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Habitat preferences of *Testudo graeca*, Linnaeus 1758 (Testudines; Testudinidae) with a new locality record from eastern Black Sea region of Turkey

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Abstract

Each species is unique in the area it lives in and while they are distributed in these areas, they are affected by many biotic and abiotic variables. These factors both create all the life requirements of the species in the habitats they live in and reveal the ecological barrier of the species between each other. In this presented study, *Testudo graeca* species was recorded for the first time in the Eastern Black Sea region and this record constitutes the most northeast locality in the range of the species. Also, it is given information about determination of vital requirement of species and what are the bioclimatic factors it uses for its distributing in Turkey. This situation shows that *T. graeca* adapts to various climates and prefers habitat requirements in this direction. As a result, with the present study, we concluded that since *Testudo graeca* has a wide distribution area, it has been revealed that it may need very different climatic factors to determine its distribution.

Keywords: Bioclimatic factors, distribution, eastern Black Sea,*Testudo graeca*, Turkey

Introduction

The tortoises belonging to the genus *Testudo* (Linnaeus 1758) are represented by 5 species in the world (*T. graeca* Linnaeus 1758, *T. hermanni* Gmelin 1789, *T. horsfieldii* Gray 1834, *T. kleinmanni* Lortet 1883 and *T. marginata* Schoepff 1792) (Uetz *et al.* 2020) and distributed widely from North Africa, Central and Southeast Asia to Europe (Uetz *et al.* 2020). The individuals of two species (*T. graeca* and *T. hermanni*) belonging to Testudo genus in almost all regions except the eastern Black Sea in Turkey is distributed (Kurnaz 2020; Baran *et al.* 2021). *T. hermanni* is distributed in only Thrace part of Turkey, while *T. graeca* has a wide distribution area including Anatolia and Thrace.

Although it is known *Testudo graeca* before in Turkey, first record of species was given by researshers as Werner (1902), Bird (1936), Bodenheimer (1944) and Mertens (1952) who worked on the herpetofauna of Turkey, and it was added to the list of reptile and amphibian. After this time, it has been recorded by many researchers from many regions from Anatolia and Thrace (Bird 1936; Clark and Clark 1973; Andren and Nilson 1976; Baran 1980; Baran 1990; Mulder 1995; Kumlutaş *et al.* 2000; Uğurtaş *et al.* 2000; Kumlutaş *et al.* 2001; Cihan *et al.* 2003; Türkozan *et al.* 2003; Baran *et al.* 2004; Türkozan *et al.* 2004; Ilgaz and Kumlutaş 2005; Kete *et al.* 2005; Hür *et al.* 2008; Türkozan *et al.* 2010; Afsar and Tok 2011; Kumlutaş *et al.* 2011; Jablonski and Stloukal 2012; Cihan and Tok 2014; Eser and Erişmiş 2014; Özcan and Üzüm 2014; Tok and Çiçek 2014; Cumhuriyet and Ayaz 2015; Ege *et al.* 2015; Çakmak *et al.* 2017; Kumlutaş *et al.* 2017; Sarıkaya *et al.* 2017; Akman *et al.* 2018; Arslan *et al.* 2018; Şahin and Afsar 2018; Yıldız *et al.* 2018; Türkozan *et al.* 2018; Yıldız *et al.* 2019). However, until today, no researcher has given a locality record information of the species from the Eastern Black Sea region. The aim of the present study was to report a new locality for the first time from eastern Black Sea region except from given the literature for the species and also give information about habitat preferences determine the potential distribution in Turkey.

Materials and Methods

All locality records belonging to the species were obtained from the literature and the field study within the scope of this study (17.06.2020; Şiran, Gümüşhane; coordinate data: 40.139903º N, 38.977886º E, 1278 m asl; leg. Ali İhsan Eroğlu). In total, coordinate data for the *T. graeca* species were collected from 468 localities (Figure 1). All of the coordinate data collected were adjusted for each locality in the decimal data system and saved as a comma separated (CSV) Excel file.

In order to establish the distribution model of the species, firstly 19 bioclimatic variables and elevation data (30 arc seconds) which are topographical data, were downloaded from the www.worldclim.org website (Fick and Hijmans 2017). Because this data is in the world scale, their scales were reduced dimension of Turkey using by ArcGIS 10.3 software. Nineteen bio-climatic data and elevation data in ArcGIS program masked the scale of Turkey. Coordinate points were processed to these twenty data and their numerical scores were obtained. These scores were subjected to Pearson correlation analysis with the SPSS program and the data with r> 0.75 were excluded from the analysis since it would negatively affect the spread (Figure 2).

