Received: 9 March 2022 | Revised: 19 July 2023 | Accepted: 19 October 2023
DOI: 10.1111/csp2.13047

CONTRIBUTED PAPER

Conservation Science and Practice
A journal of the Society for Conservation Biology
WILEY

Assessing landscape suitability and connectivity for effective conservation of two semi-desert ungulates in Iran

Kamran Almasieh[1] | **Alireza Mohammadi**[2]

[1]Department of Nature Engineering, Agricultural Sciences and Natural Resources University of Khuzestan, Mollasani, Iran

[2]Department of Environment Science and Engineering, Faculty of Natural Resources, University of Jiroft, Jiroft, Iran

Correspondence
Kamran Almasieh, Department of Nature Engineering, Agricultural Sciences and Natural Resources University of Khuzestan, Mollasani, Iran.
Email: almasieh@asnrukh.ac.ir

Funding information
Research and Technology of Agricultural Sciences and Natural Resources University of Khuzestan, Grant/Award Number: 1400/14

Abstract
Conservation outside conservation areas (CAs) is more challenging due to increased exposure to human-induced disturbances. Therefore, it is important to identify and designate new CAs that can protect core wildlife habitat patches, as well as key linkages to promote connectivity. We performed this study to identify and prioritize core habitat patches and corridors for two semi-desert sympatric gazelles in Iran (i.e., goitered gazelle *Gazella subgutturosa* and jebeer gazelle *G. bennettii*) in order to propose the expansion of existing CAs. We used an ensemble distribution modeling approach based on three algorithms (random forest, maximum entropy, and generalized boosting models) for habitat suitability assessment and a combination of resistant kernel and factorial least-cost path analysis for connectivity modeling. Our results revealed that distance to CAs, elevation, and annual mean temperature were the most influential variables for predicting the distribution of the two gazelle species. We identified 12 and six core habitat patches for goitered gazelle and jebeer gazelle, respectively with a minimum area of 210 km^2. Core habitat patches were mainly occurred in the north of the central basin of Iran with a high priority for the conservation of both species. CAs protected up to half of core habitat patches for goitered gazelle and one-third of core habitat patches for jebeer gazelle. Due to human-induced disturbances (e.g., vehicle collisions and poaching) outside CAs, it is necessary to increase regular monitoring and establish new CAs based on the identified core habitat patches for the two gazelles. Our findings highlight opportunities of designating new CAs for wildlife habitat and corridors conservation and for promoting connectivity by limiting road impacts.

KEYWORDS
conservation areas, corridors, goitered gazelle, habitat suitability, jebeer gazelle

1 | INTRODUCTION

Desertification is expected to intensify with the warming and drying climate, further limiting the resources within desert ecosystems, such as water (Liang et al., 2021; Lundgren et al., 2021). Climate change is projected to be more severe in deserts in comparison to other biomes regarding the extinction rate of organisms and alongside other anthropogenic factors such as land degradation, will probably lead to range contraction and species extinction in arid and semi-arid environments (Brito et al., 2021). For instance, the results of studies conducted by Wu et al. (2017) and Zhang, Jiang, Li, et al. (2021) revealed that the ranges of climate niche projected for the Tibetan antelope (*Pantholops hodgsoni*) would be reduced to about half of the current range. In another research, Erasmus et al. (2002) reported that the ranges of 78% of animal species in South Africa would decrease in the era of climate change. Moreover, 82% of African antelopes will lose most of their favorable habitats by 2080 under climate change (Payne & Bro-Jørgensen, 2016). This situation can be true for other arid and semi-arid regions such as western Asia.

Previous research revealed that western Asia has a high risk of exposure to extreme climatic events (Evans, 2009; Lelieveld et al., 2012; Yusefi et al., 2021). Warming and aridity are expected to increase over the entire region during the coming decades (Chenoweth et al., 2011). Within western Asia, Iran is an arid and semi-arid country, and its temperature and precipitation are projected to rise by 2.6°C and decline by 35% over the next decade, respectively (Ebrahimi et al., 2021). Rainfall in the central basin of Iran is already low (<200 mm/year); even a small decrease in precipitation due to climate change could have dangerous effects on its local biodiversity (Yusefi et al., 2021). Reductions in annual precipitation will affect the abundance of mammals, especially in arid landscapes (Heffelfinger et al., 2018; Ogutu, & Owen?Smith, N., 2005). Therefore, monitoring and predicting habitat and connectivity changes due to climate change is a pressing task for biodiversity conservation in this century. To do so, it is important to first establish the current condition through baseline assessments. These assessments are particularly critical for species conservation planning and for evaluating whether existing conservation area (CA)s are climate-change-proof (Ashrafzadeh et al., 2022).

In arid and semi-arid regions, inadequate protection of landscape connectivity has recently been identified as a major obstacle to wildlife management and conservation, especially for mammals (Ghoddousi et al., 2020; Malakoutikhah et al., 2020; Yusefi et al., 2021). Existing CAs often fail to support viable populations of mammals due to the animals' large area requirement, low density, and high dispersal ability (Ashrafzadeh et al., 2022; Mohammadi, Almasieh, Nayeri, et al., 2021; Mohammadi, Almasieh, Wan, et al., 2021). Therefore, conservation planning for species requires assessing the coverage and connectivity of existing CAs, prioritizing the establishment of new CAs in strategic locations, and protecting dispersing individuals as they move between the network of CAs (Almasieh, Mirghazanfari, & Mahmoodi, 2019; Almasieh, Rouhi, & Kaboodvandpour, 2019; Rezaei et al., 2022).

