Environmental predictors for the distribution of the Caspian green lizard, *Lacerta strigata* Eichwald, 1831, along elevational gradients of the Elburz Mountains in northern Iran

Anooshe KAFASH[1,2,3] ⓘ, Sohrab ASHRAFI[1,]* ⓘ, Annemarie OHLER[4] ⓘ, Benedikt Rudolf SCHMIDT[5,6] ⓘ

[1]Department of Environmental Science, Faculty of Natural Resources, University of Tehran, Tehran, Iran
[2]Institute of Terrestrial Ecosystems, ETH Zurich, Zurich, Switzerland
[3]Swiss Federal Institute for Forest, Snow, and Landscape Research (WSL), Birmensdorf, Switzerland
[4]Institute of Systematic, Evolution, and Biodiversity (ISYEB), UMR7205, CNRS, MNHN, UPMC, EPHE,
National Museum of Natural History, Sorbonne University, Paris, France
[5]Department of Evolutionary Biology and Environmental Studies, University of Zurich, Zurich, Switzerland
[6]Info Fauna KARCH, Neuchâtel, Switzerland

Abstract: Within its range, the Caspian green lizard, *Lacerta strigata*, occurs in the Elburz Mountains (northern Iran) at elevations from below sea level to approximately 2700 m a.s.l. To determine the environmental factors affecting the distribution of this lizard, we used an ensemble approach to model the distribution of the Caspian green lizard (*Lacerta strigata*) in Iran using four algorithms (generalized boosted model, maximum entropy, generalized linear model, random forest). Results revealed that low-elevation habitats between the Elburz Mountains and the Caspian Sea are the most suitable habitats for the species. The normalized difference vegetation index (NDVI), annual precipitation (both with positive relationships), and altitude (with a negative relationship) were the most important environmental variables influencing the distribution of the species. NDVI was likely the most important variable because it is an indicator of plant productivity, which presumably influences the availability of food resources such as insects. We also tested the validity of an old distribution record for the species near Shiraz in southwestern Iran. The results show that southwestern Iran is not ecologically suitable for the species. As our results highlighted that the NDVI strongly affects distribution of the species, we suggest protection of vegetation cover in the habitat of the species for conservation of *Lacerta strigata*.

Key words: *Lacerta strigata*, habitat, normalized difference vegetation index, distribution modeling, conservation

1. Introduction

Studying the environmental drivers that determine the distribution of species is a central theme in ecology and biogeography (Brown et al., 1996; Gaston, 2000; Lomolino et al., 2010). Distributional patterns of species are determined by a wide range of historical, abiotic, and biotic ecological factors (Gaston, 2003; Graham et al., 2014), but geology and climate are believed to be the most important drivers of spatial patterns of biodiversity in mountains (Fu et al., 2007; Antonelli et al., 2018). Mountains are characterized by steep elevational gradients that have strong effects on the distribution of species, including elevational range edges. Mountains cover one-quarter of the land surface and support one-third of the planet's biological diversity (Körner, 2004; Körner et al., 2011; Spehn et al., 2011). Mountain biodiversity is threatened by climate change and human activities (Diaz et al., 2003; Parmesan, 2006; Körner et al., 2017).

The study of species distributions along elevational gradients from lowlands to mountains can offer valuable insights into the environmental factors that determine the distribution of species (Hairston, 1949; Guisan and Hofer, 2003; Arntzen, 2006). The Elburz Mountains are a biodiversity hotspot in Iran (Anderson, 1999; Majnoonian et al., 2005; Akhani et al., 2013; Moradi et al., 2018). While plant species and the environmental drivers of their distributions have been studied extensively in the Elburz Mountains (Noroozi et al., 2010; Akhani et al., 2013; Ravanbakhsh and Moshki, 2016), animal distributions and their drivers remain poorly known (Ahmadzadeh et al., 2013; Mahmoudi et al., 2016; Ashoori et al., 2018).

Species distribution models (SDMs) are commonly used to predict suitable environmental conditions for species presence or absence (Guisan and Thuiller, 2005; Pearson et al., 2007; Elith et al., 2011; Yousefi et al., 2018b), find new potential habitats for rare and endangered species

* Correspondence: sohrab.ashrafi@ut.ac.ir

(Guisan et al., 2006; Williams et al., 2009; Yousefi et al., 2015), and explore environmental factors determining the distribution of animals and plants (Royle et al., 2005; Peterson et al., 2011; Werner et al., 2013; Kafash et al., 2018).

