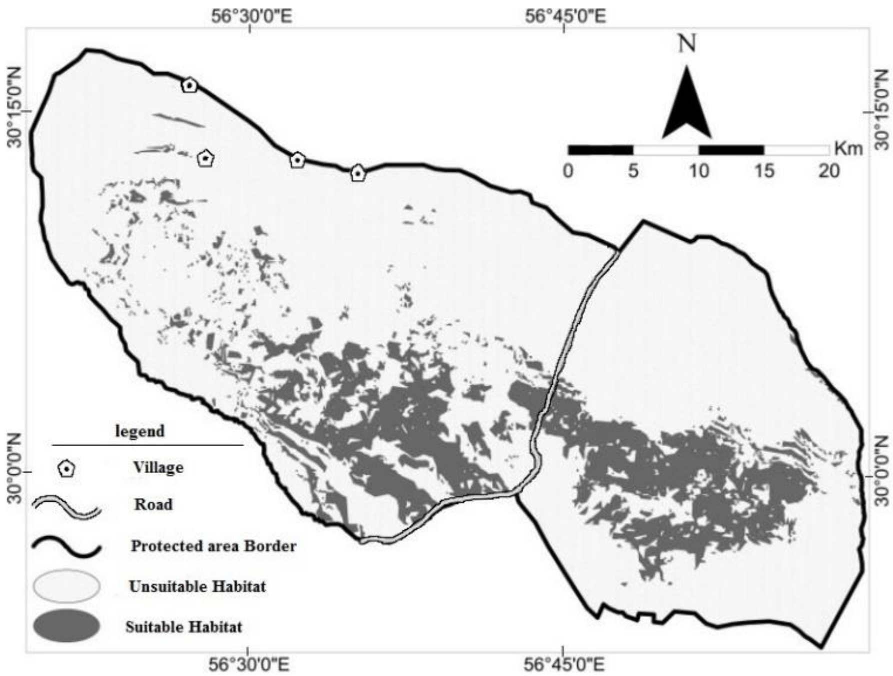

Figure 3. Habitat suitability map using Ecological Niche Factor Analysis

In the ecological niche factor analysis modeling, the factors are produced by the numbers of variables used in the analysis, the first factor explaining 100% Marginality and partial specialization, and other factors of species' specialization (Hirzel et al., 2001). The software calculates the number of factors that play the most role in explaining species specialization can be identified using the Broken-stick (MacArthur 1957). Score matrices are also provided during factor analysis, indicating the role of each variable in species HS. The score matrix produced in Table 3 shows the contribution of each environmental variable to the species HS. According to Table 3, with 19% Marginality, the first factor 21% specialization, the second factor 15%, and the third factor 12%. These three factors together account for 48% specialization of the Goitered Gazelle.

Table 3. Matrix scoring ecological niche factor analysis model

Environmental variables	Marginality factor 19%	Specialization		
		First factor 21%	*The second factor* is 15%	*Third factor* 12%
Distance to the village regions	0.134	0.214	-0.544	0.109
Distance to the irrigated farming	-0.062	0.234	-0.021	0.008
Distance to the eastern aspects	-0.14	0.1	0.006	0.033
Distance to the northern aspects	-0.171	0.058	0.011	0.00
Distance to the southern aspects	-0.202	-0.226	-0.142	-0.074
Distance to the western aspects	-0.327	0.209	0.165	0.012
Distance to the bare lands	-0.22	-0.217	-0.079	0.003
Distance to the water resource	-0.033	0.013	0.122	-0.08
Distance to the elevations < 1700 m	0.322	-0.403	0.582	-0.294
Distance to the elevations 1700-2000m	0.294	-0.216	-0.147	-0.042
Distance to the elevations 2000-2300m	-0.429	-0.174	-0.115	-0.051
Distance to the elevations more than 2300m	-0.293	-0.009	0.012	-0.127
Distance to the dry farming	-0.012	0.24	-0.119	0.517
Distance to the pastures with medium density	-0.206	-0.125	-0.044	0.618
Distance to the sealed road	-0.311	-0.021	0.15	-0.31
Distance to the rocks regions	0.122	0.646	-0.438	0.302
Distance to the areas with a slope of 0-2%	0.07	0.092	0.14	-0.133
Distance to the areas with a slope of 2-5%	-0.234	0.073	0.041	-0.018
Distance to the areas with a slope of 5-10%	-0.197	-0.005	0.092	-0.018
Distance to the areas with a slope of 10-30%	-0.14	-0.022	-0.025	-0.111

