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Identifying habitat patches and suitability for roe deer, *Capreolus capreolus* as a protected species in Iran

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ABSTRACT

Species distribution models (SDMs) are a tool for the management of wildlife including the roe deer, *Capreolus capreolus,* as an elusive and national protected herbivore in Iran. Habitat suitability modeling can be one of the most important steps to protect this species. This study was carried out to evaluate the potential distribution of the roe deer in the north and northwest of Iran and to identify the important habitat patches for this species. The habitat suitability modeling was applied 95 presence points and nine environmental variables by MaxEnt®. Thereafter, we focused on the extraction of important habitat patches based on presence points. The land cover, as the most important variable on the habitat suitability model of roe deer and its highest probability presence, is classified as the high and moderate densities in the forest. Habitat patches covered an area of about 4467.81 km^2 (i.e., 6.04%of the study area). The largest habitat patch, covering an area about 4022 km^2, created a continuous patch in the east of the study area. There were several inter-connected small patches in the most western part of the study area in Arasbaran forests. Actually, Habitat patches should be taken into consideration in the conservation of the roe deer.

Keywords: Animal conservation, Dense forests, Habitat modeling, MaxEnt.

INTRODUCTION

The expansion of human activities in landscapes had a profound impact on the habitat and conditions of natural populations (Runel *et al*. 1998). It may also have serious negative effects on the long-term life of endemic populations and ultimately lead to the extinction of species (Bagilsma *et al*. 2000; Coulon *et al*. 2004). On the other hand, endangered species are often exposed to several threats, thus evaluating them and planning for their conservation are also complex and require a variety of approaches, including demographics, population genetics, and ecological modeling (Gardner *et al*. 2007). Analyzing the existing habitat-species relationship is a useful method for improving management and ascertaining the impacts of habitat change. Modeling is repeatedly suggested in scientific contexts in order to understand wildlife population dynamics and to predict different further scenarios. The importance of ungulates in biodiversity and the rampant volume of hunting, suggested that ungulates are in need of conservation management. Habitat modeling of wildlife species is in the center of ecological studies and essential for wildlife conservation and management (Guisan & Zimmermann 2000). Species distribution models (SDMs) can be used as a tool for animal conservation, including the conservation of threatened species, studying animals' habitats and reservoir design as well as habitat assessment (Engler *et al*. 2004; Lobo *et al*. 2010), especially for elusive species (Almasieh *et al*. 2016) such as roe deer in dense forests. The MaxEnt approach requires only presence data (Graham *et al*. 2004) and performs better than other methods (Elith *et al*. 2006; Phillips *et al*. 2006).

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Roe deer, *Capreolus capreolus* is classified as a "least concern" species in the IUCN Red List because of its vast distribution and increasing trend in a number of individuals (IUCN, 2018). Poaching and habitat destruction are the main threats to this species (Karami *et al*. 2015). Grey wolf (*Canis lupus*), Persian leopard (*Panthera pardus saxicolor*) and jungle cat (*Felis chaus*) are the main predators for the roe deer especially for the fawns of this species (Karami *et al.* 2015). Given that roe deer is recognized as an ecosystem engineer (Côté *et al*. 2004; Martin 2018), it has a great impact on ecosystem physics and, consequently, the absence of this species can cause major changes in the ecosystem level. On the other hand, due to the solvency of the meat of this deer, unauthorized hunting and fragmentation of its habitat are considered as the greatest risk for the survival of this forest-dependent species (Firouz 1999).

Based on Kabiri *et al*. (2017), roe deer prefer forest habitats and communities at the early stage of ecological succession (i.e., young forests) or forests between low lands and mountainous areas, hence the compactness of forests determines habitat suitability for the roe deer. On the other hand, based on Morellet *et al*. (2011), both the availability and distribution of resources conditioned habitat selection and, so deer usually prefer open and semi-open habitats. Therefore, The GIS-based approach is applicable for assessing habitat suitability of this species and could solve these paradoxes. Based on recent studies, roe deer live in the Hyrcanian and Arasbaran forests in the north and northwestern Iran as well as a small patch in western Iran (i.e., oak forests in Ouramanat and Javanroud protected areas) (Karami *et al.* 2015).

