AES BIOFLUX

Advances in Environmental Sciences - International Journal of the Bioflux Society

Using maximum entropy to predict the distribution of a critically endangered reptile species (*Eryx jaculus*, Reptilia: Boidae) at its Northern range limit

Iulian Gherghel, Alexandru Strugariu, and Ştefan Zamfirescu

„Alexandru Ioan Cuza" University, Faculty of Biology, Iaşi, Romania;
Corresponding author: I. Gherghel, iuliangherghel@gmail.com

Abstract. The sand boa (*Eryx jaculus*) is one of the least known and rarest reptile species in Europe. In Romania, the sand boa is the rarest reptile species with only four locality records being known; at Cernavodă, Cărpiniş-Giuvegea, Cochirleni and Mahmudia (Kiriţescu 1903; Fuhn & Vancea 1961; Zinke & Hielscher 1990). To estimate the predictors and the probability distribution of the target species (*Eryx jaculus*) we used MaxEnt 3.3. The potential distribution model of *E. jaculus* in Romania have a very good score performance (AUC = 0.959). The most important variables for the model are BIO13 (92.5% of contribution), BIO9 (3.2% of contribution), BIO17 (3% of contribution) and BIO6 (1.3% of contribution). A previously mentioned hypothesis regarding the extinction of the sand boa from Romania hold the construction of the Danube River – Black Sea canal as the main responsable factor, this construction having destroyed most of the natural habitats in which the species has been recorded (Krecsak & Iftime 2006). We also support this hypothesis as the generated model indicates a suitable niche for the species along the current canal area.

Key Words: sand boa, potential distribution, MaxEnt, ecological modelling, Romania.

Rezumat. Boa de nisip (*Eryx jaculus*) este una din cele mai puţin cunoscute şi rare specii din Europa. În România, boa de nisip este cea mai rară specie de reptilă, cunoscându-se doar patru localităţi în care această specie a fost data ca fiind prezentă; Cernavodă, Cărpiniş-Giuvegea, Cochirleni and Mahmudia (Kiriţescu 1903; Fuhn & Vancea 1961; Zinke & Hielscher 1990). Pentru a stabili contribuţia fiecarei variabile si pentru a stabili distributia potenţială a speciei ţintă (*E. jaculus*) am folosit MaxEnt 3.3. Modelul generat de program pentru a stabili distribuţia potenţială a speciei *E. jaculus* in România a primit un scor de perfomanţă foarte bun (AUC=0.959). Cele mai importante variabile în generarea modelului o au variabilele BIO13 (92.5% din contribuţie), BIO9 (3.2% din contribuţie), BIO17 (3% din contribuţie) and BIO6 (1.3% din contribuţie). Ipoteza conform căreia dispariţia din România a speciei boa de nisip este datorată de construcţia canalului Dunăre-Marea Neagră care este considerat ca fiind responsabil pentru distrugerea habitatului natural în care această specie a fost gasită anterior (Krecsak & Iftime 2006). Noi, de altfel, susţinem această ipoteză mai ales datorită faptului că modelul generat arată că nişa favorabilă pentru boa de nisip se continuă de-a lungul canalului.

Cuvinte cheie: boa de nisip, distribuţie potenţială, MaxEnt, modeling ecologic, Romania.

Introduction. Studies in which GIS technics are used to predict the distribution of various species have increased in number in recent years due to the many algorithms (eg. MaxEnt; Phillips et al 2006; Phillips & Dudík 2008) which were developed to predict the potential distribution of species, habitat suitability and niche overlapping (Rödder et al 2008; Rödder 2009; Brito et al 2009). This algorithms are very useful in gaining a better understanding of the invasive character of introduced species (e.g. Thuiller et al 2005; Thuiller et al 2006; Ficetola et al 2007) or to establishing management plans for endangered or endemic species for which very few data exists with regard to ecology or biogeography (e.g. Riordan & Rundel 2009; Loarie et al 2008; Raes et al 2009).

