Ann. Zool. Fennici 56: 93–106 ISSN 0003-455X (print), ISSN 1797-2450 (online)
Helsinki 12 August 2019

Conservation of Pleske's racerunner (*Eremias pleskei*) in a changing climate

Azita Farashi* & Mohammad Alizadeh-Noughani

*Department of Environmental Sciences, Faculty of Natural Resource and Environment, Ferdowsi University of Mashhad, Iran (*corresponding author's e-mail: farashi@um.ac.ir)*

Received 12 June 2019, final version received 2 Agu. 2019, accepted 12 Aug. 2019

Farashi, A. & Alizadeh-Noughani, M. 2019: Conservation of Pleske's racerunner (*Eremias pleskei*) in a changing climate. — *Ann. Zool. Fennici* 56: 93–106.

Although reptiles are the most diverse group of terrestrial vertebrates, crucial data on their extinction risks are lacking. The reptile species assessed by IUCN are only a fraction of those at risk of extinction. Thus, conservation planning and management decisions are hindered by the lack of ecological information on the species' distribution patterns and their habitat requirements. Pleske's racerunner (*Eremias pleskei*) is a rare and critically endangered species known to occur exclusively in the eastern Anatolian Montane Steppe ecoregion. In this study, we used ten species distribution model algorithms and 62 climate change scenarios (from 19 global climate models under four representative concentration pathways) to predict future habitat suitability for Pleske's racerunner in the Anatolian Montane Steppe ecoregion. Our results indicate that this species may in future migrate from its current distribution range towards the central and western areas of the Anatolian Montane Steppe ecoregion. Our results also show that the variation in the temperature-related variables in suitable habitats will increase in future as compared with the current conditions. It seems that due to climate change, in future, deserts will be appropriate for this species. The same mechanisms, however, will make some of its current habitats unsuitable. Dealing with uncertainties in climate change and species distribution modeling is a major challenge when planning strategies for species' conservation. We recommend conservation measures to be implemented to make sure that *E. pleskei*'s current habitats are suitable for it also in future.

Introduction

Habitat loss and fragmentation have become increasingly more significant threats to biodiversity across the world (Rybicki and Hanski 2013, Matthews *et al*. 2014) with ever-expanding urban development being one of the most important factors (Levia & Page 2000, Garden *et al*. 2007). Growing cities have brought about multi-faceted changes to the structure and spatial patterns of the remaining habitats within the context of landscapes (van der Ree 2004, Tait *et al*. 2005, Garden *et al*. 2007). Among different groups of fauna, reptiles and small mammals are the most vulnerable to urbanization (Garden *et al*. 2007). Due to their limited distribution ranges, reptiles are more severely affected by human activities than other vertebrates such as birds and mammals (Anderson 1984, Anderson & Marcus 1992).

Similarly to urbanization, climate change can contribute to habitat destruction and alter species' distribution worldwide (Levinsky *et al*. 2007). In several studies, possible effects of climate change on the distribution of plants (Thuiller *et al*. 2005) and animals (Meynecke 2004, Levinsky *et al*. 2007) were predicted. Animals are affected by climate change directly through its impact on their physiology, and indirectly due to changes to land cover (Levinsky *et al*. 2007). Reptiles are particularly sensitive to climate change (Sinervo *et al*. 2010) and have been referred to as 'canaries in the coal mine' because of their sensitivity to changes in the environment (Mitchell & Janzen 2010). An assessment by Stuart *et al*. (2004) revealed that amphibians are declining faster than birds and mammals. Huey *et al*. (2010) in turn termed lizards 'the new amphibians' due to their increased extinction risk (Sinervo *et al*. 2010). Climate change contributes to the threats (Carey & Alexander 2003, Stuart *et al*. 2004), and correlative climate envelope models project extinction for 11%–49% of endemic reptiles (Thomas *et al*. 2004). Under assumptions of limited potential for evolutionary adaptation, Sinervo *et al*. (2010) predicted that 20% of lizard species will become extinct by 2080. Sufficient knowledge on threatened species' current and future habitats as well as its biology along with an accurately assigned conservation status are key to successful conservation. Evidence-based approaches should guide conservation and monitoring efforts by managers and scientists (Naveda-Rodriguez 2015). Predictive methods such as species distribution models (SDMs) play an important role in assessment and prediction of species' distribution by means of quantifying species–environment relationships (e.g. Trabucco *et al*. 2010, De Souza *et al*. 2011, Murray *et al*. 2011, Li & Wang 2013, Quisthoudt *et al*. 2013, Rhoden *et al*. 2017). SDMs can help in (1) testing biogeographical, ecological and evolutionary hypotheses can be tested, (2) assessments of species' invasion and proliferation can be made (Farashi & Najafabadi 2015), (3) predicting the effects of changes in climate and land use on species distributions (Thuiller *et al*. 2005, Ebrahimi *et al*. 2017, Farashi and Erfani 2018), (4) improving surveys of threatened species by determining sites with high occurrence probabilities (Davies *et al*. 2017), and (5) conservation planning (Farashi & Shariati 2017, Farashi *et al*. 2017).

Pleske's racerunner (*Eremias pleskei*) is classified as critically endangered on the IUCN's red list (cf. https://www.iucnredlist.org/species/164583/114550294). The distribution range of *E. pleskei*'s highly fragmented populations is limited to the to left-bank valley of the Aras river in Armenia, Nakhichevan (Nahcivan), Azerbaijan in the eastern Transcaucasia, eastern Turkey, and northwestern Iran (Ananjeva *et al*. 2006, Baran *et al*. 2013). *Eremias pleskei* prefers arid, sandy, semi-rocky areas with desert conditions. As a consequence of soil salinification and construction of waste dumps in its suitable habitats, almost no suitable habitats remain within its natural range (sandy areas) (cf. https://www.iucnredlist.org/species/164583/114550294).

Taking the entire distribution range of the species as our study area, we used SDMs to (1) identify current and future suitable habitats of *E. pleskei*, (2) identify the major environmental variables affecting habitat suitability at present and in the future, and (3) evaluate the effects of climate change on Pleske's racerunner habitat.

Material and methods

Study area

SDMs must be trained using the data from the region with the known occurrence of the spe- cies or its dispersal limits (Soberon & Peterson 2005, Barve *et al*. 2011). We modeled the dis- tribution of Pleske's racerunner using only the known distribution range which is in our case the Eastern Anatolian Montane Steppe Ecoregion (cf. https://www.worldwildlife.org/publications/terrestrial-ecoregions-of-the-world). This region is located in Anatolia (eastern Turkey, Armenia, and northwestern Iran; 36°03´26´´–48°47´06´´N and 40°34´26´´–41°43´35.547´´E). This ecoregion covers approx. 168 382 km^2 at the junc- tion of the biogeographic zones of the Lesser Caucasus and the Iranian and Mediterranean zones. It is characterized by both a great range of altitudinal variation (from 375 to 4095 m a.s.l.) and a diversity of climatic zones resulting in a wide variety of landscapes and natural resources. High mountains and extreme continental climate prevail the ecoregion, and although the most common formation is Montane steppes, other community types such as deserts and semi-deserts, forests and woodlands, alpine and subalpine meadows are also present.

Flora and fauna of the region includes many endemic, relict and rare species. However, habitat loss and modification mainly by agricul- ture, unsustainable use of biological resources, and the impact of introduced and non-native species have recently degraded natural ecosys- tems resulting in a decline in populations of native animals and plants. In Armenia, substan- tial increase in human activities such as agricul- ture, industry (including energy production), and construction have led to extensive habitat change across all landscape types. In mountainous areas, the threat comes from grazing livestock during the summer. Therefore, more natural reserves are needed to protect diverse habitats (cf. https://www.worldwildlife.org/ecoregions/pa0805).