The Caspian green lizard, *Lacerta strigata* Eichwald, 1831, belongs to the family Lacertidae. Its distribution range includes eastern Anatolia, Caucasian Russia, Armenia, eastern Georgia, Azerbaijan, northern and northeastern Iran, and southwestern Turkmenistan (Sindaco and Jeremcenko, 2008). The ecology and distribution of *L. strigata* remain poorly known. Nevertheless, it is a good model species to assess the effect of environmental conditions on the distribution of species because it is found along a wide elevational gradient. In Iran, for example, *L. strigata* occurs from below sea level (–27 m a.s.l.) to approximately 2700 m a.s.l. in elevation from East Azerbaijan eastward to North Khorasan (Anderson, 1999; Yousefi et al., 2018a). Here, we used SDMs to model the distribution of the species in Iran and determine which environmental variables are the most important predictors of the distribution of the species along elevational gradients of the Elburz Mountains. In addition, we used the model to verify whether an isolated record of this lizard from Shiraz in southwestern Iran is plausible. For this site, the identity of the species was confirmed by herpetologists (Anderson, 1999), but the locality is far away from the species' core distribution range. We tested whether southwestern Iran is ecologically suitable for the species.

2. Material and methods

2.1. Distribution data and environmental variables
Distribution records were collected through opportunistic observations during fieldwork from 2014 to 2017 (n = 14). Additional records (n = 28) were downloaded from the Global Biodiversity Information Facility (https://www.gbif.org/, which also includes the distribution records of Šmíd et al., 2014). In total, 42 distribution points were available and used in niche modeling.

Environmental variables related to climate, topography, and vegetation were used to model the distribution of *L. strigata* along the elevational gradient of the Elburz Mountains. The climatic variables were downloaded from CHELSA (Climatologies at high resolution for the earth's land surface areas). CHELSA contains high resolution (30 arcsec, ~1 km) climate data (time period: 1979–2013) for earth land surface areas and is currently hosted by the Swiss Federal Institute for Forest, Snow, and Landscape Research WSL (Karger et al., 2017). Slope was calculated using the terrain function in the Raster package (https://cran.r-project.org/web/packages/raster/index.html). The terrain function calculates slope as a function of elevation. The elevation layer was obtained from the Shuttle Radar Topography Mission (SRTM) elevation model (http://srtm.csi.cgiar.org). All environmental layers were prepared at 1-km resolution for Iranian territory and used for distribution modeling.

To avoid collinearity among variables, we selected uncorrelated climatic variables (Pearson correlation coefficient <0.7) (Zar, 1999). ENMTools 1.4.4 (Warren et al., 2010) was used to estimate correlation among the variables. This selection of variables reduced the number of environmental variables such that we had a good ratio of explanatory variables and distribution records (Yackulic et al., 2013) (Table 1).

2.2. Distribution modeling
To model the distribution of *L. strigata* along elevational gradients of the Elburz Mountains we applied an ensemble approach (Araújo and New, 2007) using four algorithms: generalized boosted models (Ridgeway, 1999), maximum entropy modeling (Phillips et al., 2006), generalized linear models (McCullagh and Nelder, 1989), and random forest (Breiman, 2001). We also determined whether the Shiraz region is ecologically suitable for the species.

As an alternative approach we used the jackknife test of variable importance in MaxEnt to explore the most important environmental drivers of the distribution of *L. strigata* in the Elburz Mountains (Phillips et al., 2006; Elith et al., 2011). We generated a randomly drawn sample of 10,000 background points (e.g., pseudo-absence points) from the extent of the study area (Iran) using the PresenceAbsence package (Freeman and Moisen, 2008) in the R environment (v. 3.4.3).

To measure the predictive performance of the models, we used three statistics: the true skills statistic (TSS), area under the receiver operating characteristic curve (AUC) (Fielding and Bell, 1997), and the Boyce index (Boyce et al., 2002; Hirzel et al., 2006). An AUC value of 0.5 indicates that the performance of the model is not better than random, while values closer to 1.0 indicate better model performance (Swets, 1988). Both TSS and Boyce index values range from –1 to +1, where +1 indicates perfect

Table 1. Environmental variables used in this study.

Variable	Abbreviation
Slope	Slope
Normalized difference vegetation index	NDVI
Mean diurnal range of temperature	Bio2
Isothermality	Bio3
Temperature seasonality	Bio4
Annual precipitation	Bio12
Precipitation seasonality	Bio15

performance, a value of zero means random predictions, and negative values indicate counter-predictions (Hirzel et al., 2006; Guisan et al., 2017). Analyses were carried out using the packages GISTools (https://rdrr.io/cran/GISTools/), dismo (https://rdrr.io/cran/dismo/), biomod2 (https://cran.r-project.org/web/packages/biomod2/index.html), maptools (http://r-forge.r-project.org/projects/maptools/), SDMTools (https://cran.r-project.org/web/packages/SDMTools/index.html), ecospat (https://cran.r-project.org/web/packages/ecospat/ecospat.pdf), and raster (https://cran.r-project.org/web/packages/raster/index.html) in the R environment (v. 3.4.3).

3. Results
Figure 1 shows the distribution records of the Caspian green lizard in Iran.

Results of modeling the distribution of the Caspian green lizard along the elevational gradients of the Elburz Mountains showed that habitats on the gentle slopes between the Elburz Mountains and the Caspian Sea are the most suitable habitats for the species in northern Iran

(Figure 2). The predictions made by the four modeling methods are comparable, but it appears that GLM is the most liberal (i.e. highest predicted suitability), whereas MaxEnt is the most conservative. Our models showed that the Shiraz region is not suitable for the occurrence of *L. strigata*.

