International Journal of Zoology Studies
ISSN: 2455-7269; Impact Factor: RJIF 5.14
Received: 13-09-2019; Accepted: 15-10-2019
www.zoologyjournals.com
Volume 4; Issue 6; November 2019; Page No. 64-69

The reduced model of distribution and habitat suitability for endemic the vulnerable Lorestan Newt, *Neurergus kaiseri* Schmidt, 1952 (Urodela: Salamandridae)

Rasoul Karamiani[1*], Nasrullah Rastegar-Pouyani[2], Sharyar Mewludi[3]
[1] Environmental Research Center, Department of Biology, Faculty of Science, Razi University, Kermanshah, Iran
[2-3] Department of Biology, Faculty of Science, Razi University, Kermanshah, Iran

Abstract
Study of the climate variability in the past and present, and correlating those with changes in the distribution range of critically endangered and vulnerable species has attracted considerable research interest. The genus *Neurergus* consists of five recognized species, of which *N. crocatus*, *N. derjugini*, *N. kaiseri*, and *N. microspilotus* are documented from Iran. In the present study, we modeled with MaxEnt the potential distribution areas and determined the suitable habitats in the past (mid-Holocene [MH], and the Last Interglacial [LIG]) as well as the current distribution of the vulnerable Lorestan Mountain newt, *N. kaiseri*. Models of the species indicated good fit by the average high area under the curve (AUC) values (0.998 ± 0.001). The annual temperature range, topography, slope as well as annual precipitation made important contributions to current distribution *N. kaiseri*. We conclude that these variables form a natural barrier for species dispersal. The MH and the LGM models indicated a larger suitable area than the current distribution. The precipitation of coldest, driest and warmest quarter of the year as well as annual temperature range made important contributions to the mid-Holocene [MH], and the Last Interglacial [LIG]) distribution in *N. kaiseri*.

Keywords: *Neurergus kaiseri*, climate condition, suitable habitat, potential distribution

1. Introduction

Climate change plays an important role on the species distributions of biota. The strategic response of species to persistent climate changes may be consistantly *in situ* at their tolerance limits, or changing ranges to regions where climate is within the species tolerance limits, and finally extinction [1, 2]. During the Last Interglacial period (LIG: 150,000–120,000 years), temperature gradient increased in polar regions toward lower latitudes and caused sea-level to rise and reduction of ice sheets [3]. The glaciations were separated by interglacial periods [4], the climate warmed and forests returned to areas that once supported tundra vegetation [2], and climate of the last interglacial had a relatively stable warm period [5]. During the mid-Holocene (6 k), summer temperatures were warmer than at present in the high-latitudes of Northern Hemisphere [6], but northern Africa, Arabia, and southern Asia underwent conditions much wetter than at present, these conditions resulting in both African and Asian monsoons [7, 8].

Analyzing species distribution models can help to understand theoretical research [9] on ecological and evolutionary processes [1], also in conservation planning [10]. Species distribution models can be used to investigate the effect of climate changes on distributions and abundances of species [11], to determine biodiversity [12], and biogeographical patterns [13], and predicting potential distribution [14] and predicting potential distribution and habitat suitability for species [16]. MaxEnt is a general approach for characterizing probability distributions from small sample sizes [17, 18, 19]. MaxEnt estimates the probability distribution of maximum entropy (i.e. closest to uniform) based on environmental variables spread over the survey area [20, 21].

Amphibian populations have declined during past decades. In 1989, a small group of scientists, attending the First World Congress of Herpetology in Canterbury, England began voicing their concerns about the disappearing of frogs in the many regions of the world, which they had seen previously [22]. There are two main leading hypotheses thought to underlie amphibian declines: Class I including alien species, over-exploitation, and land use/land cover change; and Class II including global change (increased ultraviolet radiation and global warming), increased use of pesticides and other toxic chemicals as well as infectious diseases such as chytridiomycosis [23]. Climate change has played an important role in amphibian decline especially during the few past decades [24]; Amphibians have permeable and exposed skin, shell-less eggs, complex life histories (e.g. larvae of anurans and urodels need aquatic habitats and adults require both aquatic and terrestrial habitats) and are ectothermic which render them vulnerable to both aquatic and terrestrial changes in temperature and precipitation; Important aspects of amphibian biology such as growth, development, foraging and timing of hibernation and breeding are likely to be affected by climate [25]. Moreover, climate change can alter amphibian habitats including vegetation, soil, and hydrology. Climate change can influence food availability and overall predator-prey and competitive interactions which can alter community structure [24]; also climate change can alter pathogen-host dynamics and greatly influence how diseases are manifested [26].

