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Modeling Habitat Suitability of the Red-backed Shrike (*Lanius Collurio*) in the Irano-Anatolian Biodiversity Hotspot

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ABSTRACT

Identifying suitable habitats of species is essential knowledge to conserve them successfully. Human activities cause the reduction of population size and habitat suitability of many species. Red-backed Shrike is widespread in western Palearctic. However, the population of this specie has declined in its geographical range due to the loss of suitable habitats. Therefore, it is necessary to identify its suitable habitats and factors affecting species habitat suitability and to protect its reduction population size. The aim of the present study was to identify the suitable habitat of the Red-backed Shrike and determine the most important predictors of its suitable habitat in Irano-Anatolian biodiversity hotspot. To achieve this goal, species presence points were first collected and seven environmental variables related to climate, topography and anthropogenic activities, were used to construct the species habitat suitable model. Models were built using five distribution modeling methods: Maxent, GAP, GLM, RF and GBM in sdm package. Then the models were ensemble from 5 different models and the final model was constructed. The results of this study showed that the most suitable habitats of this species are in the western and northern parts of the area of study. The mean annual temperature with 41% contribution was the most important variable in constructing the habitat suitability model for this specie. In addition, climate variables with 75% contribution were identified as the most important habitat suitability factor for this specie. Also in relation to conservation of the Red-backed Shrike species in the Irano-Anatolian region, it can be stated that the extent of distribution and presence of this specie has been extended to the northern latitudes due to climate change. As a result, the temperature and climate factor should be given special attention in the management of bird habitats in this area.

1. Introduction

Climate change and land use changes are major drivers of biodiversity changes^[1, 2, 3]. As widespread changes in habitats causes biodiversity and ecological function decreases^[4, 5] and climate change have major effects on

biomass structure^[3, 6, 7]. Therefore, given the importance of these two factors and the results of most studies, habitat degradation is now considered as a major threat to species and ecosystems^[8]. In the meantime, Semi-open habitats and grasslands are among the most frequently transformed habitats that have lost their natural cover^[9]. Birds inhab-

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iting these habitats are endangered species of the world that have lost their habitats due to different activities^[10, 11]. Therefore, management and conservation programs should be devised to prevent the destruction and degradation of these habitats^[12].

Lack of information on species distribution and abundance is currently an important challenge in identifying critical habitats for species conservation^[13, 14]. Species distribution models (SDMs) are the most widely used tools^[15, 16, 17], in identifying species suitable habitats^[18, 19, 20, 21], environmental determinates of species distribution^[22, 23, 24], prioritizing areas for biodiversity conservation^[25, 26] and predicting the impacts of climate change on species distribution^[27, 28].

Red-backed Shrike is a widespread bird species in western Palearctic. However, the population of this specie has declined in its geographical range due to the loss of suitable habitats^[29, 30]. Red-backed Shrike is one of the species that has recently been declining as a result of human activities, particularly the shift in agricultural activities across Europe, and has been largely eliminated from large areas^[31]. In addition, the status of overwintering habitats in Africa or migratory stops is influenced by the specie population status^[32, 33]. Currently, Red-backed Shrike are also a conservation priority due to their adverse demographic trends in Europe^[30, 34]. Red-backed Shrike requires open fields with thin meadows or grasslands and grazing lands, as well as shrubs or small trees for hedging and nesting which located in areas that has not directly used for purely agricultural purposes or grazing lands that is not found under heavy grazing^[35]. The aim of the present study was to identify the suitable habitat of the Red-backed Shrike, and determine the most important environmental predictors of its suitable habitats across in the Irano-Anatolian hotspot.

2. Methodology

2.1 Study Area

Irano-Anatolian hotspot covered an area of 899,773 km², which remains 134,966 km² of vegetation cover. The Irano-Anatolian hotspot covers much of central and eastern part of Turkey, a small part of southern Georgia and part of Azerbaijan and Armenia, northeast of Iraq, from northwestern Iran, Zagros Mountains area to the GNU Biosphere Reserve, Alborz Mountains area to the Kopet dag Mountains in Turkmenistan (Figure 1). This hotspot has 2,500 endemic plant species, 10 mammal species, 12 reptile species, 30 fish species and 2 endemic amphibian species. The total number of plant species of area is 6000 species, mammals 140 species, birds 362 species, reptiles

116 species, amphibians 18 species and fishes 90 species. Population density of this region is 58 people per km² and its protected area is 56.193 thousand km². The lowest point of this area is the Kopet Dag hills and west of the Zagros Mountains region with a height of 300 meters and the highest point of this area is Ararat volcano in Turkey and Damavand in Alborz with 5165 and 5671 meters respectively. The Anatolian Plateau extends to Armenia and western Iran region and its height varies between the ranges of 800 to 2,000 meters. Climatically, this area comes with hot summers and very cold winters. Its annual rainfall varies from 100 to 1000 mm^[36].