3.1. Model performance and variables importance
Results of assessing the predictive performance of models developed in this study showed that all models performed well in predicting the distribution of *L. strigata* in Iran (Figure 3). Results of estimating the importance of the environmental variables revealed that the normalized difference vegetation index (NDVI) followed by annual precipitation (Bio12) and slope were the most important environmental variables affecting the distribution of the species. The relationship between relative habitat suitability for the species and NDVI and annual precipitation was positive, while species occurrence was negatively affected by slope (Figure 4).

The results of the jackknife test of variable importance showed that the environmental variable with the highest
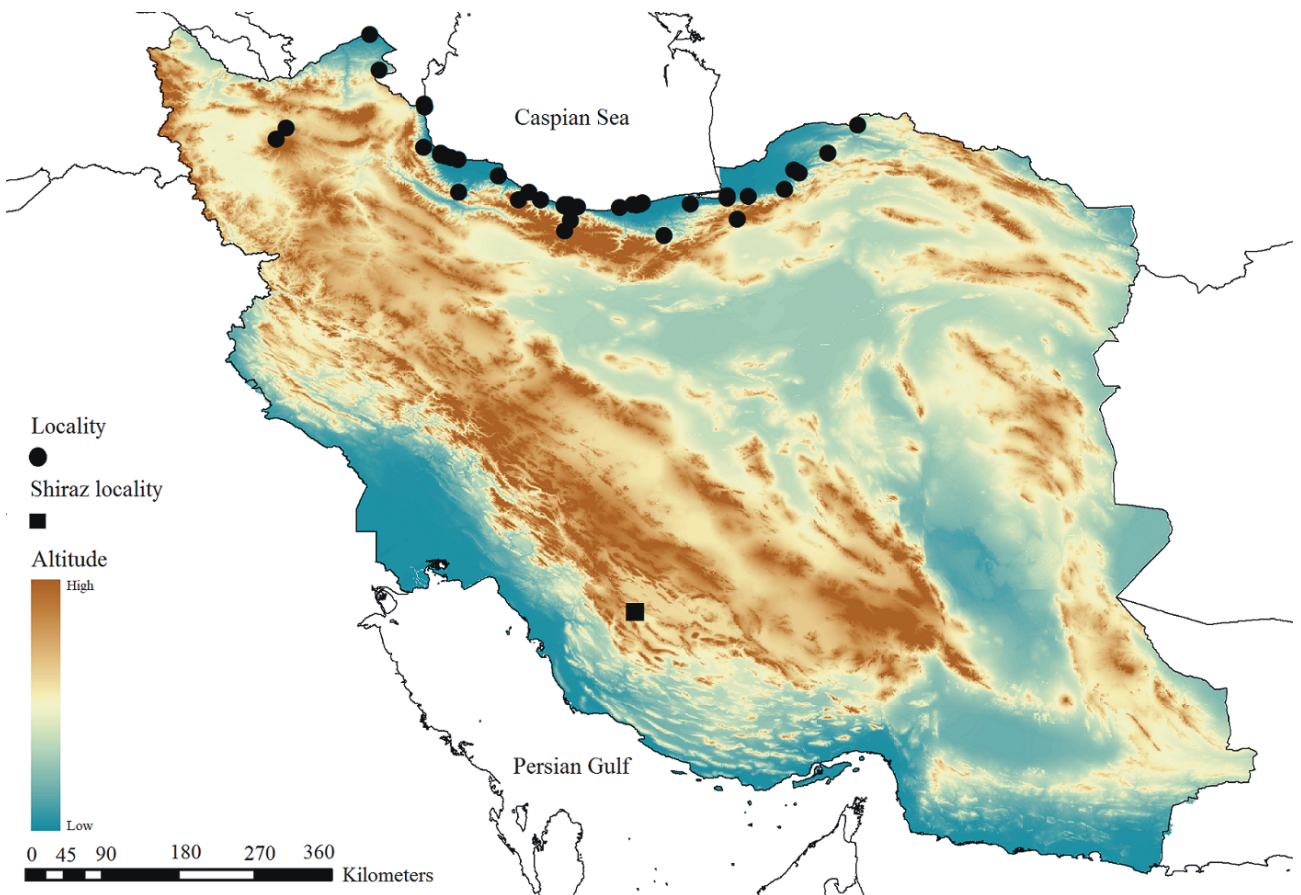