The mountain newts of the genus *Neurergus* Cope, 1862, are in the family Salamandridae. This genus comprises four species geographically distributed in Iran, Iraq, and Turkey [27]. Species in this genus are *N. crocatus* Cope, 1862 in northwestern Iran, north and northeastern Iraq, and southeastern Turkey; *N. derjugini* Nesterov, 1916 (formerly *N. microspilotus*) in the central and northern parts of the Zagros Mountains alongside the common borders of Iran and Iraq; *N. kaiseri* Schmidt, 1952 which is endemic to Iran and distributed in southwestern areas of Iran in Lorestan and Khuzestan Provinces; and finally *N. strauchii* Steindachner, 1887 that is also known as Anatolian newt because it is endemic to Turkey and is the only species in *Neurergus* with three recognized subspecies: *N. s. strauchii*, the nominal subspecies distributed in the western areas of the Lake Van; *N. s. barani* in Kubbe Mountains in Malatya Province; and recently discovered and described subspecies *N. s. munzurensis* in the vicinity of Tunceli in the northern areas of Murat River [28, 29].

The Lorestan Mountain newt, *Neurergus kaiseri* is the smallest species of *Neurergus*, considering its morphometric characteristics and special coloration pattern which make it easily distinguishable from other species of *Neurergus* [30]. It is also the only species of *Neurergus* that reproduces in stagnant water bodies, whereas other species mainly breed in mountainous well-oxygenated rivers and streams [31]. For a long time this species was reported only from its type locality around Shahbazan region in Lorestan Province, but during recent years numerous new habitats for *N. kaiseri* have been reported in Khuzestan Province [32, 33, 34]. Due to this range extension and increased number of individuals, the conservation status of *N. kaiseri* according to the IUCN criteria has been changed from Critically Endangered [35] to Vulnerable [36].

The general aim of this work is, (1) to identify potential areas of distribution of the Lorestan Mountain Newt, *Neurergus kaiseri*, during three periods of the past: Last Interglacial (LIG: ∼120,000–140,000 years BP) to mid-Holocene (MH: ∼6,000 years BP), (2) to describe current (~1950-2000s) distribution, suitable habitat, and understand the biogeographical patterns of this Vulnerable newt.

2. Materials and methods

2.1 Study area and records

Species occurrence records are from our fieldwork in Lorestan and Khuzestan Provinces (Fig. 1), and previously published records (60 records).

2.2 Data set and Analysis

We implemented Maximum Entropy modeling (MaxEnt, 3.3.3e http://www.cs.princeton.edu/~schapire/MaxEnt) of species geographic distributions with default parameters of the data to test samples. We examined 19 bioclimatic variables and two topographical variables with grids approximately 1 km^2 precision (30 s χ 30 s) for contemporary (~1950-2000), and 10 km^2 precision (5 min χ 5 min), also examined 19 bioclimatic variables in the past (LIG, and MH) in the related part of the world (Asia) [37, 38, 39]; (see the Appendix). To identify the correlation ratios between variables and presence records, Openmodeller (V. 1.0.7) [40], was used. Then we used SPPS IBM (version 19) for Pearson´s correlation coefficient [41]. We selected variables with a Pearson correlation lower than 0.75 to choose the variables that are ecologically important for species separation according to our observations and to describe habitat [42]. We conducted MaxEnt software with 15 replicates of the analysis that yield the best model for the studied species. MaxEnt provides state distribution models by the receiver operating characteristic (ROC) plots, ROC curves plot true-positive rate against false-positive rate [21, 43]. A value of the area under the curve (AUC) of 0.5–0.7 is taken to indicate that the result is a stochastic prediction [44, 45] and values of 0.7–0.9 suggest useful models, the values more than 0.9 indicate high accuracy [46]. We used DIVA-GIS 7.3.0.1 software for the mean predicted map and a logistic output of presence records with suitability ranging that show from zero (unsuitable habitat) to one (the best suitable habitat) [47].

