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Chapter 16

The Potential Distribution of *Darevskia derjugini* (Nikolsky, 1898) with New Locality Records from Turkey

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INTRODUCTION

The genus *Darevskia* (Arribas, 1997), distributed from the Caucasus to Balkans and from the Middle East to Anatolia, is represented with the most lizard species in Turkey (http://www.reptile-database.org/). Fifteen species (*D. armeniaca* Mehely, 1909; *D. bendimahiensis* Schmidtler *et al.,* 1994; *D. bithynica* Mehely, 1909; *D. clarkorum* Darevsky and Vedmederja, 1977; *D. derjugini* Nikolsky, 1898; *D. dryada* Darevsky and Tuniyev, 1997; *D. nairensis* Darevsky 1967; *D. parvula* Lantz and Cyren, 1913; *D. pontica* Lantz and Cyren, 1919; *D. raddei* Boettger, 1892; *D. rudis* Bedriaga, 1886; *D. sapphirina* Schmidtler *et al.,* 1994; *D. unisexualis* Darevsky, 1966; *D. uzzeli* Darevsky and Danielyan, 1977 and *D. valentini* Boettger, 1892) occur in Turkish populations including the Eastern and Central Anatolia as well as the Marmara and Black Sea regions (Baran & Atatür, 1998; Sindaco, Venchi, Carpaneto & Bologna, 2000; Ananjeva *et al.,* 2006; Arribas *et al.,* 2013; Baran, Ilgaz, Avcı, Kumlutaş & Olgun, 2012; http://www.reptile-database.org/).

Darevskia derjugini was first described by Nikolsky (1898) from Artvin province. The samples belonging to this species were collected by Derjugin. Nikolsky denominated the species as Derjugin's Lizard, and type locality of the species was determined to be Artvin. After a long time, in 1972, a new locality record was given by Clark from 45 km east of Ardanuç (near Şavşat) and 15 km west of Borçka in Turkey. Later, Clark and Clark (1973) recorded the species from Arsin (Trabzon), 20 km west of Borçka and 50 km northwest of Ardahan (near Şavşat). In the subsequent studies, several locality records related to the distribution in Turkey of the species were given by many researchers (Baran, 1977; Bischoff, 1982; Teynié, 1987; Mulder, 1995; Baran, Tosunoğlu, Kaya & Kumlutaş, 1997; Franzen, 1999; Franzen, 2000; Kutrup, 2001; Ilgaz, 2004; Bischoff, Franzen & Schmidtler, 2005; Afsar, Ayaz, Afsar, Çiçek & Tok, 2012). With this locality records, the distribution boundaries of the species in Turkey were determined to be the easternmost Artvin (Georgian border) and the westernmost Giresun (Güdül village).

Darevskia derjugini is one of the small-sized lizards among the Caucasian rock

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lizard species. Since the dorsum coloration of the species is brownish, it can easily hide in suitable habitats. The habitat preference of the species is generally different from other rock lizards because it lives in damp forested areas including dry leaves, tree stumps and grass but rarely in stony places (Clark & Clark, 1973; Baran & Atatür, 1998; http://www.iucnredlist.org/). The species is distributed from the sea level to high elevations (about 1700 m) including suitable habitats of populations (Baran & Atatür, 1998; Baran *et al.,* 2012).

A number of studies on the habitat preference of amphibians and reptiles have been performed by many researchers in the recent years (Fattahi *et al.,* 2014; Gül, 2015; Gül, Kumlutaş & Ilgaz, 2015; Yousefkani, Tehrani, Moodi & Gül, 2016) since their distribution in the areas and habitat preferences of these animals are important for their conservation and ecology (Kumar & Stohlgren, 2009; Gül, 2013). The present study is aimed to investigate potential distribution and climatic preferences of the *D. derjugini*, which is only endemic to the Caucasus Hotspot using new locality records from Turkey. Also, we presented climatic conditions in the potential distribution area of species was congruent with its habitat preferences in the inhabited locality.