Figure 1. Map of Iran. Colors indicate elevation and dots indicate occurrence of the Caspian green lizard (*Lacerta strigata*). Dots show presence of records for the species. The square shows the locality of the occurrence near Shiraz.
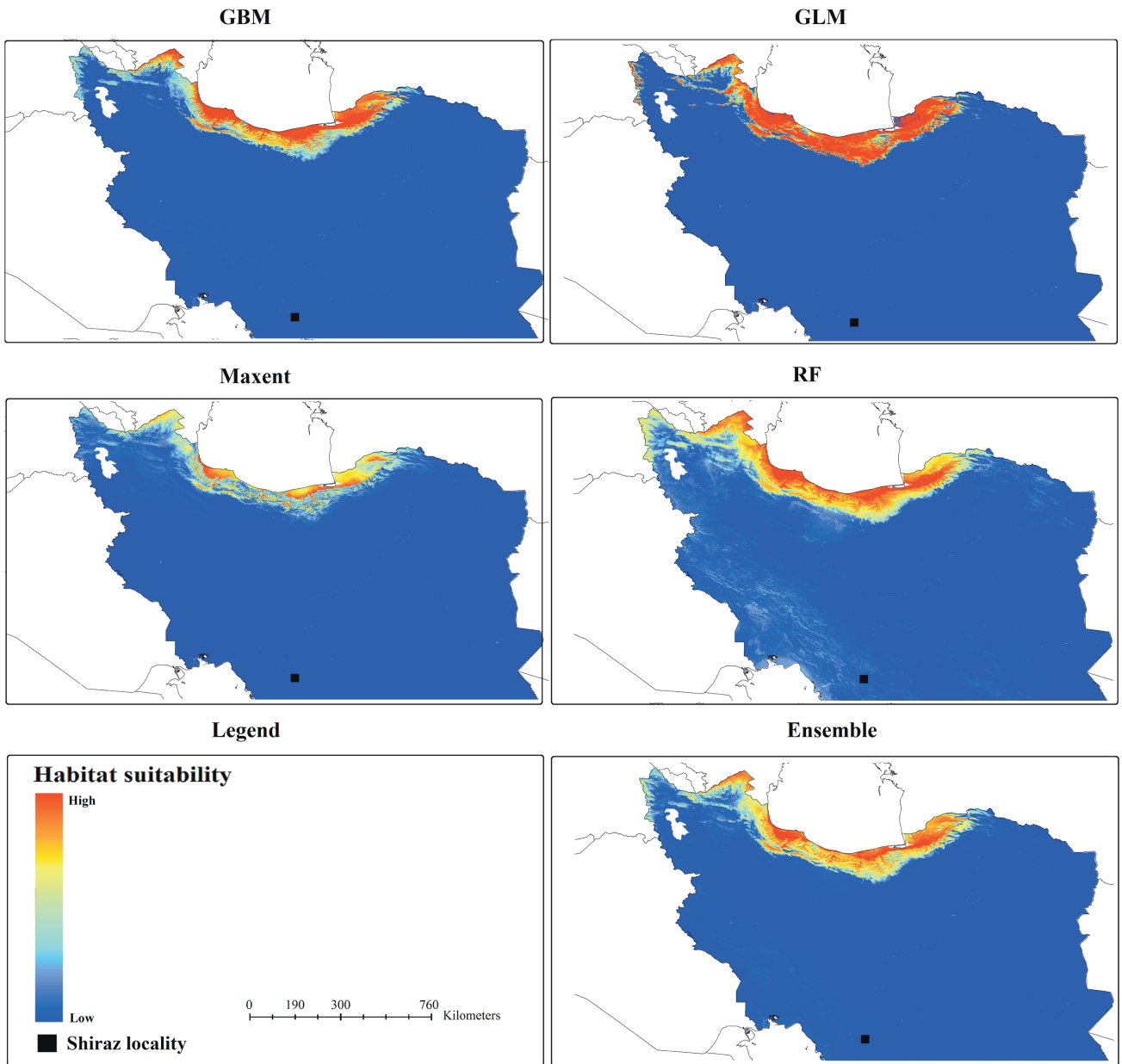
GBM

GLM

Maxent

RF

Legend

Ensemble

Habitat suitability

High

Low

0   190   300   760
Kilometers

■ **Shiraz locality**

Figure 2. The distribution models (GBM, GLM, MaxEnt, RF, and ensemble) of *Lacerta strigata* in northern Iran along with the Shiraz locality (black square).

gain when used in isolation was NDVI, which therefore appears to have the most useful information by itself. The environmental variable that decreases the gain the most when it is omitted is annual precipitation, which therefore appears to have the most information that is not present in the other variables (Table 2).

4. Discussion
Our models showed that low-altitude habitats on gentle slopes are the most suitable area for the Caspian green

lizard (*L. strigata*) along the elevational gradient of the Elburz Mountains. Except for the Shiraz locality, the distribution models produced in this study are in line with the previously published distribution maps for this species in Iran (Anderson, 1999; Rastegar-Pouyani et al., 2007), confirming the accuracy of our models to identify suitable habitats for the species.