3. Results & Discussion

The final models in the present study showed a good match and closely fitted the presence of the endangered Kaiser’s mountain newt, *Neurergus kaiseri* recorded in the study areas. Models obtained from the MaxEnt were run in 15 replicates for the five periods that suggested by high AUC values (Fig. 2). The average test AUC for the replicate runs each period as follows: LIG (AUC = 0.998 ± 0.001); MH (AUC = 0.998 ± 0.001); present (AUC = 0.998 ± 0.001. The AUC values for all models were very good. Among contribution bioclimatic layers, Bio3, BIO7, Bio12, Bio13, BIO17, BIO18, BIO19, and slope most highly for model LIG, MH, and present periods. Relative contribution performance of each variable at the periods is presented in Table 1.

A survey of past and present distribution patterns can play a significant role in understanding changing suitability of habitats and species conservation status. One of the most effective protection steps in Lorestan newt is to evaluate the suitability of potential areas [48]. Our results verify the known distribution of the Lorestan newt, based on current climatic conditions. The *Neurergus kaiseri* distribution model is able to show a set of topographically different areas that explain a reliable model of its actual and potential distribution. As well identifies locations inside adjacent provinces lacking records of occurrence for *N. kaiseri* with a high probability of occurrence. In the present study, after examining the Pearson correlation between all variables, eight variables were used for modeling. Precipitation of warmest quarter of the year variable parameter (Bio18) with 63.5%, and precipitation of coldest quarter of the year variable (Bio19) parameter with 31.1% highly influence on LIG distribution model for *N. kaiseri* so that precipitation during fall and winter contributed to more than 94.6% of the model prediction, which may be explained by snow accumulation in the highlands that supports water discharge and longer hydroperiod in streams [49]. Combination of precipitation parameters with 96.8% (Driest [31.8], warmest [29.5], and coldest [35.5]) demonstrate high importance in MH distribution model for *N. kaiseri*. The agglomeration of snow may also prevent late spring water stress, especially in lower elevations where a warmer climate could exacerbate a reduction in hydroperiod [35]. Of combination bioclimatic variables (temperatures= 48.8%, precipitation= 26.3, and slope= 24.9) demonstrate high importance in current distribution model for *N. kaiseri*. The best annual mean temperature for suitability of habitat is 15-20 °C [48]. Temperature seasonality and temperature annual range, signify variation in summer temperature [49], and are most likely to contribute to warmer spring temperatures (2017 Sharifi *et al*. 2017). The best annual precipitation for suitability of habitat is 400-450 mm [48], the warmer temperatures are associated with shorter hydroperiods in the

breeding streams, and during very warm summer the streams may dry up completely [35]. The Lorestan newt *N. kaiseri* is distributed in Lorestan and Khuzestan Provinces, with an elevational range of 385-1500 m asl (above sea level) in more fragmented geographical localities.
From the last simulation models (120 and six thousand years ago) it is clear that in those times wider distribution ranges and areas that are now part of unsuitable habitat, at that time, due to better climatic and environmental conditions influenced by precipitation during the fall, winter and spring, would have been favorable habitat. Finally, studies of the effective bioclimatic variables in a species' distribution over time provide heuristic methods for the management of important habitat by conservation assessments of current habitats and identification of habitats suitability.

4. Tables and Figures

Table 1: Relative contribution performance (in percentages) of each bioclimatic layer at the habitat suitability prediction model in the periods

Variable	Description of variables	LIG	MH	Percent
Bio3	Isothermality [(BIO2 / BIO7) × 100]	-	-	19.3
Bio7	Temperature annual range (BIO5 - BIO6)	3.6	2.3	29.5
Bio12	Annual precipitation	-	-	20.5
Bio13	Precipitation of the wettest month	-	-	5.8
Bio17	Precipitation of the driest quarter of the year	-	31.8	-
Bio18	Precipitation of the warmest quarter of the year	63.5	29.5	-
Bio19	Precipitation of the coldest quarter of the year	31.1	35.5	-
Slope	Slope	-	-	24.9

