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The potential distribution and a new locality record of Roughtail Rock Agama (*Stellagama stellio*) from northwestern Anatolıa

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Abstract

Reptiles have been distributed in limited or wide areas, therefore it is well known that distribution dynamics are affected by several abiotic and biotic factors. While this situation constituted their habitat requirements, it also provides the suitable conditions that species can maintain their population within their distribution area. Although *S. stellio* was distributed in a wide area in the Anatolian Peninsula, its distribution in the Black Sea region was limited and has only been reported from a single locality so far. With this study, another locality was added to the distribution area of the species in the Black Sea region, and this record constitutes the northwesternmost locality of the species in the distribution area. Therefore, the present study not only contributes the species distribution trend, but also provides its habitat suitability analysis via Species Distribution Model (SDM) under current bioclimatic conditions in the Anatolian Peninsula. SDM results demonstrated that *S. stellio* has an adaptation to the warm and rainy climatic regimes in terms of habitat requirements. Lastly, it is recommended to compare the genetic background of this population with other populations among Turkey.

Keywords: Black Sea region, species distribution model, *Stellagama stellio*, Zonguldak, Agamidae

Introduction

Animal species are not static like plants and are constantly in motion. In this way, they have the ability both to expand their spread against changing environments and to adapt themselves in novel situation (Kurnaz, 2019). Moreover, many new locality reports have been given among Anatolia. These studies not only enlighten us to map entire Turkey herpetofauna as a major contribution, but also contribute to explore new distribution areas for existing species (Ilgaz et al., 2016; Kurnaz and Kutrup; 2018, 2019; Candan et al., 2019a, 2019b, 2020; Şahin et al.2020; Şahin and Kurnaz 2021).

Stellagama is a monotypic genus that is represented with a single species in the world. *Stellagama stellio*, also known as roughtail rock agama, spreads in Southeast Europe, Southwest Asia and Northeast Africa (Egypt) (Uetz et al., 2021). Its distribution in Turkey consists of the following regions: Western, South, Central and Southeastern Anatolia parts (Başoğlu & Baran, 1977; Baran & Öz, 1985; Baran et al., 1989; Kumlutaş et al., 2015). However, the roughtail rock agama is only reported from a single locality from the Black Sea coast (Sinop) in Northern Anatolia (Gül et al., 2010). This species is represented with two subspecies in this wide distribution area in the Anatolian Peninsula. While *S. p. Stellio* inhabits in central, south and southeastern Anatolia, the other subspecies *S. s. daani* spreads only in western and southwestern Anatolia (Kurnaz, 2020; Uetz et al., 2021). The population spreading in Northern Anatolia is reportedly as *S. s. daani* (Gül et al., 2010).

Species distribution modeling (SDM) is a crucial approach to learn more about conservation, ecology, distribution, geography, and evolutionary biology of an organism (Guisan & Zimmermann 2000; Araújo & Guisan 2006; Phillips et al., 2006). The Maximum Entropy algorithm (MaxEnt) uses only georeferenced occurrence data of a species with environmental strata and is a popular and easy method to determine species probable distribution dynamics (Guisan & Thuiller 2005; Elith et al., 2011). Besides, SDM is a method not only for predicting current conditions but also linking the actual one with past climate cases (Thuiller et al., 2005). Lastly, SDM is based on verified georeferenced occurrence data to predict distribution of a species under different climatic scenarios (Gül et al., 2017; Rounaghi and Hosseinian-Yousefkhani 2018; Kurnaz and Şahin, 2021).

The main aims of this study is *i)* to present a new locality from Northern Anatolia, where inhabiting conditions are limited to this species and *ii)* to provide information about the distribution anong the Anatolian Peninsula by using bioclimatic variables.