Positive values of laterality indicate that the studied species prefers values more than the mean of habitat for that variable while negative values indicate preferences of values less than the mean of habitat. Specialization indicates the expertise of species in the use of regional resources (Hirzel et al., 2001). This modeling technique, computes a group of uncorrelated factors with ecological meaning, summarizing the main environmental gradients in the region considered (Chefaoui & Lobo, 2007). The models' evaluation consists of quantifying how accurately the map is predicting the presence and absence of the species (Buckland & Elston, 1993; Manel et al., 2001), as given by a set of evaluation points (Hirzel et al., 2006).

Discussion

Studying habitats has key importance for the development of wildlife conservation policies, evaluation, and conservation (Suleman et al., 2020). The marginality is a measure of the departure between the average of the species distribution and the average of the total distribution (Biomapper). The positive and negative values of each variable in the marginality of the matrix scoring table indicate the extent to which a variable is effective in the mean Goitered Gazelle distribution so that the positive numbers indicate a higher marginality and the negative numbers indicate a lower marginality. Based on the amount of the marginality rate, the value calculated for Goitered Gazelle in Bidouyeh protected area was 0.752, which indicates the low tendency of this species to select marginal habitats. Also, specialization is a measure of the choosiness of the species about the available range of the environmental variables. Moreover, for more reassurance, tolerance is defined as the inverse of specialization. This factor varies between 0 and 1, and the closer it is to 0, the species studied act more specialized toward environmental variables. The tolerance factor for Goitered Gazelle was 0.46. This factor indicates that the species has a low tolerance within its environmental conditions, in other words, Goitered Gazelle specializes in environmental variables in Bidouyeh protected area. The scoring matrix table and its results show that variables the elevations 2000-2300 m, the western aspects, and the sealed road, respectively, are the most important factors influencing the selection of Goitered Gazelle habitat in Bidouyeh protected area. Negative numbers for the above variables indicate that by increasing the distance from these variables, the desirability of the habitat decreases so that Goitered Gazelle in the study area prefer the altitude range between 2000 to 2300 meters. In the above-mentioned class, besides the lowland areas, there is a checkpoint and farm of environment organization, this has made this variable attractive to the species because it has created a safe area for the species. The results gained from this study are in agreement with Radnezhad et al (2016) because their results showed that most of the desirable habitats of this species are in the range of environmental checkpoints. The positive numbers in the scoring matrix indicate that increasing the distance from the variable will increase the desirability of the habitat. The variable, areas with a height of fewer than 1700 meters, are the most important factor in the table which shows that increasing the distance from this variable will increase the desirability. The main reason for this is the existence of residential areas and rainfed farms are among the factors that have made these areas less important for Goitered Gazelles. Roads acted as a negative factor in habitat suitability for Gazelles (Shams-Esfandabad et al., 2019), but in this study, roads played an important role in habitat suitability the reason can be attributed to the Kerman-Bardsir Road, which divides the region into two parts, as well as the presence of water sources around it. Because water resources are very important in desirability (Ashouri-Rad et al., 2018). Also, considering the value of the areas with a slope of 0-2% in the scoring matrix table, it seems that this variable is not very important in the desirability of species habitat. The Boyce index was higher in the harmonic algorithm than in other algorithms, also the level adjustment frequency diagram was used to test the validity of the model. Based on this diagram, the harmonic algorithm was the most ideal algorithm for classifying the desirability map.

Conclusion

Desirable habitat indicates the importance and interaction of all environmental classes used in modeling. The study showed that approximately 15% of the area is considered a favorable habitat for Goitered Gazelle, mostly located in the south of the region. The present study showed that Goitered Gazelles did not avoid sealed roads under normal conditions in the area and increased HS by decreasing the distance from this variable. The variable presence of water around the road has made these areas attractive. The results of the study showed that favorable Goitered Gazelles habitats are located on both sides of Kerman-Bardsir Road. It is suggested that an overpass and/or underpass be built on the Kerman-Bardsir Road to prevent species separation and increase interbreeding (reduction of genetic diversity).