NDVI was the most important predictor of *L. strigata* distribution. Habitat suitability for the species increases with increasing NDVI. This is most likely the case because
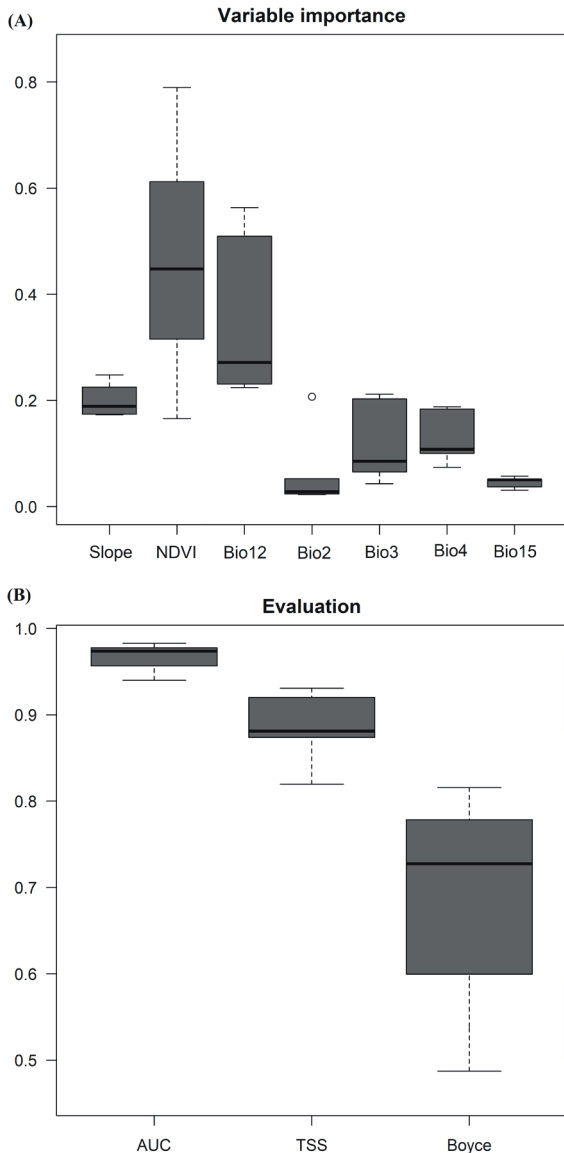
Table 2. The results of the jackknife test of importance of variables. "Without variable" refers to when each variable is excluded in turn and a model is created with the remaining variables; "With only variable" refers to when each model is constructed using only one variable (Phillips et al., 2006).

Variable	Without variable	With only variable
Slope	2.7437	1.562
Bio12	2.605	1.8908
NDVI	2.6379	2.0049
Bio4	2.7439	0.7179
Bio3	2.7826	0.9706
Bio2	2.7312	1.5041
Bio15	2.7545	0.1701

Figure 3. Results of variables importance test (A) and model evaluation using AUC, TSS, and Boyce index (B).

the NDVI is an indicator of plant productivity, which may influence the availability of food resources such as insects (Laube et al., 2015). If NDVI is indeed an indicator of resource availability (Laube et al., 2015), then this would support the suggestion of Guisan and Hofer (2003) that variables that describe resource availability improve SDMs for reptiles. However, we note that Arntzen (2006) did not find an effect of NDVI on the distribution of Schreiber's green lizard (*Lacerta schreiberi*).

Annual precipitation was identified as one of the most important variables in predicting the distribution of *L. strigata*; other studies on reptiles also found that

climatic variables predicted reptile distributions well (Guisan and Hofer, 2003; Arntzen, 2006; Kafash et al., 2016). Most likely, annual precipitation is important due to its effect on vegetation, which has been identified as the most important predictor for the species (i.e. NDVI). Habitat suitability increased asymptotically for the species with increasing precipitation, and suitability reached the maximum in areas that receive around 1000 mm of annual precipitation. Slope was another important variable that affected species distribution; habitats on gentle slopes were more suitable. We believe that the species prefers habitats with dense vegetation on gentle slopes over habitats on steep slopes with sparse vegetation (Anderson, 1999).

SDMs can be used to find previously unsampled habitats of reptiles (Raxworthy et al., 2003; Guisan et al., 2006). We applied SDMs to assess the plausibility of an old distribution record for a lizard species. Our models clearly revealed that the Shiraz record is situated in a region with very low predicted habitat suitability, whereas all other distribution records in northern Iran are found in areas with high predicted suitability (Figure 4). The distance between the Shiraz locality and the southernmost distribution record of the species range is about 730 km; the different climatic and conditions and vegetation cover between the two areas are obvious (Anderson, 1999; Šmíd et al., 2014). We conclude that the Shiraz record could be a result of labeling error in the past (Anderson, 1999; Rastegar-Pouyani et al., 2007), and more fieldwork would be needed around the Shiraz record to confirm the results of this study.