MATERIALS AND METHODS

Occurrence data of species

In the field work conducted in the northeast Anatolia region of Turkey between 2014 and 2015 years, 23 locality records for *D. derjugini* was collected. Additionally, all literature information related to the distribution of *D. derjugini* in Turkey was examined, and according to this information, a total of 17 locality records were accumulated (Avsar *et al.,* 2012; Baran, 1977; Baran, Tosunoğlu, Kaya & Kumlutaş, 1997; Bischoff *et al.,* 2005; Franzen, 1999, 2000; Kutrup, 2001; Ilgaz, 2004) (Table 1).

Table1. The locality data of *Darevskia derjugini* in Turkey

No	Species	Longitute	Latitude	References
1	*Darevskia derjugini*	38.445399	40.675779	Bischoff et al., 2005
2	*Darevskia derjugini*	39.659589	40.704547	Bischoff et al., 2005
3	*Darevskia derjugini*	39.952547	40.934941	This study
4	*Darevskia derjugini*	39.962894	40.929773	This study
5	*Darevskia derjugini*	39.972268	40.891856	This study
6	*Darevskia derjugini*	39.216114	40.856997	This study
7	*Darevskia derjugini*	39.843942	40.857591	This study
8	*Darevskia derjugini*	40.123789	40.811742	Ilgaz, 2004
9	*Darevskia derjugini*	40.144061	40.858544	This study
10	*Darevskia derjugini*	40.115726	40.883670	Ilgaz, 2004
11	*Darevskia derjugini*	40.601350	40.722272	This study
12	*Darevskia derjugini*	40.558038	40.793084	This study
13	*Darevskia derjugini*	41.060801	41.007667	Baran et al., 1997
14	*Darevskia derjugini*	41.040437	41.101624	Franzen, 1999
15	*Darevskia derjugini*	41.065849	41.118930	Baran, 1977
16	*Darevskia derjugini*	40.967515	40.990788	This study
17	*Darevskia derjugini*	41.958308	40.980923	This study
18	*Darevskia derjugini*	40.972668	40.997725	Baran, 1977
19	*Darevskia derjugini*	41.082258	40.958558	This study
20	*Darevskia derjugini*	41.424793	41.292404	Ilgaz, 2004
21	*Darevskia derjugini*	41.440422	41.280905	Ilgaz, 2004
22	*Darevskia derjugini*	41.515677	41.400657	This study
23	*Darevskia derjugini*	41.549975	41.397450	This study

24	*Darevskia derjugini*	41.881349	41.458199	This study
25	*Darevskia derjugini*	41.589373	41.379669	This study
26	*Darevskia derjugini*	41.535878	41.492032	Franzen, 1999
27	*Darevskia derjugini*	41.855905	41.442878	Afsar et al., 2012
28	*Darevskia derjugini*	41.841632	41.426802	Afsar et al., 2012
29	*Darevskia derjugini*	41.979723	41.421931	Afsar et al., 2012
30	*Darevskia derjugini*	41.978052	41.488257	Afsar et al., 2012
31	*Darevskia derjugini*	41.941301	41.494372	Afsar et al., 2012
32	*Darevskia derjugini*	41.411693	41.365255	This study
33	*Darevskia derjugini*	41.364245	41.251726	This study
34	*Darevskia derjugini*	41.532042	41.298767	This study
35	*Darevskia derjugini*	41.518898	41.290298	This study
36	*Darevskia derjugini*	41.795386	41.154517	Nikolsky, 1898
37	*Darevskia derjugini*	42.041692	41.271578	This study
38	*Darevskia derjugini*	41.704244	41.179004	This study
39	*Darevskia derjugini*	42.425691	41.239112	This study
40	*Darevskia derjugini*	41.425091	41.269943	This study

