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MAXIMUM ENTROPY NICHE-BASED PREDICTING OF POTENTIAL HABITAT FOR THE ANATOLIAN LEOPARD (*Panthera pardus tulliana* VALENCIENNES, 1856) IN TÜRKIYE

PREDIKTIVNO MODELIRANJE DISTIBUCIJE POTENCIJALNOG STANIŠTA ZA ANATOLSKOG LEOPARDA (*Panthera pardus tulliana* Valenciennes, 1856) U TURSKOJ KORIŠTENJEM MODELA MAKSIMALNE ENTROPIJE

Alptuğ SARI[1]*

SUMMARY

The Anatolian leopard (*Panthera pardus tulliana* Valenciennes, 1856) is the largest surviving cat species in Türkiye. Despite the adversity they face, leopards still exist in Türkiye. In this study, using the maximum entropy model (Max -Ent), potentially suitable habitats for the Anatolian leopard in Türkiye was surveyed. When evaluating leopard habitat preference, the fact that the species can easily adapt to its habitat and live anywhere with sufficient vegetation and sufficient prey animals was taken into account; only data on climate which affects the geographic distribution patterns and population structures of flora and fauna were examined before. When the climatic variables affecting leopard' distribution were examined, the following had the highest values: isothermally, seasonal temperature, average temperature of the coldest season, minimum temperature of the coldest month, and annual precipitation. Except for the Central Anatolia Region and coastal areas, almost every region in Türkiye contains habitats suitable for the leopard. There are scarce data on leopards' populations and habitats in Türkiye. Therefore, even though ecological niche modelling (ENM) may generate important results when determining potentially suitable habitats, it is clear that this model cannot yield accurate results without considering the areas that the species is known to inhabit but in which no studies were previously conducted. The results that were obtained in the present study can also provide background information related to the long-term conservation of this species.

KEY WORDS: Bioclimatic data, Conservation, Habitat suitability, Leopard, MaxEnt, Türkiye

INTRODUCTION
1. UVOD

The leopard is a predator with one of the widest ranges of food sources in the world, and it can adapt to various climatic zones and ecological environments as long the quantity and quality of prey are high enough (Edgaonkar and Chellam 2002; Bailey 2005; Sarı et al. 2020). Leopards live in a wide variety of habitats, from semi-desert areas to evergreen forests, and have been found from sea level to top of mountains even near major metropolitan areas (Bothma and le Riche 1989). The number of subspecies of leopard living in the world is stated as eight in total in the taxono-

[1] Associate Prof. Dr. Alptugˇ Sari, Karadeniz Teknikal University, Department of Wildlife Ekology, Management, Trabzon, Türkiye, E-mail. alptugsari@ktu.edu.tr (*corresponding author)
Corresponding author*: Alptuğ Sarı. E-mail: alptugsari@ktu.edu.tr

mic revision of the Felidea family (Kitchener et al. 2017). The subspecies of leopard living in Türkiye is the Anatolian leopard (*P. p. tulliana* Valenciennes, 1856) (Kumerloeve 1956; Kumerloeve 1975; Borner 1977; Ulrich and Riffel 1993; Kitchener et al. 2017).

Determining the factors affecting the distribution of species is important for wildlife sustainability and protection. One of the first steps in this process is to identify a species and determine the habitats where it is distributed. Also, understanding the relationships between wildlife and habitat will help us anticipate habitat changes in animal populations that may occur and the probable effects of certain policies (Başkaya et al. 2011; Arpacık et al. 2017). Modelling studies aimed at revealing the relationships between a location where a species is known to occur and that location's ecological and environmental conditions have gained significant momentum in recent years (Pearson and Dawson 2003; Peterson et al. 2006). With these models, the potential distributions of the species are determined using data on the presence of species in sample lands. This approach yields results that are significant for understanding the geographical characteristics and distribution of species' habitats (Svenning and Skov 2004). Habitat suitability models are of great importance for predicting the potential distribution of wild animals in response to changes in their habitats (Harte et al. 2008; Süel 2014; Ertuğrul et al. 2017; Evcin 2018). ENM is used extensively not only in determining the geographical distribution of species, but also in understanding biogeographic characteristics, finding unknown populations of species, predicting the results of species moving to new areas, determining conservation areas and in predicting the effects of environmental changes (Holt and Gaines 1992; Kawecki 1995; Karacaoğlu 2013).