The sand boa (*Eryx jaculus*) is one of the least known and rarest reptile species in Europe. Its range covers areas of Greece, Macedonia, southern Albania, the Aegean Islands, Bulgaria, the south-eastern part of Romania and Turkey (e.g. Fuhn & Vancea 1961; Gasc et al 1997; Krecsak & Iftime 2006). In Romania, the sand boa is the rarest reptile species with only four locality records being known; at Cernavodă, Cărpiniş-Giuvegea, Cochirleni and Mahmudia (Kirițescu 1903; Fuhn & Vancea 1961; Zinke & Hielscher 1990). The most recent record of this species was made in 1986 from a habitat located between the villages of Beştepe and Mahmudia (Zinke & Hielscher 1990), this record being the northernmost point of this species' range. None of the recently conducted extensive studies of the herpetofauna of Dobrudja have succeded in providing any further records or evidence for the species' further existance (e.g. Covaciu-Marcov et al 2006; Strugariu et al 2008).

In Romania the sand boa is considered either extinct (Cogălniceanu & Venczel 1993; Gasc et al 1997) or critically endangered (Iftime 2005). The species is protected by the Bern Convention (rattefied in Romania by Law no. 13/1993), by CITES and by European Comission (Habitat Directive 92/43 EEC – rattefied as Romanian Government Order 57/2007) as strictly protected.

This study aims to bring a better understanding of the potential distribution of *E. jaculus* in its northern range limit and to provide a perspective, useful for increasing the probability of detecting this species in the field.

Material and Method

Species records. We used all the literature records for this species in Romania (4 records) provided by Krecsak & Iftime (2006) (Figure 1). These records were georeferenced into WGS 84 coordonate system and we used the ArcGIS 9.3 software to test the accuracy of the coordinate records.

Environmental predictors. We used climate data obtained from the WordClim database (version 1.4), a database based on 1950-2000 climatic records with a 30' arc degreades cell resolution (Hijmans et al 2004). The WordClim database consists of 17 different climatic variables (Table 1). The currently available habitats from the region (Corine Biotops 2000) were introduced over the map generated by MaxEnt.

Table 1

Environmental variables used in the model analysis

Code	*Description of variable*
BIO1	Annual Mean Temperature
BIO2	Mean Diurnal Range (Mean of monthly (max temp - min temp))
BIO3	Isothermality (P2/P7) (* 100)
BIO4	Temperature Seasonality (standard deviation *100)
BIO5	Max Temperature of Warmest Month
BIO6	Min Temperature of Coldest Month
BIO7	Temperature Annual Range (P5-P6)
BIO8	Mean Temperature of Warmest Quarter
BIO9	Mean Temperature of Coldest Quarter
BIO10	Annual Precipitation
BIO11	Precipitation of Wettest Month
BIO12	Precipitation of Driest Month
BIO13	Precipitation Seasonality (Coefficient of Variation)
BIO14	Precipitation of Wettest Quarter
BIO15	Precipitation of Driest Quarter
BIO16	Precipitation of Warmest Quarter
BIO17	Precipitation of Coldest Quarter