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References

Akcakaya, H. R., & Atwood, J. L. (1997). A habitat-based metapopulation model of the California gnatcatcher. Conservation Biology, 11(2), 422-434. https://doi.org/10.1046/j.1523-1739.1997.96164.x.

Akcakaya, H. R., McCarthy, M. A., & Pearce, J. L. (1995). Linking landscape data with population viability analysis: management options for the helmeted honeyeater Lichenostomus melanops cassidix. Biological Conservation, 73(2), 169-176. https://doi.org/10.1016/0006-3207(95)90045-4.
Allouche, O., Steinitz, O., Rotem, D., Rosenfeld, A., & Kadmon, R. (2008). Incorporating distance constraints into species distribution models. Journal of Applied Ecology, 45(2), 599-609. https://doi.org/10.1111/j.1365-2664.2007.01445.x.
Araújo, M. B., & New, M. (2007). Ensemble forecasting of species distributions. Trends Ecology Evolution, 22(1), 42-47. https://doi.org/10.1016/j.tree.2006.09.010.
Ashouri Rad, A., Rahimi, R., & Shams Esfandabad, B. (2017). Modeling habitat suitability for Goitered Gazelle (Gazella subgutturosa) in Sorkheh Hesar national park. Journal of Environmental Science and Technology, 19(4), 193-207.
Barbosa, M. A., Sillero, N., Martínez-Freiría, F., & Real, R. (2012). Ecological Niche Models in Mediterranean Herpetology: Past, Present and Future. Ecological Modeling. 173-204.
Boyce, M. S., & McDonald, L. L. (1999). Relating populations to habitats using resource selection functions. Trends Ecology Evolution, 14(7), 268-272. https://doi.org/10.1016/S0169-5347(99)01593-1.
Breitenmoser, U., Zimmermann, F., Olsson, P., Ryser, A., Angst, C., Jobin, A., & Breitenmoser-Wursten, C. (1999). Beurteilung des Kantons st.Gallen als habitat fur den luchs. KORA, Bern.
Bryan, L. T., & Metaxas, A. (2007). Predicting suitable habitat for deep-water gorgonian corals on the Atlantic and Pacific Continental Margins of North America. Marine Ecology Progress Series, 330. 113-126. doi:10.3354/meps330113.
Buckland, S. T., & Elston, D. A. (1993). Empirical models for the spatial distribution of wildlife. Applaid Ecology, 30(3), 478-495. https://www.jstor.org/stable/2404188.
Calenge, C. (2006). The package “adehabitat” for the R software: A tool for the analysis of space and habitat use by animals. Ecological Modelling, 197(3-4), 516-519. https://doi.org/10.1016/j.ecolmodel.2006.03.017.
Cassinello, J., Acevedo, P., & Hortal, J. (2006). Prospects for population expansion of the exotic aoudad (Ammotragus lervia; Bovidae) in the Iberian Peninsula: clues from habitat suitability modeling. Diversity and Distributions, 12(6), 666-678. https://doi.org/10.1111/j.1472-4642.2006.00292.x.
Chefaoui, M. R., & Lobo, M. J. (2007). Assessing the conservation status of an Iberian moth using pseudo-absences. Wildlife Management, 71(8), 2507-2516. https://doi.org/10.2193/2006-312.
Cisneros-Araujo, P., Goicolea, T., Mateo-Sánchez, C. M., García-Viñás, I. J., Marchamalo, M., Mercier, A., & Gastón, A. (2021). The Role of Remote Sensing Data in Habitat Suitability and Connectivity Modeling: Insights from the Cantabrian Brown Bear. remote sensing. 13(1138), 1-22. https://doi.org/10.3390/rs13061138.
Dormann, F. C., McPherson, M. J., Araujo, B. M., Bivand, R., Bolliger. J., Carl, G., Davies, G. R., Hirzel, A., Jetz, W., Kissling, W. D., Kuhn, I., Ohlemuller, R., Peres-Neto, R. P., Reineking, B., Schroder, B., Schurr, M. F., & Wilson, R. (2007). Methods to account for spatial autocorrelation in the analysis of species distributional data: a review. Ecograph, 30(5), 609-628. https://doi.org/10.1111/j.2007.0906-7590.05171.x.
Elith, J., Graham, H. C., Anderson, P. R., Dudik, M., Ferrier, S., Guisan, A., Hijmans, J. R., Huettmann, F., Leathwick, R. J., Lehmann, A., Loiselle, A. B., Manion, G., Moritz, C., Nakamura, M., Nakazawa, Y., Overton, M. M. J., Peterson, T. A., Phillips, J. S., Richardson, K., Scachetti-Pereira, R., Schapire, E. R., Soberon, J., Williams, S., Wisz, S. M., & Zimmermann, E. N. (2006). Novel methods improve the prediction of species

