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Effects of Environmental Variables on the Distribution of the Iranian Ground Jay *Podoces pleskei* Zarudny, 1896 in Kerman Province

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Abstract
The Iranian Ground Jay or Pleske's Ground Jay *Podoces pleskei,* belonging to the genus *Podoces* and the family Corvidae, is the only endemic bird species to Iran. The distribution of this species is restricted to isolated patches in arid and semi-arid areas of the central and eastern parts of the country. There is lack of information about the species distribution and preferred habitats in Kerman Province and there have only been identified low-density patches with high distribution here. In this study, we aimed mapping the species' preferred habitats and areas with high potentiality for the species distribution. This mapping process was based on the presence points and using biogeoclimatic variables that influence the distribution of the Iranian Ground Jay. Findings of this research indicated that the annual mean temperature and precipitation were the most influential variables and the slope had the most unique information on the distribution of this species in the study area. An area of 5.5 percent of the Kerman conservation areas, are suitable habitats for the Iranian Ground Jay. The most desirable temperature ranged from 5°C to 25°C and the most desirable range of precipitation was between 100 and 200 mm. Rangeland areas with low to medium quality and plant cover of 15 to 45% were preferred areas for the species and areas with 25 to 50 percent vegetation cover density had the most suitability for the Iranian Ground Jay. Habitat suitability has inversely related to the distance from roads. The logistic predicted potential distribution map indicated that more than 17 percent of the province, an area of about 31,000 km^2, is suitable habitat for the Iranian Ground Jay. According to the results, the significant parts of the species' suitable habitats were outside of the national protected areas and should be planned for the nature conservation purposes.

1. Introduction

Birds can be considered as appropriate biological indicators for measuring wildlife habitat quality (Khalilabadi 2008; Nezami 2020), because they have specialized behavior in habitat selection and are highly sensitive to the structure of the biological communities and habitat changes (Haririfar 2014). Birds communities reflex the environmental changes and climate changes quickly and easily (Moradi *et al.* 2019). Realizing the ecological features of a bird and determining its status in nature require extensive research and data collection for a realistic analysis of the biological community, as needed for the Iranian Ground Jay *Podoces pleskei* (Hamedanian 1997).

The Iranian Ground Jay from the Corvidae family is called "Zaq-e boor" in Persian language and is the only known bird species endemic to Iran (Mansoori 2008). The bird is completely wild, and unlike most members of corvids, its habitat is generally far from human settlements (Hamedanian 1997). The main habitats of this bird are limited to steppe arid and semi-arid areas of central, eastern and southeastern Iran, including Semnan, Khorasan-e Razavi, Yazd, Isfahan, and Kerman Provinces where plains can be seen covered mainly with Zygophyllum *Zygophyllum atriplicoides* plant species (Mohamadi *et al.* 2015). While the Iranian Ground Jay needs special protection and is considered as one of the natural attractions for

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tourists (Sehhatisabet 2007), habitat destruction threatens the fragmented populations of this species. Similar to other researches who studied wildlife habitats fragmentation (Haghverdi *et al.* 2019; Sadegh Oghli *et al.* 2019), the major destructive factors are agricultural lands, exploitation of trees and shrubs, and overgrazing (Kermani *et al.* 2020). The presence of livestock threatens the bird's life by creating disturbances, especially in the breeding season through feeding on the Zygophyllum bushes, destroying their nests, eggs and chicks (Ordibi *et al.* 2013; Madadi *et al.* 2020). For harsh and fragile ecosystems, sufficient knowledge and information about the species biology can help to make accurate decisions for the habitat management of this species (Mohamadi *et al.* 2015).

Although decline of the wildlife population, especially in birdlife, began with excessive hunting, what unfortunately deprives us of the opportunity to revive the remaining populations of wildlife is a fundamental change in habitats of the species. Consequently, the study of habitats is considered vital and crucial in making awareness of their present circumstance and finding solutions for the challenges (Akbari Harouni 2008). Anthropogenic factors such as habitat destruction, especially breeding habitats, and bird accidents along roads have also severely reduced their populations (Ming 2004).