In the present study, we explored environmental predictors for distribution of a typical reptile in the Elburz Mountains, but there are many ecologically unknown endemic and endangered animals, such as *Darevskia defilippii* and *Darevskia schaekeli*, living in the Elburz
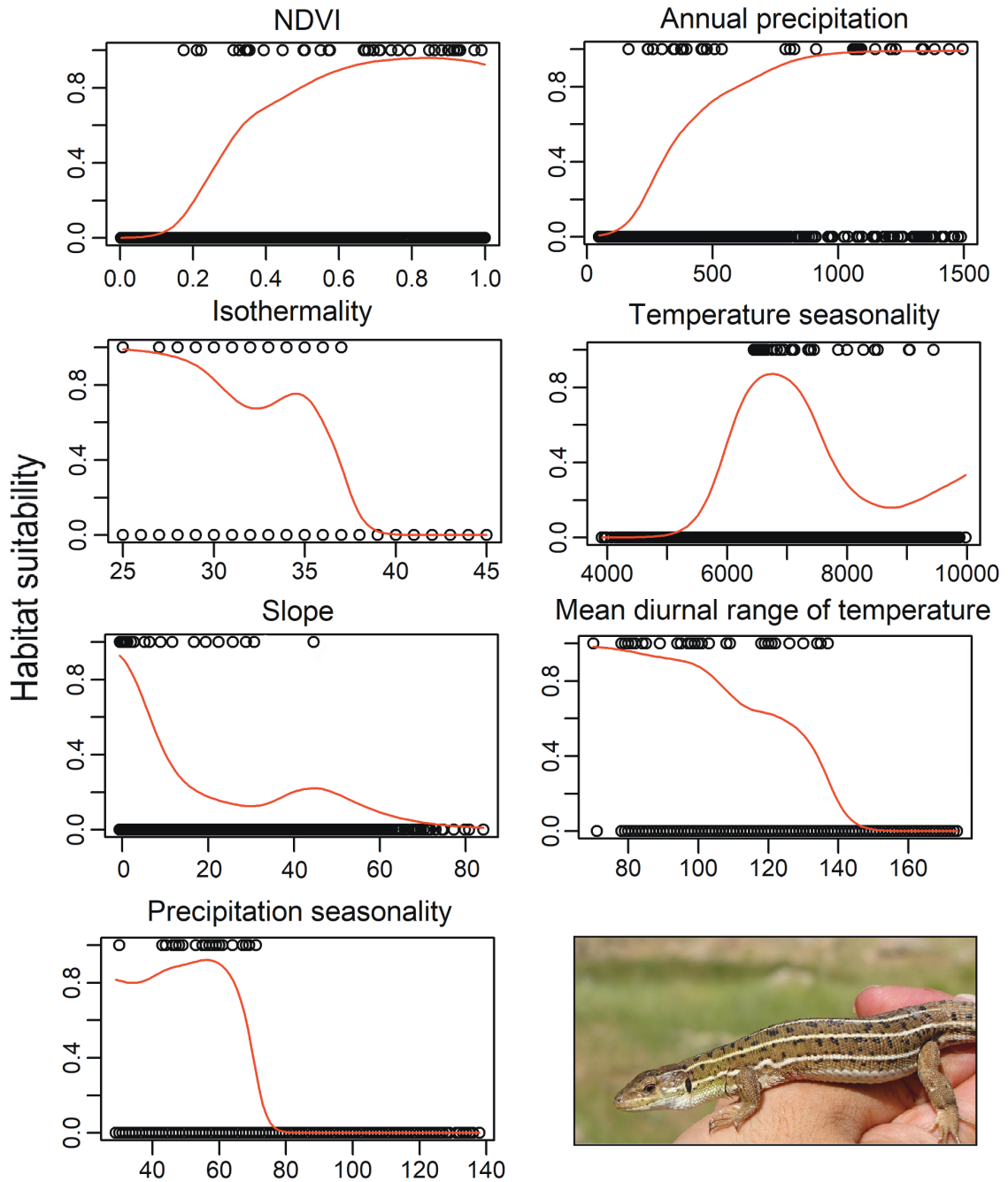
Figure 4. Response curves showing how the distribution of *Lacerta strigata* is affected by the environmental variables. Response curves were created using the GLM model. Dots are presences (at habitat suitability = 1) and absences (at habitat suitability = 0). *Lacerta strigata* was photographed in its natural habitat in the Elburz Mountains by Anooshe Kafash.

Mountains (Madjnoonian et al., 2005; Ahmadzadeh et al., 2013). We encourage ecologists and mountain scientists to study these animals' distributions and the environmental drivers of their distribution, which is a prerequisite for conservation and management of the biodiversity of the Elburz Mountains.

References

Ahmadzadeh F, Flecks M, Carretero MA, Mozaffari O, Böhme W, Harris DJ, Freitas S, Rödder D (2013). Cryptic speciation patterns in Iranian Rock Lizards uncovered by integrative taxonomy. PLoS One 8: e80563.

Akhani H, Mahdavi P, Noroozi J, Zarrinpour V (2013). Vegetation patterns of the Irano-Turanian steppe along a 3000 m altitudinal gradient in the Alborz mountains of Northern Iran. Folia Geobot 48: 229-255.

Anderson SC (1999). The Lizards of Iran. Oxford, OH, USA: Society for the Study of Amphibians and Reptiles.