distributions from occurrence data. Ecography, 29(2), 129-151. https://doi.org/10.1111/j.2006.0906-7590.04596.x.

Elith, J., Phillips, J. S., Hastie, T., Dudık, M., Chee, E. Y., & Yates, J. C. (2011). A statistical explanation of MaxEnt for ecologists. Diversity and Distributions, 17(1), 43-57. https://doi.org/10.1111/j.1472-4642.2010.00725.x.

Estrada-Pena, A., & Venzal, M. J. (2007). Climate niches of tick species in the Mediterranean region: modeling of occurrence data, distributional constraints, and impact of climate change. Medical Entomology, 44(6), 1130-1138. https://doi.org/10.1093/jmedent/44.6.1130.

Evcin, O., Kucuk, O., & Akturk, E. (2019). Habitat suitability model with maximum entropy approach for European roe (Capreolus capreolus) in the Black Sea Region. Environmental Monitoting Assessment, 191, 669. https://doi.org/10.1007/s10661-019-7853-x.

Evcin, O., Kucuk, O., & Akturk, E. (2019). Habitat suitability model with maximum entropy approach for European roe deer (Capreolus capreolus) in the Black Sea Region. Environmental Monitoring Assessment. 191(669), 1-13. https://doi.org/10.1007/s10661-019-7853-x.

Fattahi, R., Ficetola, G. F., Rastegar-Pouyani, N., Avcı, A., Kumlutaş, Y., Ilgaz, Ç., & Hosseinian Yousefkhani, S. S. (2014). Modeling the potential distribution of the Bridled Skink, Trachylepis vittata (Olivier, 1804), in the Middle East. Zoology in the Middle East, 60(3), 208-216.

Fielding, A. H., & Bell, J. F. (1997). A review of methods for the assessment of prediction errors in conservation presence/absence models. Environmental Conservation, 24(1), 38-49. https://doi.org/10.1017/S0376892997000088.

Franklin, J. (2010). Mapping species distributions: spatial inference and prediction. Cambridge University Press Cambridge, UK.

Guilbault, E., Renner, I., Mahony, M., & Beh, E. (2019). Classification of unlabelled observations in Species Distribution Modelling using Point Process Models. https://doi.org/10.1101/651125.

Guisan, A., & Zimmermann, N. E. (2000). Predictive habitat distribution models in ecology. Ecological Modeling, 135(2-3), 147-186. https://doi.org/10.1016/S0304-3800(00)00354-9.

Gür, H. (2013). The effects of the Late Quaternary glacial-interglacial cycles on Anatolian ground squirrels: range expansion during the glacial periods? Biological Journal of the Linnean Society, 109(1), 19-32.

Hirzel, A. H. (2001). When GIS comes to life. linking landscape and population ecology for large population management modeling: the case of Ibex (Capra ibex) in Switzerland p. 106. Institute of Ecology, Laboratory for Conservation Biology, University of Lausanne, Lausanne, Switzerland.

Hirzel, A. H., & Arlettaz, R. (2003a). Modeling habitat suitability for complex species distribution by environmental distance geometric mean, Springer Verlag. Environmental Management, 32, 614-623. https://doi.org/10.1007/s00267-003-0040-3.