One of the many species distribution modelling approaches is the Maximum Entropy (MaxEnt) approach. MaxEnt is a software that models the distribution of species only from existing records of that species (Elith et al. 2010). Also, MaxEnt is known for the good performance and reliability of its statistical modelling in the context of "presence only" data. The MaxEnt approach examines the characteristics of the present locations of a target species and evaluates factors that affect that species' distribution in these areas to estimate a suitability level for the entire area (Baldwin 2009). Since the MaxEnt method gives more accurate results with less data than other methods that use presence data, it is preferred over modelling studies (Hernandez et al. 2006; Wisz et al. 2008). The MaxEnt method is used to determine species' habitat preferences, methods of protection future potential distribution areas (endemic species and endangered species), and the potential spread of invasive species, and actual and potential distribution of disease-causing microorganisms (Pearson et al. 2007; DeMatteo and Loiselle 2008; Suárez-Seoane et al. 2008; Yost et al. 2008; Süel 2014; Mert and Kıraç 2017).

The number of studies conducted using ENM to determine the suitable habitats for many species with incomplete data has increased in recent years, in both Türkiye and the rest of the world (Zimmermann et al. 2007; Swanepoel et al. 2012; Karacaoğlu 2013; Mondal et al. 2012; Gül et al. 2015; Per et al. 2015; Wilting et al. 2016; Miroğlu and Demirtaş 2017). Zimmermann et al. (2007) identified suitable habitats for leopards in the Caucasus ecological region using the MaxEnt program with ENM, suggesting that this region is potentially suitable for leopard habitats and that more research should be done on the eastern borders of Türkiye. Swanepoel et al. (2012) used ENM to identify habitats in South Africa potentially suitable for protecting leopards whose habitats were shrinking with the increasing population; the study stated that these areas are at least as important as the existing areas. In Western India, Mondal et al. (2012) identified potential habitats for the leopard by ENM using data collected from camera trap images and stated that these areas should be protected to avoid conflicts between humans and leopards. In Türkiye, on the other hand, there are few studies using ENM, and these studies are generally on insect and bird species (Karacaoğlu 2013; Süel 2014; Gül et al. 2015; Per et al. 2015; Yılmaz et al. 2015; Ertuğrul et al. 2017; Mert and Kıraç 2017; Miroğlu and Demirtaş 2017). Evcin (2018) and Evcin et al. (2019) used ENM to identify habitats in Kastamonu/Türkiye potentially suitable for roe deer (*Capreolus capreolus*) which is a mammalian species.

In Türkiye, no study has been conducted to date to model the distribution of the Anatolian leopard, which 1) is at the top of the food pyramid, 2) may be a key species in conservation studies, 3) has been able to survive to date without any conservation activities, and 4) is known to settle in multiple and distant habitats. The present study is the first to create a habitat suitability model for the Anatolian leopard in Türkiye using an ENM approach.

2. MATERIALS AND METHODS
2. MATERIJALI I METODE

Distribution data on leopards in Türkiye between 1971-2021 years were gathered by searching for literature and author's previous field surveys (Sarı 2018; Sarı et al. 2020). Ninety-seven points were selected, especially considering the presence data of the last 50 years. The data older than 50 years old were discarded to remain consistent with the climatological data used for modeling. Another reason for choosing these 97 points is that the climate data of the last 50 years are more reliable. A total of 148 occurrence records in these studies were aggregated: 46 shootings, ten camera trap pictures, six thermal video camera images, twelve no-

