Modeling the potential distribution of *Ablepharus bivittatus* (MÉNÉTRIÉS, 1832), in Iran
(Squamata: Sauria: Scincidae)

Modellierung der potentiellen Verbreitung von
Ablepharus bivittatus (MÉNÉTRIÉS, 1832) im Iran
(Squamata: Sauria: Scincidae)

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KURZFASSUNG

Die Verbreitung von *Ablepharus bivittatus* (MÉNÉTRIÉS, 1832) im Iran ist weitgehend auf den Nordwesten und einige Isolate im zentralen Elbursgebirge und Kopet Dagh Gebirge beschränkt. Maxent Software wurde eingesetzt, um Aussagen zur potentiellen Verbreitung der Art im Iran zu machen und jene Klimafaktoren zu ermitteln, die das Verbreitungsmuster am besten beschreiben.

Vier Variablen erwiesen sich zur Beschreibung der Verbreitung als besonders aussagekräftig: (i) die Niederschlagsmenge im kältesten Quartal, (ii) die mittlere Temperatur im kältesten Quartal, (iii) die Hangneigung im Lebensraum und (iv) die Spannweite der Temperatur im Jahresverlauf (Saisonalität), wobei Temperatur- und Niederschlagswerte im Winter sowie die Schräglage des Lebensraumes die bestimmendsten Verbreitungsfaktoren darstellen. Die Konkurrenz durch *Ablepharus pannonicus* (FITZINGER, 1824) scheint die Ausbreitung von *A. bivittatus*-nach Osten und Süden entlang der Elburs- und Zagros-Gebirgsketten zu behindern.

ABSTRACT

In Iran, *Ablepharus bivittatus* (MÉNÉTRIÉS, 1832) is known from the northwest and some isolated records in the Central Elburz and Kopet Dagh Mountains. MaxEnt software was selected to predict its potential distribution in this country and find the most important climatic factors that influence the species' distribution pattern.

Four variables were most determinative for the species' distribution: (i) quantity of precipitation of the coldest quarter, (ii) mean temperature of the coldest quarter, (iii) slope of the habitat and (iv) temperature seasonality (= range of annual temperature variation), where winter precipitation and temperature plus habitat slope were the main determinants. In addition, competition with *Ablepharus pannonicus* (FITZINGER, 1824), is suggested to restrict the dispersion of *A. bivittatus* towards the east and south along the Elburz and Zagros Mountains, respectively.

KEY WORDS

Reptilia: Squamata: Sauria: Scincidae: *Ablepharus bivittatus*, modeling potential distribution, ecology, ecological niche modeling, climate variables, Iran

INTRODUCTION

In Iran, the Two-streaked Snake-eyed Skink, *Ablepharus bivittatus* (MÉNÉTRIÉS, 1832), inhabits the northwestern part of the country including the northern Zagros, Elburz and and Kopet Dagh Mountains (ANDERSON 1999; SMID et al. 2014) with its distribution extending into Armenia, east Anatolia, south Transcaucasia, Azerbaijan and south Turkmenistan. However, some authors hypothesized that the species' distribution may expand more continuously southward along the Zagros Mountains (SINDACO & JEREMČENKO 2008; SMID et al. 2014).

Ecological niche modeling (ENM) uses occurrence data of the studied species and environmental information of the record localities to predict suitable habitats outside the known range and to find the most suitable variables to determinie the species' distribution within its range. This predictive species distribution modeling was recently applied in many herpetological studies and used for determination of environmental priorities (ELith et al. 2006; Kozak & Wiens 2006; Phillips et al. 2006; Litvinchuk et al. 2010; Doronin 2012; Bernardes et al. 2013; Ananjeva & Golynsky 2013; Ficetola et al. 2013).

The modeling technique of the freeware package MaxEnt (< https://www.cs.princeton.edu/~schapire/maxent/ >) was used to construct a bioclimatic distribution model for *Ablepharus bivittatus* (Ménétriés, 1832), in Iran. Based on the maximum-entropy approach for species habitat modeling (Phillips, S. J. & Dudik, M. & Schapire, R. E. 2006), this software takes as input a set of environmental variables (such as elevation, precipitation, etc.) as predictors, as well as a set of georeferenced occurrence locations, and produces a model of the range of the given species.

MATERIALS AND METHODS

One hundred georeferenced distribution records of *A. bivittatus* from Iran were collected from the literature and museum records, the precise coordinates (decimal degrees) were determined. In total, 100 record localities were obtained from these resources (Appendix I).