Conservation of the ungulates is vital not only to protect these species due to climate change and mentioned threats in the desert environment, but because the species has a large impact in desert environments on the development and maintenance of other plants and animals (Kaky et al., 2023). Understanding the ungulates distribution and connectivity is important in order to mitigate their decline and effective strategies for effective conservation and management of these species (Meliane et al., 2023). Iran has a vital role in the conservation of threatened wild ungulates in western Asia (Malakoutikhah et al., 2020). Iran provides large areas of suitable habitat for ungulate populations, especially for goitered gazelle (*Gazella subgutturosa* Guldenstadt, 1780) and jebeer gazelle (also known as chinkara or Indian gazelle, *G. bennettii* Sykes, 1831) in their entire distributions in Asia (Akbari et al., 2014; Karami et al., 2002; Malakoutikhah et al., 2020). Iran has the second highest population of goitered gazelle and jebeer gazelle in the world (IUCN SSC Antelope Specialist Group, 2017a; IUCN SSC Antelope Specialist Group, 2017b). These two gazelles are found across the country; however, habitat degradation (especially by expanding road networks) and poaching have reduced their population size (Fadakar et al., 2020; Ghoddousi et al., 2019; Hemami & Groves, 2001). IUCN Red List categorizes the global conservation status of goitered gazelle as vulnerable (VU) and jebeer gazelle as least concern (LC) (IUCN SSC Antelope Specialist Group, 2017a, 2017b). Because of severe population declines in these two species (Karami et al., 2016), especially for jebeer gazelle (Akbari et al., 2014, 2015; Torabian et al., 2021), Yusefi et al. (2019) categorize these two gazelles as endangered (EN) at the national scale. According to IUCN Red List, currently, about 2.6% and 5.9% of distribution ranges of goitered gazelle and jebeer gazelle in Iran are protected, respectively. Identifying the most influential environmental characteristics on habitat suitability for these species, as well as their core habitat patches and the corridors among them are essential steps for conservation, especially in creating new CAs (Mohammadi et al., 2022).

This research aimed to conduct a baseline assessment of habitat suitability and landscape connectivity for these two sympatric ungulates in Iran. The objectives of our research were (1) determination of the most significant environmental and anthropogenic factors influencing habitat suitability; (2) identification of core habitat patches and corridors, and (3) identification of the coverage of core habitat patches by existing CAs.

2 | MATERIALS AND METHODS

2.1 | Study area

The study area was the entire land area of Iran (1,648,000 km^2), located in southwest of Asia (Figure 1), because both ungulate species are broadly distributed in the entire country. Except for the western parts of the country and the northern coastal areas, Iran's climate is mainly arid or semi-arid (Mansouri Daneshvar et al., 2019). About 52.4% of Iran's total area is composed of grasslands/steppes, 8.6% of forests, and 19% of deserts, including bare saline lands (Noroozi et al., 2008). Two mountain ranges of Alborz and Zagros prevent moisture reaching the central arid plains of Iran (Khosravi et al., 2018). The central arid plains of Iran with about 30% of Iran's area and average elevation of 900 m above sea level receive annual precipitation of 50–250 mm (Emadodin et al., 2019; Qadir et al., 2008).

There are 246 CAs in Iran, covering about 11.5% of the country's land area (DoE, 2022) (Figure 1). Due to its topographic and geographical diversity, Iran is one of the richest countries in western Asia in terms of biodiversity. Iran has about 190 terrestrial mammals (Karami et al., 2016; Yusefi et al., 2019) and is home to six members of the family Bovidae: urial (*Ovis vignei*), mouflon (*Ovis gmelini*), bezoar goat (*Capra aegagrus*), goitered gazelle, jebeer gazelle, and mountain gazelle (*Gazella gazelle*) (Karami et al., 2008; Yusefi et al., 2019). In addition, the central basin of Iran is home to other species of conservation concern, including Asiatic cheetah (*Acinonyx jubatus venaticus*), Persian leopard (*Panthera pardus tulliana*), and Persian onager (*Equus hemionus onager*), which are threatened by poaching and habitat loss (Ghoddousi et al., 2019; Shams-Esfandabad et al., 2010; Soofi et al., 2022). Flat plains of semi-deserts, steppes, bush lands, and woodlands especially covered with *Artemisia* sp. are the habitat of goitered gazelle in Iran and jebeer gazelle inhabits deserts and semi-deserts of Iran (Karami et al., 2016). Habitat degradation and poaching are two main threats for both gazelle species in Iran (Karami et al., 2016).

2.2 | Occurrence records

We collected occurrence points for goitered gazelle and jebeer gazelle from rangers and officers of Iran's Department of Environment (DoE) during 2010–2020. Most of these occurrence points were obtained during daily field surveys and direct observations. We removed two occurrence points from a CA in the southwest of Iran because