Figure 1. Anatolian Leopard distribution records used in this study (■)
Slika 1. Zapisi o distribuciji anatolskog leoparda korišteni u ovoj studiji (■)

tices by local people, 56 sets of tracks, 13 pieces of scat, two ground-scrapings, and three tree-scratchings (Kumerloeve 1971; Baytop 1973; Gürpınar 1974; Kumerloeve 1975; Kumerloeve 1976; Borner 1977; Ulrich and Riffel 1993; Gürpınar 2000; Başkaya 2003; Başkaya and Bilgili 2004; Üstay 2008; GDNP 2012; GDNP 2016; Arpacık 2018; Sarı 2018; Toyran 2018; Sarı et al. 2020; Karatas et al. 2021). Some photographs of these records are presented in Appendix-I. In order to prevent overlapping during the implementation of the model and due to the lack of precision/resolution of climate data or presence points, care was taken to ensure that the distance between the points was not less than 10 km; to this end, when there were areas that were too close to each other, one was randomly selected (Boria et al. 2014; Varela et al. 2014; Zhang et al. 2019a). A total of 97 known leopard occurrence points were generated using ArcGIS 10.2 (Esri, Redlands, California, USA). The distribution of these points on the map is given in Figure 1.

Table 1. Bioclimatic variables used in this study
Tablica 1. Bioklimatske varijable korištene u ovoj studiji

Code Kod	Variable Varijabilna	Code Kod	Variable Varijabilna
BIO1	Annual Mean Temperature	BIO11	Mean Temperature of Coldest Quarter
BIO1	Srednja godišnja temperatura	BIO11	Srednja temperatura najhladnijeg kvartala
BIO2	Mean Diurnal Range (Mean of monthly (max temp - min temp))	BIO12	Annual Precipitation
BIO2	Srednji dnevni raspon (srednja mjesečna (max temp - min temp))	BIO12	Godišnje oborine
BIO3	Isothermality (BIO2/BIO7) (x100)	BIO13	Precipitation of Wettest Month
BIO3	izotermnost (BIO2/BIO7) (x100)	BIO13	Oborine najkišnijeg mjeseca
BIO4	Temperature Seasonality (standard deviation x 100)	BIO14	Precipitation of Driest Month
BIO4	Sezonska temperatura (standardna devijacija x 100)	BIO14	Oborine najsušnijeg mjeseca
BIO5	Max Temperature of Warmest Month	BIO15	Precipitation Seasonality (Coefficient of Variation)
BIO5	Maksimalna temperatura najtoplijeg mjeseca	BIO15	Sezonske oborine (koeficijent varijacije)
BIO6	Min Temperature of Coldest Month	BIO16	Precipitation of Wettest Quarter
BIO6	Minimalna temperatura najhladnijeg mjeseca	BIO16	Oborine najvlažnijeg kvartala
BIO7	Temperature Annual Range (BIO5-BIO6)	BIO17	Precipitation of Driest Quarter
BIO7	Godišnji raspon temperature (BIO5-BIO6)	BIO17	Oborine najsušnijeg kvartala
BIO8	Mean Temperature of Wettest Quarter	BIO18	Precipitation of Warmest Quarter
BIO8	Srednja temperatura najkišnijeg kvartala	BIO18	Oborine najtoplijeg kvartala
BIO9	Mean Temperature of Driest Quarter	BIO19	Precipitation of Coldest Quarter
BIO9	Srednja temperatura najsušeg kvartala	BIO19	Oborine najhladnijeg kvartala
BIO10	Mean Temperature of Warmest Quarter		
BIO10	Srednja temperatura najtoplijeg kvartala		