Information to 19 bioclimatic variables representing conditions from 1950-2000 were downloaded from the WorldClim website (Hijmans et al. 2005, < www.worldclim.org >) [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 and the altitude (resolution of variables: 30 arc-seconds; representing approximately 1 km). In addition, the topographic factor 'slope', which represents the topographic effect on the species' presence, was entered in the analysis as a percentage value derived from elevation data. A common subset of distribution points and climatic layers restricted to the territory of Iran was computed by Openmodeller ver. 1.0.7 (Muñoz et al. 2011). Bivariate (Pearson) correlation coefficients were used to identify variable-pairs with correlations > 0.75, which were subsequently removed from the analysis. Thus, the number of variables was reduced from initially 21 to 7 lowest correlated variables (Table 1).

MaxEnt 3.3.3e was employed to predict the species distribution patterns (Philips et al. 2006). MaxEnt uses environmental data as predictors and presence-only records as response (Elith et al. 2011). MaxEnt modeling was accomplished by evaluating the suitability of each grid cell in the study area as a unit of environmental variables at that cell, then calculating the most important grids for niche of each species.

Seventy percent of occurrence data were used for model training and 30 % for model testing. Default parameter settings comrised: maximum 500 iterations, convergence threshold 10-5, regularization multiplier 0.2 and 10 replicates (Phillips et al. 2006). Model validation was conducted by calculating the area under the curve (AUC), which reflects the model's ability to distinguish between presence records and random background points (Hanley & McNeil 1982; Phillips et al. 2006). Normally, the AUC of models is between 0.5 (the predicted model is not better than random points) and 1 (the predicted model is perfect). Thus, an AUC value > 0.9 is considered as very good, > 0.8 - 9.0 as good and 0.7 - 8.0 as better than random prediction (Swets 1988). A jackknife test (Shcheglovitova & Anderson 2013) was run to evaluate the important variables.

RESULTS

The predicted areas suitable for the occurrence of *Ablepharus bivittatus* (Fig. 1) have high training AUC (0.989 ± 0.005) and test AUC (0.991 ± 0.002) values indicating good model fit.

Four variables out of 21 considered in this study contributed most accurately to the explanation of the distribution of *A. bivittatus* in Iran. The relevant contribution levels were: BIO19 - Precipitation of Coldest Quarter (34.6 %); BIO11 - Mean Temperature of Coldest Quarter (20.4 %); slope (19.3 %) and BIO4 - Temperature Seasonality (12.7 %) (Table 1). Specifically, suitability of the territory was highest in regions meeting the conditions (i) high winter precipitation, (ii) low winter mean temperatures, (iii) steep relief and (iv) wide range of mean monthly temperatures.

DISCUSSION

The model is well in agreement with the known distribution of *Ablepharus bivittatus* (ANDERSON 1999; ILGAZ et al. 2007; SMID et al. 2014). In addition, the northwestern corner of Iran, eastern Turkey, central Elburz Mountains and some parts in northeastern Iran were predicted as potential distribution areas of high and highest suitability. In an eastward direction, the degree of suitability decreases in parallel with decreasing winter precipitation (Fig. 1). Furthermore, eastern and western Azerbaijan and the Iranian Provinces of Ardabil, Mazandaran, Tehran, Guilan, Semnan, Northern Khorasan and Khorasan Razavi were predicted as suitable regions. There are records of the species from all these provinces except for the Khorasan Razavi province.

The habitat descriptions of the species mention rocky slopes with dense shrubs where the latter are used as habitat as well as retreats when pursued (ANDERSON 1999). *Eremias strauchi* KESSLER, 1878 and *Ophisops elegans* MÉNÉTRIES, 1832 were found in sympatry with *A. bivittatus* in the Province of Ardabil (AHMADZADEH et al. 2008). ORAIE et al. (2014) evaluated the potential distribution of *O. elegans* in Iran using the MaxEnt method. As was noted for *A. bivittatus* in the present paper, they found that

Table 1: Percentage contribution (average of ten replicates) of the climate variables to the model that most accurately explained the distribution of *Ablepharus bivittatus* (MÉNÉTRIÉS, 1832) in Iran.

Tab. 1: Prozentualer Beitrag (Mittel von zehn Replikationen) der Klimavariablen zum Modell, das die Verbreitung von *Ablepharus bivittatus* (MÉNÉTRIÉS, 1832) im Iran am besten erklärte.