So far, a few studies have been conducted about this species in Iran. Inceichen *et al*. (2015) studied twelve roe deer using GPS collars in Switzerland and determined their habitat, home range and nuclear habitat areas reporting that this species prefers the dense cover of the canopy at night and coniferous trees in general. Mirsanjari & Khalvandi (2017), also used the Maximum Entropy (MaxEnt) method to determine the desirable habitat of this species in the summer and autumn seasons in Bouzin and Markhil protected areas. Their results showed that the habitat of this species was not uniform but was fragmented. They found that village, road, and elevation had the highest impact on the distribution of this species. Roe deer was also studied in both autumn and winter seasons by Bakhshi *et al*. (2015), at Golestan national park, Iran reporting that this species is influenced by several variables such as elevation, slope, aspect, water resources and human effects. Pandin & Cesaris (1992) performed a study in the Monte Carso region (Italy) on two young male roe deer reporting that they avoid areas with open vegetation (grassland and plain lands) and urban areas. Welch (1990) also studied the *Cervus elaphus* and roe deer habitats in Scottish poplar fields from 1978 to 1984 finding that the least used areas were forest ones without vegetation on land and also observing that the areas most used by these two species were herb covered forests. Therefore, due to lack of work on maximum entropy of roe deer in Iran, this study aims to evaluate the distribution of *C. capreolus* as a protected species in the north and northwest of Iran using this method.

MATERIALS AND METHODS

Study area

The study area includes a geographic range of about 74000 Km^2 in the north of Iran (Fig. 1). The elevation of the area is highly variable, ranging from -41 to 4638 m, with annual precipitation of 913 mm and a mean temperature of 10.5 °C. (IRIMO 2017).

Occurrence Data

Presence data of the roe deer (n= 95) were recorded from the entire distribution range of this species across the study area (including forest and non-forest regions) from 2015 to 2018 based on direct observation and indirect signs of presence such as scats and footprints using a Global Positioning System (GPS) device.

Environmental variables

Nine variables were chosen based on the behavioral and ecological characteristics of the roe deer: the topographic variables (elevation, slope, and aspect), bioclimatic data (the maximum temperature of warmest month and precipitation), the food and cover variables including land cover, distance from rivers and the tree density classes (Inechen *et al*. 2015; Bakhshi *et al*. 2017; Mirsajeri *et al*. 2018). The land cover map was reclassified into six classes including water, urban, the high, moderate and low densities of the forest and also agriculture. The human disturbance variables (distance from roads and from villages) (IFRWO 2010), all in 1-km resolution (Inichen 2015) (Table 1). Digital Elevation Model (DEM, https://earthexplorer.usgs.gov/) was used to create the slope and aspect variables using the Spatial Analyst tool in ArcGIS version 10.4. Among 19 bioclimatic variables, the

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maximum temperature of the warmest month (bio5) and precipitation (bio12) were chosen. The other bioclimatic variables, due to autocorrelation were not greatly correlated to this study. Because of animal dependence on the water resource, the distance from rivers was used in habitat modeling. Collinearity among the nineteen variables was examined using the Pearson correlation coefficient, then all pairwise correlations lower than 0.7 were accepted.