Leopards can easily adapt to their habitat and live anywhere with sufficient vegetation and sufficient prey animals (Edgaonkar and Chellam 2002; Bailey 2005; Sarı et al. 2020). Leopards' habitat selection is mainly based on prey abundance. The leopard is a predator with one of the widest ranges of food sources in the world, and it can adapt to various climatic zones and ecological environments as long the quantity and quality of prey are high enough (Bailey 1993; Nowell and Jackson 1996; Edgaonkar and Chellam 2002; Bailey 2005; Sarı et al. 2020). The other ecological parameters such as vegetation, elevation, slope etc. are indirectly important for the species' ecological needs (Sarı et al. 2020). When the literature records of the Anatolian leopard in Türkiye are examined, it will be seen that it is recorded in a wide variety of habitats, from semi-desert areas to evergreen forests, from sea level to top of mountains, from forest areas with high closure rate to open areas. When evaluating leopard habitat preference in this study, only climatic data have been examined before and, although climate is a crucial variable affecting the dispersal and layout of plant and animal communities, should also be taken into account (Walck et al. 2011; Zhang et al. 2019a). Another reason for using only climate data is that the exact location of the leopard literature records as points is unknown due to the diversity of observations source/type (shooting, observations, signs of presence). Ninety-seven variables were selected related to leopard distribution, representing bioclimatic factors (Bio 1–Bio 19), these were downloaded from the World Climate Database (www.worldclim.org) (Hijmans et al. 2005) (Table 1).

Data Analysis – *Analiza podataka*

The main principle of the MaxEnt software is that there are a random variable and uncertainty related to it (Elith et al. 2010). In the maximum similarity method of MaxEnt, the probability of a species being present at each pixel in the studied area is generalized to the entire studied area (Yost et al. 2008). In this study, ten replications were used for each model, and 10% of the dataset included in the analysis was evaluated as test data. To obtain the best results from the modelling methods, the data used in the analyses were obtained at the highest resolution obtained from WorldClim 30" (~900m²). All datasets obtained were in the decimal coordinate system and WGS84 map datum. These datasets were generated by interpolating average monthly climatic data from climate stations around the world (Hijmans et al. 2005). These datasets include data on monthly total precipitation and data on average, minimum, and maximum temperature, and 19 climatic datasets derived from these data. These 19 ecological factors were evaluated to identify potential distribution areas that can provide the same conditions in different regions. Geographical coordinates of the areas where the leopard was found were entered into the program by taking into account the current climate data consisting of 19 climate dataset; then these coordinates were analysed.

MaxEnt (version 3.3.3e), a software that models species niches and distributions, was used to complete ENM (Philips et al. 2006). MaxEnt predicts species' distributions from bioclimatic data (Elith et al. 2006; Phillips et al. 2006). The MaxEnt algorithm uses bioclimatic and locality point data to find the maximum entropy distribution, and from there predicts species' niches (0 = lowest probability and 1 = highest) (Philips et al. 2006, Kozak et al. 2008; Phillips and Dudik 2008). Ninety-one presence points were used for the model, and ArcGIS 10.2 software (Esri 2012) was used to estimate distribution maps and climatic variables (Figure 1). The area under the receiver operating characteristic curve (AUC) helped to determine the importance of the model, evaluate its results, and perform a sensitivity analysis on it; a jackknife test was performed to assess the relative importance of variables in the species distribution prediction (Phillips et al. 2006; Zhang et al. 2019b). Threshold independent receiver-operating characteristic analysis (ROC) was used to calibrate the model and evaluate its accuracy. The AUC values of the ROC curve were analyzed to determine the model's success. AUC values close to 1 were considered excellent, descriptive if close to 0.7 and non-informative if close to 0.5 (Philips et al. 2006; Elith et al. 2006).

3. RESULTS
3. REZULTATI

The model determined the habitat suitability for leopards in Türkiye, and the relationship between suitability and climatic variables was analyzed. When the results were evaluated, the habitat suitability model was found to be highly reliable (Figure 2).

The ROC value of the obtained habitat suitability model was 0.914 (Figure 3). The data analysis found the training data to be AUC values close to 1 as a result of the data anal-

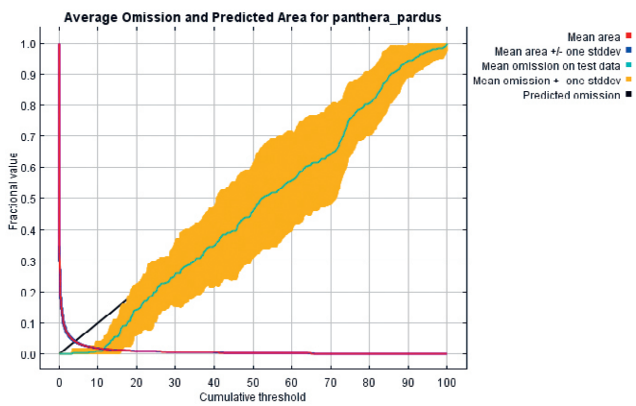

Figure 2. The performance of the habitat suitability model.
Slika 2. Kretanje modela prikladnosti staništa.