Species data

Occurrence records of the *E. pleskei* were collected from four sources, (1) scientific papers (Kaska *et al*. 2004, Düşen *et al*. 2013), (2) atlases (Mozaffari *et al*. 2014), (3) IUCN database, and (4) publicly available species information databases such as Global Biodiversity Information Facility (GBIF), VertNet, iNaturalist, and Berkeley Ecoinformatics Engine. GBIF is an international network and research infrastructure funded by the world's governments and aimed at providing anyone, anywhere, open access to data about all types of life on Earth. GBIF collects data from several sources including museum records. VertNet — funded by the National Science Foundation (NSF) which is a United States government agency — is the result of the combination and expansion of FishNet, MaNIS, HerpNET, ORNIS. iNaturalist is a crowd sourced species identification system and an organism occurrence recording tool. Berkeley Ecoinformatics Engine allows access to several biodiversity information repositories (https://holos.berkeley.edu/LearnMore/datasources/).

Each database was accessed through their respective packages in R (https://www.r-project.org/): *rgbif*, *rvertnet*, *rinat* and *ecoengine*. Queries were made using the species' scientific name and its synonyms, and georeferenced occurrence records since 1 January 1998 were extracted. Duplicates were omitted in R but were later used to model habitat suitability. In total, 71 presence points were collected. Spatially correlated presence points were removed using spatial autocorrelation and Moran's *I* test. Since we only had the presence records of the species, the pseu- do-presence/pseudo-absence data points equal in number to the number of presence points were randomly generated (Elith *et al*. 2011). It has been shown that randomly selected pseudo-absence points yield the most reliable logistic-regression species-distribution models (Stokland *et al*. 2011, Lunney *et al*. 2014).

Environmental variables

We used a set of environmental variables based on the available data, knowledge of species ecology and factors affecting distribution of lizards (Kearney & Porter 2004, Pawar *et al*. 2007, Kaliontzopoulou *et al*. 2008, Bombi *et al*. 2009, de Pous *et al*. 2011, Valdeón *et al*. 2014, e Silva *et al*. 2014, Fattahi *et al*. 2014, Block *et al*. 2016, Ribeiro-Júnior & Amaral 2016, Sanchooli 2017). To avoid including highly correlated variables in the model, we screened all the variables for pairwise correlations using Pearson's correlation analysis ('Raster Correlations and Summary Statistics' implemented in SDMToolbox: cf. Brown 2014). We considered the variables to be highly correlated if $r > 0.75$ or $r < -0.75$ (Wen *et al*. 2015, Kalboussi & Achour 2018). The analysis did not revealed only few correlations with $r > 0.5$. This method of variable selection resulted in nine variables for potential use in modeling (Table 1). The environmental parameters included climatic and topographic variables. Nineteen bioclimatic predictors were collected from the World Clim 1.4 database (Hijmans *et al*. 2005) at 1-km resolution. The four most important topographic factors (mean and standard deviation (SD) of elevation, and slope of all raster cells included in a 1-km radius) were calculated based on the Shuttle Radar Topography

Mission (SRTM) elevation model (http://srtm.csi.cgiar.org), to describe physiographic properties (Table 1). The habitat suitability models were projected to the 62 climate change scenarios for the year 2070, obtained from the WorldClim 1.4 database at a resolution of 1-km.

Climate change models

Representative concentration pathways (RCPs) are four greenhouse gas concentration trajectories adopted by the IPCC for its 5th Assessment Report (AR5) in 2014 (Rogelj 2013). The CO_2-equivalent concentrations are 490, 650, 850, and > 1370 ppm for RCPs 26, 45, 60, and 85, respectively (Meinshausen *et al*. 2011).

A general circulation model (GCM) is a type of climate model that employs a math- ematical model of the general circulation of a planetary atmosphere or ocean. Models of such type are used by the Navier–Stokes equations for various energy sources (radiation, latent heat). These equations are used to simulate Earth's atmosphere or oceans. Atmospheric and oceanic GCMs (AGCM and OGCM, respectively) are the main principles along with sea ice and land-surface components (Rogelj 2013). We used 19 GCMs (cf. Table 2) under four representative RCPs (26, 45, 60, 85) to predict habitat suitability for Pleske's racerunner in its entire distribution range.

Species distribution model

We applied ten species distribution modeling (SDM) algorithms for the studied species using the *biomod2* package in R ver. 3.1.25 (https://cran.r-project.org/web/packages/biomod2/index.html; cf. also Thuiller *et al*. 2009). These ten algorithms can be classified into four categories: (1) regression, (2) machine-learning, (3) classification, and (4) enveloping.

Regression-based SDMs are generalized linear models (GLMs) and generalized addi- tive models (GAMs) that build linear and non- linear relationships between species occurrence and environmental parameters, respectively. The machine-learning methods include artificial neural networks (ANN), boosted regression trees (BRT), multivariate adaptive regression splines (MARS), maximum entropy (MaxEnt), and random forest (RF). These methods use training data to derive the environmental space of species occurrence.

Classification methods include classification and regression trees (CART) and flexible discriminate analysis (FDA). The objective of these methods is to partition consecutive data into homogeneous groups of responses.

Surface range envelope (SRE) is the method that takes into account the ecological conditions in which the species is present and extrapolates the results into similar areas (Elith & Leathwick 2009, Franklin 2010, Merow *et al*. 2015).

Table 1. Environmental variables and their relative contributions to modeled Pleske's racerunner habitat suitability. Most important variables for predicting the potential geographic distribution of the species are set in boldface.

	Current	Future
Climatic variables		
BIO1 (Annual mean temperature)	0	6.1
BIO3 (Isothermality)	10.4	0
BIO4 (Temperature seasonality)	0	0
BIO6 (Minimum temperature of coldest month)	**26.2**	**32.7**
BIO8 (Mean temperature of wettest quarter)	1.1	9.3
BIO9 (Mean temperature of driest quarter)	**35.4**	**30.8**
BIO10 (Mean temperature of warmest quarter)	0	0
BIO16 (Precipitation of wettest quarter)	0	0
BIO18 (Precipitation of warmest quarter)	0	1.8
BIO19 (Precipitation of coldest quarter)	1	0
Topographic variables		
Altitude	4.6	3.4
Slope	**21.3**	**15.9**

Considering recent concerns regarding robustness of the traditional ROC (receiver operating characteristic) approach (Fielding & Bell 1997, Lobo *et al*. 2008), we used partial ROC area under the curve (AUC; cf. Peter- son *et al*. 2008) to evaluate distribution mod- eling algorithms. Partial ROC, while based on the traditional approach, considers the extent of coverage of the commission error axis by model performances. Model robustness is also assessed by priority to omission *versus* commis- sion error (Peterson *et al*. 2008). We compared model AUCs against null expectations using the software 'Tool for Partial-ROC' (Barve 2008); the parameters were: bootstrapping 70% of the evaluation data 1000 times, and *E* = 5% of error among occurrences.