Antonelli A, Kissling WD, Flantua SGA, Bermúdez MA, Mulch A, Muellner-Riehl AN, Kreft H, Linder HP, Badgley C, Fjeldså J et al. (2018). Geological and climatic influences on mountain biodiversity. Nat Geosci 11: 718-725.

Araújo MB, New M (2007). Ensemble forecasting of species distributions. Trends Ecol Evol 22: 42-47.

Arntzen JW (2006). From descriptive to predictive distribution models: a working example with Iberian amphibians and reptiles. Front Zool 3: 8.

Ashoori A, Kafash A, Varasteh Moradi H, Yousefi M, Kamyab H, Behdarvand N, Mohammadi S (2018). Habitat modeling of the Common Pheasant *Phasianus colchicus* (Galliformes: Phasianidae) in a highly modified landscape: application of species distribution models in the study of a poorly documented bird in Iran. Eur Zool J 85: 373-381.

Boyce MS, Vernier PR, Nielsen SE, Schmiegelow FKA (2002). Evaluating resource selection functions. Ecol Model 157: 281-300.

Breiman L (2001). Random forests. Mach Learn 45: 5-32.

Brown JH, Stevens GC, Kaufman DM (1996). The geographic range: size, shape, boundaries, and internal structure. Annu Rev Ecol Evol Syst 27: 597-623.

Diaz HF, Grosjean M, Graumlich L (2003). Climate variability and change in high elevation regions: past, present and future. Clim Change 59: 1-4.

Elith J, Phillips SJ, Hastie T, Dudík M, Chee YE, Yates CJ (2011). A statistical explanation of MaxEnt for ecologists. Divers Distrib 17: 43-57.

Fielding AH, Bell JF (1997). A review of methods for the assessment of prediction errors in conservation presence/absence models. Environ Conserv 24: 38-49.

Freeman EA, Moisen G (2008). PresenceAbsence: an r package for presence-absence model analysis. J Stat Softw 23: 1-31.

Fu C, Wang J, Pu Z, Zhang SL, Chen HL, Zhao B, Chen JK, Wu JH (2007). Elevational gradients of diversity for lizards and snakes in the Hengduan Mountains, China. Biodivers Conserv 16: 707-726.

Gaston KJ (2000). Global patterns in biodiversity. Nature 405: 220-227.

Gaston KJ (2003). The Structure and Dynamics of Geographic Ranges. Oxford, UK: Oxford University Press.

Graham CH, Carnaval AC, Cadena CD, Zamudio KR, Roberts TE, Parra JL, McCain CM, Bowie RCK, Moritz C, Baines SB et al. (2014). The origin and maintenance of montane diversity: integrating evolutionary and ecological processes. Ecography 37: 711-719.

Guisan A, Broennimann O, Engler R, Vust M, Yoccoz NG, Lehmann A, Zimmermann NE (2006). Using niche-based models to improve the sampling of rare species. Conserv Biol 20: 501-511.

Guisan A, Hofer U (2003). Predicting reptile distributions at the mesoscale: relation to climate and topography. J Biogeogr 30: 1233-1243.

Guisan A, Thuiller W (2005). Predicting species distribution: offering more than simple habitat models. Ecol Lett 8: 993-1009.

Guisan A, Thuiller W, Zimmermann NE (2017). Habitat Suitability and Distribution Models: With Applications in R. Cambridge, UK: Cambridge University Press.

Hairston NG (1949). The local distribution and ecology of the plethodontid salamanders of the southern Appalachians. Ecol Monograph 19: 49-73.

Hirzel AH, Le Lay G, Helfer V, Randin C, Guisan A (2006). Evaluating the ability of habitat suitability models to predict species presences. Ecol Model 199: 142-152.

Kafash A, Kaboli M, Köhler G, Yousefi M, Asadi A (2016). Ensemble distribution modeling of the Mesopotamian spiny-tailed lizard (*Saara loricata*) in Iran: an insight into the impact of climate change. Turk J Zool 40: 262-271.

Kafash A, Malakoutikhahh S, Yousefi M, Ataei F, Heidari H, Rastegar-Pouyani E (2018). The Gray Toad-headed Agama, *Phrynocephalus scutellatus*, on the Iranian Plateau: the degree of niche overlap depends on the phylogenetic distance. Zool Middle East 64: 47-54.

Karger DN, Conrad O, Bohner J (2017). Climatologies at high resolution for the earth land surface areas. Sci Data 4: 170122.

Körner C (2004). Mountain biodiversity, its causes and function. Ambio Special Report 13: 11-17.

Körner C, Jetz W, Paulsen J, Payne D, Rudmann-Maurer K, Spehn EM (2017). A global inventory of mountains for bio-geographical applications. Alpine Bot 127: 1-15.

Körner C, Spehn EM, Paulsen J (2011). A definition of mountains and their bioclimatic belts for global comparisons of biodiversity data. Alpine Bot 121: 73-78.