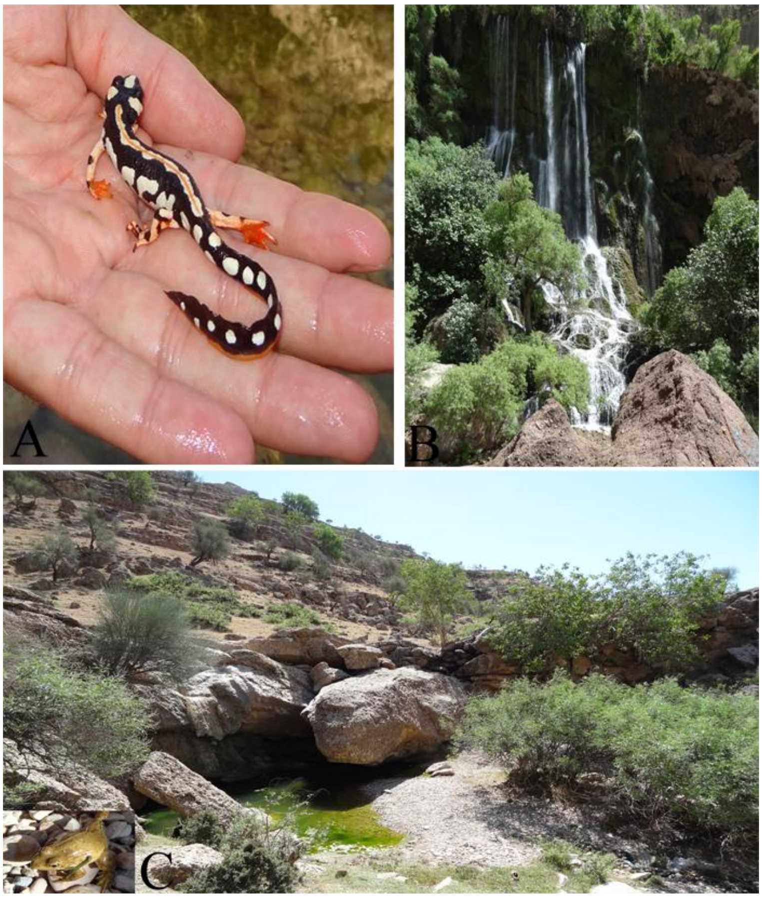

Fig 1: Alive adult specimen of the Lorestan newt *Neurergus kaiseri* (A), Habitats of the Lorestan newt *Neurergus kaiseri* Shevi waterfall (B), and Dej-e Mohammad Ali khan (C) in Lorestan and Khuzestan Provinces southwestern Iran.