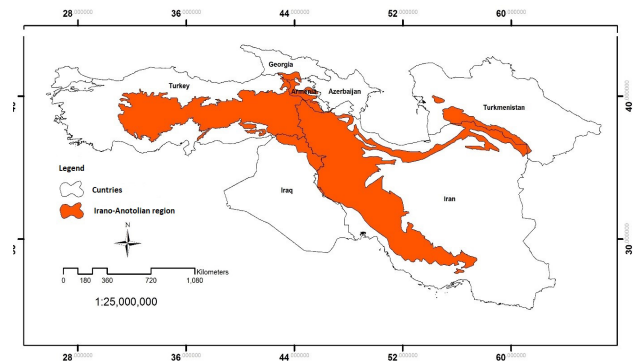


Figure 1. Geographical Location of the Irano-Anatolian Biodiversity Hot Zone and Countries Covered by this area

2.2 Spatial Data

The species distribution records were collected from Global Biodiversity Information Facility (<https://www.gbif.org/>) and eBird (<https://ebird.org>) then we mapped the distribution records in ArcGIS 10.5. By checking the produced map, we identified areas without distribution records. Subsequently, field surveys were conducted during 2017-2018 collect the species occurrence records. In addition, birdwatchers were interviewed to collect presence data.

2.3 Environmental Data

We used climatic, topographic, anthropogenic as well as the Normalized Difference Vegetation Index (NDVI) (Table 1), to model the species distribution. Climatic variables were downloaded from Worldclim database^[37]. This database contains 19 climate variables for the Earth, derived from interpolation of meteorological data from 1950 to 2000. In this study, the elevation layer is also obtained from United States Geological Survey (USGS) database and the slop layer constructed in ArcGIS 10.5. Since there is a high correlation between environmental variables, first the correlation of the variables in the study area was

investigated and then the variables with high correlation were eliminated and with the remaining variables modeling was performed. ENM Tools ^[38] was used to test the correlation between climate variables.

Table 1. Environmental variables used in habitat suitability modeling.

Variable	Variable discretion	Source
NDVI	NDVI	[39]
Topography	Slope	U.S.G.S
Anthropogenic	Human footprint	[40]
Climate	Annual Mean Temperature, Temperature Annual Range, Annual Precipitation, Precipitation Seasonality	[41]

2.4 Modeling

In recent years, species distribution modeling (SDM) has been widely used to estimate the species ecological needs as well as identify the spatial distribution occupied by species in landscapes scale ^[42, 43], but one of the challenges of using SDM is the increasing number of quantitative models that make it difficult to select the best modeling approach ^[44]. In addition, focusing on a study on only one model increases the likelihood of achieving inaccurate results ^[45]. Therefore, Araujo and New, (2007) ^[44] showed that one possible solution is to use an ensemble approach. This model is more efficient among modeling algorithms and can be used as multiple simulations in a range of elementary conditions (input data), model types, parameters (coefficients) or boundary conditions (New predictions) ^[44]. Therefore, in the present study, habitat suitability modeling of Red-backed Shrike in sdm package ^[46] and in R version 3.3.2 software environment was performed by 5 different species distribution models including Maximum entropy model (MaxEnt), Generalized Additive Model (GAM), General Linear Model (GLM), Random Forest (RF) and Generalized Boosted Model (GBM), Finally, ensemble model approach was used to reduce the uncertainty and obtain more accurate results.

3. Results

3.1 Suitability Model

The results of the modelling of the data from the Red backed shrike in the Irano-Anatolian biodiversity hotspot, showed that this species mostly prefers the habitats in some west parts of the Irano-Anatolian region which is

located in Turkey (Figure 1). According to the results, in addition to the west and east of the Irano-Anatolian region, some areas of the center, north and north east of this hotspot biodiversity also include suitable habitats for the Red backed shrike (Figure 1). The common borders among Turkey, Armenia and Georgia have suitability for this species as well. Speaking about Iran, it should be said that a couple of patches generally in the north west of Iran and in several areas of the central Alborz mountains and central Zagros mountain range indicate suitability for the red backed shrike (Figure 2).