The program MaxEnt 3.4.1k (Philips *et al.* 2017) was used to determine the distribution of the species. Data with a correlation lower than 0.75 with coordinate data converted to CSV format were used in the distribution analyze. The MaxEnt program was run with a 0.00001 convergence threshold, 500 highest iterations, and an adjustment factor of 0.5. In addition, 25% of the formation data was allocated as test scores, and 10,000 background points were used to determine the distribution. Finally, ten maps (ten repetitions) were created in the analysis and the most suitable distribution map was selected. Jackknife test was conducted to determine the significance of the data affecting the distribution. The best model was selected by Akaike Information Criterion corrected (AICc) for small sample sizes (Hurvich and Tsai 1989). In addition to AICc, the power of the model was also determined by the values of the area under the receiver-operator (ROC) curve (AUC) (Raes and Ter Steege 2007; Gallien *et al.* 2012). According to Manel *et al.* (2002), model scores are assessed as follows: AUC = 0.5 reflects a performance equivalent to random, AUC > 0.7 reflects a useful performance, AUC > 0.8 reflects a good performance and AUC ≥

0.9 reflects an excellent performance. Finally, model inputs were transformed to binary predictions via using 10-percentile thresholding approach to visualize the "best" model (Perktaş *et al.* 2017).

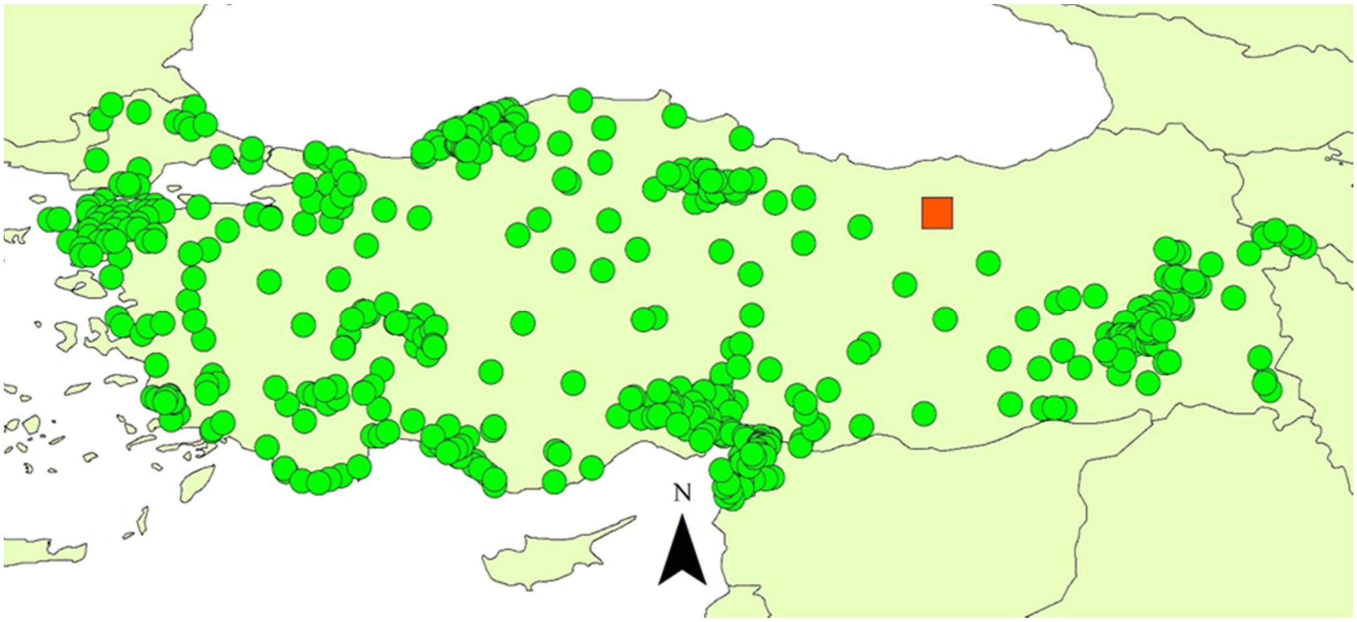

Figure 1: The map shows the current distribution of the *Testudo graeca* in Turkey using by occurrence points.