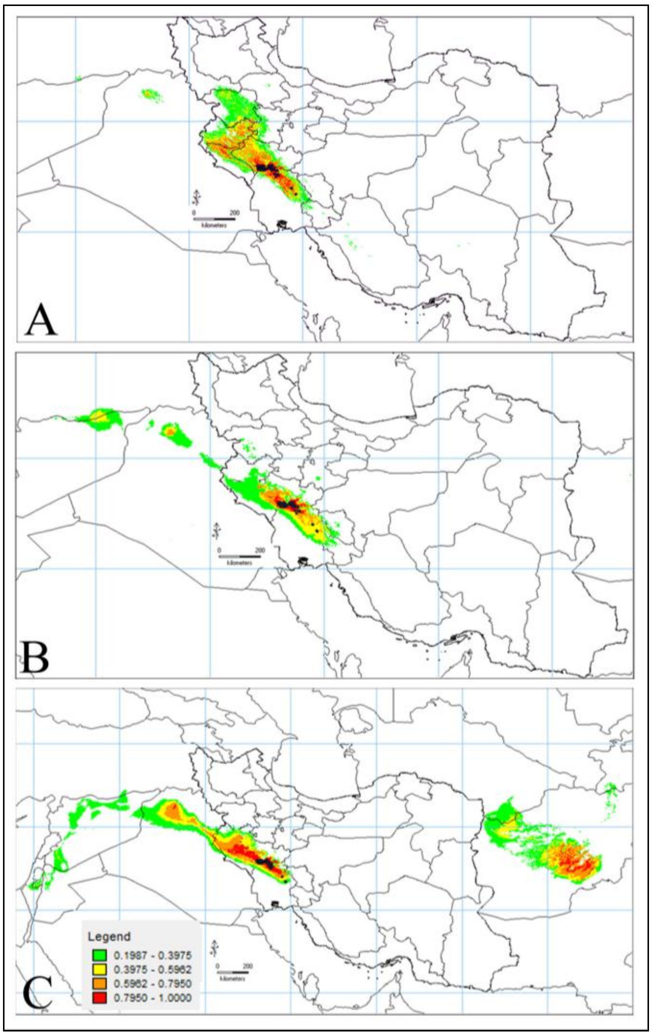

Fig 2: Distribution map of the Lorestan newt *Neurergus kaiseri* in its habitats and much of their potential distribution pattern in the region during: A) currently (1950-2000), B) the mid-Holocene (6 ka), C) the last interglacial (120 ka).

5. Conclusions

According to results obtained based on this study, the Lorestan newt, *N. kaiseri* is a good indicator for assessing the effects of climatic changes on distribution range of the species over time. In summary, during recent years, changes have occurred in the IUCN conservation status of *N. kaiseri*, in which was endangered (EN) in 2004, critically endangered (CR) in 2006- 2009, and vulnerable (VU) in 2016. The two reasons for the changes are the conservation status of the Lorestan newt, *N. kaiseri*: 1) range expansion from 10-200 km^2 to 8000 km^2; 2) increasing in the number of observed individuals from less than 1000 [33, 34] to 9000 adults. Considering the distribution models of the Lorestan newt and its affinity with precipitation and temperature, also global warming due to decreasing suitability of habitat, we have to conserve and protect the remaining natural habitats of this newt and for a better estimation of the populations capture-recapture techniques should be employed.

6. Acknowledgments

We thank Hussein Farasat for assisting us with field work in Lorestan and Khuzestan Provinces.

7. References

1. Davis MB, Shaw RG, Etterson JR. Evolutionary responses to changing climate. Ecology. 2005; 86(7):1704-1714.
2. Sillero N, Carretero MA. Modelling the past and future distribution of contracting species. The Iberian lizard *Podarcis carbonelli* (Squamata: Lacertidae) as a case study. Zoologischer Anzeiger-A Journal of Comparative Zoology. 2013; 252(3):289-298.
3. Nikolova I, Yin Q, Berger A, Singh UK, Karami M. The last interglacial (Eemian) climate simulated by LOVECLIM and CCSM3. Climate of the Past. 2013; 9(4):1789-1806.
4. Ray LL. The Great Ice Age. US Department of the Interior, US Geological Survey, 1992.
5. Pickarski N. Vegetation and climate history during the last glacial-interglacial cycle at Lake Van, eastern Anatolia. Thesis, 2014. Universitäts-und Landesbibliothek Bonn.
6. Kerwin MW, Overpeck JT, Webb RS, DeVernal A, Rind DH, Healy RJ. *et al*. The role of oceanic forcing in mid-Holocene northern hemisphere climatic change. Paleoceanography. 1999; 14(2):200-10.
7. Texier D, De Noblet N, Braconnot P. Sensitivity of the African and Asian monsoons to mid-Holocene insolation and data-inferred surface changes. Journal of Climate. 2000; 13(1):164-81.
8. Wanner H, Beer J, Bütikofer J, Crowley TJ, Cubasch U, Flückiger J, *et al*. Mid-to Late Holocene climate change: an overview. Quaternary Science Reviews. 2008; 27(19-20):1791-1828.
9. Phillips SJ, Dudík M, Elith J, Graham CH, Lehmann A, Leathwick J, *et al*. Sample selection bias and presence-only distribution models: implications for background and pseudo-absence data. Ecological Applications. 2009; 19(1):181-197.
10. Graham CH, Ferrier S, Huettman F, Moritz C, Peterson AT. New developments in museum-based informatics and applications in biodiversity analysis. Trends in ecology & evolution. 2004; 19(9):497-503.
11. Thomas CD, Cameron A, Green RE, Bakkenes M, Beaumont LJ, Collingham YC, *et al*. Extinction risk from climate change. 2004; 427(6970):145-148.
12. Kleidon A, Mooney HA. A global distribution of biodiversity inferred from climatic constraints: results from a process-based modelling study. Global Change Biology. 2000; 6(5):507-523.
13. Yousefkhani SSH, Ficetola GF, Rastegar-Pouyani N, Ananjeva NB, Rastegar-Pouyani E, Masroor R. *et al*. Environmental suitability and distribution of the Caucasian Rock Agama, *Paralaudakia caucasia* (Sauria: Agamidae) in western and central Asia. Asian Herpetological Research. 2013; 4(3):207-213.
14. Ananjeva NB, Golynsky EA, Yousefkhani SSH, Masroor R. Distribution and environmental suitability of the smallscaled rock agama, *Paralaudakia microlepis* (Sauria: Agamidae) in the Iranian Plateau. Asian Herpetology Research. 2014; 5(3):161-167.
15. Ramirez-Villegas J, Cuesta F, Devenish C, Peralvo M, Jarvis A, Arnillas CA. *et al*. Using species distributions models for designing conservation strategies of Tropical Andean biodiversity under climate change.