Habitat suitability models are important tools for estimating suitable habitat in wide ranges for biodiversity studies and wildlife management purposes (Shams-Esfandabad *et al.* 2021; Kermani *et al.* 2020). Habitat modeling increases the knowledge of the spatial distribution of species and their relationship with the environmental variables (Praca *et al.* 2009), and it is widely used to evaluate the effects of management decisions or consequences of environmental threats to the spatial distribution of species (Shahparian *et al.* 2017).

Species Distribution Models (SDMs) (Guisan & Zimmermann 2000) have widely been used for the following purposes on a very large scale to identify habitats suitable for rare and endangered species (Franklin 2009): to examine species diversity in the vast and inaccessible remote landscapes (Brito *et al.* 2009), to prioritize areas for conservation (Carvalho *et al.* 2011; Kermani *et al.* 2020; Shams-Esfandabad *et al.* 2021) and to assess the possible impact of climate changes or species distribution changes (Thuiller *et al.* 2006; Philips *et al.* 2006; Maiorano *et al.* 2013). Habitat assessment models predict the occurrence or animals' existence within the habitats, but they cannot show the overall quality of the habitat based on demographic performance (Guisan & Thuiller 2005; Rabinowitz & Zeller 2010). Typically, these models are used to investigate the relationship between environmental variables and species presence points to predict environmental conditions in which the species can survive (Mirzaee *et al.* 2013).

Although the Iranian Ground Jay is the only confirmed endemic bird to Iran, there is limited knowledge about the habitat use of this species around the country. A lot of habitats of this species in the corridors are also additionally suitable habitats, while these habitats have a low survival rate for the species, maybe because of the weak protection or being unprotected (Ahmadi *et al.* 2017). These habitat patches are local population sinks, known as attractive sinks (Delibes *et al.* 2001; Naves *et al.* 2003) or ecological traps (Dwernychuk & Boag 1972; Ratti & Reese 1988; Donovan & Thompson 2001). Identifying these habitats was vital for the conservation programs of the species.

In this research, we made an effort to identify suitable habitats for the Iranian Ground Jay in Kerman Province, as one of the provinces in which there is a shortage of information about the species distribution. The output of the survey was habitat suitability maps that could be applied with several applications for conservation programs such as conservation prioritizing and determining the performance of the Department of the Environment (DoE) Conservation Area's (CA) borders. Furthermore, the results of this model can assist the researchers to predict the distribution of this species by identifying the role of environmental variables in the species habitat suitability (Hoseinnejad *et al.* 2019).

This research aimed to: a) predict the species distribution range, b) identify the most effective environmental variables of the species habitat suitability, c) produce map of potential habitats in Kerman province, and d) evaluate the efficiency of the CAs to provide the species habitat requirements.

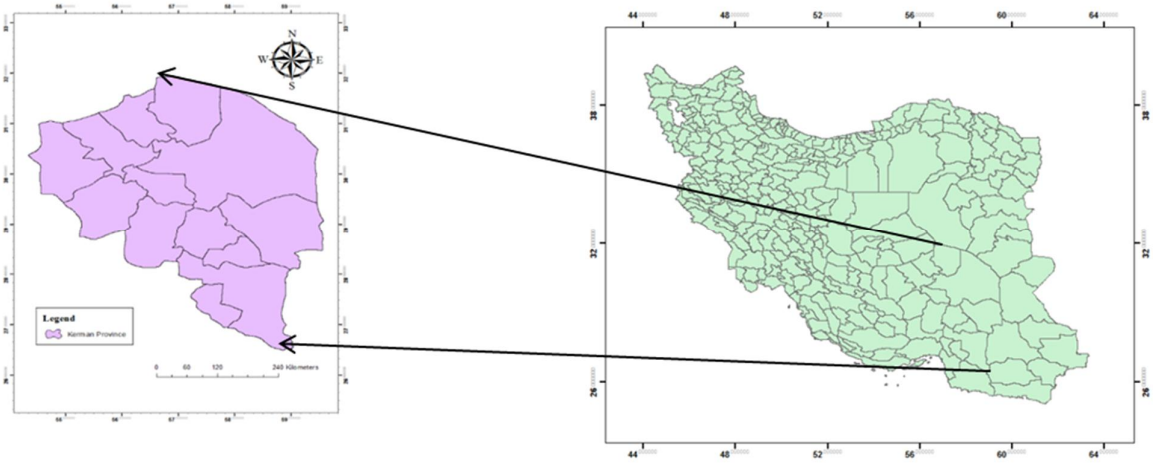

Fig. 1. The situation of Kerman province in Iran.