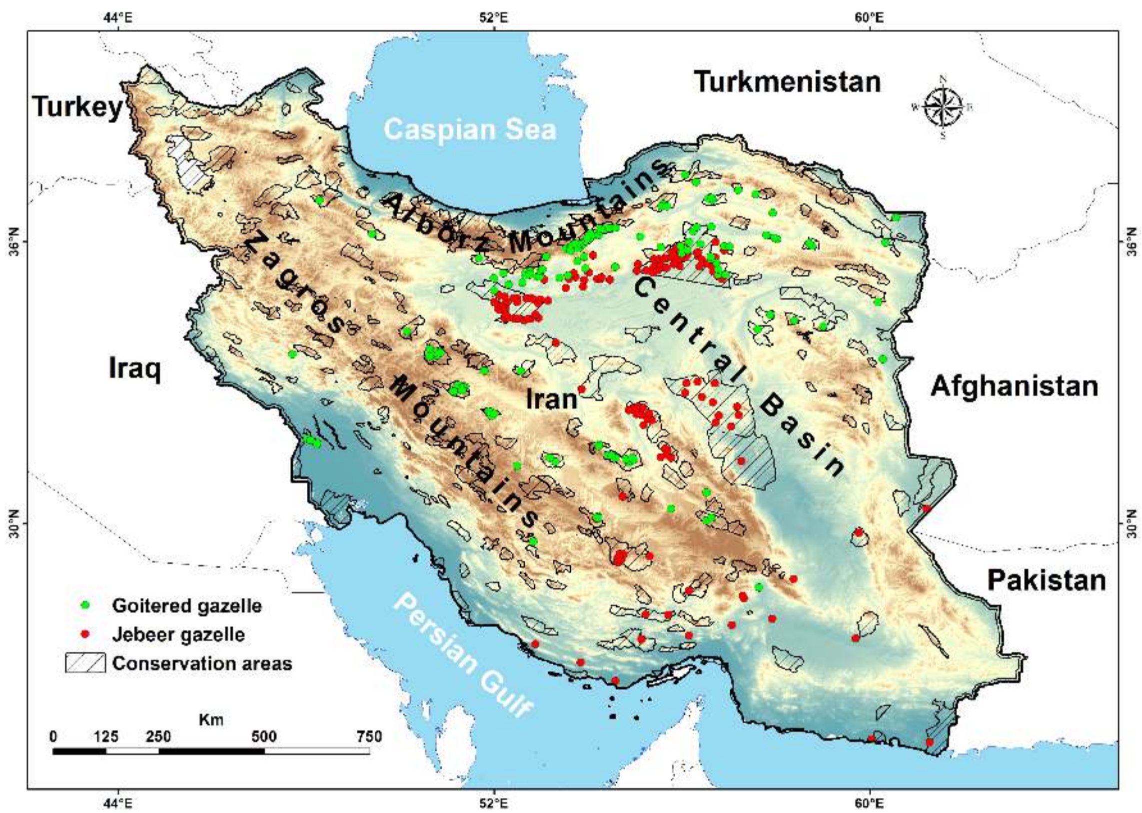


FIGURE 1 Study area, conservation areas and occurrence points of goitered gazelle and jebeer gazelle in Iran.

the taxonomic status of these records is unclear (Fadakar et al., 2019). In addition, we did not consider occurrence points in the islands of southern Iran due to the lack of data on environmental variables (climatic layers) for the islands. In total, we obtained 158 and 173 occurrence points for goitered gazelle and jebeer gazelle, respectively. To minimize spatial-autocorrelation, we considered a radius of 2 km (the radius of the circular home range of goitered gazelle in Turkey (15 km^2), Durmus, 2010) around each occurrence point to spatially filter occurrence records using the Spatially Rarify Occurrence Data tool in SDMtoolbox (Brown, 2014). Following data cleaning, we retained 145 and 158 occurrence points for habitat modeling of goitered gazelle and jebeer gazelle, respectively.

2.3 | Environmental variables

According to the ecology of two gazelle species and previous studies (Akbari et al., 2014; Akbari et al., 2015; Farashi et al., 2017; Hosseini et al., 2019; Khosravi et al., 2016; Malakoutikhah et al., 2020; Shams-Esfandabad et al., 2019), the related environmental variables used for habitat modeling included (1) topographic and (2) climatic variables, (3) land cover and (4) anthropogenic variables (Table 1). We considered a digital elevation model (DEM) with a resolution of 1 km based on the 30 m Shuttle Radar Topography Mission (downloaded from http://earthexplorer.usgs.gov). We downloaded annual mean temperature (BIO1) and annual precipitation (BIO12) from http://worldclim.org (Fick & Hijmans, 2017) with a resolution of 1 km as the climatic variables.

According to occurrence points of the two gazelles, we considered two land-cover types for each species: low density of semi-arid grasslands and moderate density of semi-arid grasslands for goitered gazelle, and low density of semi-arid grasslands and arid bare lands for jebeer gazelle. Land-cover data were based the land-cover map of Iran resample to a cell size of 1 km (created from Landsat images with a 30 m resolution by FRWMO, 2010). In addition, we considered agricultural lands density as another habitat variable for these two gazelles. We used a moving window routine based on a circle with a radius of 5 km to create continuous density maps (with values ranging from 0 to 1) for these four cover types using the Focal Statistics tool (Malakoutikhah et al., 2020). We used 16-day composite MODIS data (MOD13A1 V6 at 500-m resolution; http://earthexplorer.usgs.gov) to calculate the normalized difference vegetation index (NDVI) according to the mean values for 2020 and then resampled NDVI to a cell size of 1 km. To take into account the protection of herbivores from poaching in CAs, we considered distance to CAs as the protection factor for herbivores by using the Euclidean Distance tool. We used distance to roads (asphalted roads in Iran) (DoE, 2022) and distance to villages (DoE, 2022) as the two main anthropogenic variables for habitat modeling. We resampled all variables with a cell size of 1 km. We checked for multicollinearity by evaluating the correlation between variables. We checked the correlation between variables to exclude variables with a correlation coefficient of >0.7. All of the above-mentioned variables had a correlation coefficient of <0.7.

2.4 | Habitat modeling

We performed a prediction of habitat suitability for the two species using an ensemble approach in the biomod2 package in R (Thuiller et al., 2016). The ensemble approach avoids over-dependence and over-fitting on one

TABLE 1 Predicted variables used for habitat modeling of goitered gazelle and jebeer gazelle in Iran.