Species distribution modelling

In order to create species distribution modelling, 19 bioclimatic data were downloaded from Global Climate Data (available at www.worldclim.org). These data were generated from global esri grids in the highest resolution (30 arc-seconds (~1 km)) for current conditions (~ 1950-2000). For the elevation, SRTM30 dataset from CGIAR-SRTM aggregated to 30 seconds were used (available at http://srtm.csi.cgiar.org/). Arc Toolbox was used to extract by mask covering the land border of Turkey, and applied to this process for each bioclimatic data. 19 bioclimatic variables are similar to each other; therefore, Mean Diurnal Range (Bio2), Isothermality (Bio3), Mean Temperature of Wettest Quarter (Bio8), Annual Precipitation (Bio12), Precipitation of Driest Month (Bio14) and Precipitation Seasonality (Bio15) using ENMTools 1.4 (Warren et al., 2010) were selected to the model distribution of *D. derjugini*. ENMTools analyzed the relationship between variables using Pearson correlation coefficient ($0.75 < r < -0.75$).

Maxent 3.3.3k (Philips, Anderson & Schapire, 2006) software was used to perform species distribution modelling. To develop the model, 40 occurrence data that are based on literature and new locality records were used. 25% of the occurrence data were set aside as test points, and 10.000 background points were used to determine the distribution. Additionally, the regularization multiplier = 0.5, maximum iterations = 500, convergence threshold = 0.00001 were chosen in Maxent. In order to test the variable importance, the jackknife test of variable importance was chosen in Maxent, and the model was run as ten replicates.

RESULTS

The species distribution modeling of *D. derjugini* under the current climatic conditions showed that the northeast of Turkey has optimal requirements for its habitat preference (Figure 1). The environmental variables with the highest gain that best describes the presence of *D. derjugini* were Bio14 (Precipitation of Driest Month, 73.8%) and Bio15 (Precipitation Seasonality, 19.1%). Additionally, the jackknife regularized the training which provided additional support for this result, as Bio14 gave only the most useful information for predicting the potential distribution of *D. derjugini*, and the performance of the model was the lowest without Bio14 (Figure 2). All other variables used in the model had a contribution less than 5% (Table 2).

According to the model, the average test AUC that is the area under the receiver operating characteristic curve (ROC) for the replicate runs is 0.986, and the standard deviation is 0.012.

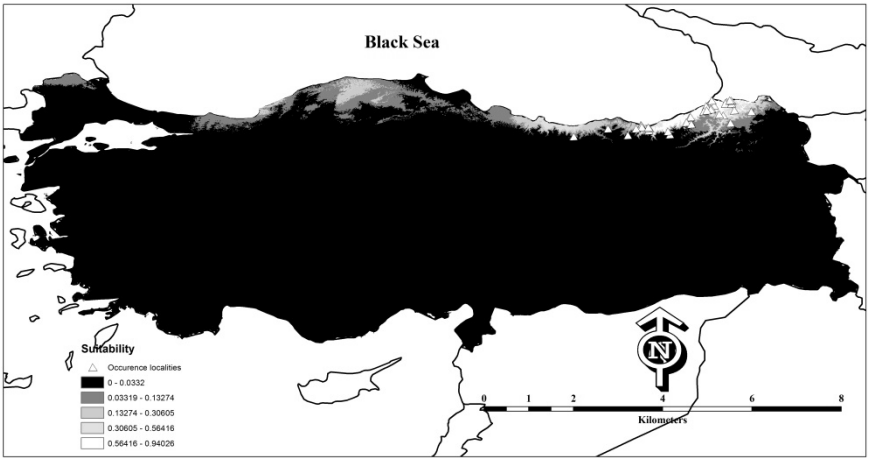

Figure 1. The expected potential distribution of *Darevskia derjugini* based on climatic conditions.