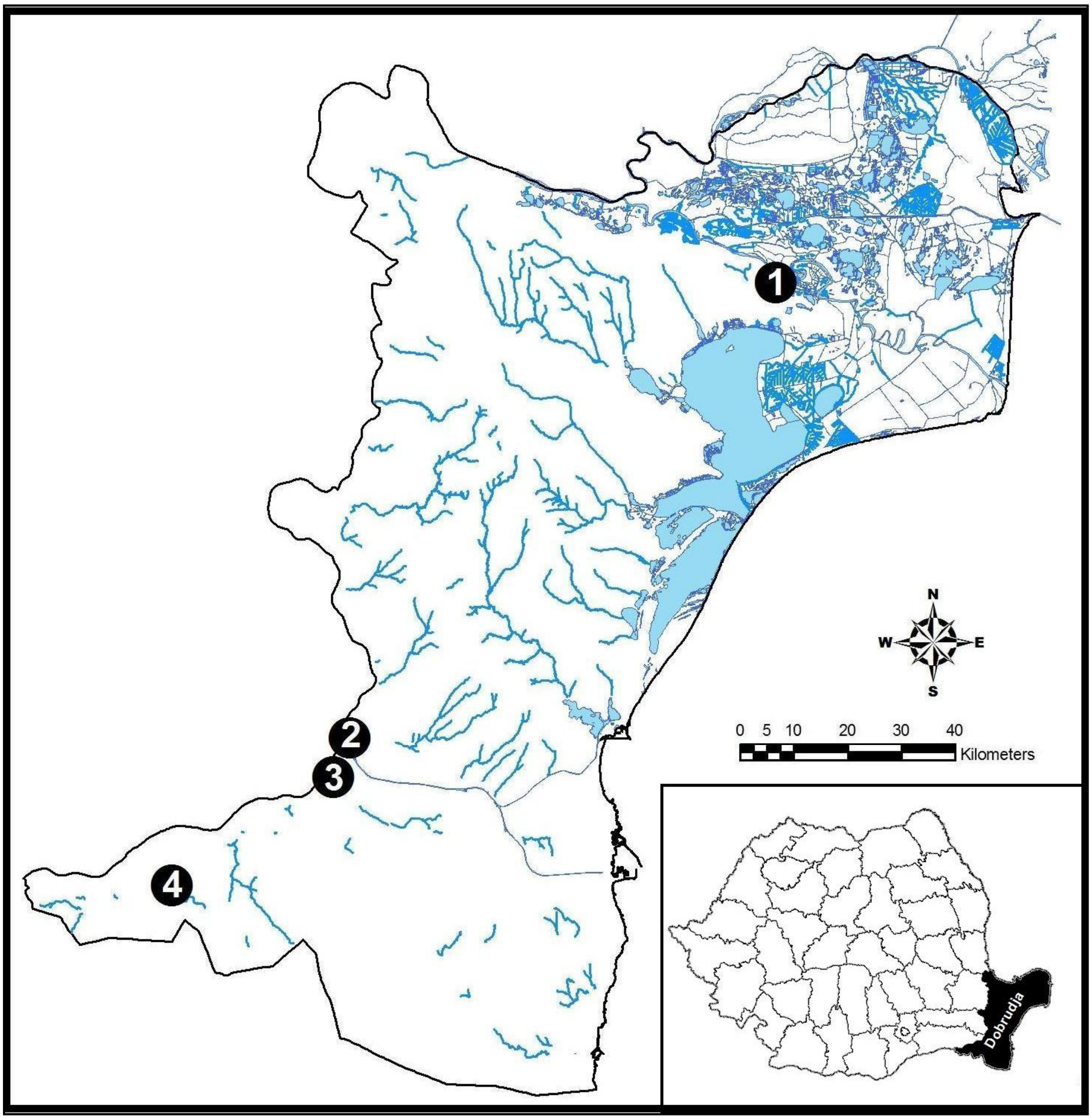

Figure 1. Distribution of *E. jaculus* in Romania (after Krecsak & Iftime 2006, modified). Legend: 1- Mahmudia, 2- Cernavodă, 3- Cărpiniş-Giuvegea, 4- Cochirleni.

Model generation. To estimate the predictors and the probability distribution of the target species (*E. jaculus*) we used MaxEnt 3.3 (Phillips et al 2006). MAXENT algorithm finds the probability distribution of maximum entropy from all of environmental predictors (climatic variables) to manage over-fitting by regularizing factors. The good performance of the model was provided by AUC (Area Under ROC Curve) which is a very good predictor for the performance of models provided by different algorithms for ecological modelling, including MAXENT.

Results. The potential distribution model of *E. jaculus* in Romania has a very good score performance (AUC = 0.959) (Figure 2). The most important variables for the model are BIO13 (precipitation seasonality) (92.5% of contribution), BIO9 (mean temperature of coldest quarter) (3.2% of contribution), BIO17 (precipitation of coldest quarter) (3% of contribution) and BIO6 (min temperature of coldest month) (1.3% of contribution).