Category	Variables	*Gazella subgutturosa*	*Gazella bennettii*
Topographic variable	Elevation (DEM)	Selected	Selected
Bioclimatic variables	Annual mean temperature (BIO1)	Selected	Selected
	Annual precipitation (BIO12)	Selected	Selected
Land-cover	Low density of semi-arid grasslands	Selected	Selected
	Moderate density of semi-arid grasslands	Selected	-
	Arid bare lands density	-	Selected
	Agricultural lands density	Selected	Selected
	Normalized Difference Vegetation Index (NDVI)	Selected	Selected
Anthropogenic variables	Distance to conservation areas (CAs)	Selected	Selected
	Distance to roads	Selected	Selected
	Distance to villages	Selected	Selected

algorithm (Jorgensen et al., 2021). We applied three machine-learning algorithms for habitat modeling: Random Forest (RF), Maximum Entropy (MaxEnt), and Generalized Boosting Model (GBM). We checked the accuracy of the models for each species using the area under the ROC curve (AUC) and true skill statistic (TSS); Eskildsen et al. (2013) reported AUC >0.9 and TSS >0.75 as excellent performance. We considered 75% of the occurrence points as the training data set and the other 25% as test data. We generated background points in biomod2 for all models according to the method used by Barbet-Massin et al. (2012) and Kaboodvandpour et al. (2021). We randomly created 1500 background points across the whole study area and outside a radius of 5 km around each occurrence point for each species. We selected a 1:10 ratio as the best ratio between occurrence and background points (Barbet-Massin et al., 2012). We carried out the analyses by applying 20 replicates for each model to achieve higher confidence (Barbet-Massin et al., 2012). In addition, we considered a prevalence of 0.5 for presence and background points (the same importance for the presence and background points in model) (Calambás-Trochez et al., 2021). We used mean variable contributions in the three models calculated by biomod2 for each species. In addition, we determined response curves of habitat suitability to the variables for the model with the highest performance for each species.

2.5 | Core habitat patches and connectivity modeling

We created the resistance map for each species from the ensemble suitability map according to Wan et al. (2019). First, by using the linear method in the Rescale by Function tool in ArcGIS, we rescaled the ensemble map for the species to a map of values between 0 and 1. Then, we used a negative exponential function to create the resistance map using the following formula: $R = 1000^{(-1 \times \text{Ensemble Suitability Map})}$, where R represents the cost resistance value assigned to each pixel (Mateo-Sánchez et al., 2015). Finally, we rescaled the resistance values using linear interpolation to yield values ranging from 1 to 10; where 1 and 10 represent the minimum and maximum resistance, respectively (Wan et al., 2019). Although we used distance to roads as a variable in habitat modeling for each gazelle species, due to the importance of the road in disruption of habitat connectivity, we added the main road layer with a resistance value of 10 to the resistance layer of each species using CorridorDesigner software (Majka et al., 2007).

We carried out core habitat patch and connectivity modeling using Universal Corridor (UNICOR) software (Landguth et al., 2012) at a resolution of 1 km. According to information provided by DoE rangers regarding the dispersal ability and movement of gazelles, we considered 100 km as the maximum dispersal distance for goitered gazelle between two CAs in Iran during summer. We used the resistance map for each species to obtain core habitat patches and the connectivity among them. We created a continuous map of core habitat patch for each species using resistant kernels and calculated the resistance cost-weighted dispersal around each occurrence point up to the defined dispersal threshold (100 km). We converted the contiguous maps of core habitat patches created from resistance maps of gazelle species to categorical maps based on >10% of the highest suitability of contiguous core habitat patch maps (Ahmadi et al., 2020; Almasieh & Cheraghi, 2022; Ashrafzadeh et al., 2020; Cushman et al., 2013). We implemented connectivity prediction among core habitat patches over the resistance map for each species in UNICOR to find the single-source shortest path from every core habitat patch in the landscape to every other core habitat patch (Cushman et al., 2013; Landguth et al., 2012). The analysis predicted least-cost paths from each source patch to each destination patch regardless of the dispersal threshold to assess all potential corridors, including long-distance dispersal corridors (Cushman et al., 2013). We eliminated small habitat patches that cannot host a viable population based on the minimum home range of goitered gazelle herd (i.e., 15 km^2 for goitered gazelle in Turkey, Durmus, 2010). We separately calculated coverage of categorical core habitat patches by CAs for each species as the ratio of total CA or CAs area within core habitat patches to the total area of core habitat patches for each gazelle species. We overlapped core habitat patches of goitered gazelle and jebeer gazelle in Iran as gazelles' niche overlap hotspots. We calculated the coverage of these hotspots by CAs. We highlighted the locations where corridors are bisected by main roads to show roadkill hotspots.

3 | RESULTS

3.1 | Habitat suitability and variable contributions

Values of AUC and TSS for all models were larger than 0.9 and 0.75, respectively, indicating excellent performance (Table 2). The RF model had the highest performance among the three models for both gazelle species (i.e., highest values of AUC and TSS). Based on the average of the three models, distance to CAs (20.9%), elevation (14.6%), annual mean temperature (BIO1)

TABLE 2 AUC and TSS of three models in the habitat suitability of goitered gazelle and jebeer gazelle in Iran.

Species	Models	AUC	TSS
Gazella subgutturosa	RF	0.925	0.83
	MaxEnt	0.91	0.79
	GBM	0.918	0.78
Gazella bennettii	RF	0.932	0.82
	MaxEnt	0.922	0.76
	GBM	0.926	0.79

(11.2%), and low density of semi-arid grasslands (10.1%) were the most influential variables for predicting the distribution of goitered gazelle, and distance to CAs (21.3%), annual mean temperature (BIO1) (13.2%), elevation (11.6%) and NDVI (9.4%) were the most influential variables for predicting the distribution of jebeer gazelle in the study area (Table S1).