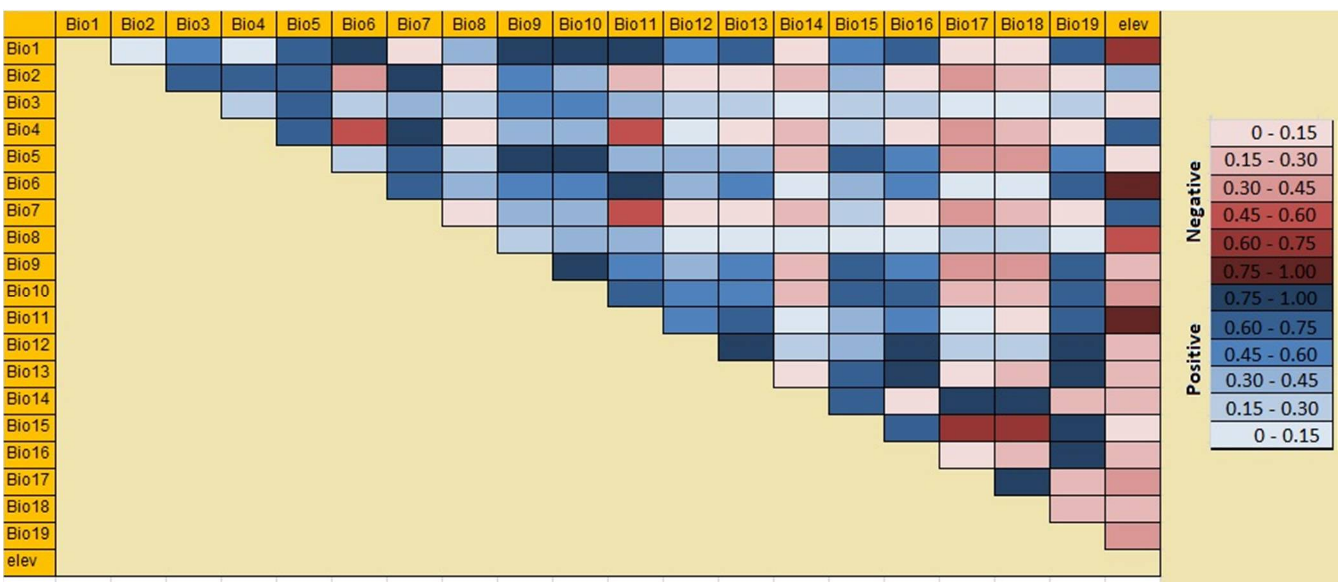

Figure 2: Correlation matrix among bioclimatic variables used in the present study

Results

In this presented study, a locality record of *T. graeca* species from Gümüşhane province and Eastern Black Sea region was given for the first time. This new locality is located very close to Alıç Village of Şiran district of Gümüşhane province and it is approximately 90 km away from the previously known locality of the species in Sivas. The area where the species was detected is on the Şiran-Alucra road and there are wooded and open areas on the roadside. *T. greca* lives sympathetically with *Lacerta media* as a reptile.

Distribution analysis of *T. graeca* species under current bioclimatic conditions revealed that the spread of the species is in accordance with the habitat requirements (Figure 3). As a result of these analyzes, nine of the nineteen bioclimatic variables (Bio-1: Annual Mean Temperature, Bio-3: Isothermality, Bio-5: Max Temperature of Warmest Month, Bio-7: Temperature Annual Range, Bio-8: Mean Temperature of Wettest Quarter, Bio-12: Annual Precipitation, Bio-14: Precipitation of Driest Month and Bio-15: Precipitation Seasonality), the altitude variable, among topographic variables, greatly influences the distribution of the species. Of these variables, elevation, Bio-1 and Bio-12 are the bioclimatic variables that most affect the distribution of the species. This situation constitutes approximately 65% of the distribution (Table 1). However, the Bio-7 and Bio-8 variants also contribute closely. The reason why these three variables determine the prevalence of this species is that it determines the vital preferences of the species in both hot and rainy environments. This is a situation with all the climatic characteristics of the species. In the jackknife analysis for distribution, it was revealed that the elevation variable is the most useful variable for the distribution of the species and can determine the distribution of the species when used alone (Figure 4). The result of the receiver operating characteristic (ROC) curve found as a result of the analysis was found to be compatible with the model sensitivity and the value of the area under the curve (AUC) was found to be 0.850 ± 0.022. The fact that this value is very close to 1 indicates that the geographical distribution of the species is compatible with the analysis. It also shows that current bioclimatic and geographical variables have the most appropriate effect on the distribution of the species. The fact that the standard deviation is close to zero indicates that the margin of error in the analysis is very low and the compatibility of the habitat selection of the species with these variables.