To convert the habitat suitability map into a binary map representing suitable and unsuitable areas, a threshold value had to be assigned for the species. The selection was accomplished by maximizing both training sensitivity and specificity (Liu *et al*. 2011). The values of 0 and 1 were respectively assigned to pixels with habitat suitability lower and higher than the computed threshold value, specifying whether those pixels were suitable or unsuitable for the target species. Variable importance was calculated using a permutation procedure in BIOMOD, which is independent of the modeling technique. Once the models were trained (i.e., calibrated), a standard prediction was made. Then, one of the variables was randomized and a new prediction was made. The correlation score between the new prediction and the standard prediction was calculated to estimate the variable importance in the model (Thuiller *et al*. 2009).

The mobility-oriented parity (MOP) and the multivariate environmental similarity surface (MESS) analyses (Elith *et al*. 2010, Owens *et*

Table 2. Global climate models (GCMs) used in the study.

GCM	Source
ACCESS1-0	CSIRO (Commonwealth Scientific and Industrial Researc Organisation, Australia), and BOM (Bureau of Meteorology, Australia)
BCC-CSM1-1	Beijing Climate Center, China Meteorological Administration
CCSM4	National Center for Atmospheric Research
CESM1-CAM5-1-FV2	National Science Foundation, Department of Energy, National Center for Atmospheric Research
CNRM-CM5	Centre National de Recherches Meteorologiques, Centre Europeen de Recherche et Formation Avancees en Calcul Scientifique
GFDL-CM3	Geophysical Fluid Dynamics Laboratory
GFDL-ESM2G	Geophysical Fluid Dynamics Laboratory
GISS-E2-R	NASA Goddard Institute for Space Studies
HadGEM2-AO	National Institute of Meteorological Research, Korea Meteorological Administration
HadGEM2-CC	Met Office Hadley Centre (additional HadGEM2-ES realizations contributed by Instituto Nacional de Pesquisas Espaciais)
HadGEM2-ES	Met Office Hadley Centre (additional HadGEM2-ES realizations contributed by Instituto Nacional de Pesquisas Espaciais)
INMCM4	Institute for Numerical Mathematics
IPSL-CM5A-LR	Institut Pierre-Simon Laplace
MIROC-ESM-CHEM	Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo) & National Institute for Environmental Studies
MIROC-ESM	Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies
MIROC5	Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies & Japan Agency for Marine-Earth Science and Technology
MPI-ESM-LR	Max Planck Institute for Meteorology (MPI-M)
MRI-CGCM3	Meteorological Research Institute
NorESM1-M	Norwegian Climate Centre

al. 2013) were used to characterize future climate conditions. MOP identifies environmental conditions not existing at present, while MESS evaluates the level of similarity between cli- mate scenarios. Both helped to identify suit- able habitats by extrapolating climate conditions currently prevailing in the Eastern Anatolian Montane Steppe ecoregion (Owens *et al*. 2013). The analysis was performed in R using a sample including 10% of the available environmental variable cells.

Finally, suitable habitats in at present and in future were projected onto a simplified land-cover map (Friedl *et al*. 2017) and a protected area map (defined as Ia: Strict Nature Reserve, Ib: wilderness area, II: national park, III: natural monument or feature, iv: habitat/species management area, V: protected landscape/seascape/ area, VI: protected area) (cf. http://www.protectedplanet.net) to give a better sense of the habitat type the species could potentially occupy.

Results

The MESS analysis revealed broad areas with environmental conditions in the future similar to those at present for all 62 climate change scenarios. According to the MOP analysis, some sites in Turkey and in the Black Sea area were not suitable for the species under current climate conditions. The MOP analysis also revealed that future projection with BCC-CSM1-1 and RCP45 had the smallest extrapolation areas of all 62 climate change scenarios.

Under current condition, ten models showed good performance (partial ROC > 1) with MaxEnt being the best of those (MARS = 1.12 ± 0.10, RF = 1.16 ± 0.12, GLM = 1.19 ± 0.09, ANN = 1.20 ± 0.10, FDA = 1.24 ± 0.09, SRE = 1.29 ± 0.11, CART = 1.32 ± 0.10, GAM = 1.38 ± 0.08, BRT = 1.44 ± 0.15, MaxEnt = 1.61 ± 0.01). Also, all the distribution models under future conditions performed significantly better than random with BCC-CSM1-1, RCP45 and MaxEnt being more accurate than the others (partial ROC = 1.53).

The most important environmental variables for predicting the potential geographic distribution of the species at present and in future (cf. Table 1) were the mean temperature of driest quarter, minimum temperature of the coldest month and slope.

According to MaxEnt, parts of the Eastern Anatolian Montane Steppe ecoregion suitable for the species are small and scattered in the center of this ecoregion (Figs. 1a and 2a). Plotting habitats suitable for Pleske's racerunner (Figs. 1b and 2b) on the land-cover map revealed that those habitats are at present and will be in future located mostly in grasslands, barelands and croplands (Fig. 3).

Under current and future conditions, 15 286 km^2 (9%) and 21 248 km^2 (13%) of the Eastern Anatolian Montane Steppe ecoregion, respectively, can be regarded as suitable habitats for Pleske's racerunner. Of the habitats suitable at present, around 12 157 km^2 (80%) will remain suitable in the future and 3129 km^2 (20%) of them will be lost by 2070. Moreover, by 2070, suitable habitats will grow by around 9091 km^2, i.e., an area which is equal to 59% of the current suitable habitats. However, under current and future conditions, only 1964 km^2 (13%) and 3753 km^2 (18%) of the total suitable habitat area, respectively, is or will be within areas which are currently protected (Figs. 1 and 2).

Response curves of the MaxEnt model revealed that and increase in mean temperature of the driest quarter results in an increase in suitable-habitat area at present and in the future, and an increase in minimum temperature of the coldest month has the opposite effect (cf. Fig. 4).

Discussion

Climate change is expected to affect species distributions worldwide. Our analyses corroborate the hypothesis that increasing temperatures will pose a threat to wildlife as discussed by Levinsky *et al*. (2007), Waltari and Guralnick (2009), Ebrahimi *et al*. 2017.

Comparisons of the predicted current and future suitable habitats indicate future migration of Pleske's racerunner from its current distribution areas in the Eastern Anatolian Montane Steppe ecoregion towards central and western regions of the area.

We also found a relation between new suitable habitats and climatic patterns, hinting that