Response curves of habitat suitability to environmental variables in the RF model (as the model with the best performance) for the two species are presented in Supplementary Materials (Figures S1, S2). Distance to CAs appears to be an important factor in determining habitat suitability for the species since the probability of occurrence decreased severely as distance from CAs increased. Goitered gazelle selected 1000–2000 m elevation above sea level and 10–20°C annual mean temperature. As the prevalence of low-density semi-arid grasslands increased, the probability of goitered gazelle occurrence stabilized and then increased sharply. Similar to goitered gazelle, jebeer gazelle exhibited a declining response to distance from CAs as the probability of occurrence decreased farther from these areas. Jebeer gazelle selected 1000–2000 m elevation above sea level and 15–20°C annual mean temperature. NDVI negatively affected jebeer gazelle as habitat suitability decreased where NDVI were more and then stabilized.

Ensemble suitability maps showed that the central plain of Iran had the highest suitability for the two gazelles. However, the suitable habitats extended more to the west and northeast for goitered gazelle and to the south for jebeer gazelle (Figure 2). Habitat suitability maps generated by the RF, MaxEnt, and GBM models for the two species are shown in Figures S3 and S4, respectively.

3.2 | Core habitat patches and corridors

Within the estimated dispersal distance of 100 km, we identified 12 core habitat patches for goitered gazelle with a total area of about 74,000 km^2, 40% of which was covered by CAs (Figure 3). The main core habitat patches were located in the north and west of the central basin of Iran. The largest core habitat patch was Core1 (Parvar area), located in the northern part of the central basin of Iran (about 28,500 km^2, 30% CAs coverage). The second-largest core habitat patch was Core2 (Touran area), located close to Core1 (about 19,800 km^2, 55% CAs coverage). The third-largest core habitat patch was Core3 (Mooteh area) in the west of the central basin of Iran (about 10,500 km^2, 35% CAs coverage) (Figure 3, Table S2). Total road density in core habitat patches was about 29 m/km^2; the highest road density was observed in Core8 (ShirAhmad area) (about 67 m/km^2) and the lowest in Core10 (Taghestan area), Core11 (Raeisi area) and Core12 (Bidoeeyeh area) (0 m/km^2) (Table S2).

Within the estimated dispersal distance of 100 km, we identified six core habitat patches for jebeer gazelle with a total area of about 76,000 km^2, with about 53% coverage by CAs (Figure 4). The main core habitat patches were located in the north and center of the central basin of Iran. The largest core habitat patch was Core1 (Kavir area), located in the northern part of the central basin of Iran (about 25,300 km^2, 26% CAs coverage). The second-largest core habitat patch was Core2 (Touran area), located near Core1 (about 24,500 km^2, 60% CAs coverage). The third-largest core habitat patch was Core3 (Naybandan area) in the center of the central basin of Iran (about 10,000 km^2, 90% CAs coverage) (Figure 4, Table S3). Overall road density in core habitat patches was about 2 m/km^2, with the highest road density seen in Core4 (DarehAnjir area) and Core5 (Bahram–e-Goor area) (about 17 m/km^2) and the lowest in Core3 (Naybandan area) and Core6 (Boroeeyeh area) (0 m/km^2) (Table S3). The gazelles' niche overlap hotspots included four overlapped core habitat patches with a total area of about 19,400 km2, with about 66% coverage by CAs (Figure 5).

The connectivity for goitered gazelle was mainly maintained in the northern and western parts of the central basin of Iran (Figure 3). The highest connectivity was predicted to be among Core1 (Parvar area), Core2 (Touran area), and Core3 (Mooteh area). We identified roadkill hotspots of goitered gazelle within corridors, which were 27 times bisected by roads (Figure 3). The connectivity for jebeer gazelle was mainly maintained from the north to south parts of the central basin of Iran (Figure 4). The highest connectivity was predicted to be among Core1 (Kavir area), Core2 (Touran area), Core3 (Naybandan area) and Core4 (DarehAnjir area). We identified roadkill hotspots of jebeer gazelle within corridors, which were 10 times bisected by roads (Figure 4).