Journal for Nature Conservation. 2014; 22(5):391-404.
16. Karamiani R, Rastegar-Pouyani N, Rastegar-Pouyani E. Modeling the past and current distribution and habitat suitability for *Ablepharus grayanus* and *A. pannonicus* (Sauria: Scincidae) Asian Herpetological Research. 2018; 9(1):56-64.
17. Elith J, Graham CH, Anderson RP, Dudík M, Ferrier S, Guisan A, *et al*. Novel methods improve prediction of species' distributions from occurrence data. Ecography. 2006; 29(2):129-51.
18. Hernandez PA, Graham CH, Master LL, Albert DL. The effect of sample size and species characteristics on performance of different species distribution modeling methods. Ecography. 2006; 29(5):773-785.
19. Phillips SJ, Anderson RP, Schapire RE. Maximum entropy modeling of species geographic distributions. Ecological Modelling. 2006; 190(3-4):231-259.
20. Pearson R, Raxworthy CJ, Nakamura M, Townsend Peterson A. Predicting species distributions from small numbers of occurrence records: a test case using cryptic geckos in Madagascar. Journal of biogeography. 2007; 34(1):102-117.
21. Kaliontzopoulou A, Brito J, Carretero M, Larbes S, Harris D. 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. 2008; 86(9):992-1001.
22. Gardner T. Declining amphibian populations: a global phenomenon in conservation biology. Animal Biodiversity and Conservation. 2001; 24(2):25-44.
23. Collins JP, Storfer A. Global amphibian declines: sorting the hypotheses. Diversity and distributions. 2003; 9(2):89-98.
24. Whittaker K, Koo MS, Wake DB, Vredenburg VT. Global declines of amphibians, 2013, 691-699.
25. Li Y, Cohen JM, Rohr JR. Review and synthesis of the effects of climate change on amphibians. Integrative Zoology. 2013; 8(2):145-161.
26. Blaustein AR, Walls SC, Bancroft BA, Lawler JJ, Searle CL, Gervasi SS. *et al*. Direct and indirect effects of climate change on amphibian populations. Diversity. 2010; 2(2): 281-313.
27. Barabanov AV, Litvinchuk SN. A new record of the Kurdistan newt (*Neurergus derjugini*) in Iran and potential distribution modeling for the species. Russian Journal Herpetology. 2015; 22(2):107-115.
28. Schneider C, Schneider W. The Kurdistan newts of the Genus *Neurergus* in Iraq (Caudata: Salamandridae). Herpetozoa. 2011; 23(3-4):3-20.
29. Hendrix R, Fleck J, Schneider W, Schneider C, Geller D, Avci A. *et al*. First comprehensive insights into nuclear and mitochondrial DNA based population structure of Near East mountain brook newts (Salamandridae: genus *Neurergus*) suggest the resurrection of *Neurergus derjugini*. Amphibia–Reptilia. 2014; 35(2):173-187.
30. Sparreboom M, Steinfartz S, Schultschik G. Courtship behaviour of *Neurergus* (Caudata: Salamandridae). Amphibia Reptilia. 2000; 21(1):1-12.
31. Steinfartz S, Hwang UW, Tautz D, Öz M, Veith M. Molecular phylogeny of the salamandrid genus *Neurergus*: evidence for an intrageneric switch of reproductive biology. Amphibia-Reptilia. 2002; 23(4):419-431.
32. Sharifi M, Rastegar-Pouyani N, Akmali V, Narengi SA. On distribution and conservation status of *Neurergus kaiseri* (Caudata: Salamandridae). Russian Journal of Herpetology. 2008; 15(3):169-172.
33. Sharifi M, Farasat H, Barani-Beira H, Vaissi S, Foroozanfar E. Notes on the distribution and abundance of the endangered Kaiser's mountain newt, *Neurergus kaiseri*, in southwestern Iran. Herpetological Conservation and Biology. 2013; 8(3):724-731.