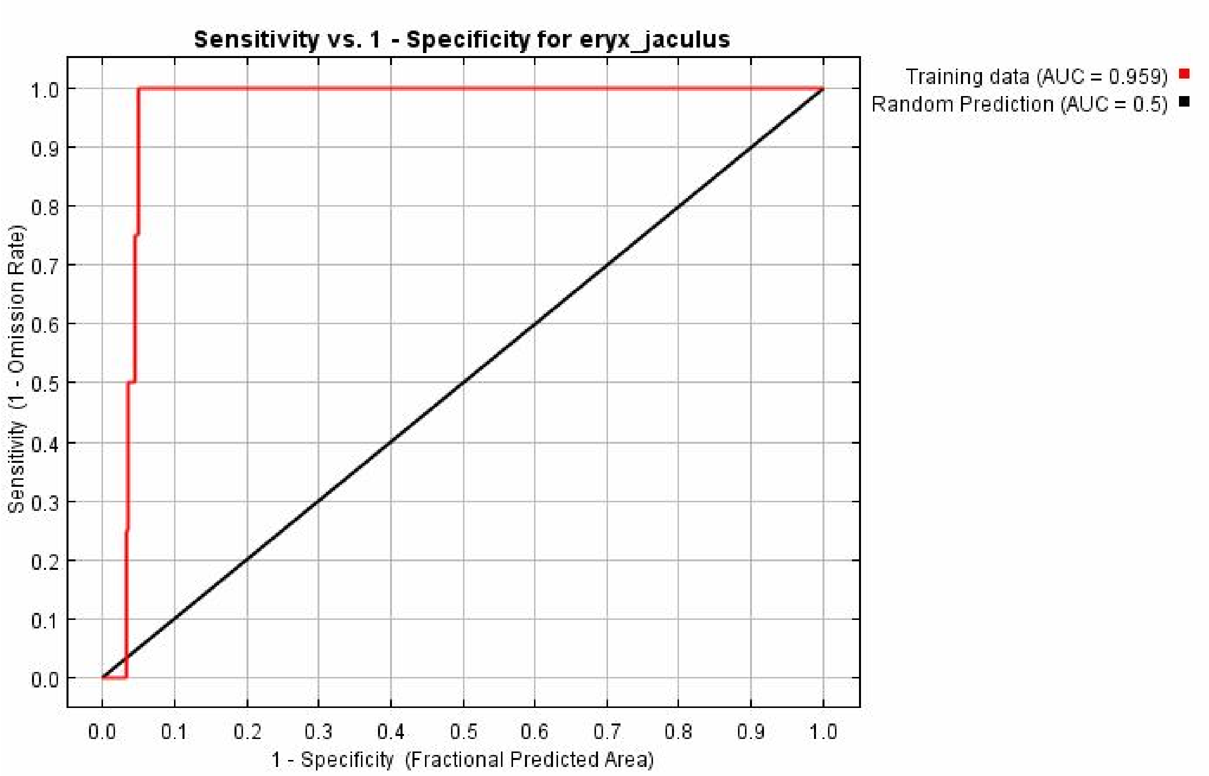

Figure 2. Receiver operating characteristic (ROC) curve for the *Eryx jaculus* sample data.

The Măcin Mountains and Babadag Platou obtained a very low suitability niche and most parts of Dobroudja received a suitability niche for *E. jaculus* which is conservative, very close to the algorithm's random prediction (AUC = 0.5). The Danube Delta and Razelm-Sinoe Lagoon Complex presented the apropriate ecological niche for *Eryx jaculus* in the southern-eastern part of Dobroudja, mainly in Constanţa County (Figure 3 a, b).

In the areas (except Danube Delta and Razelm-Sinoe lake complex) where the model indicated the highest niche suitability for the sand boa, the habitats are mainly composed by agriculture areas (82.3%), vineyards and orchards (5.6%), pastures (4.1%), artificial areas (5.3%), beaches (0.5%) and lakes and water bodies (3.2%) (Figure 3 c)