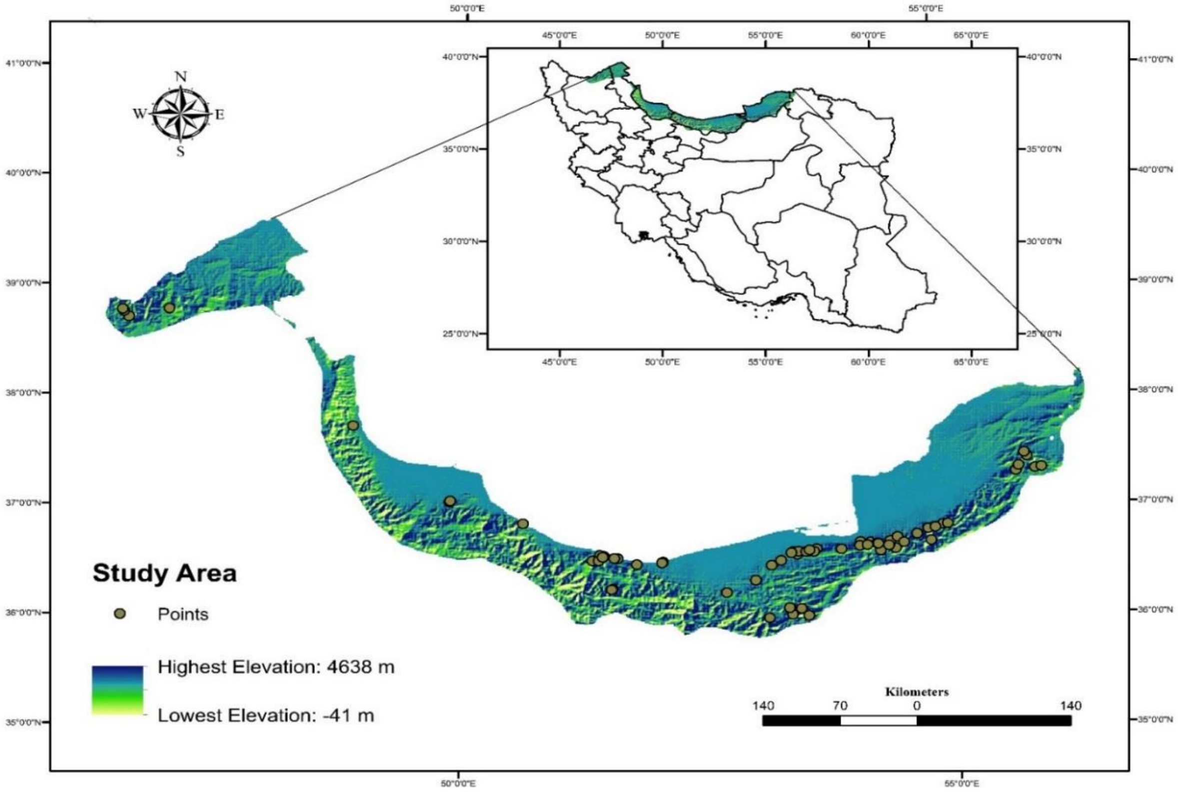

Fig. 1. Study area located in the north and northwest of Iran.

Table 1. Environmental variables used for habitat modeling of the roe deer.

Category	Variable	Unit	Source
Topographic variables	Digital elevation model (DEM)	meter	https://earthexplorer.usgs.gov/
	Slope	%	DEM
	Aspect	Class	DEM
Bioclimatic variables	the temperature of the warmest month (BIO5)	˚C×10	www.worldclim2.org (Fick et al., 2017)
	precipitation (BIO12)	Millimeter	
Food and water resources	Land cover		FRWMO, 2010
	Distance from rivers	Meter	DoE, 2018
Human security	Distance from roads	Meter	DoE, 2018
	Distance from villages	Meter	DoE, 2018

Habitat modeling

Maximum entropy approach (i.e., MaxEnt software version 3.4.1) was employed to produce a model for the potential distribution of the roe deer in the north and northwest of Iran (Phillips *et al*. 2017). MaxEnt software requires species presence and predictor environmental variables (Phillips *et al*. 2006). 75% of presence points were randomly selected to build the model. The remaining were used to evaluate the model. (Evcin *et al*. 2019) The Jackknife procedure and response curves were used to assess the variable importance and to evaluate the probability of roe deer presence concerning to each variable, respectively (Yost et al., 2008). The receiver operating characteristic (ROC) curve, the most common statistical methods which is widely used to test model performance (Wang 2007), has been applied to evaluate the species distribution models. The model was run 10 times and each time with 1000 iterations. The performance of the model was examined using the area under the

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receiver operating (AUC), which is a quantitative index displaying the performance and power of the model. An AUC of 0.5 is poor, values ranging 0.5-0.7 is fair, 0.7-0.9 is good, and > 0.9 is excellent (Swets 1988; Elith 2002).

Habitat patches

Continuous habitat suitability map was converted to a binary map (i.e. suitable / non-suitable map) based on logistic threshold maximum training sensitivity plus specificity in the MaxEnt model (Jimenez-Valverde & Lobo 2007). Accuracy of the binary map was obtained using sensitivity, specificity and true skill statistic (TSS). TSS was calculated according to the formula: sensitivity + specificity-1 from Allouche *et al*. (2006). Only habitat patches with presence points of the roe deer were considered.