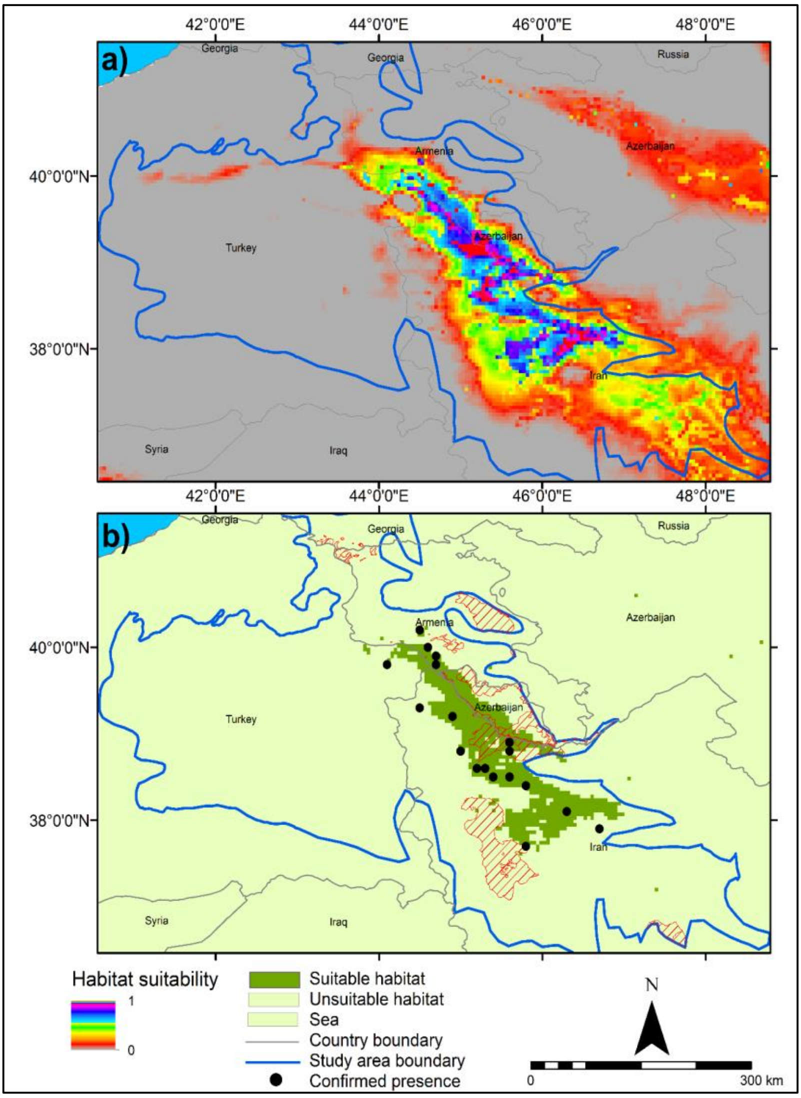

Fig. 1. Maps present- ing (**a**) habitat suitability for Pleske's racerunner at present according to MaxEnt, and (**b**) suitable and unsuitable habitats at present with current confirmed occurrences of the species within those habitats.

deserts may become suitable habitats for this species. Pleske's racerunner is thermophilic and thus prefers warmer areas (Darevsky 1957, Aslanyan 2004, Tadevosyan 2007). Due to climate change, however, some habitats suitable at present will in future become unsuitable.

Changes in temperature can also throw sex ratio of reptiles out of balance since sex of many reptilian species is determined by incubation temperature (Eggert 2004, Bull 2008, Nakamura 2009, Pezaro *et al*. 2017). Depending on the species, a temperature increase of 2–4 °C can result in all female (Ewert *et al*. 1994, Janzen 1994), or all male offspring (Ciofi & Swingland 1997, Pieau *et al*. 1999).

When comparing the current land-use in the study area with the area of suitable habitats in 2070, it became apparent that 13% of suitable habitats in the future will be located in areas currently used for agriculture or other human activities (Fig. 3). If human activities expand at the current pace, the area of suitable habitats will greatly shrink.

Our results also revealed a low level of protection of the reptiles in the region. There are two possible reasons for that. First, protected areas are established mainly with big mammals in mind. Second, reptiles have narrow ecological niches, thus parts of their suitable habitats are located outside currently protected areas. Con-

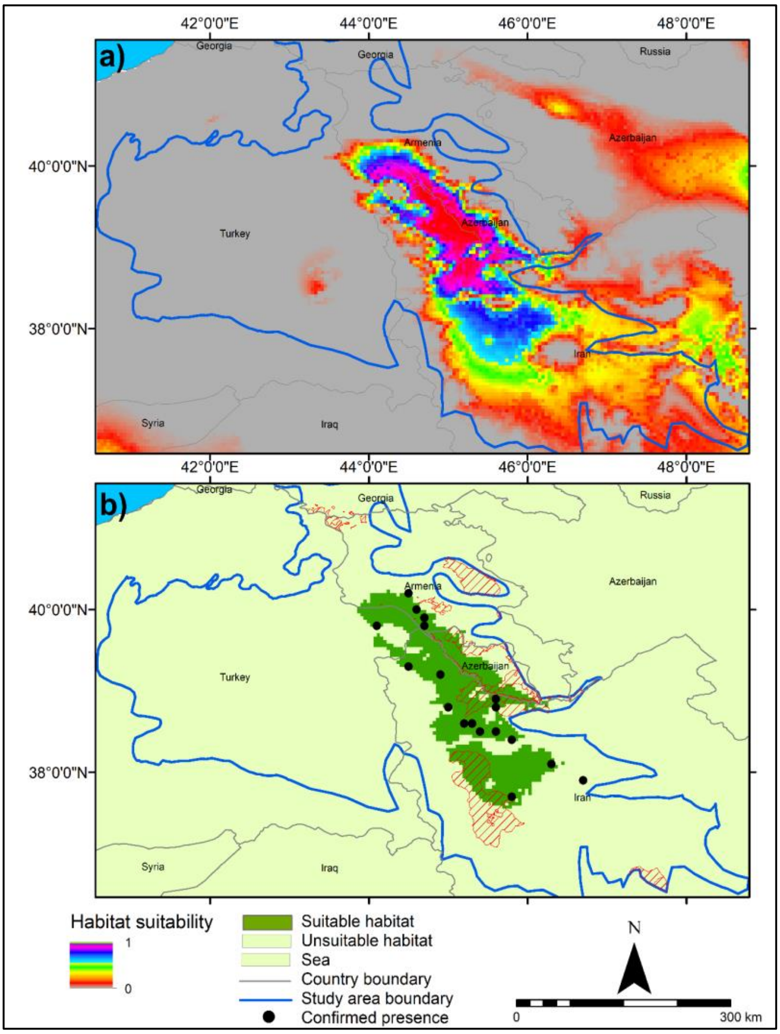

Fig. 1. Maps present- ing (**a**) habitat suitability for Pleske's racerunner in future according to MaxEnt, and (**b**) suitable and unsuitable habitats in future (2070) with current confirmed occurrences of the species within those habitats.

sidering the above, new protected areas should be established within habitats suitable for *E. pleskei*, and if necessary, cross country borders. Moreover, conservation strategies should view the local people as an integral part of the solution (Fischer *et al*. 2012, Popescu *et al*. 2013). Traditionally-managed areas in Romania are a good example of protected landscapes for reptile and amphibian conservation (e.g., Popescu *et al*. 2013).

The results of our study offer insight into the future distribution of Pleske's racerunner at a large scale. For any particular sites, we recommend habitat modeling at the site level. Guisan and Thuiller *et al*. (2005) and Bradley (2010) suggested the hierarchical framework of species dispersal models, land-use disturbance factors, and/or resource models using bioclimatic envelope models to forecast the species' potential distribution.

One of the major challenges in conserva- tion efforts is managing uncertainties in climate change and species distribution. Based on our findings, we suggest conservation activities to be focused on parts of *E. pleskei* suitable habitats that will retain their properties in the future.