Table 1. Variables used in modeling.

Variable	Explanation	Reference
Bio 1	Average annual temperature	Worldclim.org
Bio 12	Average annual rainfall	Worldclim.org
Slope	Slope percentage	Prepared from DEM layer
Forest_dist	Distance from forest lands	Prepared from DEM layer
Agriculture_dist	Distance from agricultural lands	Kerman Department of Environment
Pasture_dist	Distance from rangeland habitats	Kerman Department of Environment
Range	Vegetation density	Kerman Department of Environment
Road_dist	Distance from the road	Kerman Department of Environment
Water_dist	Distance from water resources	Kerman Department of Environment
Urban_dist	Distance from human-made settlements	Kerman Department of Environment

2. Materials and Methods

2.1. Study Area: Kerman province with an area of 18,329,701 ha is located between 25°55' to 33°N, 53°26' to 59°29'E (Fig. 1). A very large area of the province is mountainous and the mountain range of Jebal Barez at the center divides the province into four parts: Lut Desert (Bam and Shahdad) in the east, Sirjan Desert (Sirjan) in the west, Bafgh Desert (Kerman and Rafsanjan) in the north and Hamun-e Jazmourian (Kahnooj) in the south. The climate varies from the extremely dry to semi-arid and desert in Baft, Rabor, Kuhbanan, Bardsir, and in some regions of Shahr-e Babak, it is temperate even cold. Due to the low rainfall, extreme evaporation, and high temperatures, Kerman province is very poor in terms of vegetation cover.

2.2. Collecting species presence data: In this study, while reviewing all available scientific documents as well as reports available in the Kerman Provincial Office of DoE, we conducted field surveys and also used the knowledge of local experts. The accuracy of the predefined species present points was examined using the Google Earth program. Finally, 63 points of the species present were collected within the study area.

2.3. Environmental variables: The habitat suitability model was applied by species present point and environmental variables, which are including land cover, human activities, topography, water resources and climatic variables. The variables used in the habitat preference modeling were selected based on the previous related studies on the species (Pakniat 2015, Mousavinejad *et al.* 2012, Hoseinnejad *et al.* 2019, Moshtaqi *et al.* 2014, Haghani *et al.* 2016). Climatic variables were extracted from the Global Climate Center with a resolution of 1

km^2. Topographic variables were prepared by the digital elevation model with 90 m resolution and other variables were obtained using the existing land use map with the scale of 1: 150,000 (Table 1).

2.4. Model construction: Environmental layers were created and processed in ArcMap 10.3 software, and finally, the cell size and the same boundary were assigned to them. ASCII output was generated from the layer and entered into the software to run the model. To prepare the species distribution model, the presence points were divided randomly into two data sets of training (70%) and cross-validation (30%). Maximum background points 10,000, and 15 replicates were selected for the model. MaxEnt is one of the most commonly used machine learning algorithms. Choosing this model for this study was due to the higher efficiency of this method compared to other proposed methods (Elith *et al.* 2006).

Jackknife's chart prioritizes the most significant environmental variables in predicting the model outputs. The prepared model is evaluated by calculating the area under the curve (AUC) for the ROC graphs. The maximum value of AUC is 1 indicating a complete performance. The AUC values lower than 0.5 indicate that it is not better than the random state. To assess the sensitivity of the model in response to each variable, the statistical percentage of each variable was calculated by the MaxEnt (Pierce & Ferrier 2000).

The producing continuous map of the possibility of the species present, the final suitability map was classified in ASCII format in the GIS software. According to the MaxEnt output table, areas between zero and 0.25 were considered as unsuitable, areas between 0.25 and 0.7 as areas with moderate suitability, and areas above 0.7 as areas with high suitability (Phillipes & Dudik 2008; Shams-Esfandabad *et al.* 2021). To investigate the area and the percentage of suitable habitats for the Iranian Ground Jay in the Conserved Areas, the boundaries of these areas were overlaid on classified map (Fig. 2).