Hirzel, A. H., Halfer, V., & Metral, F. (2001). Assessing habitat suitability models with a virtual species. Ecological Modelling, 145(2-3), 111-121. https://doi.org/10.1016/S0304-3800(01)00396-9.

Hirzel, A. H., Hausser, J., & Perrin, N. (2004). Biomapper 3.1.Division of Conservation Biology, University of Bern. Available at http://www.unil.ch/biomapper.

Hirzel, A. H., Hausser, J., Chessel, D., & Perrin, N. (2002). Ecological niche factor analysis: How to compute habitat suitability maps without absence data?. Ecology, 83(7), 2027-2036. https://doi.org/10.1890/0012-9658(2002)083[2027:ENFAHT]2.0.CO;2.

Hirzel, H. A. (2008). Using the relative capacity to measure habitat suitability. Israel Journal of Ecology and Evolution, 54(3-4), 421-434. https://doi.org/10.1560/IJEE.54.3-4.421.
Hirzel, H. A., & Arlettaz, R. (2003b). Environmental-Envelope-based habitat-suitability models. 67-76.
Hirzel, H. A., & Le Lay, G. (2008). Habitat suitability modeling and niche theory. Journal of Applied Ecology, 45(5), 1372-1381. https://doi.org/10.1111/j.1365-2664.2008.01524.x.
Hirzel, H. A., Le lay, G., Helfer, V., Randin, Ch., & Guisan, A. (2006). Evaluating the ability of habitat suitability models to predict species presences. Ecological modeling, 199(2), 142-152. https://doi.org/10.1016/j.ecolmodel.2006.05.017.
Hoseinnejad, Z., Sheykhi, A., Goshtasb, H., Nezami, B., & Jahani, A. (2019). Habitat Evaluation of Alectoris Chukar using Ecological Niche Factor Analysis (ENFA)(Case study: Eshkevarte NO-Hunting Area). Environmental Researches, 10(19), 179-186.
Hu, J., & Jiang, Z. (2010). Predicting the potential distribution of the endangered Przewalski's gazelle. Zoology, 282(1), 54-63. https://doi.org/10.1111/j.1469-7998.2010.00715.x.
IUCN SSC Antelope Specialist Group. (2017). Gazella subgutturosa. The IUCN Red List of ThreatenedSpecies2017:e.T8976A50187422. http://dx.doi.org/10.2305/IUCN.UK.20172.RLTS.T8976A50187422.en.
Jiménez-Valverde, A., Gómez, F. J., Lobo, M. J., Baselga, A., & Hortal, J. (2008). Challenging species distribution models: the case of Maculinea nausithous in the Iberian Peninsula. Annual Zoology. Fennici, 45(3), 200-210. https://doi.org/10.5735/086.045.0305.
Kurnaz, M., & Şahin, M. K. (2021). A contribution to the biogeography and taxonomy of two Anatolian mountain brook newts, Neurergus barani and N. strauchii (Amphibia: Salamandridae) using ecological niche modeling. Turkish Journal of Zoology, 45(1), 54-64.
Le Lay, G., Clergeau, P., & Hubert-Moy, L. (2001). Computerized map of risk to manage wildlife species in urban areas. Environmental Management, 27, 451-461. https://doi.org/10.1007/s002670010161.
Lehmann, A., Overton, J. M., & Austin, M. P. (2002). Regression models for spatial prediction: their role for biodiversity and conservation. Biodiversity and Conservation, 11, 2085-2092. https://doi.org/10.1023/A:1021354914494.
Long, R. P., Zefania, S., French-Constant, H. R., & Szekely, T. (2008). Estimating the population size of an endangered shorebird, the Madagascar plover, using a habitat suitability model. Animal Conservation, 11(2), 118-127. https://doi.org/10.1111/j.1469-1795.2008.00157.x.
MacArthur, R. (1957). On the relative abundance of bird species, proceedings of the national academy of sciences of the United States of America. Proc Natl Acad Sci USA, 43(3), 293-295. https://dx.doi.org/10.1073%2Fpnas.43.3.293.
Manel, S., Williams, H. C., & Ormerod, S. J. (2001). Evaluating presence-absence models in ecology: the need to account for prevalence. Applaid Ecology, 38(5), 921-931. https://doi.org/10.1046/j.1365-2664.2001.00647.x.
Manly, B. F., McDonald, L. L., Thomas, D. L., McDonald, T. L., & Erickson, W. P. (2002). Resource selection by animals: statistical design and analysis for field studies, 2nd ed Kluwer Academic Publishers, Dordrecht.
Mladenoff, D. J., Haight, R. C., Sickley, T. A., & Wydeven, A. P. (1997). Causes and implications of species restoration in altered ecosystems. A spatial landscape projection of wolf population recovery. Bioscience, 47(1), 21-31. https://www.jstor.org/stable/1313003.
Naimi, B., Hamm, A. S. N., Groen, A. T., Skidmore, K. A., & Toxopeus, G. A. (2014). Where is positional uncertainty a problem for species distribution modeling?. Ecography, 37(2), 191-203. https://doi.org/10.1111/j.1600-0587.2013.00205.x.