SDMs can shed light on attributes of the natural distribution of species within their current range given the appropriate survey data and relevant predictors are used in a correctly

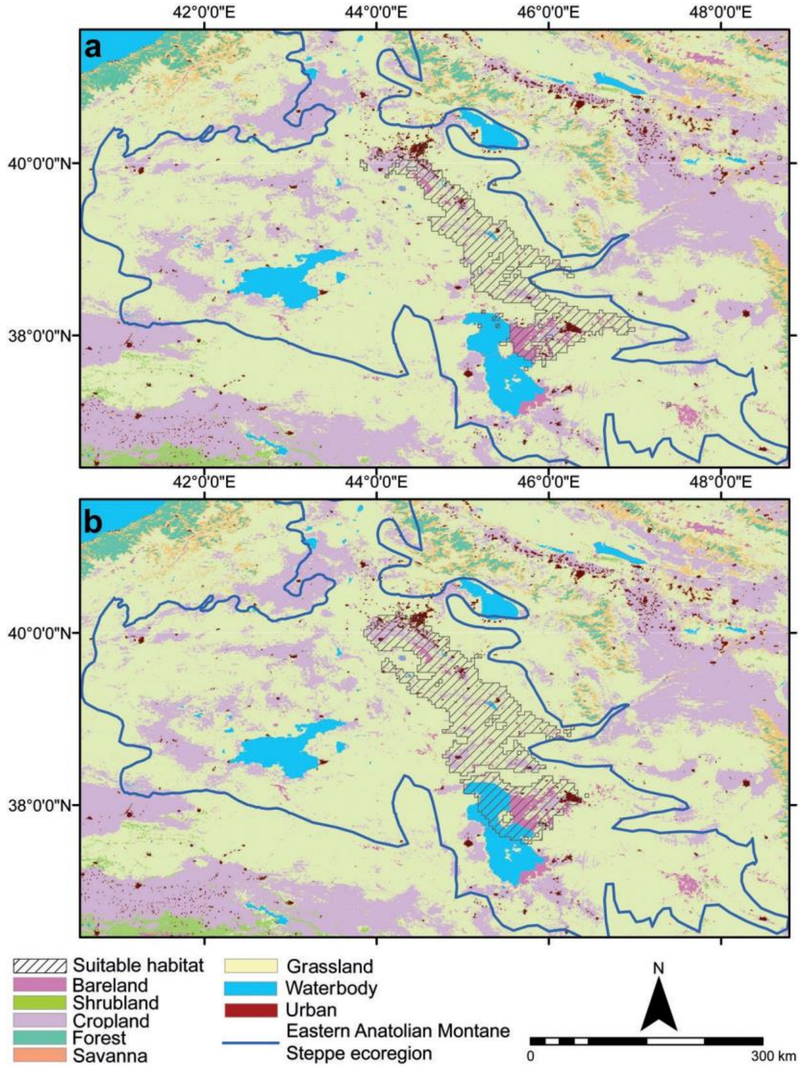

Fig. 3. Land-cover types in habitats suitable for Pleske's racerunner (**a**) at present and (**b**) in future.

adjusted model. Under such conditions, models can generate useful ecological information and offer accurate predictions. On the other hand, in cases of species not in equilibrium with their environment, models extrapolating in time or space, and/or using insufficient data, will not be free of uncertainties (Elith & Leathwick 2009). Model accuracy also differs for different species with different levels of mobility (Pearce *et al*. 2001, Seoane *et al*. 2005, Carrascal *et al*. 2006, Pawar *et al*. 2007). Thus, for less mobile species such as amphibians and reptiles modeling techniques which are more conducive to interpretation should be employed (Stockman *et al*. 2006). It should also be noted that models can take advantage of museum or atlas data. Such data, however, could be biased toward more accessible areas or areas where species are expected to be present (Kadmon *et al*. 2004). Same could be true for our species occurrence input data as they also were not collected according to a sampling strategy or with a specific goal in mind (Elith *et al*. 2006). Sampling bias can, therefore, occur if samples are not collected according to set criteria (such as random or stratified sampling) (Phillips *et al*. 2009, Yackulic *et al*. 2013, Guillera-Arroita *et al*. 2015), especially if the data are used presence-only models. To overcome this, we employed ten different models to select the most accurate one, which in our case was MaxEnt.

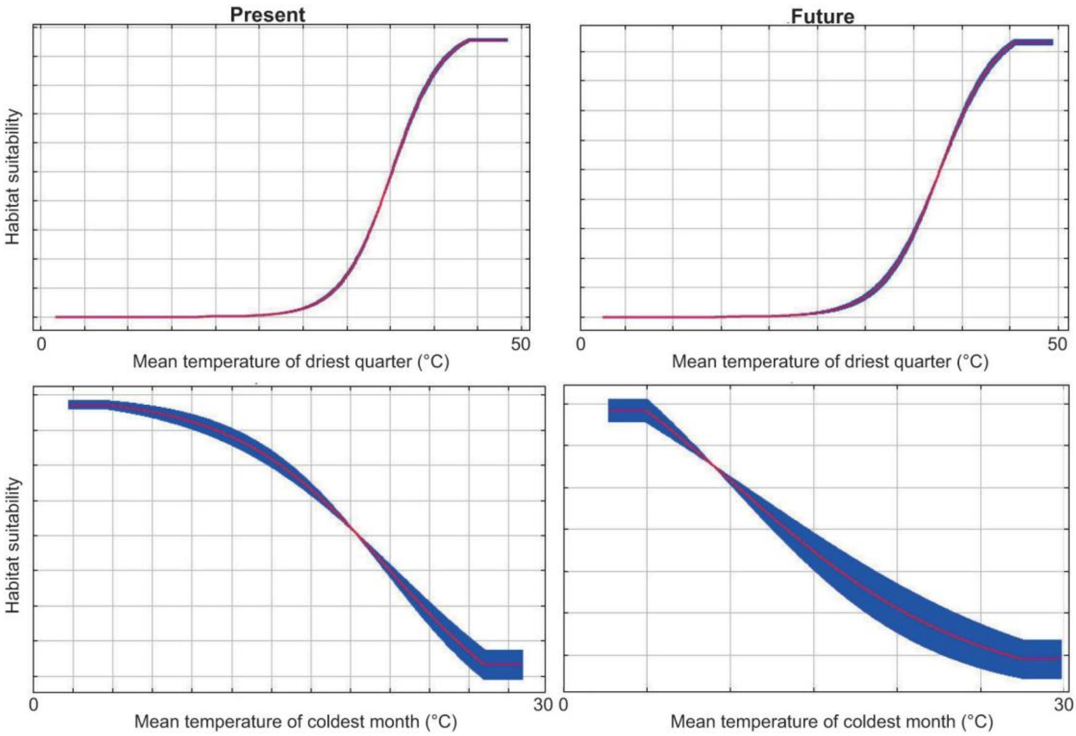

Fig. 4. Response curves of the MaxEnt model for Pleske's racerunner.

References

Allouche, O., Tsoar, A. & Kadmon, R. 2006: Assessing the accuracy of species distribution models: prevalence, kappa and the true skill statistic (TSS). — *Journal of Applied Ecology* 43: 1223–1232.

Ananjeva, N. B., Orlov, N. L., Khalikov R. G., Darevsky, I. S., Ryabov, S. A. & Barabanov, A. V. 2006: *The reptiles of northern Eurasia: taxonomic diversity, distribution, conservation status*. — Pensoft Publishers (Series Faunistica no. 47), Sofia, Bulgaria.

Anderson, S. 1984. Areography of North American fishes, amphibians, and reptiles. — *American Museum Novitates* 2802: 1–16.

Anderson, S. & Marcus, L. F. 1992. Aerography of Australian tetrapods. — *Australian Journal of Zoology* 40: 627–651.

Araújo, M. B. & New, M. 2007: Ensemble forecasting of species distributions. — *Trends in Ecology & Evolution* 22: 42–47.

Aslanyan, A. V. 2004: *Ecological-faunistic analysis of lizards of Armenia*. — Ph.D. thesis, Institute of Zool- ogy, National Academy of Sciences of The Republic of Armenia, Yerevan.

Baran, İ., Ç. Ilgaz., A. Avci., Y. Kumluta, Ş. & K. *Olgun. 2013: Türkiye Amfibi ve Sürüngenleri*. — Tübitak Popüler Bilim Kitapları, Tübitak.