RESULTS

The area under the curve (AUC) is equal to the probability of distinguishing between presence and absence points by a model (Phillips *et al*. 2006). Different values of the area under the curve are between 0.5 and 1. Hence, the area under the curve is 0.5, indicating that the model is random. If this value is equal to 1, the model could have the best distinguishing between presence and absence points (Engler *et al*. 2004). In these outputs, the habitat suitability of the species was considered with respect to the process of changing each of the shown variables. Response curves, in addition to measuring the probability of species being present with each variable, also take into account the hidden correlation relationships between that particular variable and other ones (Baldwin 2009). The average AUC of training data for 10 times was 0.919, exhibiting the excellent performance of the model. The Jackknife graph which illustrates the importance of each of the variables used in the model, and also as a result of repetition in the model run, indicated that the land cover had the most important effect on the habitat suitability model of the roe deer in the study area. In addition, elevation, aspect and the maximum temperature of warmest month were other important variables. The distance from the river had the least important effect on the distribution of the species (Fig. 2).

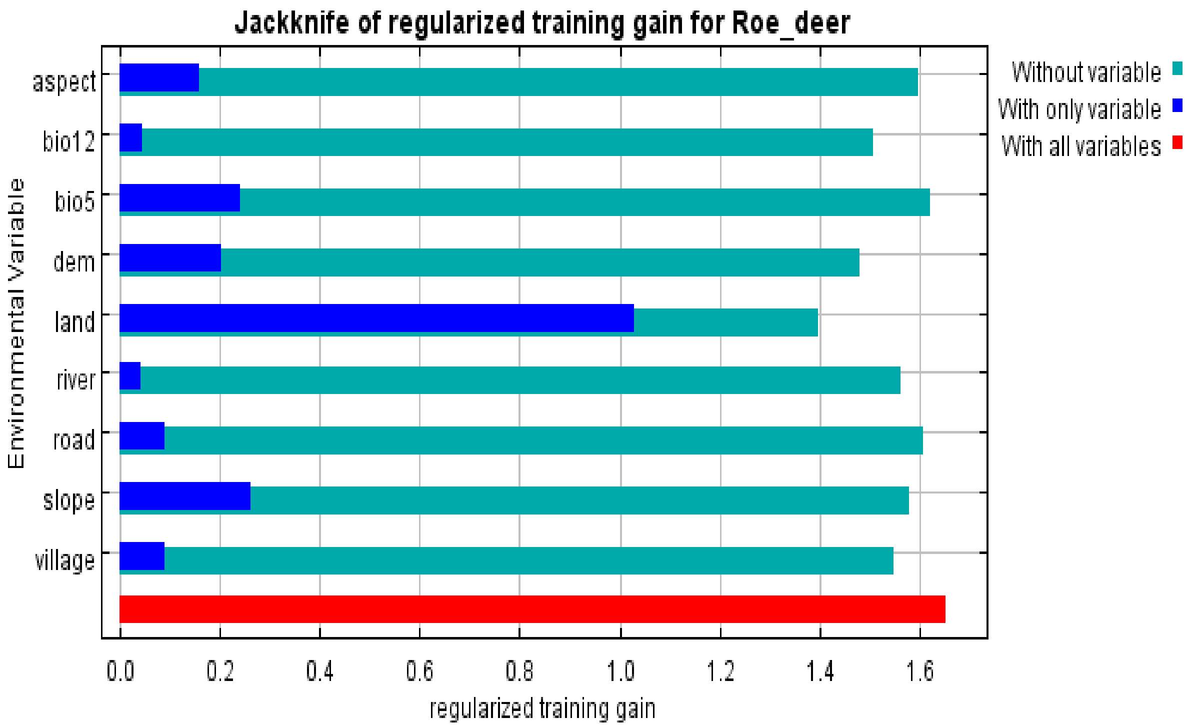

Fig. 2. Jackknife test within MaxEnt to detect important variables in habitat modeling of the roe deer.