Olson, K. A., Fuller, T. K., Mueller, T., Murray, M. G., & Nicolson, C. (2010). Annual movements of Mongolian gazelles: nomads in the eastern steppe. Arid Environments, 74(11), 1435-1442. https://doi.org/10.1016/j.jaridenv.2010.05.022.

Palma, L., Beja, P., & Rodgrigues, M. (1999). The use of sighting data to analyze Iberian lynx habitat and distribution. Applaid Ecology, 36(5), 812-824. https://doi.org/10.1046/j.1365-2664.1999.00436.x.

Pearce, J. L., & Boyce, M. S. (2006). Modeling distribution and abundance with presence-only data. Applaid Ecology, 43(3), 405-412. https://doi.org/10.1111/j.1365-2664.2005.01112.x.

Phillips, J. A., & Dudık, M. (2008). Modeling of species distributions with Maxent: new extensions and a comprehensive evaluation. Ecography, 31(2), 161-175. https://doi.org/10.1111/j.0906-7590.2008.5203.x.

Phillips, S. J., Anderson, R. P., & Schapire, R. E. (2006) Maximum entropy modeling of species geographic distributions. Ecological Modelling, 190(3-4), 231-259. https://doi.org/10.1016/j.ecolmodel.2005.03.026.

Radnezhad, H., Moshtaghie, M., Amoeian, I., & Jamali, A. (2016). Modeling the distribution of (Gazella subgutturosa) in Bamboo National Park with maximum entropy methods: (MAXENT). Journal of Animal Environment, 8(2), 17-27.

Reutter, B. A., Helfer, V., Hirzel, H. A., & Vogel, P. (2003). Modeling habitat-suitability on the base of museum collections: an example with three sympatric Apodemus species from the Alps. Biogeography, 30(4), 581-590. https://doi.org/10.1046/j.1365-2699.2003.00855.x.

Rouhi, H., Tahsini, H., Salman Mahini, A., & Rezaei, H. (2018). Modeling Habitat Suitability of Persian Leopard (Pantera pardus saxicolous) in Khoshyeilagh Wildlife refuge using ENFA method. Journal of Animal Environment, 10(4), 13-22.

Rushton, S. P., Ormerod, S. J., & Kerby, G. (2004). New paradigms for modeling species distributions?. Applied Ecology, 41(2), 193-200. https://doi.org/10.1111/j.0021-8901.2004.00903.x.

Sanchez-Zapata, J. A., & Calvo, J. F. (1999). Raptor distribution about landscape composition in semi-arid Mediterranean habitats. Applaid Ecology, 36(2), 254-262. https://doi.org/10.1046/j.1365-2664.1999.00396.x.

Santos, X., Brito, C. J., Sillero, N., Pleguezuelos, M. J., Llorente, A. G., Fahd, S., & Parellada, X. (2006). Inferring habitat-suitability areas with ecological modeling techniques and GIS: A contribution to assess the conservation status of Vipera latest. Biological Conservation, 130(3), 416-425. https://doi.org/10.1016/j.biocon.2006.01.003.

Segurado, P., & Araujo, M. B. (2004). An evaluation of methods for modeling species distributions. Biogeography, 31(10), 1555-1568. https://doi.org/10.1111/j.1365-2699.2004.01076.x.