Table 1: Bioclimatic variables and contribution rates contributing to the potential spread of *T.graeca*

No	Variables	Contributions (%)
1	Bio 1	11.7
2	Bio 3	7.6
3	Bio 5	10.5
4	Bio 7	10.7
5	Bio 8	8.1
6	Bio 12	18.7
7	Bio 14	4.8
8	Bio 15	2.6
9	Elevation	25.1

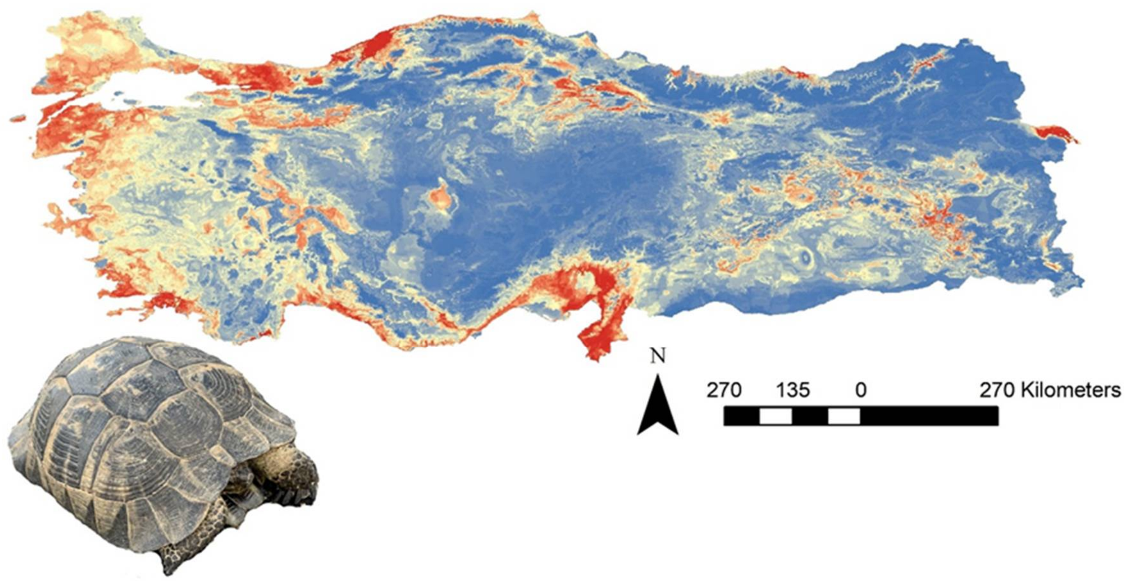

Figure 3: The map shows the range of current climate suitability predicted by MaxEnt model for *Testudo graeca* in Turkey.

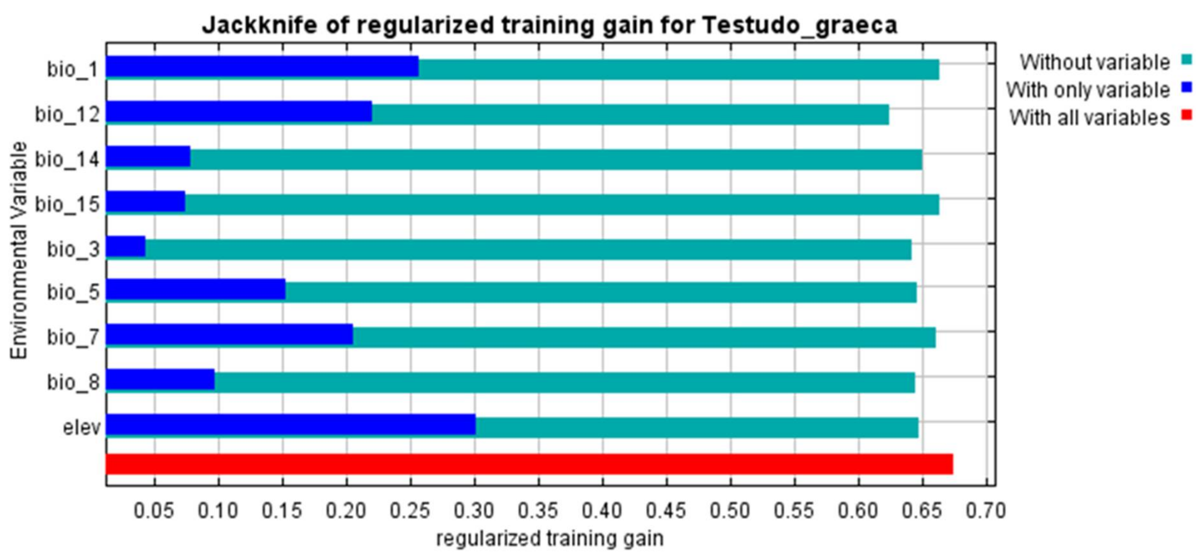

Figure 4: Relative predictive power of the four bioclimatic variables predicted by the jackknife of regularized training gain in MaxEnt model for the species.