The response curve of the species to the land cover showed that the most probability presence of roe deer is located in the classes of high and moderate densities in the forest. The response curve of the species to slope indicated that by increasing in slope, the presence probability of the roe deer was elevated. Finally, the response curve of the species to aspect exhibited that the species tends to inhabit the western aspect. Roe deer preferred 0-2000

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meter elevation, 600-1000 mm annual precipitation and 26-34 °C maximum temperature of the warmest month (Fig. 3). The habitat suitability map illustrated continuous suitability in the north of Iran and a distinct suitable area in the northwest regions (Fig. 4). Continuous habitat suitability map (i.e., ranging 0-1) was converted to a binary map by the aforementioned logistic threshold (i.e., 0.381) (Fig. 5). Sensitivity, specificity, and TSS were 0.9, 0.7 and 0.6, respectively, indicating the good accuracy of binary model. Habitat patches with presence points covered an area of about 4467.81 km^2 (i.e., 6.04% of the study area). The largest patch (i.e., Patch 1; all numbers in Fig. 5), covering an area about 4022 km^2, created a continuous patch in the east of the study area. Also, some small patches close to each other located in the west of the study area, covered an area of about 342 km^2. Habitat patches with presence points covered an area of about 4467.81 km^2 (i.e., 6.04% of the study area). The largest patch (i.e., Patch 1; all numbers in Fig. 5), covering an area about 4022 km^2, created a continuous patch in the east of the study area. Properties of habitat patches of the roe deer are summarized in Table 2.

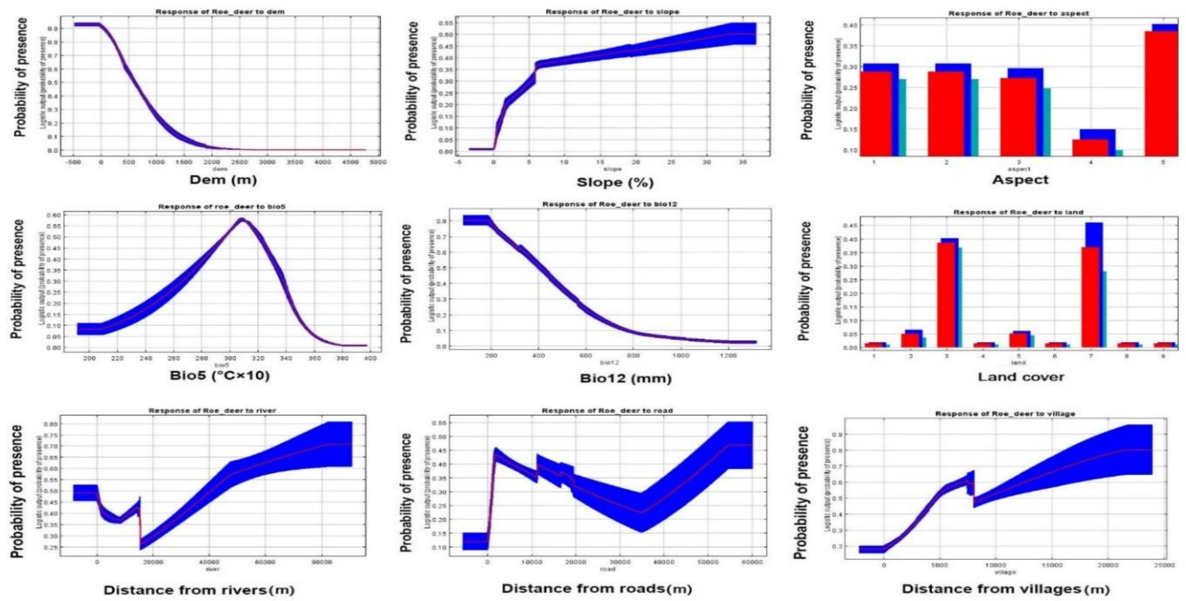

Fig. 3. Response curves of roe deer presence to environmental variables in the MaxEnt model (Numbers in X-axis of aspect variable: 1 = plain, 2 = north, 3 = east, 4 = south and 5 = west).