Materials and Methods

A total of 402 occurrence data for spatial analysis were obtained from the literature and field surveys (Boulenger, 1855; Werner, 1902; Steindachner, 1905; Venzmer, 1919; Bird, 1936; Bodenheimer, 1944; Mertens, 1952; Kosswigg, 1959; Daan, 1967; Clark, 1972; Clark & Clark, 1973; Pans, 1976; Andren & Nilson, 1976; Teynie, 1987; Baran et al., 1989; Teynie, 1991; Mulder, 1995; Uğurtaş et al., 2000; Cihan et al., 2003; Kumlutaş et al., 2004; Gül et al., 2010; Afsar & Tok, 2011; Akman & Göçmen, 2014; Eser & Erişmiş, 2014; Özcan & Üzüm, 2014; Tok & Çiçek, 2014; Ege et al., 2015; Kumlutaş et al., 2015; Sarıkaya et al., 2017; Akman et al., 2018; Şahin & Afsar, 2018; Yıldız et al., 2019). In cases where the locality information was not directly given in any GPS format, online geographic system software Google Earth was used to determine the most accurate location. (Figure 1). In order to avoid misinterpretation of distribution maps, the occurrence records for the species were rarefied spatially with removing one locality in each 5 km by using SDM Toolbox 2.0 in ArcGIS 10.3 (Brown 2014).

Species distribution pattern (SDM) were determined via 19 bioclimatic variables, and a topographical data (elevation) (downloaded on www.worldclim.org) in MaxEnt (Fick and Hijmans 2017; Phillips et al., 2017) (Table 1). Twenty data were tested by Pearson correlation analysis in ENMTools 1.4 program and data with r > │0.75│ were excluded from the analysis since it would negatively affect the spread (Figure 2) (Warren et al., 2010).

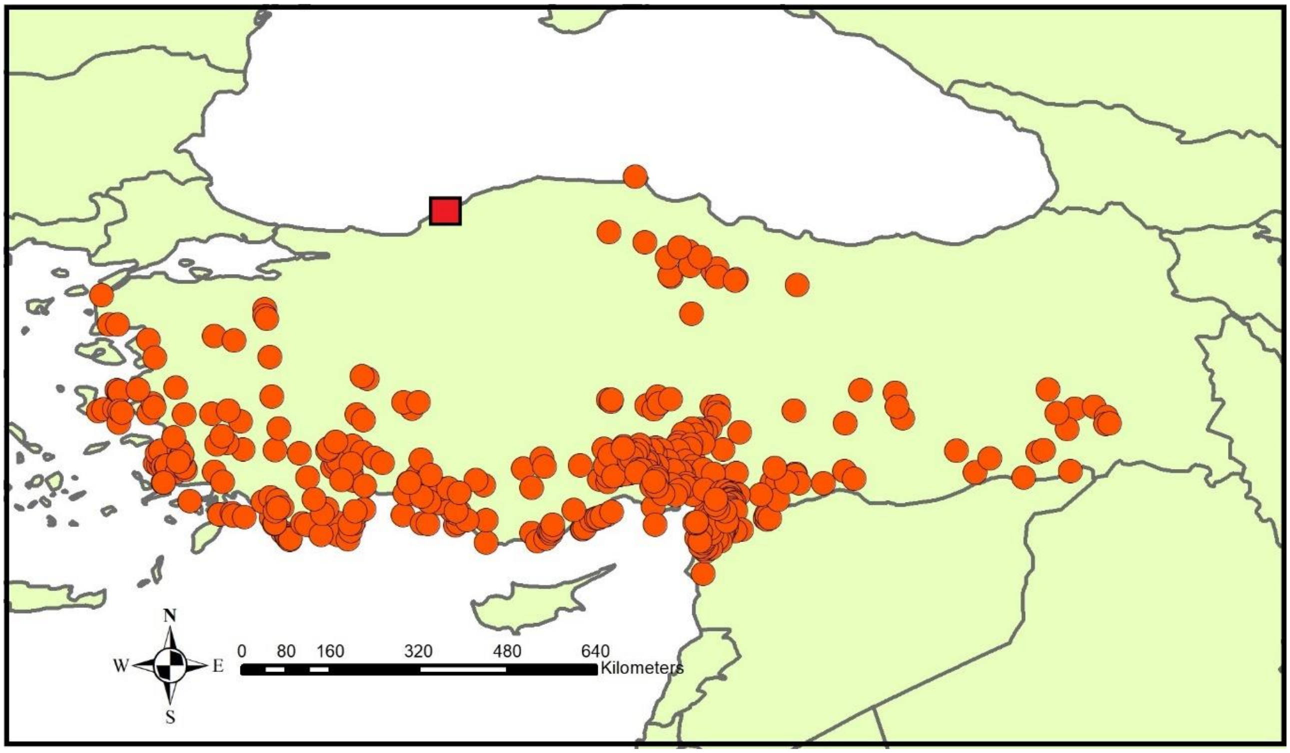

Figure 1: Occurrence records of *S. stellio.* Red circle points were obtained from references and the red square point was from Zonguldak