Discussion

Reptile species are highly affected by annual temperature changes and this determines their annual activity (Adolph and Porter 1993). For example, high altitude species have a shorter life cycle than those living at low altitudes. *T. graeca* is accustomed to living at altitudes up to 2000 m above sea level for his vital needs. Since the habitats they live in show many climatic characteristics (humid, dry and steppe), they determine their annual activities according to the temperature changes of the environment they live in. For example, individuals living at high altitudes have to complete their vital activities in a shorter time and hibernate earlier than individuals of a species living at low altitudes. The most important factor affecting this situation is the annual temperature changes. In this study presented, the variable Bio-7 affected the spread of the species at a rate of 9.6%. This shows quite impressed that the annual temperature variation of *T. graeca* species in Turkey.

The conservation of the niche is a phenomenon that preserves ancestral traits between different species (Wiens and Graham 2005). Habitat preference is indispensable for determining the range of a species, and this constitutes both the biogeography of a species and its ecological niche that will enable it to separate from other species (Kurnaz and Eroğlu 2020; Kurnaz and Hosseinian-Yousefkhani 2020). The scarcity or disappearance of suitable habitats reduces a species' habitat and may cause the species to be endangered. This limits the areas a species can choose to live in (Kurnaz and Eroğlu 2020). Literature studies showed that *T. graeca* species is distributed highly broad area except from the Eastern Black Sea in Turkey (Baran *et al.* 2021). Although this species has a large distribution area, it is classified Vulnerable (VU) category in the IUCN red list of threatened species.

Species are influenced by many variables, including biotic (such as competitors or predictors) and abiotic factors (such as environmental factors or micro-habitat structures) to determine their distribution (Hosseinian Yousefkhani *et al.* 2016; Kurnaz and Şahin 2021). Climate variables are also one of the most important factors limiting the distribution of species (Cahill *et al.* 2013). These variables are very important for species which preferring their spatial requirements and determining their niches in these areas (Peterson *et al.* 1999). For the determination of the potential distribution of *T. graeca* in Turkey, it should be noted that it uses many climatic variables and even altitude contributes to this spread. This is one of the important findings of the study, as the presented study is aimed at this. In the similar this, almost the same result was found for *T. graeca* in the literature (Javanbakht *et al.* 2017). In addition, in a study of potential distribution analyze of the species including Iran, Azerbaijan, Russia and Armenia populations, bio-4, Bio-7, Bio-9, Bio-12, Bio-15, Bio-16, Bio-17, Bio-18 and Bio -19 bioclimatic variables showed to affect the distribution of *T. graeca* (Javanbakht *et al.* 2017). In the study conducted for these populations, as in our study, the highest contributing bioclimatic variable is Bio-12. This situation showed that the findings obtain from the present study is same with results of other populations based on potential distribution and the species used the same bioclimatic factors to designate their distribution in both Turkey and other populations. However, since there is a significant geography difference between the two studies, there are different bioclimatic variables for both studies in terms of factors determining the spread of the species. These differences may be due to both the topographic difference between the two countries and the fact that the bioclimatic requirements of the species may differ, even if it is small, between the two countries. It can be concluded to differ the Turkish population from other countries populations each with this situation. The taxonomic situation among almost all populations in the whole distribution area of species has been revealed using molecular markers (Türkozan *et al.* 2018). The results of the phylogenetic study, it can be said that the bioclimatic difference between these geographies may be related to the habitat types preferred by the subspecies of the species. Because, in general *T. graeca* is represented with 4 subspecies in Turkey (*ibera*, *terrestris*, *buxton* and *armeniaca*) and with 3 subspecies (*armeniaca*, *buxton* and *zarudnyi*) in Iran, Azerbaijan, Russia and Armenia. This subspecies difference also reveals the bioclimatic diversity. As a result, this study is very important in terms of both determining the potential distribution of the species and making a locality registration (Şiran, Gümüşhane) for the first time from the Eastern Black Sea region of the species. Also, with this study, the species has now been revealed that the show distribution in all regions of Turkey. Furthermore, the preferred habitat of the species in Turkey and in terms of bioclimatic variables affecting the determination of these preferences is a very important study. In addition, the distribution findings obtained in this study were found to be compatible with the findings given in the literature.

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