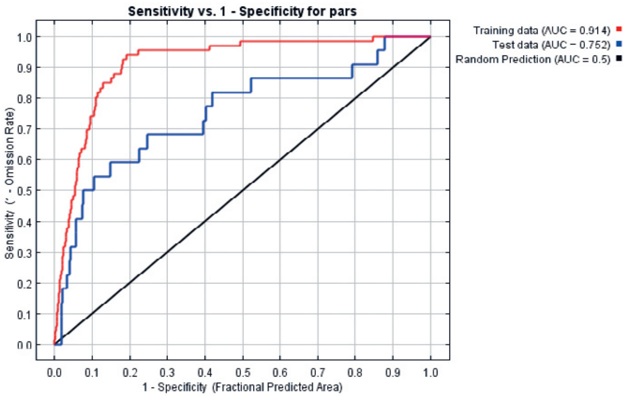

Figure 3. Predicting the area under the receiver operating characteristic (ROC) curve (AUC) to determine the habitat suitability model for leopards in Turkey.
Slika 3. Predviđanje područja ispod krivulje radne karakteristike prijamnika (ROC) (AUC) za određivanje modela prikladnosti staništa za leoparde u Turskoj.

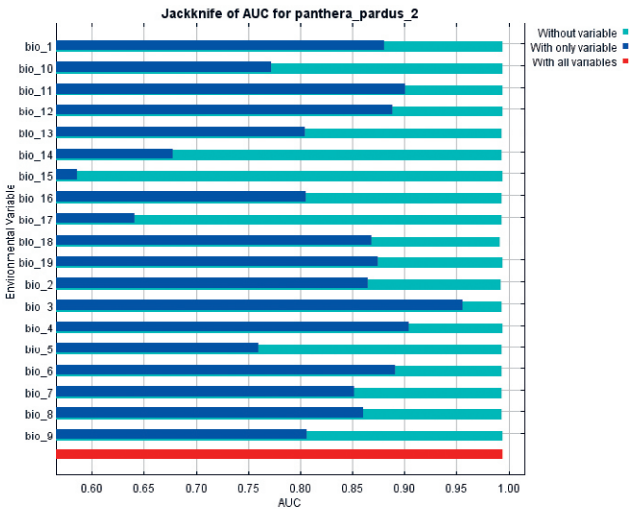

Figure 4. AUC values from modelling the results of the jackknife analysis.
Slika 4. Vrijednosti AUC iz modeliranja rezultata analize nožem.

ysis, indicating that the model was being excellent (Elith et al. 2006; Philips et al. 2006).

When the effect of climatic variables on distribution was examined according to the results of the jackknife test, the following had the highest values: isothermally (bio_3), seasonal temperature (bio_4), average temperature of the coldest season (bio_11), minimum temperature of the coldest month (bio_6), and annual precipitation (bio_12) (Figure 4). When the climatic data were examined based on the results of the model, cold hard winter months were a determining factor in the habitat preference of the leopard.

A habitat map was created for Türkiye based on the program (MaxEnt) and results of the analyses. In the map, red indicates potentially suitable habitats that leopard would prefer the most, and blue colour indicates potentially suitable habitats that are less preferred (Figure 5). The maximum entropy principle of MaxEnt yielded a maximum possible AUC training value of 0.914, indicating that the MaxEnt model can accurately predict the locations of potentially suitable leopard habitats.

According to these results and depending on the climatic data, the leopard populations are distributed in a large area in Türkiye. MaxEnt predicts that leopards have a wide distribution in Türkiye. These results show that, except for the Central Anatolia Region and coastal areas, there are many potentially suitable habitats for leopards in almost all regions in Türkiye.