Discussion. In Romania, the sand boa was recorded mostly from Western Dobroudja (in Constanţa County: three of the four locality records), being identified only in one site from the Northen part (in Tulcea County: Krecsak & Iftime 2006). Our model shows other areas, more suitabile from a climate point of view in South-Eastern part of Dobroudja. However, in these regions, many of the natural habitats have been destroyed by human impact and one of the largest metropolitan areas fom Romania (Năvodari-Constanţa-Mangalia) is present in the area. A massive percentage (82.3%) of the areas indicated as suitable for the sand boa are occupied by intensive agricultural areas. Because of this, we consider that the probability that *E. jaculus* is extinct from this area is very high. If the species exists, it is most likely that it is represented by very small propulations wich are isolated in small areas occupied by non-intensive agricultural areas like vineyards or orchards (5.6% of territory). Surprisingly, these latter habitat types are the ones in which most of the sand boas captured in Romania were found in (e.g. Fuhn 1969). A previously mentioned hypothesis regarding the extinction of the sand boa from Romania hold the construction of the Danube River – Black Sea canal as the main responsable factor, this construction having destroyed most of the natural habitats in which the species has been recorded (Krecsak & Iftime 2006). We also support this hypothesis as the generated model indicates a suitable niche for the species along the current canal area. However, natural, nondegraded habitats from the area are now absent (Figure 3 c). If populations of *E. jaculus* still occur in Romanian Dobrudja, then the construction of the canal has surely isolated the one(s) from Northern Dobrudja from the ones from the Southern parts.

In conservation terms, we suggest that more attention should be payed to investigating vineyards or orchards during future herpetofaunal surveys in Romanian Dobrudja.