3. Results

All observations of Iranian Ground Jay were in single individual or a group of two individuals, except for a group of four Iranian Ground Jay in the Chah-Alam in Shahr-e Babak. Accordingly, 68 percent of the observations were solitary and other observations were a group of two Iranian Ground Jay. Most observations are related to the spring season and Shahr-e Babak. Some 59 percent of the observation were in the morning before 10 am and 29 percent were between 10 am to 14 pm. We have never had two observations less than 2 km apart. Although we had several observations of inactive nests, there was only one observation of one juvenile.

The AUC values showed that the model determined optimal areas for the Iranian Ground Jay in the studied region (AUC = 0.907). The Jackknife's test results revealed that the average annual temperature and average annual precipitation were the most influential factors in prediction outputs; while the land slope was prioritized as the last factor affecting model outputs. The slope followed by the average annual temperature had the most unique information, which eliminates the most reduction in AUC (Fig. 3). Temperature with 44 percent had the most contribution and distance from the road and rangeland habitat with 0.1 percentage had the least contribution to the final model (Table 2).

Evaluation of the final model's response curves for the Iranian Ground Jay shows that by an increase in the annual average temperature and precipitation, the habitat suitability also increases. The most desirable temperature ranged from 5°C to 25°C (Fig. 4). The optimal range of precipitation for the species in Kerman province was estimated between 50 to 300 mm, while the most desirable range resulted between 100 and 200 mm. Habitat suitability for the species reduced after 16°C temperature and 160 mm of precipitation per year. By distancing from agricultural lands, at first, the suitability increases but decreases then. We could not document any observation of the species in the farmlands areas. All of the observations were in the plain areas where Zygophyllum, Artemisia *Artemisia* sp., and Alhagi *Alhagi persarum* were dominanted, respectively. The response curve illustrates a decrease in habitat suitability in the areas adjacent to forest lands (including man-made forests and shrublands), and with a small distance from forests, the suitability increases with an equable grade. Rangeland habitats bring the most suitability for the species, decreased with the distance from rangelands. Rangeland areas with low to medium quality and plant

cover of 15 to 45% were preferred areas for the species and areas with 25 to 50 percent vegetation cover density had the most suitability for the Iranian Ground Jay. The species avoids areas with more than 50 percent vegetation cover. Habitat suitability has inversely related to the distance from roads. Therefore, as the distance from the road increases, there was a sharp decrease in the suitability. This bird has a strong tendency to live in marginal habitats. Habitat suitability increases with the distance from man-made areas, but this trend is not linear and after increasing the distance, habitat suitability decreases. Water resources had a highly positive effect on habitat suitability and with a little distance from these vital resources, the suitability has sharply decreased. As the land slope increases, up to about 5 percent, we can see an instantaneous increase in the variable curve, but then the suitability reduced immediately for the species. This species probably does not live on slopes above 40% (Fig. 4).

The continuous map of the presence probability of the Iranian Ground Jay and habitat distribution pattern showed that the suitable habitats for this endemic species in Kerman province are in the western parts, in the counties of Shahr-e Babak, Sirjan, and Zarand. In total, 3,097,100 ha, an area about 17.3 percent of the surface area of this province were covered by suitable areas (red and green areas on the map) for this species (Fig. 2). Currently, this vast province consists of 24 Conserved Areas (CAs) including one national park, 10 protected areas, 4 wildlife refuges, one national natural monument, 7 no-hunting areas, and a community conserved area. Overlaying the DoE CAs map in the province with the classified map of suitable habitat indicates low protection efficiency for protecting the Iranian Ground Jay. An area of about 157,319.65 ha which is about 5.5 percent of the Kerman DoE CAs, are suitable habitats for the Iranian Ground Jay. This range consists 26,703.99 ha of the protected area, 36,423.13 ha of wildlife refuge, 17,153.92 ha of no-hunting areas, and 77,038.7 ha of community conserved area. Khabr National Park and Sarv-e-Sirch National Natural Monument were not located in suitable areas.