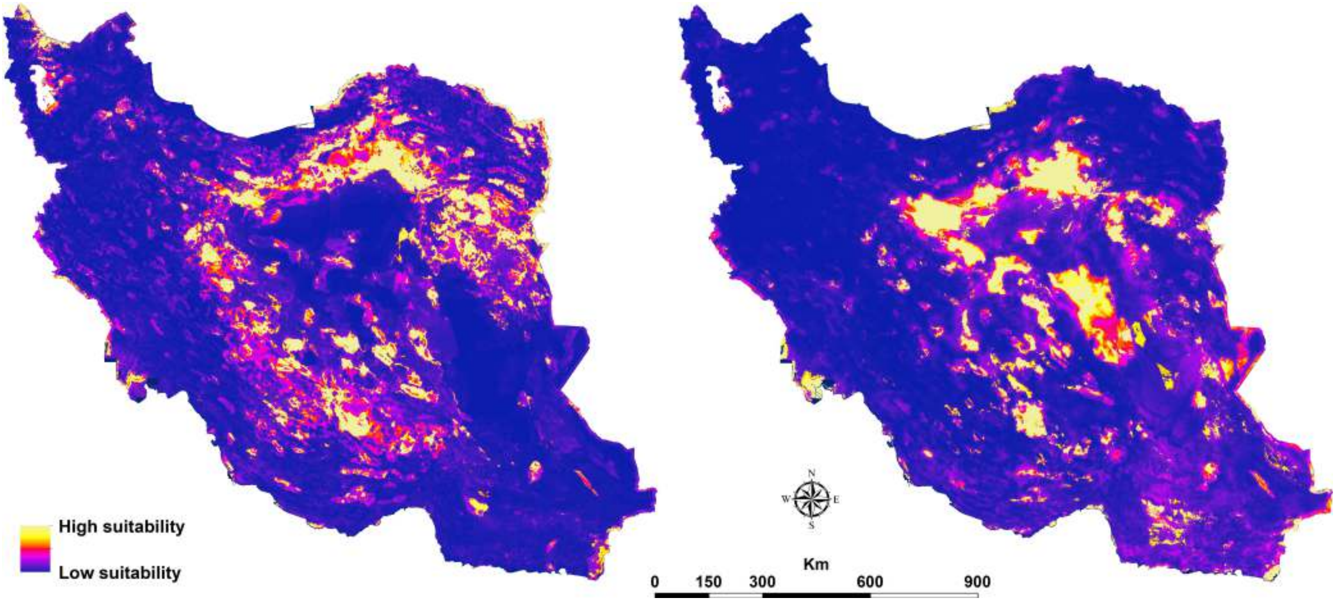
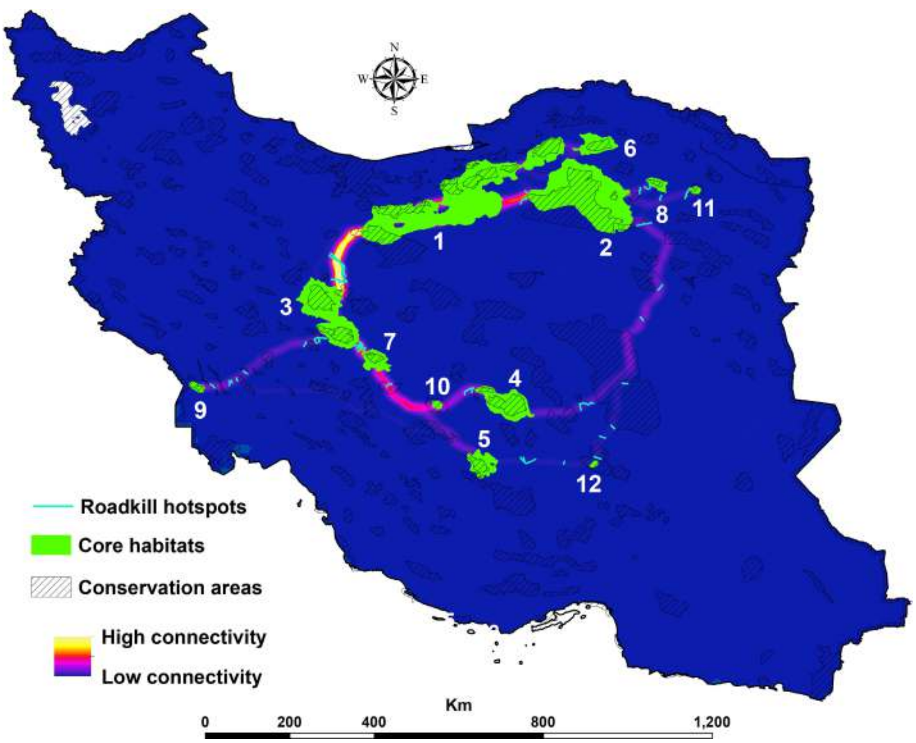


FIGURE 2 Ensemble habitat suitability map for goitered gazelle (right) and jebeer gazelle (left) with occurrence points of each gazelle species in Iran based on RF, MaxEnt, and GBM models.

FIGURE 3 Core habitat patches, contiguous corridors and roadkill hotspots for goitered gazelle in Iran (the name of core number s are available in Table S2).



4 | DISCUSSION

The study of species in arid ecosystems can be difficult because the harsh environmental conditions constrain research in these ecosystems. The scarcity of information on ungulate species makes managing them a challenge, as managers often have to rely on anecdotal and not empirical evidence to determine how to protect and manage them. Identifying core habitat patches and connectivity paths in arid environments, such as those we demonstrated in this study provides better accuracy over anecdotal information and enables the management and conservation efforts in these harsh desert environments. This study is the first to identify core habitat patches and corridors for two sympatric semi-desert gazelles in Iran. Our results revealed that distance to CAs, elevation,

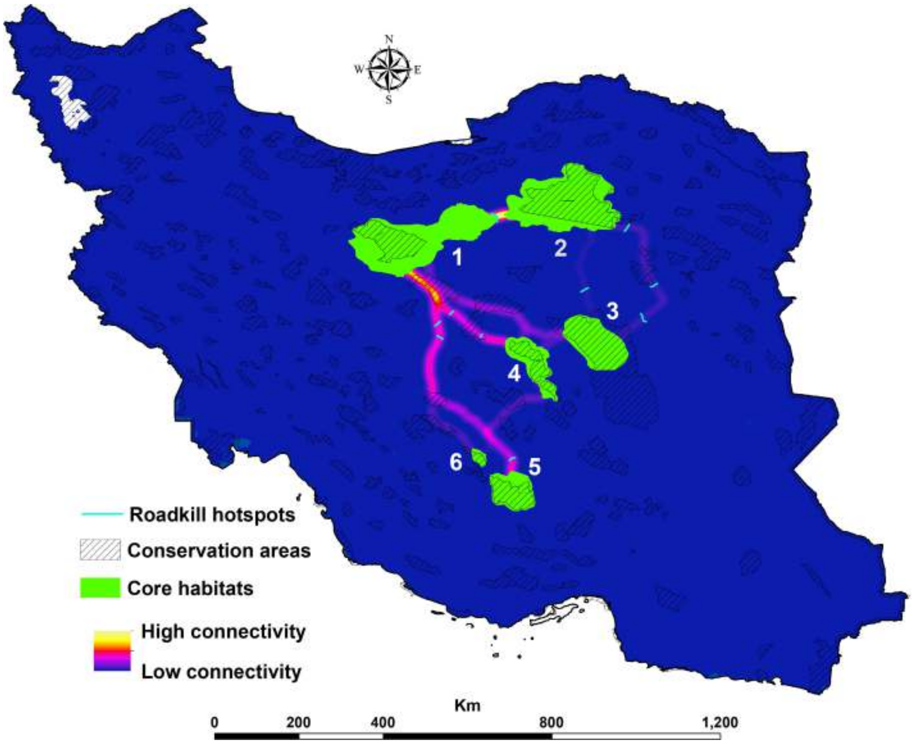


FIGURE 4 Core habitat patches, contiguous corridors and roadkill hotspots for jebeer gazelle in Iran (the name of core numbers are available in Table S3).