Barve, N. 2008: *Tool for partial-ROC*. — Biodiversity Institute, Lawrence, KS.

Barve, N., Barve, V., Jiménez-Valverde, A., Lira-Noriega, A., Maher, S. P., Peterson, A. T., Soberóna, J. & Villalobos, *F.* 2011: The crucial role of the accessible area in ecological niche modeling and species distribution modeling. — *Ecological Modelling* 222: 1810–1819.

Block, C., Pedrana, J., Stellatelli, O. A., Vega, L. E. & Isacch, J. P. 2016: Habitat suitability models for the sand lizard *Liolaemus wiegmannii* based on landscape characteristics in temperate coastal dunes in Argentina. — *Austral Ecology* 41: 671–680.

Bombi, P., Salvi, D., Vignoli, L. & Bologna, M. A. 2009: Modelling Bedriaga's rock lizard distribution in Sardinia: An ensemble approach. — *Amphibia-Reptilia* 30: 413–424.

Bradley, B. A. 2010: Assessing ecosystem threats from global and regional change: hierarchical modeling of risk to sagebrush ecosystems from climate change, land use and invasive species in Nevada, USA. — *Ecography* 33: 198–208.

Brown, J. L. 2014: SDMtoolbox: a python-based GIS toolkit for landscape genetic, biogeographic and species distribution model analyses. — *Methods in Ecology and Evolution* 5: 694–700.

Bull, J. J. 2008: Sex determination: are two mechanisms better than one? — *Journal of Biosciences* 33: 5–8.

Carey, C. & Alexander, M. A. 2003: Climate change and amphibian declines: is there a link? — *Diversity and*

Distributions 9: 111–121.
Carrascal, L.M., Seoane, J., Palomino, D., Alonso, C. L. & Lobo, J. M. 2006. Species-specific features affect the ability of census-derived models to map winter avian distribution. — *Ecological Research* 21: 681–691.
Ciofi, C. & Swingland, I. R. 1997: Environmental sex determination in reptiles. — *Applied Animal Behaviour Science* 51: 251–265.
Darevsky, I. S. 1957: Fauna of reptiles of Armenia and its zoogeographical analysis. — Ph.D. thesis, Zoological Institute, Academy of Sciences of Armenian SSR, Yerevan, Armenia. [In Russian].
Davies, H. F., McCarthy, M. A., Firth, R. S., Woinarski, J. C., Gillespie, G. R., Andersen, A. N., Geyle, H. M., Nicholson, E. & Murphy, B. P. 2017: Top-down control of species distributions: feral cats driving the regional extinction of a threatened rodent in northern Australia. — *Diversity and Distributions* 23: 272–283.
de Pous, P., Mora, E., Metallinou, M., Escoriza, D., Comas, M., Donaire, D., Comas, M. & Carranza S. 2011: Elusive but widespread? The potential distribution and genetic variation of *Hyalosaurus koellikeri* (Günther, 1873) in the Maghreb. — *Amphibia-Reptilia* 32: 385–397.
De Souza, T. V., Lorini, M. L., Alves, M. A. S., Cordeiro, P. & Vale, M. M. 2011: Redistribution of threatened and endemic Atlantic Forest birds under climate change. — *Natureza a Conservacao* 9: 214–218.
Düşen, S., Kumlutaş, Y., Ilgaz, Ç., Yaka, H. & Karadayi, F. 2013: Helminth parasites of the three racerunner lizards: *Eremias pleskei* Nikolsky, 1905 (Pleske's racerunner, Transcaucasian racerunner), *Eremias strauchi* Kes- sler, 1878 (Strauch's racerunner) and *Eremias suphani* Basoglu & Hellmich, 1968 (Suphan racerunner) collected from Eastern Part of Turkey. — *Helminthologia* 50: 108–111.
e Silva, V. D. N., Pressey, R. L., Machado, R. B., VanDerWal, J., Wiederhecker, H. C., Werneck, F. P. & Colli, G. R. 2014: Formulating conservation targets for a gap analysis of endemic lizards in a biodiversity hotspot. — *Biological conservation* 180: 1–10.
Ebrahimi, A., Farashi, A. & Rashki, A. 2017: Habitat suitability of Persian leopard (*Panthera pardus saxicolor*) in Iran in future. — *Environmental Earth Sciences* 76: 697, https://doi.org/10.1007/s12665-017-7040-8.
Eggert, C. 2004: Sex determination: the amphibian models. — *Reproduction nutrition development* 44: 539–549.
Elith, J. & Leathwick, J. R. 2009: Species distribution models: ecological explanation and prediction across space and time. — *Annual Review of Ecology, Evolution, and Systematics* 40: 677–697.
Elith, J., Graham, C. H., Anderson, R. P., Dudík, M., Fer- rier, S., Guisan, A., Hijmans, R. J., Huettmann, F., Leathwick, J. R., Lehmann, A., Li, J., Lohmann L. G., Loiselle, B. A., Manion, G., Moritz, C., Nakamura, M., Nakazawa, Y., McC. M. Overton, J., Peterson A. T., Phillips, S. J., Richardson, K., Scachetti-Pereira, R., Schapire, R. E., Soberón, J., Williams, S., Wisz, M. S. & Zimmermann, N. E. 2006: Novel methods improve prediction of species' distributions from occurrence data. — *Ecography* 29: 129–151.
Elith, J., Kearney, M. & Phillips, S. 2010: The art of modelling range-shifting species. — *Methods in Ecology and Evolution* 1: 330–342.
Elith, J., Phillips, S. J., Hastie, T., Dudík, M., Chee, Y. E. & Yates, C. J. 2011: A statistical explanation of MaxEnt for ecologists. — *Diversity and Distributions* 17: 43–57.
Ewert, M. A., Jackson, D. R. & Nelson, C. E. 1994: Patterns of temperature-dependent sex determination in turtles. — *Journal of Experimental Zoology* 270: 3–15.
Farashi, A. & Erfani, M. 2018: Modeling of habitat suitability of Asiatic black bear (*Ursus thibetanus gedrosianus*) in Iran in future. — *Acta Ecologica Sinica* 38: 9–14.
Farashi, A. & Najafabadi, M. S. 2015: Modeling the spread of invasive nutrias (*Myocastor coypus*) over Iran. — *Ecological complexity* 22: 59–64.
Farashi, A. & Shariati, M. 2017: Biodiversity hotspots and conservation gaps in Iran. — *Journal for nature conservation* 39: 37–57.
Farashi, A., Shariati, M. & Hosseini, M. 2017: Identifying biodiversity hotspots for threatened mammal species in Iran. — *Mammalian Biology* 87: 71–88.
Fattahi, R., Ficetola, G. F., Rastegar-Pouyani, N., Avcı, A., Kumlutaş, Y., Ilgaz, Ç. & Hosseinian Yousefkhani, S. S. 2014: Modelling the potential distribution of the bridled skink, *Trachylepis vittata* (Olivier, 1804), in the Middle East. — *Zoology in the Middle East* 60: 208–216.
Fielding, A. H. & Bell, J. F. 1997: A review of methods for the assessment of prediction errors in conservation presence/absence models. — *Environmental Conservation* 24: 38–49.
Fischer, J., Hartel, T. & Kuemmerle, T. 2012: Conservation policy in traditional farming landscapes. — *Conservation Letters* 5: 167–175.
Franklin, J. 2010. *Mapping species distributions: spatial inference and prediction*. — Cambridge University Press.
Friedl, D. S.-M. M. 2015: *MCD12Q1 MODIS/Terra+Aqua Land Cover Type Yearly L3 Global 500m SIN Grid V006 [Data set]*. — NASA EOSDIS Land Processes DAAC, https://doi.org/10.5067/MODIS/MCD12Q1.006.
Friedman, J. H. 1991. Multivariate adaptive regression splines. — *The Annals of Statistics* 19: 1–141.
Garden, J. G., McAlpine, C. A., Possingham, H. P. & Jones, D. N. 2007. Habitat structure is more important than vegetation composition for local-level management of native terrestrial reptile and small mammal species living in urban remnants: a case study from Brisbane, Australia. — *Austral Ecology* 32: 669–685.
Guillera-Arroita, G., Lahoz-Monfort, J. J., Elith, J., Gordon, A., Kujala, H., Lentini, P. E., McCarthy, M. A., Tingley, R. & Wintle, B. A. 2015: Is my species distribution model fit for purpose? Matching data and models to applications. — *Global Ecology and Biogeography* 24: 276–292.
Guisan, A. & Thuiller, W. 2005: Predicting species distribution: offering more than simple habitat models. — *Ecology Letters* 8: 993–1009.
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* 25: 1965–1978.