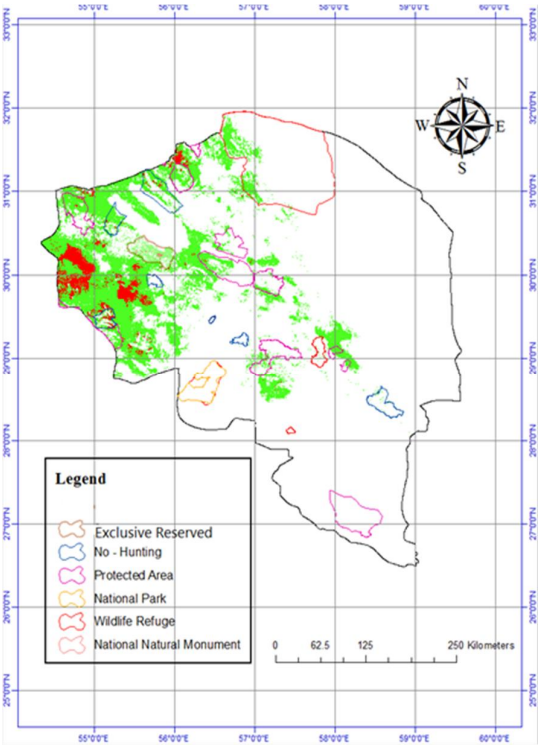

Fig. 2. Map of habitat utility and overlap of desirable habitats and areas under management. Red areas indicate the highest level of desirability and green areas indicate the average desirability for the habitat of the Iranian Ground Jay.

Table 2. Percentage of variable participation in model construction.

Variables	Percentage of participation
Average annual temperature	44
Slope percentage	23.4
Distance from water resources	15.1
Distance from agricultural lands	5.5
Vegetation density	4.9
Distance from human-made settlements	4
Distance from forest lands	1.8
Average annual rainfall	0.9
Distance from roads	0.1
Distance from rangeland habitats	0.1