Variable	Percentage contribution Prozentualer Anteil
Precipitation of Coldest Quarter Niederschlagsmenge im kältesten Quartal	34.6
Mean Temperature of Coldest Quarter Temperaturmittel im kältesten Quartal	20.4
Slope Hangneigung	19.3
Temperature Seasonality Variabilität der Temperatur innerhalb des Jahres	12.7
Isothermality Mittlere Tagesamplitude / Jahresamplitude der Temperatur	7.1
Precipitation Seasonality Variabilität der Niederschlagsmenge innerhalb des Jahres	3.1
Mean Temperature of Warmest Quarter Temperaturmittel des wärmsten Quartals	2.8

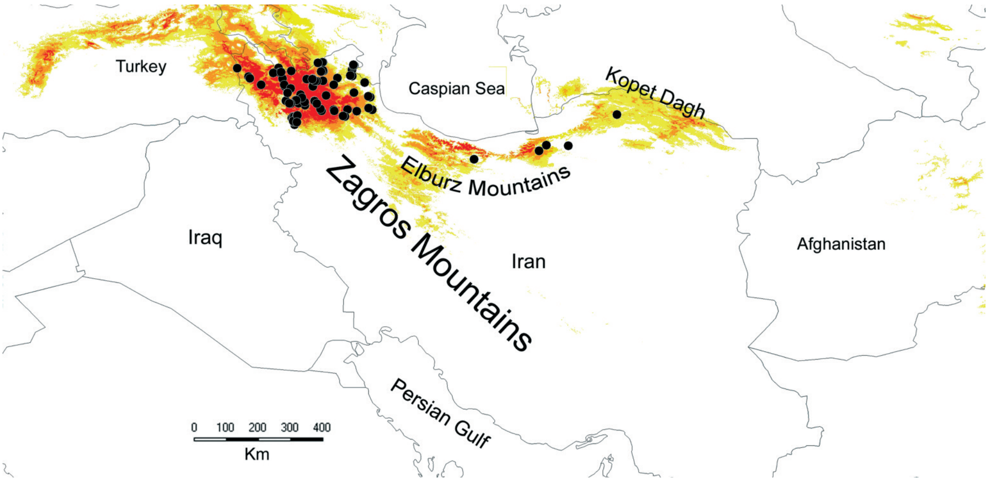

Fig. 1: Distribution model of *Ablepharus bivittatus* (MÉNÉTRIÉS, 1832) in Iran. Colors indicate different habitat AUC (Area under the curve) suitability values within the skink's potential range: Yellow: < 0.42; Orange: 0.42 - 0.75; and Red: > 0.75. Black dots represent known record localities. For practical reasons the graduation of the threshold values differs from that in SWETS (1988).

Abb. 1: Verbreitungsmodell von *Ablepharus bivittatus* (MÉNÉTRIÉS, 1832) im Iran. Farben bezeichnen unterschiedliche Eignung des Lebensraumes innerhalb des potentiellen Verbreitungsgebietes des Skinks. Gelb: < 0.42; Orange: 0.42 - 0.75; Rot: > 0.75. Schwarze Punkte repräsentieren die bekannten Fundorte. Aus praktischen Gründen wurde eine andere Abstufung der Grenzwerte gewählt als in SWETS (1988).

the variable 'amount of precipitation in winter' had the most important effect on the presence or absence of *O. elegans*.

Some northeast Iranian areas outside the known range of *A. bivittatus* were predicted as potential distribution areas in the present model, for example, the Kopet Dagh Mountains where, only one record of the species is known (SMID et al. 2014). The variable 'slope' (degree of inclination) ranks third in importance (Table 1) telling us that steep regions are favorable for the species. As in precipitation, its value decreases from west to east which negatively affects the habitat suitability.

In Iran, the distribution of *Ablepharus pannonicus* (FITZINGER, 1824) has some similarity to the distribution of *A. bivittatus*. *Ablepharus pannonicus* occurs in the Elburz, Kopet Dagh and Zagros Mountains from where its territory extends to the east Iranian Provinces of Sistan and Baluchestan (ANDERSON 1999; SINDACO & JEREMČENKO 2008; SMID et al. 2014). One may hypothesize that low densities of *A. bivittatus* records in northeast Iran (Elburz and Kopet Dagh Mountains) and the high densities of *A. bivittatus* records in northwestern Iran are the result of competition between these two congeners, which causes *A. pannonicus* to disperse eastward and prevents *A. bivittatus* from extending its territory to the east and south.