Houlahan, J. E., Findlay, C. S., Schmidt, B. R., Meyer, A. H. & Kuzmin, S. L. 2000: Quantitative evidence for global amphibian population declines. — *Nature* 404: 752.

Huey, R. B., Losos, J. B. & Moritz, C. 2010: Are lizards toast? — *Science* 328: 832–833.

Janzen, F. J. 1994: Climate change and temperature-dependent sex determination in reptiles. — *Proceedings of the National Academy of Sciences* 91: 7487–7490.

Kadmon, R., Farber, O. & Danin, A. 2004: Effect of roadside bias on the accuracy of predictive maps produced by bioclimatic models. — *Ecological Applications* 14: 401–413.

Kalboussi, M. & Achour, H. 2018: Modelling the spatial distribution of snake species in northwestern Tunisia using maximum entropy (Maxent) and Geographic Information System (GIS). — *Journal of Forestry Research* 29: 233–245.

Kaliontzopoulou, A., Brito, J. C., Carretero, M. A., Larbes, S. & Harris, D. J. 2008: Modelling the partially unknown distribution of wall lizards (*Podarcis*) in North Africa: ecological affinities, potential areas of occurrence, and methodological constraints. — *Canadian Journal of Zoology* 86: 992–1001.

Kaska, Y., Olgun, K., Türkozan, O. & Ïret, F. 2004: On two herpetological collections made in East Anatolia (Turkey). — *Herpetozoa* 16: 99–11.

Kearney, M. & Porter, W. P. 2004: Mapping the fundamental niche: physiology, climate, and the distribution of a nocturnal lizard. — *Ecology* 85: 3119–3131.

Levia, D. F. Jr. & Page, D. R. 2000: The use of cluster analysis in distinguishing farmland prone to residential development: a case study of Sterling, Massachusetts. — *Environmental Management* 25: 541–548.

Levinsky, I., Skov, F., Svenning, J. C. & Rahbek, C. 2007: Potential impacts of climate change on the distributions and diversity patterns of European mammals. — *Biodiversity and Conservation* 16: 3803–3816.

Li, X. & Wang, Y. 2013: Applying various algorithms for species distribution modelling. — *Integrative Zoology* 8: 124–135.

Liu, C., White, M. & Newell, G. 2011. Measuring and comparing the accuracy of species distribution models with presence–absence data. — *Ecography* 34: 232–243.

Lobo, J. M., Jiménez-Valverde, A. & Real, R. 2008: AUC: a misleading measure of the performance of predictive distribution models. — *Global ecology and Biogeography* 17: 145–151.

Lunney, D., Stalenberg, E., Santika, T. & Rhodes, J. R. 2014: Extinction in Eden: identifying the role of climate change in the decline of the koala in south-eastern NSW. — *Wildlife Research* 41: 22–34.

Matthews, T. J., Cottee-Jones, H. E. & Whittaker, R. J. 2014: Habitat fragmentation and the species–area relationship: a focus on total species richness obscures the impact of habitat loss on habitat specialists. — *Diversity and Distributions* 20: 1136–1146.

Meinshausen, M., Smith, S. J., Calvin, K., Daniel, J. S., Kainuma, M. L. T., Lamarque, J. F., Matsumoto K., Montzka, S. A., Raper, S. C. B., Riahi, K., Thomson, A., Velders, G. J. M. & van Vuuren, D. P. P. 2011: The RCP greenhouse gas concentrations and their extensions from 1765 to 2300. — *Climatic Change* 109: 213, https://doi.org/10.1007/s10584-011-0156-z.

Merow, C., Smith, M.J., Edwards, T.C., Guisan, A., McMahon, S.M., Normand, S., Thuiller, W., Wüest, R. O., Zimmermann, N. E. & Elith, J. 2014. What do we gain from simplicity versus complexity in species distribution models? — *Ecography* 37: 1267–1281.

Meynecke, J. O. 2004: Effects of global climate change on geographic distributions of vertebrates in North Queensland. — *Ecological Modelling* 174: 347–357.

Mitchell, N. J. & Janzen, F. J. 2010: Temperature-dependent sex determination and contemporary climate change. — *Sexual Development* 4: 129–140.

Mostafavi, H., Pletterbauer, F., Coad, B. W., Mahini, A. S., Schinegger, R., Unfer, G., Trautwein, C. & Schmutz, S. 2014: Predicting presence and absence of trout (*Salmo trutta*) in Iran. — *Limnologica* 46: 1–8.

Mozaffari, O., Kamali, K. & Fahimi, H. 2014. *The atlas of reptiles of Iran*. — Iran Department of the Environment, Tehran, Iran.

Murray, K. A., Retallick, R. W., Puschendorf, R., Skerratt, L. F., Rosauer, D., McCallum, H. I., Berger, L., Speare, R. & VanDerWal, J. 2011: Assessing spatial patterns of disease risk to biodiversity: implications for the management of the amphibian pathogen, *Batrachochytrium dendrobatidis*. — *Journal of Applied Ecology* 48: 163–173.

Nakamura, M. 2009: Sex determination in amphibians. — *Seminars in Cell & Developmental Biology* 20: 271–282.

Naveda-Rodríguez, A. 2015: Conservation status of diurnal raptors in Venezuela. — *Journal of Raptor Research* 49: 441–449.

Owens, H. L., Campbell, L. P., Dornak, L. L., Saupe, E. E., Barve, N., Soberón, J., Ingenloff, K., Lira-Noriega, A., Hensz, C M., Myers, C. E. & Peterson, A. T. 2013: Constraints on interpretation of ecological niche models by limited environmental ranges on calibration areas. — *Ecological modelling* 263: 10–18.

Pawar, S., Koo, M. S., Kelley, C., Ahmed, M. F., Chaudhuri, S. & Sarkar, S. 2007. Conservation assessment and prioritization of areas in northeast India: priorities for amphibians and reptiles. — *Biological Conservation* 136: 346–361.

Pearce, J., Ferrier, S. & Scotts, D. 2001: An evaluation of the predictive performance of distributional models for flora and fauna in north-east New South Wales. — *Journal of Environmental Management* 62: 171–184.

Peterson, A. T., Papeş, M. & Soberón, J. 2008: Rethinking receiver operating characteristic analysis applications in ecological niche modeling. — *Ecological Modelling* 213: 63–72.