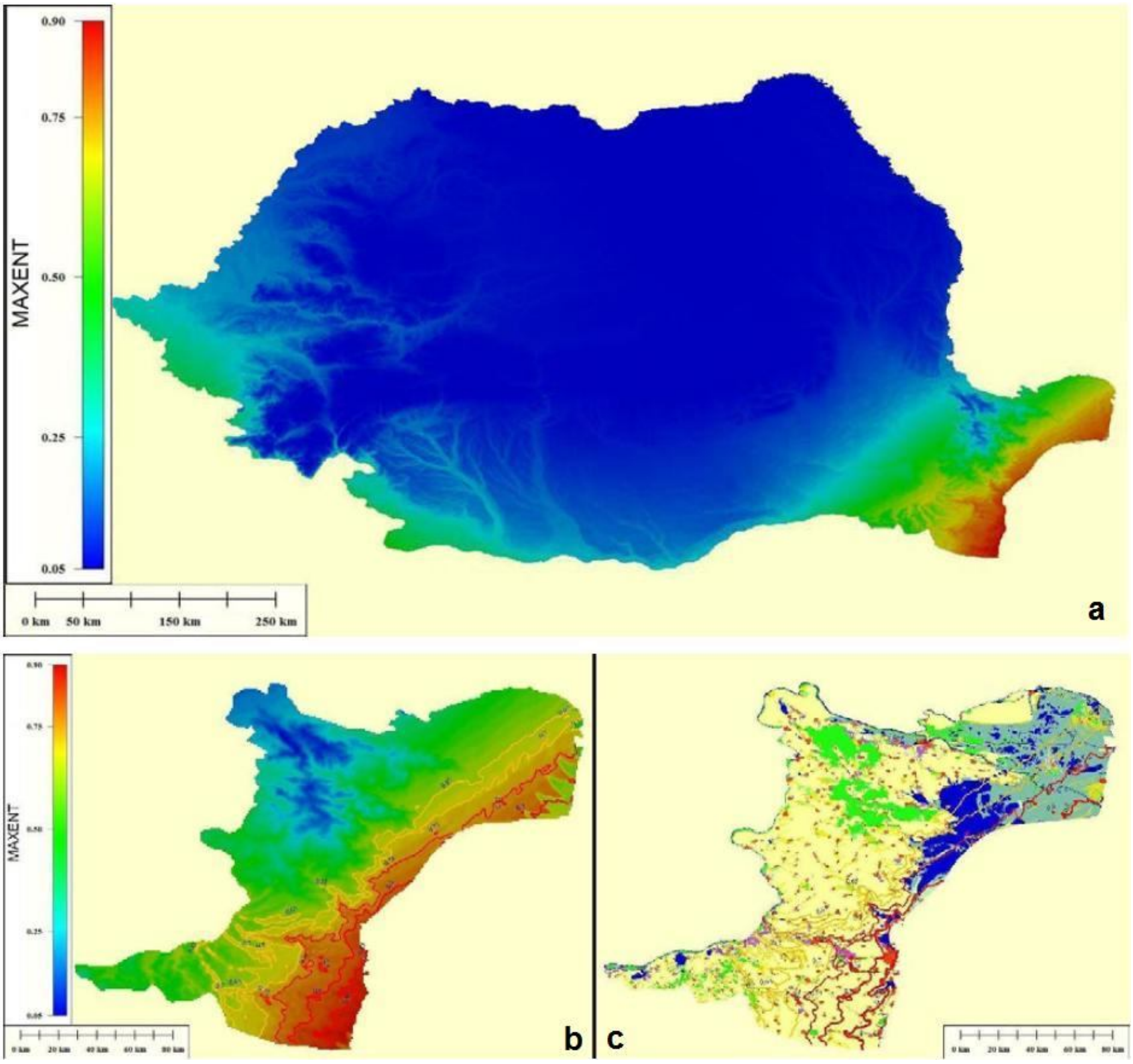

Figure 3. The potential distribution map for *Eryx jaculus* in Romania. In figures 3 a and 3 b the warm colors represent areas where this species have the highest suitability niche to spread and the coldest colors represent the lowest suitability niche. In figure 3 c green pallet represents forests, blue pallet represents water bodies and lakes, yellowish pallet represents agricultural areas, red pallet represents artificial areas, orange pallet represents pastures and mauve pallet represents vineyards and orchards.

Acknowledgements. The authors would like to thank to Pricop Emilian for some suggestions about the earlier version of the manuscript. We thank to two anonymous referees for useful comments on the manuscript.

References

Brito J. C, Acosta A. L., Alvares A., Cuzin F., 2009 Biogeography and conservation of taxa from remote regions: An application of ecological-niche based models and GIS to North-African Canids. Biological Conservation **142**:3020-3029.

Cogălniceanu D., Venczel M., 1993 [Considerations on the protection and conservation of populations of amphibians and reptiles]. Ocrotirea Naturii Mediului Înconjurător **37**:109–114. [In Romanian]

Covaciu-Marcov S. D., Ghira I., Cicort-Lucaciu A. S., Sas I., Strugariu A., Bogdan H., 2006 Contributions to knowledge regarding the geographical distribution of the herpetofauna of Dobrudja, Romania. North-Western Journal of Zoology **2**:88-125.

European Comission, 1992 [European Council Directive 92/43 EEC on the conservation of natural habitats and wild flora and fauna adopted on May 21, 1992]. [In Romanian]

Ficetola G. F., Thuiller W., Miaud C., 2007 Prediction and validation of the potential global distribution of a problematic alien invasive species – the American bullfrog. Diversity & Distributions **13**:476-485.

Fuhn I. E., Vancea S., 1961 [Reptilia (Turtles, Lizards, Snakes)]. In: Fauna RPR.Vol. 14(2). Bucharest: Editura Academiei RPR, 338 pp. [In Romanian]

Fuhn I.E., 1969 [Frogs, Snakes, Lizards]. Bucharest, Editura Natura și Omul, 246 pp. [In Romanian].

Gasc J.-P., Cabel A., Crnobrnja-Isailovic J., Dolmen D., Grossenbacher K., Haffner P., Lescure J., Martens H., Martínez-Rica J.P., Maurin H., Oliveira M.E., Sofianidou T.S., Veith M., Zuiderwijk A. (eds.) 1997 Atlas of Amphibians and Reptiles in Europe. Paris: Societas Europaea Herpetologica Muséum National d'Historie Naturelle (IEGB/SPN), 496 pp.

Hijmans R. J., Cameron S. E., Parra J. L., Jones P. G., Jarvis A. 2004 The WorldClim interpolated global terrestrial climate surfaces. Version 1.4. http://biogeo.berkeley.edu. (last accesed: 12 September 2009).

Iftime A., 2005 [Reptiles]. In: Cartea Rosie a vertebratelor României, pp. 173–196. Botnariuc N. & Tatole V. (Eds.), Bucharest, Editura Curtea Veche. [In Romanian]

Kiritescu C., 1903 [On the presence of *Eryx jaculus* Romania]. Bulletin Société des Sciences, Bucarest **11**:620–626. [In French].

Krecsak L., Iftime A., 2006 A review of the records of the Sand Boa (*Eryx jaculus*) in Romania. Herpetological Bulletin **98**:31-34.