34. Mobaraki A, Amiri M, Alvandi R, Tehrani ME, Kia HZ, Khoshnamvand A. *et al*. A conservation reassessment of the Critically Endangered, Lorestan newt *Neurergus kaiseri* (Schmidt 1952) in Iran. Amphibian and Reptile Conservation. 2013; 9:16-25.
35. Sharifi M, Shafiei Bafti S, Papenfuss T, Anderson S, Kuzmin S, Rastegar-Pouyani N. *Neurergus microspilotus*. International Union for Conservation of Nature Red List of Threatened Species, 2009.
36. Sharifi M, Karami P, Akmali V, Afroosheh M, Vaissi S. Modeling Geographic Distribution for the Endangered Yellow Spotted Mountain Newt, *Neurergus microspilotus* (Amphibia: Salamandridae) in Iran and Iraq Herpetological Conservation and Biology. 2017; 12(2):488-497.
37. Hijmans RJ, Cameron SE, Parra JL, Jones PG, Jarvis A. Very high resolution interpolated climate surfaces for global land areas. International journal of climatology. 2005; 25(15):1965-1978.
38. Otto-Bliesner BL, Marshall SJ, Overpeck JT, Miller GH, Hu A. Simulating Arctic climate warmth and icefield retreat in the last inter glaciation. Science. 2006; 311(5768):1751-1753.
39. http:/www.worldclim.org. 23 July, 2019.
40. de Souza Muñoz ME, De Giovanni R, de Siqueira MF, Sutton T, Brewer P, Pereira RS. *et al*. open Modeller: a generic approach to species' potential distribution modelling. GeoInformatica. 2011; 15(1):111-135.
41. Elith J, Leathwick JR. Species distribution models: ecological explanation and prediction across space and time. Annual Review of Ecology. Evolution and Systematics. 2009; 40:677-697.
42. Yousefkhani SSH, Tehrani SJ, Moodi B, Gül S. Distribution patterns and habitat suitability for three species of the genus *Hyla* Laurenti, 1768 in the Western Palearctic. Turkish Journal of Zoology. 2016; 40(2):257-261.
43. Phillips SJ, Dudík M, Schapire RE. A maximum entropy approach to species distribution modeling. In Proceedings of the twenty-first international conference on Machine learning, 2004, (p. 83). ACM.
44. Raes N, Ter Steege H. A null-model for significance testing of presence-only species distribution models. Ecography. 2007; 30(5):727-736.
45. Gallien L, Douzet R, Pratte S, Zimmermann NE, Thuiller W. Invasive species distribution models–how violating the equilibrium assumption can create new insights. Global Ecology and Biogeography. 2012; 21(11):1126-1136.
46. Manel S, Williams HC, Ormerod SJ. Evaluating presence–absence models in ecology: the need to account for prevalence. Journal of applied Ecology. 2001; 38(5):921-931.
47. Hijmans R, Cruz M, Rojas E, Guarino L. DIVA-GIS,

version 1.4. A geographic information system for the management and analysis of genetic resources data. Plant Genetic Resources Newsletter. 2001; 127:15-19

48. Zangene MT, Fakheran S, Poormanafi S, Senn J. Assessment of the conservation status and habitat suitability of critically endangered Lorestan newt (*Neurergus kaiseri*) in Lorestan and Khuzestan Provinces. Iranian Journal of Applied Ecology. 2016; 5(17):11-24.
49. Farasat H, Akmali V, Sharifi M. Population genetic structure of the endangered kaiser's mountain newt, *Neurergus kaiseri* (Amphibia: Salamandridae). PloS one. 2016; 11(2):e0149596.