Laube I, Graham CH, Böhning-Gaese K (2015). Niche availability in space and time: migration in *Sylvia* warblers. J Biogeogr 42: 1896-1906.

Lomolino MV, Riddle BR, Whittaker RJ, Brown J.H (2010). Biogeography. Fourth edition. Sunderland, MA, USA: Sinauer Associates, Inc.

Mahmoudi S, Sheykhi Ilanloo S, Keyvanloo Shahrestanaki A, Valizadegan N, Yousefi M (2016). Effect of human-induced forest edges on the understory bird community in Hyrcanian forests in Iran: implication for conservation and management. Forest Ecol Manag 382: 120-128.

Madjnoonian H, Kiabi BH, Danesh M (2005). Readings in Zoogeography of Iran. Tehran, Iran: Department of Environment.

McCullagh P, Nelder JA (1989). Generalized Linear Models. London, UK: Chapman and Hall.

Moradi S, Sheykhi Ilanloo S, Kafash A, Yousefi M (2019). Identifying high-priority conservation areas for avian biodiversity using species distribution modeling. Ecol Indic 97: 159-164.

Noroozi J, Akhani H, Willner W (2010). Phytosociological and ecological study of the high alpine vegetation of Tuchal Mountains (Central Alborz, Iran). Phytocoenologia 40: 293-321.

Parmesan C (2006). Ecological and evolutionary responses to recent climate change. Annu Rev Ecol Evol Syst 37: 637-669.

Pearson RG, Raxworthy CJ, Nakamura M, Peterson AT (2007). Predicting species distributions from small numbers of occurrence records: a test case using cryptic geckos in Madagascar. J Biogeogr 34: 102-117.

Peterson AT, Soberón J, Pearson RG, Anderson RP, Martínez-Meyer E, Nakamura M, Araújo MB (2011). Ecological Niches and Geographic Distributions. Princeton, NJ, USA: Princeton University Press.

Phillips SJ, Anderson R, Schapire RE (2006). Maximum entropy modeling of species geographic distributions. Ecol Model 190: 231-259.

Rastegar-Pouyani N, Johari M, Rastegar-Pouyani E (2007). Field Guide to the Reptiles of Iran. 2nd ed. Kermanshah, Iran: Razi University Publishing.

Ravanbakhsh H, Moshki A (2016). The influence of environmental variables on distribution patterns of Irano-Turanian forests in Alborz Mountains, Iran. J Mt Sci 13: 1375.

Raxworthy CJ, Martinez-Meyer E, Horning N, Nussbaum RA, Schneider GE, Ortega-Huerta MA, Peterson AT (2003). Predicting distributions of known and unknown reptile species in Madagascar. Nature 426: 837-841.

Ridgeway G (1999). The state of boosting. Comput Sci Stat 31: 172-181.

Royle JA, Nichols JD, Kéry M (2005). Modelling occurrence and abundance of species when detection is imperfect. Oikos 110: 353-359.

Sindaco R, Jeremčenko VK (2008). The Reptiles of the Western Palearctic. Latina, Italy: Edizioni Belvedere.

Spehn EM, Rudmann-Maurer K, Körner C (2011). Mountain biodiversity. Plant Ecol Divers 4: 301-302.

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

Swets JA (1988). Measuring the accuracy of diagnostic systems. Science 240: 1285-1293.

Warren DL, Glor RE, Turelli M (2010). ENMTools: a toolbox for comparative studies of environmental niche models. Ecography 33: 607-611.

Werner P, Lötters S, Schmidt BR, Engler JO, Rödder D (2013). The role of climate for the range limits of parapatric European land salamanders. Ecography 36: 1127-1137.

Williams JN, Seo C, Thorne J, Nelson JK, Erwin S, O'Brien J, Schwartze MW (2009). Using species distribution models to predict new occurrences for rare plants. Divers Distrib 15: 565-576.

Yackulic CB, Chandler R, Zipkin EF, Royle JA, Nichols JD, Grant EHC, Veran S (2013). Presence-only modelling using MAXENT: when can we trust the inferences? Methods Ecol Evol 4: 236-243.

Yousefi M, Ahmadi M, Nourani E, Behrooz R, Rajabizadeh M, Geniez P, Kaboli M (2015). Upward altitudinal shifts in habitat suitability of mountain vipers since the last glacial maximum. PLoS One 10: e0138087.

Yousefi M, Ataei F, Kafash A, Rezaei H (2018a). The lizard fauna of Alborz Province: distribution and conservation. Exp Animal Biol 6: 117-126.

Yousefi M, Kafash A, Malakoutikhah S, Ashoori A, Khani A, Mehdizade Y, Ataei F, Sheykhi Ilanloo S, Rezaei HR, Silva JP (2018b). Distance to international border shapes the distribution pattern of the growing Little Bustard *Tetrax tetrax* winter population in Northern Iran. Bird Conserv Int 28: 499-508.

Zar JH. Biostatistical Analysis. 4th ed. Upper Saddle River, NJ, USA: Prentice Hall.