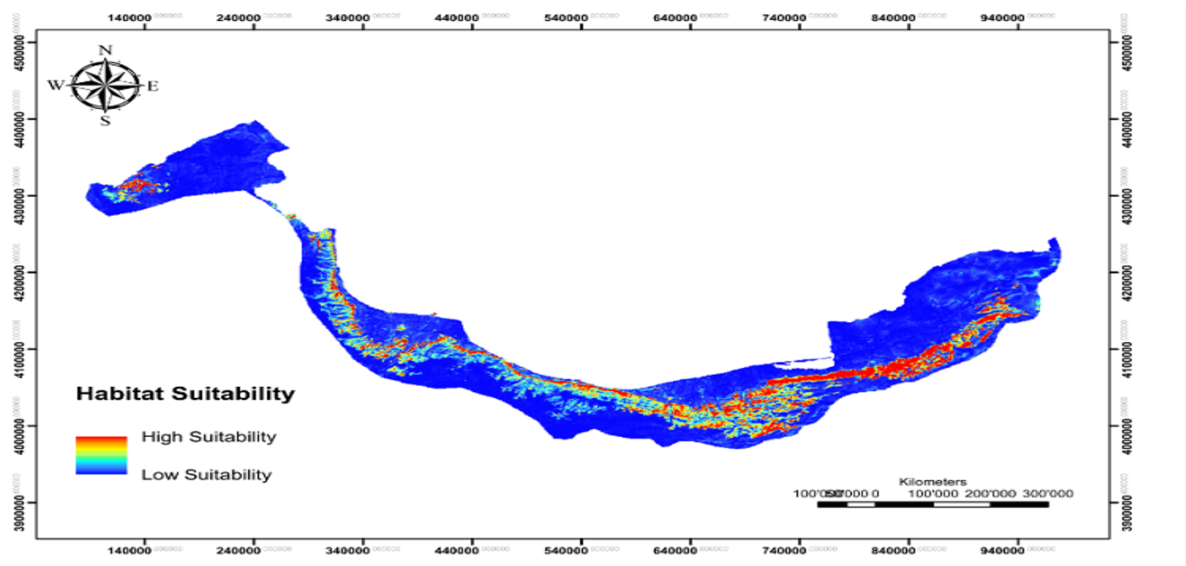

Fig. 4. Habitat suitability map of the roe deer in the study area using MaxEnt.

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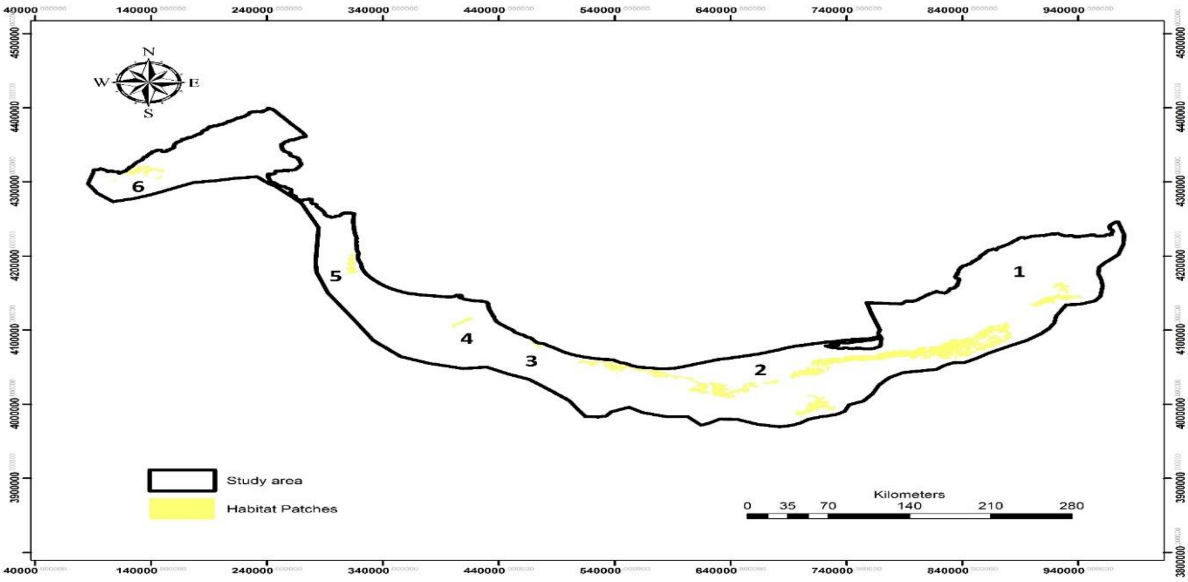

Fig. 5. Habitat patches with the presence points of the roe deer in the study area.