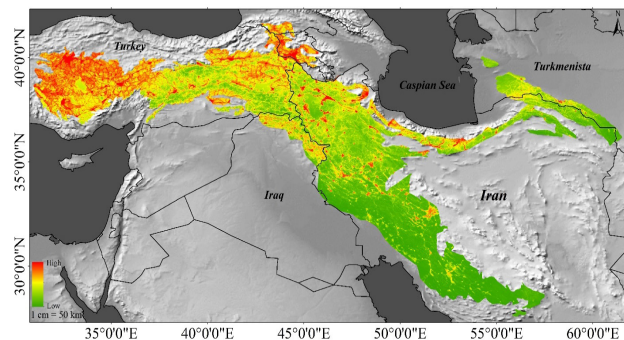


Figure 2. The habitat suitability model of the Red backed shrike in the Irano-Anatolian biodiversity hotspot.

3.2 Variables Importance

With 41 percent contributions average annual temperature was the most important predictor of the species distributions in the Irano-Anatolian biodiversity hotspot. Seasonal precipitation change with 22 percent contribution was the second most important variable in predicting the species distribution. Moreover, the results demonstrated that variables like NDVI (6%), Human footprint (7%) and slope (6%) are altogether contributing to making of the habitat suitability model for Red backed shrike at the Irano-Anatolian region with an impact percentage of 25% (Figure 2).

As it is shown in the curves (Figure 3), firstly the impact of the annual temperature average variable (at selecting suitable habitats) becomes the most, as it reaches to 10 °C. After that, when the annual temperature average gets higher than 10 °C, the habitat suitability for this species decreases and in the temperature average of 25 °C, the suitability level becomes zero. Moreover, the curve of the annual precipitation change variable indicated that the habitat suitability level for this species in the study area, decreases with the rise at the precipitation change; in fact, it showed us that the species chooses the areas with the lowest precipitation change with regards to that variable.

Table 2. Contribution of environmental variable in the Red backed shrike habitat suitability models.

Variable	GAM	GLM	MaxEnt	GBM	RF	Ensemble
Slope	0.02	0.04	0.08	0.00	0.16	0.06
NDVI	0.03	0.04	0.06	0.00	0.16	0.06
Annual mean temperature	0.60	0.55	0.29	0.40	0.21	0.41
Annual precipitation	0.01	0.01	0.04	0.03	0.18	0.05
Precipitation seasonality	0.17	0.15	0.27	0.24	0.25	0.22
Temperature annual range	0.02	0.03	0.05	0.05	0.18	0.07
Human footprint	0.03	0.03	0.12	0.01	0.16	0.07

4. Discussion

The population of Red backed shrike have dropped due to reasons such as climate change, land use change and human effects and are considered on the European endangered species red list [30, 34, 47]. In the current study, the habitat suitability of the species and the impacting parameters on its presence at the Irano-Anatolian biodiversity hotspot are investigated. Totally, the results of our study showed that this species distribution is mostly influenced by the climatic factors of the region and according to that, the west, central and north parts of the studied area are considered as the suitable habitats for this species.

Temperature is one of the factors that impacts directly and indirectly on species in large scale [48] in way that it is considered as a contributing factor to vegetation classification in the altitude gradient [49, 50]. Generally, based on different models, it is demonstrated that there is a link between habitat loss and higher temperature change [51]. In regards to the Red backed shrike, De Juana (1980) [52] addressed discussions on the limitations of Red backed

shrike by Temperature and precipitation. The studies of the last couple of years have revealed that rise in temperature is effective on the biological trend properties of Red backed shrike like the migration time to breeding habitats [53] and egg volume [54]. Furthermore, the studies carried out in the Mediterranean region have disclosed that this species refuses to appear at areas with high temperatures, warm islands, heights below 700 meters and Mediterranean weather [47]. It should be said that in our study, the annual temperature average variable is shown as the most impacting factor on the habitat selection of Red backed shrike. Therefore, according to the weather condition of the Irano-Anatolian region which has a higher temperature average rather than the European and Mediterranean regions, the importance of this variable is regarded more than ever.

The results from modelling the suitable habitats for this species disclosed that the northern areas have more suitability for this species it appears at them more than other regions; so we can draw conclusion that temperature rise probably leads to more appearance of this species at upper zones of the Irano-Anatolian region. In fact, the temperature enhancement, increases the number of species that are inhabitant in the southern areas and are limited by the low temperature of winter and spring. The decline of the species of the northern areas also can be influenced by stress temperature [55], Pathogen pressure increase [56, 57] and competition with the colony of the expanded southern species in the northern areas.