Shams-Esfandabad, B., Ahmadi, A., & Yusefi, T. (2019). Seasonal changes in the distribution of suitable habitats for the Persian goitered Gazelle (Gazella subgutturosa) in Isfahan Province. Journal of Wildlife and Biodiversity, 3(1): 58-65.

Sharma, S., Arunachalam, K., Bhavsar, D., & Kala, R. (2018). Modeling habitat suitability of Perilla frutescens with MaxEnt in Uttarakhand—A conservation approach. Journal of Applied Research on Medicinal and Aromatic Plants. 2-8. https://doi.org/10.1016/j.jarmap.2018.02.003.

Skov, H., Humphreys, E., Garthe, S., Geitner, K., Gremillet, D., Hamer, C. K., Hennicke, J., Parner, H., & Wanless, S. (2008). Application of habitat suitability modeling to tracking data of marine animals as a means of analyzing their feeding habitats. Ecological modeling, 212(3-4), 504-512. https://doi.org/10.1016/j.ecolmodel.2007.11.006.

Soberón, J. (2007). Grinnellian and Estonian niches and geographic distributions of species. Ecological Letter, 10(12), 1115-1123. https://doi.org/10.1111/j.1461-0248.2007.01107.x.

Song, W., Kim, E., Lee, D., Lee, M., & Jeon, S. (2013). The sensitivity of species distribution modeling to scale differences. Ecol Mod, 248, 113-118. https://doi.org/10.1016/j.ecolmodel.2012.09.012.

Suleman, S., Khan, A. W., Anjum, M. K., Shehzad, W., & Hashemi, M. G. S., (2020). Habitat suitability index (HSI) model of Punjab urial (Ovis veggie punjabiensis) in Pakistan. Animal Plant Science, 30(1).

Thomas, L., Buckland, S. T., Rexstad, E. A., Laake, J. L., Strindberg, S., Hedley, S. L., Bishop, J. R. B., Marques, T. A., & Burnham, K. P. (2010). Distance software: design and analysis of distance sampling surveys for estimating population size. Applied Ecology, 47, 5-14. https://doi.org/10.1111/j.1365-2664.2009.01737.x.

Traill, W. L., & Bigalke, C. R. (2006). A presence-only habitat suitability model for large grazing African ungulates and its utility for wildlife management. Ecology, 45(3), 347-354. DOI: 10.1111/j.1365-2028.2006.00717.x.

Waltert, M., Meyer, B., Shanyangi, M. W., Balozi, J. J., Kitwara, O., Qolli, S., Krischke, H., & Muehlenberg, M. (2008). Foot surveys of large mammals in woodlands of western Tanzania. Wildlife Management, 72(3), 603-610. https://doi.org/10.2193/2006-456.

Wisdom, M. J., Nielson, M. R., Rowland, M. M., & Proffitt, M. K. (2020). Modeling Landscape Use for Ungulates: Forgotten Tenets of Ecology, Management, and Inference. Frontiers in Ecology and Evolution. 8(211), 1-19. DOI: 10.3389/fevo.2020.00211.

Wu, W., Li, Y., & Hu, Y. (2016). Simulation of potential habitat overlap between red deer (Cervus elaphus) and roe deer (Capreolus capreolus) in northeastern China. PeerJ, 4, e1756. https://doi.org/10.7717/peerj.1756.

Wunderlich, F. R., Lin, P. Y., Anthony, J., & Petway, R. J. (2019). Two alternative evaluation metrics to replace the true skill statistic in the assessment of species distribution models. Nature Conservation, 35, 97-116. doi:10.3897/natureconservation.35.33918.

Yusefi, H. G., Faizolahi, K., Darvish, J., Safi, K., & Brito, C. J. (2019). The species diversity, distribution, and conservation status of the terrestrial mammals of Iran. Journal of Mammalogy. 100(1):55–71. DOI:10.1093/jmammal/gyz002.

Zaniewski, A., Lehmann, A., & Overton, J. M. (2002). Predicting species spatial distributions using presence-only data: A case study of native New Zealand ferns. Ecological Modelling, 157(2-3), 261-280. https://doi.org/10.1016/S0304-3800(02)00199-0.