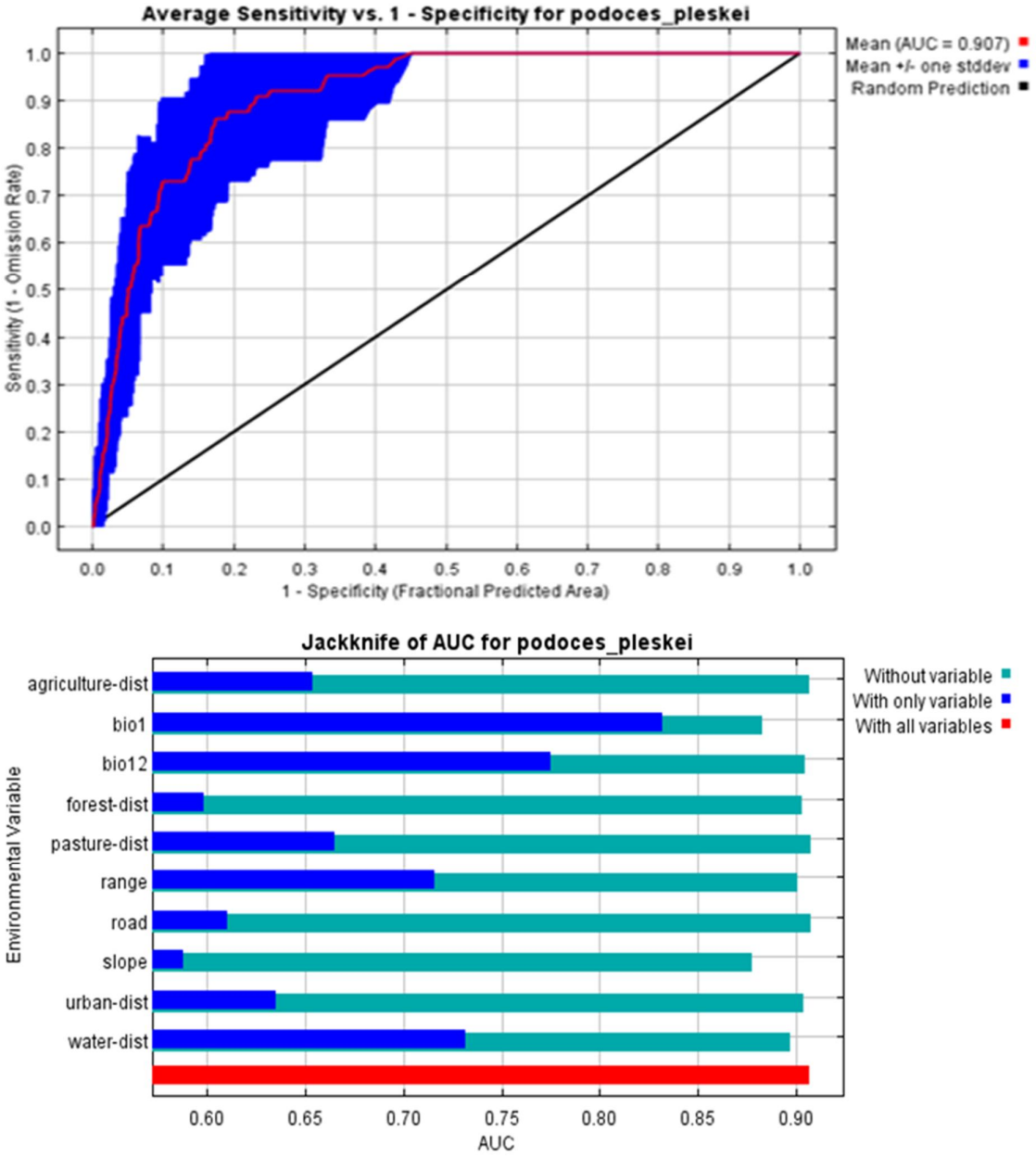

Fig. 3. ROC curve and Jackknife's diagram.