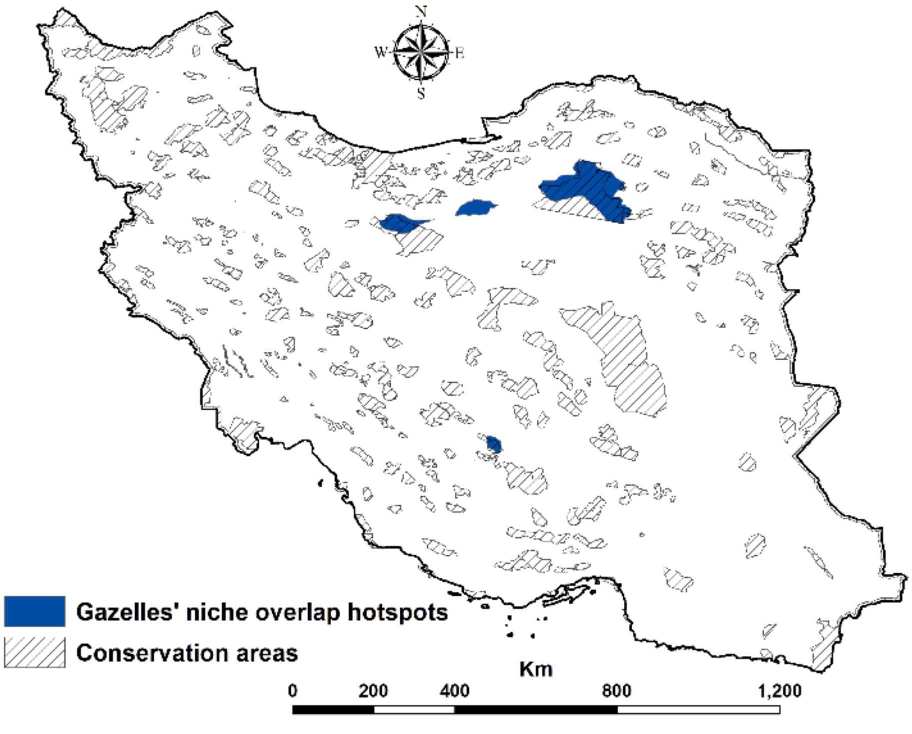


FIGURE 5 The niche overlap hotspots of goitered gazelle and jebeer gazelle in Iran.

annual mean temperature (BIO1), low density of semi-arid grasslands, and NDVI were the most influential variables for predicting habitat suitability for two gazelle species in Iran. We identified the crucial core habitat patches for the conservation of both species in Iran; these habitats concentrated in the northern parts of the central basin of Iran. CAs covered 40% and 53% of core habitat patches for goitered gazelle and jebeer gazelle in Iran, respectively. About two-thirds of gazelles' niche overlap hotspots were covered by CAs.

4.1 | Variable contributions

Many large mammals only persist in fragmented populations, often confined to CAs that are increasingly isolated

(DeFries et al., 2007). In addition, many CAs are isolated and not large enough for a viable population of herbivores (Kuemmerle et al., 2011). Karami et al. (2016) reported that the population of herbivores has declined severely in non-CAs in Iran; consequently, CAs have an important role in protecting gazelle species from poaching and habitat loss. Soofi et al. (2022) introduced goitered gazelle and jebeer gazelle as the fourth and sixth most poached ungulates in Iran and indicated that poaching in non-CAs is significantly higher than CAs. Distance to CAs has not been widely used in previous studies of herbivores in Iran (e.g., Hosseini et al., 2019; Khosravi et al., 2016; Shams-Esfandabad et al., 2019) and our results revealed that this variable is important for habitat modeling of gazelles.

Elevation may indirectly affect the distribution of goitered gazelle as it has a direct effect on climatic conditions. The preferred elevation by goitered gazelle was 1000 to 2000 m, which could show the dependence of the species on *Artemisia* sp. vegetation type (Khosravi et al., 2016). Shams-Esfandabad et al. (2019) introduced elevation as the most important factor for goitered gazelle in Isfahan Province, central Iran. They also revealed that elevation of 1000 m above sea level was the threshold for increasing the probability of occurrence for goitered gazelle in their study area, which is consistent with our results.

Annual mean temperature was the third most important environmental variable for goitered gazelle and the second most important variable for jebeer gazelle. Our results confirm the findings of previous studies on the importance of annual mean temperature in habitat modeling for these two gazelles in Iran (i.e., Farashi et al., 2017; Hosseini et al., 2019; Khosravi et al., 2016). Low density of semi-arid grasslands and NDVI were the fourth most important variable in habitat modeling for goitered gazelle and jebeer gazelle, respectively. Farashi et al. (2017) introduced NDVI as the second most important variable for threatened mammal species in Iran and Khosravi et al. (2016) proposed vegetation type as the second most important variable for goitered gazelle in their study area, which is in line with our observations.