According to this research, *A. bivittatus* appears better adapted to the northwest Iranian regions with steep relief and hibernal snowfall. It will be important to study the ecological niche differentiation between *A. bivittatus* and *A. pannonicus* to better understand the niche differentiation between these two species.

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REFERENCES

Ahmadzadeh, F. & Kiabi, B. H. & Kami, H. G. & Hojjati, V. (2008): A preliminary study of the lizard fauna and their habitats in northwestern Iran.- Asiatic Herpetological Research, Berkeley; 11: 1-9.

Ananjeva, N. B. & Golynsky, E. A. (2013): Analysis of distribution of the Turkestan rock agama, *Paralaudakia lehmanni* (Nikolsky, 1896): Using of MaxEnt modelling.- Proceedings of the Zoological Institute of the Russian Academy of Sciences, Sankt-Peterburg; 317 (4): 426-437 (In Russian)

Anderson, S. C. (1999): The lizards of Iran. Saint Louis (Society for the Study of Amphibians and Reptiles), pp. vii, 442.

Bernardes, M. & Rödder, D. & Nguyen, T. T. & Pham, C. T. & Nguyen, T. Q. & Ziegler, T. (2013): Habitat characterization and potential distribution of *Tylototriton vietnamensis* in northern Vietnam.- Journal of Natural History, London; 47: 1161-1175.

Doronin, I. V. (2012): The use of GIS for the analysis of the distribution of rock lizards *Darevskia (saxicola)* complex (Sauria: Lacertidae).- Sovremennaya gerpetologiya [Modern Herpetology], Saratov University Press, Saratov; 12: 91-122 (In Russian).

Elith, J. & Graham, C. H. & Anderson, R. P. & Dudík, M. & Ferrier, S. & Guisan, A. & Hijmans, R. J. & Huettmann, F. & Leathwick, J. R. & Lehmann, A. et al. (2006): Novel methods improve prediction of species' distributions from occurrence data.- Ecography, Oxford; 29: 129-151.

Elith, J. & Phillips, S. J. & Hastie, T. & Dudík, M. & Chee, Y. E. & Yates, C. J. (2011): A statistical explanation of MaxEnt for ecologists.- Diversity & Distributions, Oxford etc.; 17: 43-57.

Ficetola, G. F. & Bonardi, A. & Sindaco, R. & Padoa-Schioppa, E. (2013): Estimating patterns of reptile biodiversity in remote regions.- Journal of Biogeography, Oxford; 40: 1202-1211.

Hanley, J. & McNeil, B. (1982): The meaning of the use of the area under a receiver operating characteristic (ROC) curve.- Radiology, Oak Brook; 143: 29-36.

Hijmans, R. J. & Cameron, S. E. & Parra, J. L. & Jones, P. G. & Jarvis, A. (2005): Very high resolution interpolated climate surfaces for global land areas.- International Journal of Climatology, Chichester etc.; 25: 1965-1978.

Ilgaz, C. & Kumlutaş, Y. & Olgun, K. & Baran, I. (2007): The morphology and distribution of *Ablepharus bivittatus* (Ménétriés, 1832) (Reptilia: Sauria: Scincidae) in Turkey. Russian Journal of Herpetology, Moskva; 14: 91-97.

Kozak, K. H. & Wiens, J. J. (2006): Does niche conservatism promote speciation? A case study in north american salamanders.- Evolution, Hoboken; 60: 2604-2621.

Litvinchuk, S. N. & Kazakov, V. I. & Pasynkova, R. A. & Borkin, L. J. & Kuranova, V. N. & Rosanov, J. M. (2010): Tetraploid green toad species (*Bufo pewzowi*) from the Altay Mountains: The first record for Russia.- Russian Journal of Herpetology, Moskva; 17: 290-298

Muñoz, M. E. S. & Giovanni, R. & Siqueira, M. F. & Sutton, T. & Brewer, P. & Pereira, R. S. & Canhos, D. A. L. & Canhos, V. P. (2011): OpenModeller: a generic approach to species' potential distribution modeling.- GeoInformatica, Berlin; 15: 111-135.

Oraie, H. & Rahimian, H. & Rastegar-Pouyani, N. & Rastegar-Pouyani, E. & Ficetola, G. F. & Hosseinian Yousefkhani, S. S. & Khosravani, A. (2014): Distribution pattern of the Snake-eyed Lizard, *Ophisops elegans* Ménétriés, 1832 (Squamata: Lacertidae), in Iran.- Zoology in the Middle East, London etc.; 60: 125-132.