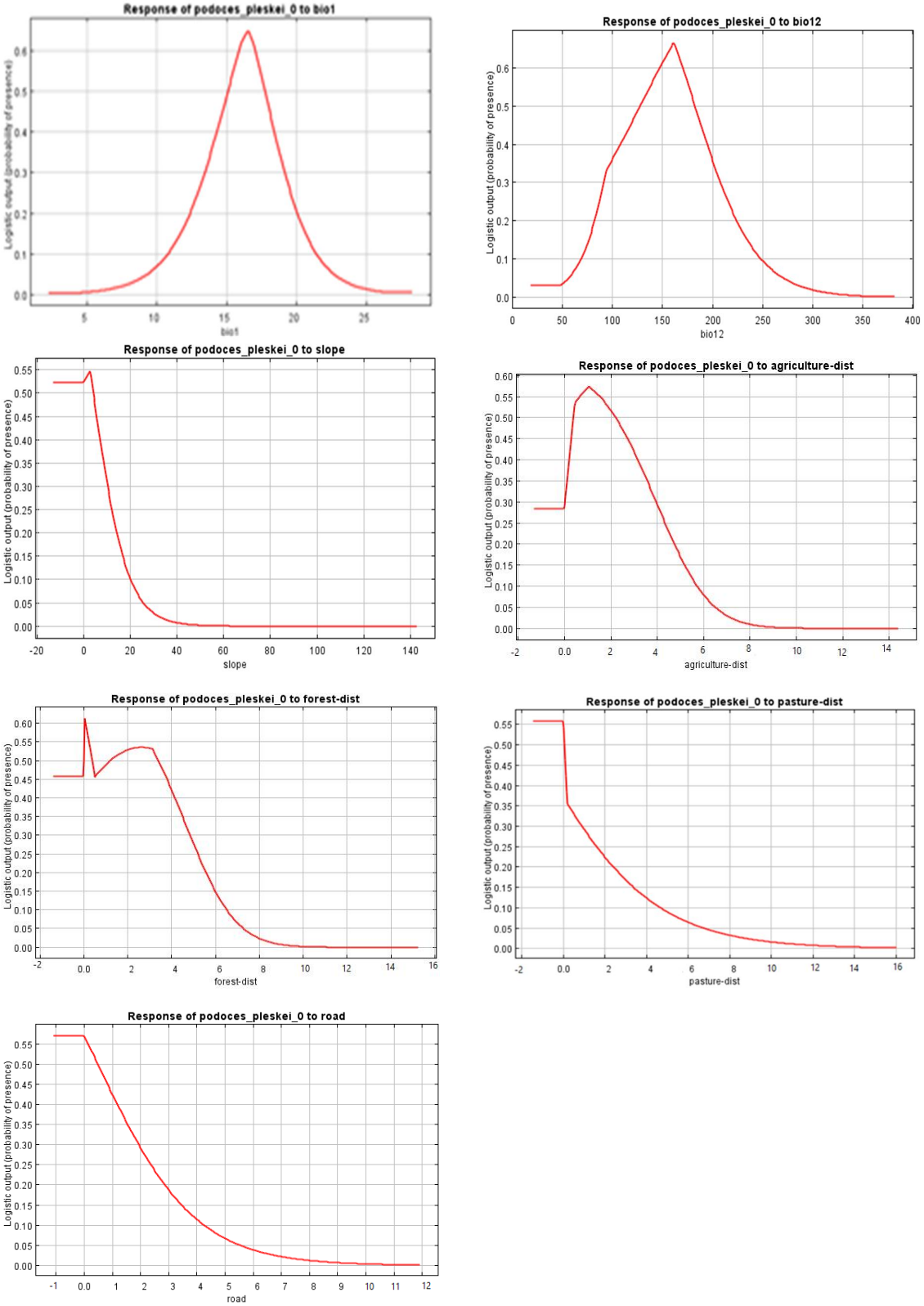

Fig. 4. Answer curve of the variables of average annual temperature, average annual rainfall, slope, agriculture distance, forest distance, pasture distance and road distance.

4. Discussion

Iranian Ground Jay is the only known endemic bird species to Iran (Radnezhad *et al.* 2011). The distribution of this species in Iran is limited somewhat in patchy desert and semi-desert parts of central and eastern Iran, which is still the causes of this fragmentation of the distribution of this species not specified (Radnezhad *et al.* 2011; Kaboli 2009). Habitat suitability modeling with topographic data also showed that these types of areas are often in the central parts to the eastern parts of Iran to the border of Pakistan and Afghanistan (Moosavinejad 2012).

The most of our observations of this species in Kerman Province have been in the Shahr-e Babak, as confirmed by the previous study (Sehhatisabet 2006). The abundance of the Iranian Ground Jay in the study area was very low and observations were recorded at a long distance from each other. Food resources are limited in the arid and semi-arid habitats and this species, especially in the breeding season, have territorial behavior (Radnezhad *et al.* 2013). On the other hand, the rangelands of central Iran are under severe pressure for livestock grazing (Kaboli *et al.* 2016).

According to the results, the annual mean temperature was determined as the most influential variable on the distribution of the ground jay. According to Mousavinejad *et al.* (2012), due to the importance and effects of temperature and rainfall on the habitat selection of the Ground Jay, the distribution of this species is restricted to the central and eastern parts of Iran, which are one of the driest regions in the world (Ahmadi *et al.* 2017). Due to the short winter seasons in the desert and semi-desert areas, plants usually start growing with the first rainfall (Kermani *et al.* 2017; Kermani *et al.* 2020; Nezami 2018). The precipitation, to some extent, is also very important in the nutritional behavior and other biological cycles of the species (Mousavinejad *et al.* 2012). According to Khaleghizadeh & Sehatisabet (2006), some of the food sources of this bird includes some parts of roots and stems of desert plants such as Zygophyllum *Zygophyllum* spp. and Tamarix *Tamarix* spp. which grow after rainfall. The response curve showed that this jay species reacted to the distance from water resources and the species depends on it to supply for biological needs. The Iranian Ground Jay nests near seasonal waterways because springs and streams are places where insect colonies are found which play the main role in the Jay diet (Mousavinejad *et al.* 2012).

Based on the contribution of the vegetation density in the construction of the species suitablility model, the species tend to live in areas with moderate vegetation. Moderate vegetation cover provides suitable habitat for the species camouflage and a good cover to see the enemies, running, short flights and escape among bushes by the ground jay. Moreover, the area with dense vegetation protects the species from possible harsh weather conditions (Ordibi *et al.* 2013). For instance, in Abbas Abad Wildlife Refuge in Esfahan province, the average percentage of vegetation density was 67.8% for this species, of which the average cover percentage of Zygophyllum was 13.68% and the average cover percentage of Artemisia was 26.8% (Ordibi *et al.* 2013). The increase in the density of these plants improves the chances of nesting and camouflage and reduces the likelihood of predation, inter- and intra-species competition (Radnezhad *et al.* 2011). In the habitats of Khorasan-e Razavi province, areas with 43% vegetation coverage were preferred by this species in the summer season (Mousavinejad *et al.* 2012).