4. DISCUSSION AND CONCLUSION
4. RASPRAVA I ZAKLJUČAK

This study created a habitat suitability model for leopards in Türkiye from presence-only data. Presence-only data is

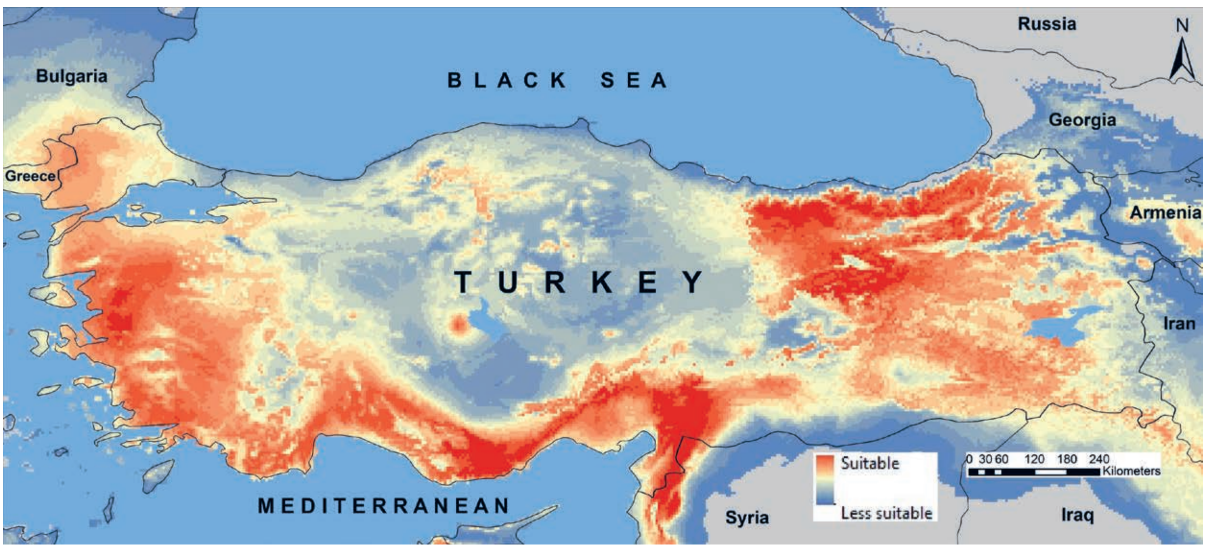

Figure 5. Maximum entropy niche-based potential habitat for the Anatolian leopard in Türkiye
Slika 5. Potencijalno stanište anatolskog leoparda u Turskoj temeljeno na maksimalnoj entropiji

becoming more widely used to model species distributions, which has led to discussions about the types of distributions (e.g., potential vs. realized) it can model that presence-absence data cannot (Hirzel and Le Lay 2008; Soberon and Nakamura 2009; Lobo et al. 2010). As mentioned in previous studies, the subject is complex because of the interplay among data quality (amount and accuracy of species data; ecological relevance of predictor variables; and access to data on disturbances, dispersal limitations, and biotic interactions), modelling method, and scale of analysis (Elith et al. 2011; Mondal et al. 2012).

A pre-requisite for properly rehabilitating a species in an ecosystem understands that species' distribution in detail (Franklin 2013). Although discrepancies exist between various climate modelling systems (Cheaib et al. 2012), the species distribution approach nevertheless functions as an important research tool that is used to estimate and predict the changes occurring in terms of species distribution.

The leopard has the broadest range of prey of all predators in *Felidae*, and it can adapt to multiple climates zones and environments with various ecological features as long as there is an ample food supply; leopards can also inhabit non-mountainous areas (Balme et al. 2009; Henschel et al. 2011). I suggest that leopards frequently use mountainous areas because they offer both a refugia from anthropogenic disturbance and less direct competition with humans for living space (Norton et al. 1996; Gavashelishvili and Lukarevskiy 2008).