Table 2. Properties of habitat patches of the roe deer.

Habitat patch	Area (km^2)
1*	338.73
2	3683.42
3	33.88
4	69.43
5	130.58
6	211.77

DISCUSSION

Roe deer is considered as a sensitive species in terms of access to resources (Gashtasb *et al*. 2016). Therefore, accurate identification of habitat requirements and identifying important resources in roe deer habitat distribution can play an important role in the conservation of this species. The results of this study showed that land cover, altitude, aspect and climate variables (namely the maximum temperature in the warmest month of the year) can play a very important role in the presence and distribution of this species in the Hyrcanian and Arasbaran forests of Iran (Gashtasb *et al*. 1395). The results of this study, like other studies in Iran and also Eurasian regions, indicated that the presence of dense forest can play an important role in the presence of roe deer (Alizadeh 1379; Dept 2009; Pellerin, 2010; Lineichen, 2015; Gashtasb *et al*. 2016). Dense forest habitats reduce the visibility of predator species and also the likelihood of deer to be seen in these habitats. Roe deer is an inactive species with low-level food stock that has little weight fluctuating during the year that causes choosing different parts of the habitat especially shrub and forest lands (Peterolli 2003). Furthermore, the roe deer are mainly displaced by more oak-covered forest structures, which themselves are a mix of grass and shrub species and trees that provide the resources needed for this species, including food and shelter (Heidari Safari Kouchi *et al*. 2015). Dense vegetation can provide sufficient heat to the animals and prevent severe light radiation to the living organisms, hence reducing the cost of heat regulation (Coulombe *et al*. 2011).

The results of this study showed that altitude could be one of the important factors in roe deer distribution. Seasonal migrations of altitude in large grass-eating species such as roe deer can increase its strategy of access to high-quality food. Typically, these changes in this species are toward the high lands in summer and low lands in winter (Mysteroud 1999). In the case of the Iranian roe deer, the habitat quality and desirability usually decrease by elevating altitude. So that, the best range for distribution of this species is about 1000 m (Bakhshi *et al*. 2013) and the maximum observed for this species is 1800 m (Mersangi 1397). These areas are in associated with oak and other species found at low altitudes. Therefore, the height determines the type of vegetation grown in each region, including Hyrcanian forests (Sedighi *et al*. 2020). By increasing in height, the number of trees will reduce, leading to negative impact on roe deer survival.

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The results of this study identified climate as one of the most important factors affecting habitat suitability. Winter-affected climates may directly lead to weight loss and adversely affect species survival, or indirectly threaten species survival through reducing the summer forage quality (Mysterud & Eivind 2006). In areas with cold climates, snowy winters lead to an increased mobility costs (Parke *et al*. 1984) as well as limited access to the food layers (Mysterud & Eivind 2006). This coincides with a period when food availability is low and forage quality is poor (Mautz 1978). Such conditions can be more severe for small deer such as *C. capreolus* (Holand *et al*. 1998), because they are not well tolerated. Roe deer are not compatible with snow (Telfer & Kelsall 1984; Mysterud & Eivind 2006). Snow depth is one of the most important factors in determining the diet and habitat use for deer.

Although, anthropogenic variables can have a significant impact on the distribution and selection of the optimal habitat of deer and there is a negative relationship between human-born factors and the presence of a shock (Myersang *et al*. 1977; Jiang *et al*. 2000), however, the human-made variables in the present study (distance from road and from village) had little effect on the distribution of roe deer. While human density is higher in the downstream of the Hyrcanian forest, these areas are usually located in high-density forests (Sectional 2013), which are suitable habitats for deer. So, in cold winters due to lack of food in the highland, roe deer may will show their interest to agricultural areas (Bakhshi 2013).