DISCUSSION

According to the phylogenetic data, a split between the species of group *mixta* (*raddei*, *derjugini*, *caucasica*, *daghestanica*, *clarkorum*, *mixta*) occurred 2.5-5.0 millions of years ago, and this time was called as "Pliocene" (Tarkhnishvili, 2012). The Pliocene climatically can be divided into three phases, (1) early period of the Pliocene is warm, (2) a relatively warm period in the Mid-Pliocene, (3) the climate was in the process of becoming worse during the Late Pliocene, and this era was warmer than today (Haywood *et al.,* 2009). Many patterns in ecology, evolution and conservation are related to the geographical distribution of species, and these distributions depend on several factors that set range limits of species.

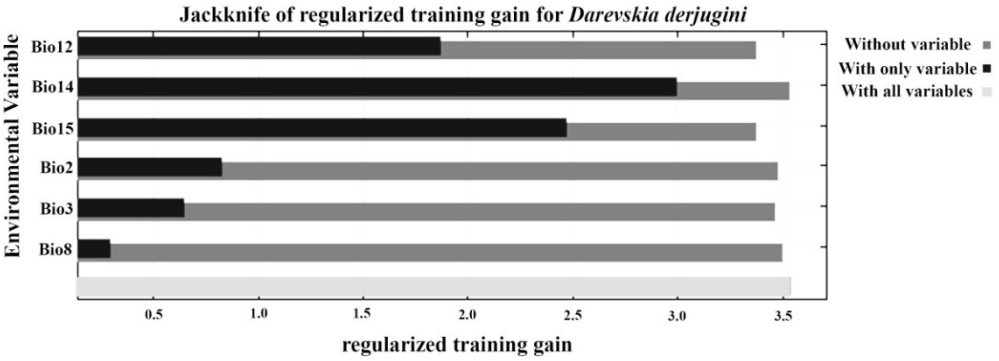

Figure 2. The results of the jackknife test of variable importance used in the model.

Table 2. Table indicates estimates of relative contributions of the climatic conditions to distribution modelling of *Darevskia derjugini*.

Variables	Percent Contribution
Bio14	**73,8**
Bio15	**19,1**
Bio12	2,6
Bio3	2,5
Bio2	1,1
Bio8	0,9

Climatic conditions is one of these factors that may restrict distribution of species (Cahill *et al.,* 2013). It seems that our results verify this situation because the geographical distribution of *D. derjugini* based on current climatic conditions only indicates the northeast of Turkey (Figure 1). Rainfall has an important effect on the distribution of *D. derjugini* according to our model. Especially, precipitation of driest month (Bio14) and precipitation seasonality (Bio15) are the limiting factors on *D. derjugini*'s dispersal. Precipitation of driest month (Bio14) contributes the most range limits of *D. derjugini*. This points out that summer precipitation provides a suitable environment for life history activities, such as, reproduction, mating and foraging. The northeast of the Black Sea has a big difference in respect to the total rainfall between the other regions of Turkey, and particularly the greatest amount of rainfall emerges in Rize and Artvin provinces of the Black Sea region (Şensoy, Demircan, Ulupinar & Balta, 2008). Similarly, Tarkhnishvili (2012) showed that minimum annual rainfall (600 mm <) in the Western Caucasia covering the Black Sea region of Turkey provided a restrictive environment for most of the species like *D. derjugini.* Furthermore, our model showed that there was a suitable habitat for *D. derjugini* in the middle part of the northeast and middle Black Sea (Figure 1). In fact, *D. derjugini* is not found in the middle of Black Sea, but this region is similar to the northeast Black Sea in terms of summer precipitation. Probably, it is a result of this pattern in Figure 1.

D. derjugini is presently listed as Near Threatened (TN) in the IUCN Red List, and populations of this species are considerably decreased due to habitat loss and fragmentation of remaining populations through much of its range, which makes the species close to qualifying for Vulnerable (Ananjeva *et al.,* 2009). Climate change including global warming and alteration of temperature and precipitation patterns as well as these threats can highly affect the world's herpetofauna (Badger & Netherton, 2002).

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