A number of studies have identified potentially suitable leopard habitats using ENM and argued that these habitats are as important as those that leopards currently inhabit (Zimmermann et al. 2007; Gavashelishvili and Lukarevskiy 2008; Mondal et al. 2012; Swanepoel et al. 2012; Farhadinia et al. 2015; Ebrahimi et al. 2017). However, this model uses ecological values of the areas where findings related to the species were obtained to make predictions. The current data on the density and habitat use of the leopard, a species that is difficult to study, may be considered insufficient in Türkiye. Therefore, although the habitats predicted by the ecological niche model to be suitable are important, it is clear that this model cannot produce sound results without evaluating the areas known to host the species. Moreover, there are regions where the current data indicate that the leopard density is low or the leopard has gone extinct; acting on the basis of these data can produce very dangerous consequences for the continuity of the species.

The habitat in northeastern and eastern Türkiye would be suitable for the Anatolian leopard, and the area remains interesting for further surveys – mainly the regions bordering Armenia and Iran (Zimmermann et al. 2007). Kumerloeve (1956), Başkaya (2003), Başkaya and Bilgili (2004), Arpacık (2018) and Sarı (2018) also stated that the Eastern Black Sea Region is a leopard habitat, and there is a settled leopard population in this region. Furthermore, using the MaxEnt program, Zimmermann et al. (2007) identified suitable habitats for the leopard in the Caucasus ecological region, suggesting that this region is potentially suitable for the leopard and that research should be intensified on the eastern borders of Türkiye. Predicted suitable habitats produced using the same program in this research was found to be consistent with the results reported by Zimmerman et al. (2007). Some studies have determined potentially suitable habitats for the leopard using ENM, noting that these areas are at least as important as the existing ones (Zimmermann et al. 2007; Swanepoel et al. 2012; Mondal et al. 2012). However, this model is based on the ecological values of the areas where more species are found. In fact, the results obtained using the program in this study did not reveal all of the available habitats for the leopard in Türkiye. For example, the habitats that the results suggest are suitable for the leopard in Türkiye, such as Çoruh Valley, Çemçe-Madur mountain range, mountainous areas between Lake Van and Hakkari, and the areas ranging from Erzincan-Sivas-Tokat to Sinop forests –in reality-, do not contain any suitable habitats, which render the results of the program somewhat inaccurate. Also, although there is no record of the Anatolian leopard in the Thrace region, the program has shown these areas as suitable habitats by evaluating the climate data.

Presence-only data are useful and can be used to model the same ecological relationships as presence-absence data, provided that biases can be dealt with. Finally, although MaxEnt can predict suitable habitats, it may be less robust in predicting how specific environmental variables influence habitat suitability (Elith et al. 2010; Swanepel et al. 2012).

Climate change often makes environments hotter and drier (IPCC 2014; Ebrahimi et al. 2017). Drought reduces prey availability, which is an important factor for leopards choosing a territory (Carbone and Gittleman 2002; Hebblewhite et al. 2011; Farhadinia et al. 2015; Ebrahimi et al. 2017); it is therefore necessary to take prey distribution into account when modelling potential habitats for the leopard in Türkiye.

Addressing the needs of human beings without defining and preserving the habitats of leopards threatens the latter's survival, and this has important downstream effects on biodiversity. Leopards are timid animals that lead solitary lives, are mostly active at night (they are nocturnal) in large areas, and are difficult to study scientifically; subsequently, there is little data on their population and habitats in Türkiye. Therefore, although ENM may generate important results when determining potentially suitable habitats, it is clear that this model cannot yield accurate results without considering the areas known to host the species but where no studies have yet been conducted. Moreover, in the regions where the current data indicate that the leopard density is low or the leopard has gone extinct, acting based on these data can produce very dangerous consequences for the continuity of the species.