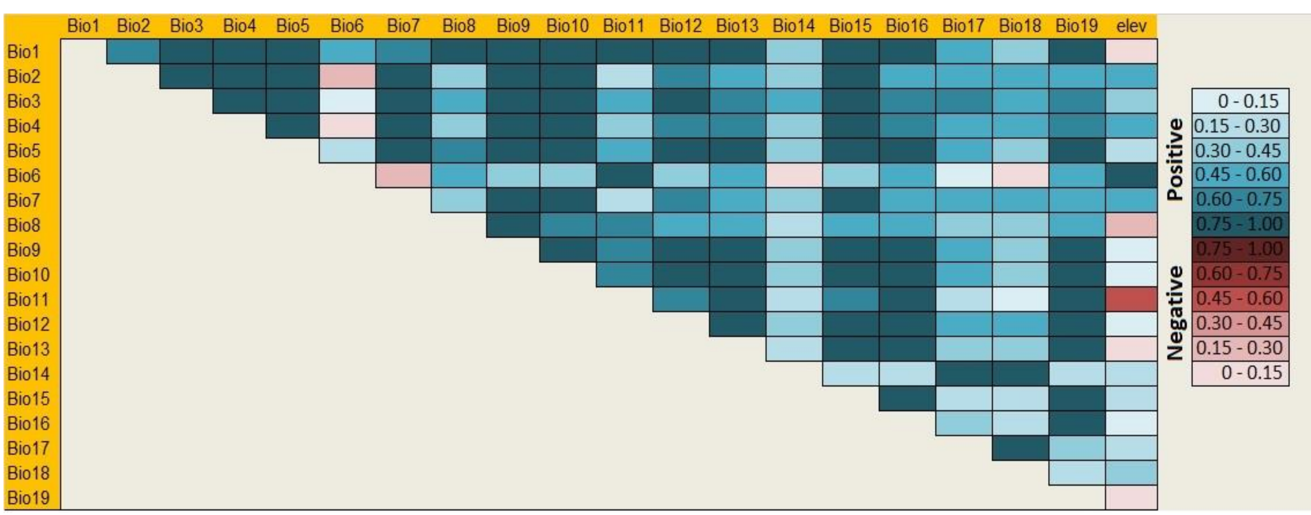

Figure 2: Correlation matrix of all variables used in the analysis.

Table 1: Bioclimatic variables from WorldClim database

Variable = Explanation
BIO1 = Annual Mean Temperature
BIO2 = Mean Diurnal Range (Mean of monthly (max temp - min temp))
BIO3 = Isothermality (BIO2/BIO7) (×100)
BIO4 = Temperature Seasonality (standard deviation ×100)
BIO5 = Max Temperature of Warmest Month
BIO6 = Min Temperature of Coldest Month
BIO7 = Temperature Annual Range (BIO5-BIO6)
BIO8 = Mean Temperature of Wettest Quarter
BIO9 = Mean Temperature of Driest Quarter
BIO10 = Mean Temperature of Warmest Quarter
BIO11 = Mean Temperature of Coldest Quarter
BIO12 = Annual Precipitation
BIO13 = Precipitation of Wettest Month
BIO14 = Precipitation of Driest Month
BIO15 = Precipitation Seasonality (Coefficient of Variation)
BIO16 = Precipitation of Wettest Quarter
BIO17 = Precipitation of Driest Quarter
BIO18 = Precipitation of Warmest Quarter
BIO19 = Precipitation of Coldest Quarter
ELEV = Elevation

The MaxEnt software was run with a convergence threshold of 0.00001, the highest iteration of 500, and a correction 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, 10 maps (10 repetitions) were created in the analysis and the most suitable distribution map was selected via AICc score. Jackknife test was conducted to determine the significance of the data affecting the distribution. The result of the receiver operating characteristic (ROC) curve is important for the model sensitivity, and the value of the area under the curve closest to 1 (AUC) indicates the best model performance. For model validation, we adopted the values of the area under the receiver-operator (ROC) curve (AUC) as indicators of the predictive power and accuracy of the model: (<0.5: strongly recommended not to run, >0.6: is not bad to run, >0.7: is relatively good, >0.8: good, >0.9: very good, =1: excellent) (Raes & ter Steege, 2007, Gallien et al., 2012).