Loarie S. R., Carter B. E., Hayhoe K., McMahon S., Moe R., Knight C. A., Ackerly D. D., 2008 Climate change and the future of California's endemic flora. PLoS ONE **3**: e2502.

Phillips S. J., Anderson R. P., Schapire R. E., 2006 Maximum entropy modeling of species geographic distributions. Ecological Modelling **190**:231–259.

Phillips S. J., Dudík M., 2008 Modeling of species distributions with Maxent: new extensions and a comprehensive evaluation. Ecography **31**:161–175.

Raes N., Roos M. C., Ferry Slik J. W., van Loon E. E., ter Steege H., 2009 Botanical richness and endemicity patterns of Borneo derived from species distribution models. Ecography **32**:180-192.

Riordan E.C., Rundel P. W., 2009 Modelling the distribution of a threatened habitat: the California sage scrub. Journal of Biogeography **36**:2176-2188.

Rödder D., Solé M., Böhme W. 2008 Predicting the potential distributions of two alien invasive Housegeckos (Gekkonidae: *Hemidactylus frenatus, Hemidactylus mabouia*). North Western Journal of Zoology **4**:236-246.

Rödder D. 2009 'Sleepless in Hawaii' – does anthropogenic climate change enhance ecological and socioeconomic impacts of the alien invasive *Eleutherodactylus coqui* Thomas 1966 (Anura: Eleutherodactylidae)? North Western Journal of Zoology **5**: 16-25.

Romanian Government, 1993 [Law no. 13/11.03.1993 on Romania's accession to the Convention on the conservation of wildlife and natural habitats in Europe, adopted at Berne on September, 19 (1979). Official Monitor of Romania **62**: 25.03.1993, Bucharest]. [In Romanian]

Romanian Government, 2007 [Governmental Order no. 57/20.06.2007 concerning the rules of natural protected areas, conservation of natural habitats, flora and fauna. Official Monitor of Romania **442**: 29.06.2007, Bucharest]. [In Romanian]

Strugariu A., Sos T., Gherghel I., Sahlean T.C., Puscacu C.M, Hutuleac-Volosciuc M.V., 2008 Distribution and current status od the herpetofauna from the northen Macin Mountains area (Tulcea county, Romania. Analele Stiintifice ale Universitatii “Al. I. Cuza”, Iași, Seria Biologie Animala **54**:191-206.

Thuiller W., Richardson D. M., Pysek P., Midgley G. F., Hughes G. O., Rouget M., 2005 Niche-based modelling as a tool for predicting the risk of alien plant invasions at a global scale. Global Change Biology **11**:2234–2250.

Thuiller W., Richardson D. M., Rouget M., Proche S., Wilson J. R. U., 2006 Interactions between environment, species traits, and human uses describe patterns of plant invasions. Ecology **87**:1755–1769.

Zinke O., Hielscher K., 1990 [Proof of presence of Western boa (*Eryx jaculus turcicus* [Oliver]) in Romania (Reptilia, Serpentes: Boidae)]. Abhandlungen Staatliche Naturhistorische Sammlung Dresden **17**:191–192. [In German]

Received: 18 September 2009. Accepted: 27 December 2009. Published online: 30 December 2009.
Authors:
Iulian Gherghel, „Alexandru Ioan Cuza” University, Faculty of Biology, Carol I. Blvd. No. 20A, 700556, Iaşi, Romania, EU, iuliangherghel@gmail.com ;
Alexandru Strugariu, „Alexandru Ioan Cuza” University, Faculty of Biology, Carol I. Blvd. No. 20A, 700556, Iaşi, Romania, EU, alex.strugariu@gmail.com;
Ştefan Zamfirescu, „Alexandru Ioan Cuza” University, Faculty of Biology, Carol I. Blvd. No. 20A, 700556, Iaşi, Romania, EU, s_zamfirescu@yahoo.com .
How to cite this article:
Gherghel I., Strugariu A., Zamfirescu Ș., 2009 Using maximum entropy to predict the distribution of a critically endangered reptile species (*Eryx jaculus*, Reptilia: Boidae) at its Northern range limit. AES Bioflux **1**(2):65-71.