Pezaro, N., Doody, J. S. & Thompson, M. B. 2017: The ecology and evolution of temperature-dependent reaction norms for sex determination in reptiles: a mechanistic conceptual model. — *Biological Reviews* 92: 1348–1364.

Phillips, S. J., Dudík, M., Elith, J., Graham, C. H., Lehmann, A., Leathwick, J. & Ferrier, S. 2009: Sample selection bias and presence-only distribution models: implications for background and pseudo-absence data. — *Ecological* *applications* 19: 181–197.

Pieau, C., Dorizzi, M. & Richard-Mercier, N. 1999: Temperature-dependent sex determination and gonadal differentiation in reptiles. — *Cellular and Molecular Life Sciences* 55: 887–900.

Popescu, V. D., Rozylowicz, L., Cogălniceanu, D., Niculae, I. M. & Cucu, A. L. 2013: Moving into protected areas? Setting conservation priorities for Romanian reptiles and amphibians at risk from climate change. — *PloS ONE* 8(11): e79330. https://doi.org/10.1371/journal.pone.0079330.

Quisthoudt, K., Adams, J., Rajkaran, A., Dahdouh-Guebas, F., Koedam, N. & Randin, C. F. 2013: Disentangling the effects of global climate and regional land-use change on the current and future distribution of mangroves in South Africa. — *Biodiversity and conservation* 22: 1369–1390.

Rhoden, C. M., Peterman, W. E. & Taylor, C. A. 2017: Maxent-directed field surveys identify new populations of narrowly endemic habitat specialists. — *PeerJ*, 5, e3632, https://doi.org/10.7717/peerj.3632.

Ribeiro-Júnior, M. & Amaral, S. 2016: Diversity, distribution, and conservation of lizards (Reptilia: Squamata) in the Brazilian Amazonia. — *Neotropical Biodiversity* 2: 195–421.

Rogelj, J. 2013: Long-term climate change: projections, commitments and irreversibility. — In: *Climate change 2013: the physical science basis*: 1029–1136. IPCC Working Group I contribution to AR5, Cambridge University Press, Cambridge UK and New York, USA.

Rybicki, J. & Hanski, I. 2013. Species–area relationships and extinctions caused by habitat loss and fragmentation. — *Ecology Letters* 16: 27–38.

Sanchooli, N. 2017: Habitat suitability and potential distribution of *Laudakia nupta* (De Filippi, 1843) (Sauria: Agamidae) in Iran. — *Russian Journal of Ecology* 48: 275–279.

Santos, X., Badiane, A. & Matos, C. 2016. Contrasts in short- and long-term responses of Mediterranean reptile species to fire and habitat structure. — *Oecologia* 180: 205–216.

Seoane, J., Carrascal, L. M., Alonso, C. L. & Palomino, D. 2005. Species-specific traits associated to prediction errors in bird habitat suitability modelling. — *Ecological Modelling* 185: 299–308.

Sinervo, B., Méndez-de-la-Cruz, F., Miles, D. B., Heulin, B., Bastiaans, E., Villagrán-Santa Cruz, M., Lara-Re- sendiz, R., Martínez-Méndez, N., Calderón-Espinosa, M. L., Meza-Lázaro, R. N., Gadsden, H., Avila, L. J., Morando, M., De la Riva, I. J., Sepulveda, P. V., Rocha, C. F. D., Ibargüengoytía, N., Puntriano, C. A., Massot, M., Lepetz, V., Oksanen, T. A., Chapple, D. G., Bauer, A. M., Branch, W. R., Clobert, J. & Sites, J. W. Jr. 2010: Erosion of lizard diversity by climate change and altered thermal niches. — *Science* 328: 894–899.

Soberon, J. & Peterson, A. T. 2005: Interpretation of models of fundamental ecological niches and species' distributional areas. — *Biodiversity Informatics* 2: 1–10.

Stokland, J. N., Halvorsen, R. & Støa, B. 2011: Species distribution modelling — effect of design and sample size of pseudo-absence observations. — *Ecological Modelling* 222: 1800–1809.

Stuart, S. N., Chanson, J. S., Cox, N. A., Young, B. E., Rodrigues, A. S., Fischman, D. L. & Waller, R. W. 2004: Status and trends of amphibian declines and extinctions worldwide. — *Science* 306: 1783–1786.

Tadevosyan, T. L. 2007: The role of vegetation in microhabitat selection of syntopic lizards, *Phrynocephalus persicus*, *Eremias pleskei*, and *Eremias strauchi* from Armenia. — *Amphibia-Reptilia* 28: 444–448.

Tait, C.J., Daniels, C. B. & Hill, R. S. 2005. Changes in species assemblages within the Adelaide metropolitan area, Australia, 1836–2002. — *Ecological Applications* 15: 346–359.

Thomas, C. D., Cameron, A., Green, R. E., Bakkenes, M., Beaumont, L. J., Collingham, Y. C., Erasmus, B. F. N., de Siqueira, M. F., Grainger, A., Hannah, L., Hughes, L., Huntley, B., van Jaarsveld, A. S., Midgley, G. F., Miles, L., Ortega-Huerta, M. A., Townsend Peterson, A., Phillips, O. L. & Williams, S. E. 2004: Extinction risk from climate change. — *Nature* 427: 145–148.

Thuiller, W., Lafourcade, B., Engler, R. & Araújo, M. B. 2009. BIOMOD — a platform for ensemble forecasting of species distributions. — *Ecography* 32: 369–373.

Thuiller, W., Lavorel, S., Araújo, M. B., Sykes, M. T. & Prentice, I. C. 2005: Climate change threats to plant diversity in Europe. — *Proceedings of the National Academy of Sciences of the United States of America* 102: 8245–8250.

Trabucco, A., Achten, W. M., Bowe, C., Aerts, R. A. F., ORSHOVEN, J. V., Norgrove, L. & Muys, B. 2010: Global mapping of *Jatropha curcas* yield based on response of fitness to present and future climate. — *GCB Bioenergy* 2: 139–151.

Valdeón, A., Martínez del Castillo, E., Castilla, A. M., Cogălniceanu, D. & Saifelnasr, E. O. H. 2014: Realized niche modelling of four sand-dwelling lizard species in Qatar. — In: Cámara-Artigas, R., Rodríguez-Pérez, B. & Muriel-Gómez, J. L. (eds.), *Biogeografía de Medios Litorales: Dinámicas y conservación*: 287–290. Vicerrectorado de Investigación de la Universidad de Sevilla (V Plan Propio de Investigación) & Grupo de Geografía Física de la AGE.

van der Ree, R. 2004. The impact of urbanisation on the mammals of Melbourne — do atlas records tell the whole story or just some of the chapters. — In: (eds.), *Urban wildlife*: 195–204. Australian Research Centre for Urban Ecology, Royal Botanic Gardens Mel- bourne.

Waltari, E. & Guralnick, R. P. 2009: Ecological niche modelling of montane mammals in the Great Basin, North America: examining past and present connectivity of species across basins and ranges. — *Journal of Biogeography* 36: 148–161.

Wen, L., Saintilan, N., Yang, X., Hunter, S. & Mawer, D. 2015: MODIS NDVI based metrics improve habitat suitability modelling in fragmented patchy floodplains. — *Remote Sensing Applications: Society and Environment* 1: 85–97.

Yackulic, C. B., Chandler, R., Zipkin, E. F., Royle, J. A., Nichols, J. D., Campbell Grant, E. H. & Veran, S. 2013: Presence-only modelling using MAXENT: when can we trust the inferences? — *Methods in Ecology and Evolution* 4: 236–243.