Results and Discussion

Within the scope of this study, the new locality record of the species was given from Zonguldak province. This new locality is about 300 km away from Bursa in the west and Sinop in the east, which are the closest known distribution areas of this species. The retaining walls, where the species can live in this locality. Roughtail rock agama specimens share this narrow area with two different lizard species, *Darevskia bithynica* and *Lacerta viridis*. This area is located at the edge of the Zonguldak-Devrek highway (41.451920° N and 31.824599 ° E, 40 m a.s.l.). The specimen was observed in its microhabitat in 11 July 2020 (Figure 3).

As a result of SDM, it was revealed that the distribution of *S. stellio* under today's bioclimatic conditions was in accordance with the habitat requirements (Figure 4). For instance, 5 out of 19 bioclimatic variables (Bio-6, Bio-14, Bio-12, Bio-2, and Bio-8) have a greatly influence on the spread of the species. Among these variables, the most contributed ones are Bio-6 and Bio-12 (totally ~80%) (Table 2). According to the outputs of SDM, it can be claimed that the distribution of the roughtail rock agama was affected by seasonal temperature and precipitation dynamics especially in terms of both diurnal trends and the coldest and/or driest months.

Table 2: Contribution of low correlated bioclimatic variables in SDM of *S. stellio*

Variables	Contribution percent (%)
Bio 6	54.9
Bio 14	23.3
Bio 12	13.5
Bio 2	5.2
Bio 8	6.8

Figure 3: General view of *Stellagama stellio* in its habitat from Devrek, Zonguldak, Turkey

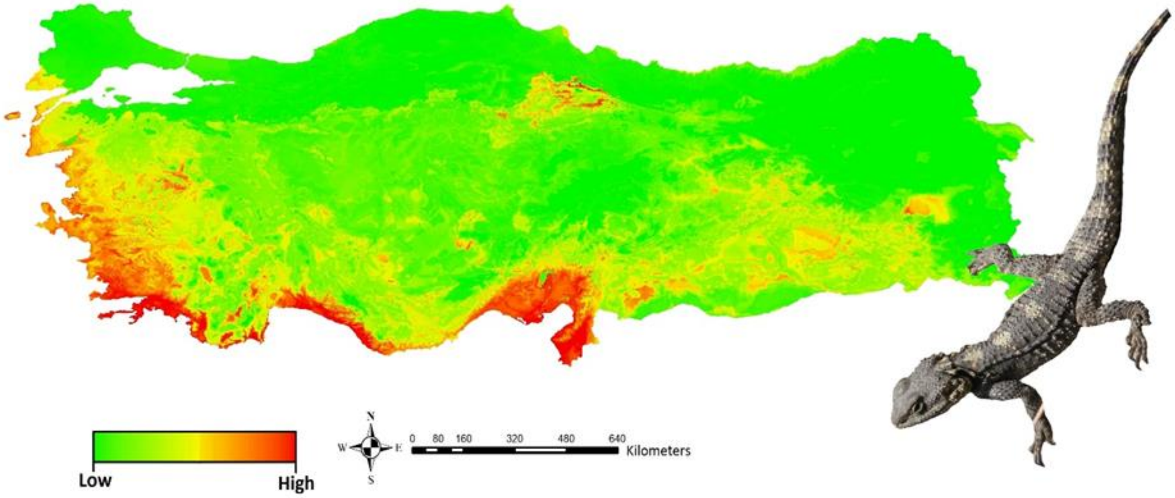

Figure 4: Species distribution model of *Stellagama stellio* in the Anatolian Peninsula

In addition to these bioclimatic data, elevation as an important topographic variable was also inducted to the analysis. Jackknife analysis results revealed that minimum temperature of the coldest month (Bio-6) is the most useful variable for the determining the distribution of the species (Figure 5). The result of the receiver operating characteristic (ROC) curve was found to be compatible with the model sensitivity and the value of the area under the curve (AUC) (0.848 ± 0.027). Due to this value was greater than 0.8, it also made the analysis outputs in a strong position. In addition to them, the standard deviation was not too high that indicates the margin of error in the analysis is low and the species distribution can be mapped via using these variables.