The response curves revealed the high desirability of the species for living in the vicinity of the rangelands due to the high dependency of the species on insects, plants and seeds (Khaleghizadeh & Sehatisabet 2006). According to Pakniat (2015) and Ordibi *et al.* (2013), this species preferred habitats with poor to moderate vegetation cover (less than 50 percent), without tree and shrub cover. The presence of the livestock in these lands can attract insects which are important for the insectivorous species (Pakniat 2015). According to Khaleghizadeh & Sehatisabet (2006) insects include 75% of the diet.

With the distance from human settlements, habitat suitability first increases and then reduces. Due to its special behavior and preference to stay away from human-made areas, unlike other members of the family Corvidae, this pattern of increasing habitat suitability by distancing from human settlements is understandable. This sinusoidal and dual behavior in dealing with human communities is due to the species absorption by farmlands and the importance of seeds and insects in the species

diet (Pakniat 2015). Forest landscape margins are less desirable due to the greater impact of human activities (Pakniat 2015; Hoseinnejad *et al.* 2019). This kind of habitat selection behavior has also been observed in other desert species such as Macqueenii Bustard *Chlamydotis macqueenii* (Habibi 2008). Despite its avoidance behavior from human societies, this species has a high tendency to appear around the roads (Londei 2011). There is also a tendency to nest near roads (Satei *et al.* 2011; Mohammadi *et al.* 2015; Mousavinejad *et al.* 2012). This behavior is probably due to the availability of water and food in thess areas. The positive effects of the road on the abundance of this bird species include spilled food left by trucks and presence of insects on the carcasses of dead animals which are rare elsewhere in the desert areas (Londei 2011). This adaptation with human societies is seen in most members of the Corvidae family (Juozaityte-Ngugu *et al.* 2021).

The land slope was recognized as the most unique variable and most important limiting factor. Results showed that Iranian Ground Jay prefers plain areas up to the lands with moderate slopes (Hamedanian 1997; Sehhatisabet 2007; Satei *et al.* 2011; Mohammadi *et al.* 2015; Mousavinejad 2012; Dayani & Baloutch 1985). Suitable habitats of this species are steppes, deserts, and semi-desert areas and it is commonly not present near areas with steep slopes (Mohammadi *et al.* 2015). Desert birds living in areas with less natural phenomenon, keep more flight distances (Pakniat 2015). This type of habitat in desert areas is suitable for the behavior of short flights, at altitudes close to the ground and sitting on the ground with a quick run among the bushes (Rasooli Nasab *et al.* 2017).

Road accident is one of the most important factors threatening the Iranian Ground Jay. As mentioned above, this bird often wanders around the roads looking for food (Hamedanian 1997). Habitat destruction and fragmentation due to the presence of the livestock and agricultural lands are other threats to this species (Mohammadi *et al.* 2015). The livestock also creates unsafety for the species, especially during the breeding season, by destroying the bird's nests, eggs, chicks, and feeding on Zygophyllum bushes. The other threats are their natural predators such as Common Fox *Vulpes vulpes*, Golden Jackal *Canis aureus*, and Desert Monitor *Varanus griseus* (Satei *et al.* 2011; Mohammadi *et al.* 2015). Consecutive droughts in recent years have also resulted in a significant impact on vegetation and seed reduction, which has caused the Iranian Ground Jay to approach the roads, livestock and nomads. Therefore, the clutch size of the species reduces or even does not hatch during continuation droughts (Ordibi *et al.* 2013).

According to the results, habitats of Shahr-e Babak, Sirjan and Zarand districts have the most suitability for the Iranian Ground Jay, respectively. Unfortunately, the most suitable identified areas for the species are not within the DOE Conserved Areas categories. Even though Shahr-e Babak has the most suitable areas for this endemic bird, there is not any overlap between its only protected area, Dahaj, and no-hunting areas, Goud-e chah, within the recommended suitable habitats. In Zarand district, high suitability areas are only located in the margins and adjacent to Chah-Koucheh protected area, and only small parts of the high-suitability areas are in the Nodarhang no-hunting area. Hence, a significant portion of potentially suitable habitats for the Iranian Ground Jay are located in free zones or on the outskirts of Conserved Areas. Therefore, it is suggested that for further protection of this valuable and attractive species, the new CAs be established based on predicted suitable areas, especially in Shahr-e Babak. It is also recommended to review the boundaries of the current protected and no-hunting areas.

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