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SAŽETAK

Anatolski leopard (*Panthera pardus tulliana* Valenciennes, 1856.) je najveća preživjela vrsta mačaka u Turskoj. Unatoč nedaćama s kojima se suočavaju, leopardi još uvijek postoje u Turskoj. U ovoj studiji istražena su korištenjem modela maksimalne entropije (MaxEnt), potencijalno pogodna staništa za anatolskog leoparda u Turskoj. Prilikom procjene preferiranog staništa leoparda, u obzir je uzeta činjenica da se vrsta može lako prilagoditi svom staništu i živjeti bilo gdje ako ima dovoljno vegetacije i lovine; jedino su podaci o klimi koja utječe na zemljopisne obrasce rasprostranjenosti i populacijske strukture flore i faune prethodno ispitani. Nakon ispitivanja klimatskih varijabli koje utječu na distribuciju leoparda, dobivene su sljedeće najviše vrijednosti: izotermno, sezonska temperatura, prosječna temperatura najhladnijeg godišnjeg doba, minimalna temperatura najhladnijeg mjeseca i godišnja količina oborina. Osim regije središnje Anatolije i obalnih područja, gotovo svaka regija u Turskoj sadrži staništa pogodna za leoparda. Nema puno podataka o populacijama i staništima leoparda u Turskoj. Stoga, iako ekološko modeliranje niša (ENM) može proizvesti važne rezultate pri određivanju potencijalno prikladnih staništa, jasno je da ovaj model ne može dati točne rezultate ako ne uzmemo u obzir područja za koja znamo da ih ta vrsta naseljava, ali u kojima još nisu provedena istraživanja. Rezultati dobiveni u ovoj studiji mogu dodatno doprinijeti već poznatim informacijama vezano uz dugoročno očuvanje ove vrste.

KLJUČNE RIJEČI: Bioklimatski podaci, Očuvanje, Pogodnost staništa, Leopard, MaxEnt (model maksimalne entropije), Turska

APPENDIX – I
DODATAK – I

Anatolian leopard hunters from the past in Türkiye (URL-1 2021)
Anatolijski lovci na leoparde iz prošlosti u Turskoj (URL-1 2021)

A shooted Anatolian leopard from Ankara in 1974 (URL-1, 2021)
Ustrijeljeni Anatolski leopard iz Ankare 1974 (URL-1, 2021)

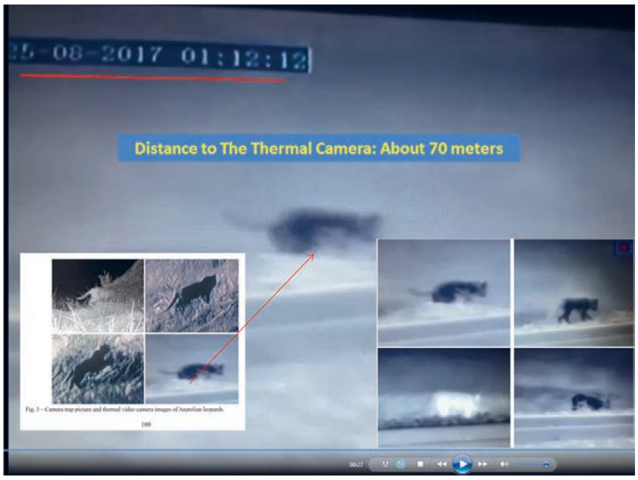
A shooted Anatolian leopard from Bitlis in 2008 (Toyran, 2018)
Ustrijeljeni Anatolski leopard iz Bitlisa 2008. (Toyran, 2018.)

APPENDIX – I
DODATAK – I

A shooted Anatolian leopard from Şırnak in 2010 (URL-2, 2021)
Ustrijeljeni Anatolski leopard iz Şırnaka 2010 (URL-2 2021.)

A shooted Anatolian leopard from Diyarbakır in 2013 (URL-3, 2021)
Ustrijeljeni Anatolski leopard iz Diyarbakıra 2013 (URL-3, 2021.)

Screenshots taken from the thermal camera video from Bingöl in 2015 (Sarı 2018; Sarı et al., 2020)
Snimke zaslona preuzete iz videa termalne kamere iz Bingöla 2015. (Sarı 2018.; Sarı et al., 2020.)



Screenshots taken from the thermal camera video from Erzincan in 2017 (Sarı 2018; Sarı et al., 2020)
Snimke zaslona preuzete iz videa termalne kamere iz Erzincana 2017. (Sarı 2018; Sarı et al. 2020)