Other results of the present study indicated the small effect of the distance from water resources on the species presence. The results exhibited that water is not a limiting variable for roe deer in the area, because it is easily accessible due to the conditions of the study area. This study contributes to the decision of conservation managers to conserve roe deer by identifying its suitable habitats in Iran. Therefore, habitat modeling should be considered as a management tool by the departments of environment in Iran.

Based on Fig. 4 the best integrated large habitats (patches 1 and 2) for roe deer were located in an area with low human density and dense forest which are usually protected areas. According to the results of this study and those of Kabiri *et al*. (2017), roe deer usually prefer the high-density forest areas in Iran. It seems that most areas of low-density forest have low security due to the overcrowded human population and illegal hunting. So, they are forced to refuge to uplands and high-dense forests which are usually protected by the DoE.

Identifying habitat patches showed that the main patches were located in the east side of the study area (i.e., Patches 1 and 2). Patch 1 was located in Golestan national park, which is the first protected area in Iran with dense deciduous forest. This national park is located in the far east of Hyrcanian forests and is considered as one of the last refuges for the large mammals including roe deer (Soofi *et al*. 2017). The second large patch provided a continuous suitable area for the roe deer. Detecting three distinct small patches (i.e., patches 3-5) suggests that this region of the study area had relatively low suitability to support population/populations of roe deer. Finally, there are several inter-connected small patches (i.e., Patch 6) in the most western part of the study area in Arasbaran forests. Patch 6 was located in Arasbaran National Park. This area encompasses the Iranian section of the Caucasus biodiversity hotspot with high diversity (Meyers *et al*. 2000).

In this study, we considered all the distribution ranges of roe deer in Iran except a small patch in the west (i.e., oak forests in Ouramanat and Javanroud areas). To include this excepted area in further studies, it is needed to expand the study area to a nearly double size which could create some errors larger than real background area for pseudo-absence points (Anderson & Raza 2010; Barbet-Massin *et al*. 2012). Buzin-Marakhil protected area in Iran-Iraq border with an area of about 24000 ha is the only refuge for the roe deer in the west of Iran and has been monitored since 1999 with the aim of protecting a small distribution of the roe deer in the west of Iran (Henareh Khalyani *et al*. 2011).

The present study delimited the habitat patches of roe deer in Iran which helps conservation managers and decision-makers to find easily the hotspots of roe deer. Habitat patch modeling should be considered as a managerial tool by the DoE in designing new protected areas.

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شناسایی لکه‌های زیستگاهی و مدل‌سازی مطلوبیت زیستگاه گونه شوکا به عنوان گونه حفاظت شده ایران

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چکیده

مدل‌سازی توزیع گونه ابزاری برای مدیریت حیات وحش از جمله شوکا به عنوان یک گونه گیاه‌خوار حفاظت شده ملی و مخفی‌کار است. مدل‌سازی مطلوبیت زیستگاه، می‌تواند گام خیلی مهم برای حفاظت این گونه باشد. این مطالعه برای ارزیابی توزیع گونه شوکا در شمال و شمال غرب ایران و برای شناسایی لکه‌های مهم زیستگاه این گونه انجام شد. مدل‌سازی با ۹۵ نقطه حضور و نه متغیر زیست محیطی با استفاده از نرم افزار مکسنت انجام شد و سپس لکه‌های مهم بر اساس نقاط حضور مشخص شدند. متغیرکاربری زمین به عنوان مهم‌ترین متغیر مدل‌سازی مطلوبیت زیستگاه گونه شناخته شد. همچنین بیشترین احتمال حضور گونه شوکا در طبقه جنگل‌های متراکم و تراکم متوسط بود. وسعت لکه‌های زیستگاهی حدوداً ۴۴۶۷/۸۱ کیلومتر مربع (۰/۰۴٪ مساحت منطقه مورد مطالعه) بود. بزرگترین لکه زیستگاهی حدوداً ۴۰۲۲ کیلومتر مربع وسعت داشت که شامل لکه‌های شرق منطقه حفاظت شده بودند. چندین لکه کوچک در قسمت غربی منطقه مطالعاتی در جنگل‌های ارسباران وجود داشت. در واقع، لکه‌های زیستگاهی به‌دست آمده باید برای حفاظت از گونه شوکا در نظر گرفته شود.

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