The precipitation changes at the breeding season, have a negative impact on Red backed shrike. In fact, the precipitation level impacts the successful reproduction of the species by impressing the chickens in such a way that when the nests have eggs yet, low precipitations also lead to failure at reproduction. While the chickens come out of eggs and are close to exit of the nests, the reproduction success is impacted by heavy precipitation [58]. In the study by Reino et.al (2006) [47] in the north of Portugal,

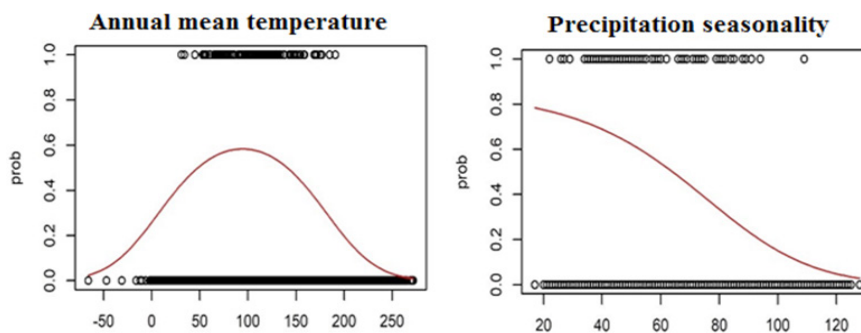


Figure 3. The response of the Red backed shrike to the annual mean temperature and precipitation seasonality.

it was revealed that the precipitation level is one of the substantial climatic factors on the presence range of this species. Sfougaris et al (2014) ^[59] as well disclosed that precipitation is a substantial factor on the seasonal pattern of bird species and bird community composition. In the Irano-Anatolian region, seasonal change of precipitation, is proven to be the second effective factor on selecting the suitable habitats; in fact the results of the recent study indicated that northern and eastern parts of the region, have lower precipitation change than the central, western and southern parts of the region. Hence, the most suitable habitats for this species were the habitats with the lowest annual precipitation change.

Climatic changes will cause a change at desirable climate niches of species at future; the niches will be moved from their current position and be replaced at areas with influence of extreme human activities or the favorable protected areas will be driven to the out of the borders of the existing protected areas ^[60]. Several researchers believe that the decline of the population of the European Red backed shrike is likewise affected by climatic changes and this claim is addressed by various studies ^[61]. If this trend continues and the global temperature, the population climatic changes and its migration system change keep rising, it looks like the population of the species will be reduced over and over in the Irano- Anatolian region. It's clear that in the last couple of decades, the evidences have told us that the number of migrating birds with a long migration path has dropped (by climatic factors) which has caused a concern at the conservation authorities. In the recent study, it was disclosed that climatic factors are the most significant predictors of suitable habitats of a species. Hence, by the climatic changes, the various climatic parameters will be changed and consequently the species habitat suitability will be impacted. Therefore, it is suggested that the researchers investigate the way the species responds to climatic changes and the managers design plans for managing the species influenced by climatic changes. It is important to know that the 75% impact percentage of climatic factors on the selection of suitable habitats of Red backed shrike, requires paying lots of attention to climatic changes when designing conservation plans for this species.

5. Conclusions

Birds are species that respond to environmental changes swiftly and have been studied very well at this field; so some researchers study the communities of birds as indicators for environment of the condition of other animal classes ^[62, 63]. The Red backed shrike exists as a typical species at farming landscapes which are a combination

of farming and steppe lands; the edge of the farming landscapes consists of trees, shrubs and hedges ^[30, 34, 64, 65, 66, 67, 68]. In such way that among the decline birds of the agricultural lands that are in danger of extinction, the Red backed shrike is a key species of Ecotone habitats and is a result of traditional and semi modern agricultural systems ^[69]. Furthermore, regarding that the Irano-Anatolian biodiversity hotspot is adjacent to the European and Mediterranean regions, this hotspot is as well under the influence of the limiting factors of the species. In fact, the climatic factor is the most contributing factor that impacts the population and range of this species in the Irano-Anatolian biodiversity hotspot and this will lead to losing a couple of its habitats and presence periods in connection to temperature limitations in the southern areas. All of above can have a negative impact on numerous species especially the species in the same habitat also species that are dependent on agricultural lands and grasslands. According to the above results, it looks like that we will witness some changes of presence ranges of birds communities from the lower latitudes to upper latitudes in future; so it is essential that management measures will be taken in order to implement conservational plans for these species at northern areas of the region. Regarding that the Irano-Anatolian region is one of the biodiversity hotspots of the globe, the species conservation at this region must be considered at ecological triage (the conservation at this region is of high priority).

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