Phillips, S. J. & Anderson, R. P. & Schapire, R. E. (2006): Maximum entropy modeling of species geographic distributions.- Ecological Modelling, Amsterdam; 190: 231-259.

Shcheglovitova, M. & Anderson, R. P. (2013): Estimating optimal complexity for ecological niche models: A jackknife approach for species with small sample sizes.- Ecological Modelling, Amsterdam; 269: 9-17.

Sindaco, R. & Jeremčenko, V. K. (2008): The reptiles of the Western Palearctic. 1. Annotated checklist and distributional atlas of the turtles, crocodiles, amphisbaenians and lizards of Europe, North Africa, Middle East and Central Asia. Latina (Edizioni Belvedere) [Monografie della Societas Herpetologica Italica], pp. 579.

Šmíd, J. & Moravec, J. & Kodym, P. & Kratochvíl, L. & Hosseinian Yousefkhani, S. S. & Rastegar-Pouyani, E. & Frynta, D. (2014): Annotated checklist and distribution of the lizards of Iran.- Zootaxa, Auckland; 3855: 1-97.

Swets, K. (1988): Measuring the accuracy of diagnostic systems.- Science, Washington; 240: 1285-1293.

Appendix I: Coordinates (decimal degrees) of 100 processed record localities of *Ablepharus bivittatus* (Ménétriés, 1832) in Iran (geographic latitude in ascending sequence / geographic longitude).

Appendix I: Koordinaten (Dezimalgrade) der 100 verarbeiteten Fundorte von *Ablepharus bivittatus* (Ménétriés, 1832) im Iran (geographische Breite in aufsteigender Reihe / geographische Länge).

27.133333/59.1; 27.216667/60.683333; 27.328056/52.985361; 27.816667/60.2; 28.6/61.1; 28.616667/60.766667; 28.933333/61.316667; 28.966667/58.866667; 29.083767/57.545083; 29.1/58.35; 29.1/58.35; 29.1/58.35; 29.1/58.35; 29.1/58.35; 29.1/58.35; 29.1/58.35; 29.266667/53.216667; 29.5/60.866667; 29.6/52.533333; 29.643639/51.902639;

29.666667/51.983333; 29.685/52.640194; 29.6905/52.664972; 29.6905/52.664972; 29.816667/51.983333; 29.966667/60.85; 29.98529/52.91763; 30.024258/57.28475; 30.083333/52.916667; 30.102223/52.92001; 30.119151/52.98968; 30.283333/57.083333; 30.283333/57.083333; 30.283333/57.083333; 30.302311/56.3664; 30.383433/57.052083; 30.383433/57.052083; 30.383433/57.052083; 30.383433/57.052083; 30.416667/48.2; 31.640833/50.650278; 31.65/48.866667; 31.664833/50.678833; 31.664833/50.678833; 31.883333/48.516667; 31.995/48.7311; 32.033333/51.483333; 32.095688/51.057571; 32.165848/48.386722; 32.2/59.416667; 32.25/48.516667; 32.25/48.516667; 32.25/48.51667; 32.25/48.51667; 32.25/48.51667; 32.25/48.51667; 32.270443/48.236341; 32.333333/48.5; 32.659617/51.455811; 32.659617/51.455811; 32.670833/59.797667; 32.702421/52.12103; 32.716667/47.35; 32.873056/48.729722; 32.873056/48.729722; 33.066667/47.483333; 33.135278/47.105278; 33.135278/47.105278; 33.19771/47.706716; 33.204644/47.665664; 33.266667/47.633333; 33.6/48.15; 33.7/48.45; 33.716667/49.9; 33.733333/47.466667; 33.75/47.616667; 33.75/47.75; 33.816667/47.816667; 33.825767/46.310809; 33.9/47.75; 33.916667/47.75; 34.0678/46.070998; 34.116667/47.883333; 34.166667/50.016667; 34.5/52; 34.566667/60.55; 34.566667/60.55; 35.398186/58.516753; 35.638803/60.703753; 35.774043/52.063761; 35.845236/52.054134; 36.416667/55.016667; 36.5/51.166667; 36.512901/54.70543; 37.05/55.983333; 37.366667/58.5; 37.366667/58.533333; 37.436196/56.704454; 37.457242/56.728476; 37.683333/56.383333; 37.95/55.533333.

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