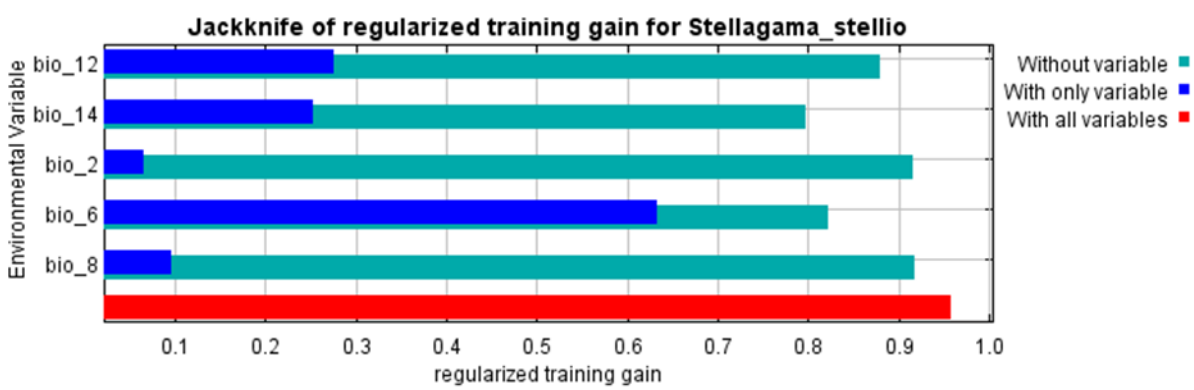

Figure 5: Relative predictive power of the five bioclimatic variables predicted by the jackknife for *Stellagama stellio* in MaxEnt model

Species have been affected by many biotic (such as competitors or predictors) and abiotic (i.e. environmental factors or microhabitat structures) factors under the terms of their distributional range and habitat preferences (Hosseinian-Yousefkhani et al., 2016). Therefore, species have taken their position in niche interactions within their habitats and isolate themselves from other species in a serious time (Peterson et al., 1999). Although the variables that shape the distribution of *S. stellio* have revealed that the species can spread in a very wide area, when it comes to narrow perspective, it is better to to examine its survival conditions in new conditions. Because in *situ* observations showed that this species is sympatric with native species, such as *D. bithynica* and *L. viridis*, and it can compete with these lizards and is successful for ensuring the continuity of its generation.

Although this area provides a small habitat for this species, it is suitable for the fundamental ecological requirements for a distinct population from the main ones (Kurnaz, 2019; Kurnaz and Eroğlu 2020; Kurnaz and Hosseinian-Yousefkhani, 2020). The species general spread trend in the Anatolian Peninsula showed that the habitat conditions for this species were more suitable in the western and southern parts, and the central part followed them with relatively low probability. Moreover, the Northern Anatolia seemed to be unsuitable for this species. Therefore, this new locality record seemed to be a consequence of indirect transportation under the construction work of Ankara – Zonguldak Highway. It might be speculated that the founder individuals might be carried via large stones on the trucks and this new microhabitat conditions were suitable for *S. stellio* to adapt themselves. The similar scenario was demonstrated in Georgian population of *Phoenicolacerta laevis* (Tarkhnishvili et al., 2017). In this research, the authors investigated the origins of this population and they found that the lizards might be transported during the construction activity of Anaklia castle. Because their results showed that there is a significant genetical similarity between Georgian and Eastern Mediterranean populations.

Conclusion

In conclusion, this study provides us a species distribution map with a new locality record from the northwesternmost place in the Anatolian Peninsula. However, further studies include its global distribution pattern might enlighten us more for not only current situation but also compare to several alternative predictions according to global climate change scenarios. In addition to that, determining the genetic patterns of this population can allow us new sights for questioning the influence of anthropogenic based transportation on the genetic flow of the populations.

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