4.2 | Core areas, connectivity, and CAs

Less than 30% of Core1 and about 50% of Core2 for both species were protected by CAs; in addition, these cores had the highest contribution to connectivity for these two gazelle species. Therefore, considering Core1 and Core2 as the areas of the landscape for conservation is critical for expanding network connectivity. Core8 (ShirAhmad area) for goitered gazelle, and Core4 (DarehAnjir area), and Core5 (Bahram–e- Goor area) for jebeer gazelle had the highest density of roads. The vulnerability of these cores is due to the potential for vehicle collisions and the concentration of human activities. Human access in these areas increases the risk of poaching as a common threat for both species (Soofi et al., 2019). Road networks facilitate human access to remote areas and increase the intensity of poaching (Carter et al., 2020). Based on the results of Soofi et al. (2022), nearly 40% of poached goitered gazelles and jebeer gazelles were shot or captured by poachers, which indicates the risk of road expansion outside the CAs in Iran (Mohammadi et al., 2018).

Roads bisected goitered gazelle corridors more often than jebeer gazelle. It seems that the habitat was more fragmented and connectivity had more challenges for goitered gazelle than jebeer gazelle. In this regard, identifying roadkill hotspots for mitigating mortality risk and improving connectivity are necessary for improving the conservation and management of both species. Results of research conducted by Zhang, Jiang, Cai, et al. (2021) revealed that railways and highways were the most important factors that affected the distribution of the Przewalski's gazelle (*Procapra Przewalskii*) by fragmenting the habitat corridors of the species.

Our resistant kernel analysis revealed that CAs covered about 40% and 55% of identified core habitat patches for goitered gazelle and jebeer gazelle, respectively. In addition, this coverage was about two-thirds of gazelles' niche overlap hotspots. Our result is consistent with Malakoutikhah et al. (2020) in the central basin of Iran; their results revealed that about 23% of identified suitable habitats for goitered gazelle were covered by CAs. Similarly, Liang et al. (2021) showed that about half of suitable habitats and corridors for an endemic gazelle species in the Tibetan Plateau were unprotected. Our finding reveals that the current CAs inadequately cover and protect the core habitat patches and corridors identified in this study. Hence, our findings serve as crucial guidance for the expansion of existing CAs and establishment of new CAs in locations that could optimally preserve core habitat patches and promote connectivity for both gazelle species.

4.3 | Limitations in the habitat suitability modeling

The Lack of access to the variable of water stations for gazelle species was one of our limitations in habitat suitability modeling. However, these water stations are located mainly in CAs, and applying distance to CAs variable in habitat modeling could be able to overcome this limitation. We also considered distance to river as a water source variable in primary modeling; however, this variable had a minor importance in the modeling. Therefore, we did not consider this variable for habitat modeling. Even by considering this limitation, the results of the model evaluation for both gazelle species were excellent. In addition, we consider a conservative threshold (i.e., 10%) to categorize continuous habitat suitability maps (Almasieh et al., 2023; Puddu & Maiorano, 2016), which core habitat patches represent highly suitable areas.

4.4 | Implications for conservation

Landscapes with small CAs that lack intermediate corridors can lead to a decline in the populations of wild species (Carter & Linnell, 2016; Farr et al., 2019). Almost half of the identified core habitat patches of both species were located outside CAs. Due to poaching outside these areas (Soofi et al., 2022), it is necessary for conservation managers to increase regular monitoring and establish new CAs according to the core habitat patches introduced here for the two gazelles. We did not include no-hunting areas (NHAs, a non-IUCN conservation category in Iran in order to prevent poaching (Soofi et al., 2022)) in distance to CAs variable and to assess the CAs coverage as they do not have an IUCN status. As a post hoc analysis, NHAs covered 7.1% and 2.3% of core habitat patches for goitered gazelle and jebeer gazelle, respectively. However, these areas have inadequate personnel and facilities (i.e., rangers and stations), which means poaching is widespread even inside NHAs (Soofi et al., 2022). Therefore, we recommend a higher level of protection in NHAs to prevent poaching. In addition, non-CAs of gazelles' niche overlap hotspots have the highest priorities for expanding CAs, which could protect both gazelle species at the same time and with a lower budget.

Large herbivores including migratory species need extensive spatial requirements to support their populations (Ripple et al., 2015). For this reason, we strongly recommend the establishment of new CAs that are strategically positioned to effectively safeguard the identified network of core habitat patches and corridors of studied herbivores (Macdonald et al., 2019; Mohammadi, Lunnon, Moll, et al., 2021).

5 | CONCLUSION

The research presented here focused on identifying suitable habitats, core habitat patches, and the strongest potential corridors that connect the habitats of goitered gazelle and jebeer gazelle. Based on our results, both species are more strongly associated with areas of low human influence (away from roads, villages, and agricultural lands). Moreover, our results showed that both species are highly dependent on CAs. Based on our results, we recommend: (1) conservation of habitats identified in unprotected portions of gazelles' niche overlap hotspots and important core habitat patches (particularly Core1 and Core2), (2) protection and enhancement of habitat quality and connectivity along important corridors between core habitat patches, particularly between Core1 and Core2. The present study highlighted the opportunity of designating new CAs for conservation of two widespread gazelle species and for promoting connectivity by limiting road impacts.

AUTHOR CONTRIBUTIONS

Kamran Almasieh and Alireza Mohammadi: Conceptualization, Methodology, Software. **Kamran Almasieh and Alireza Mohammadi**: Data curation, Writing- Original draft preparation. **Alireza Mohammadi**: Visualization, Investigation. **Kamran Almasieh**: Supervision. **Kamran Almasieh and Alireza Mohammadi**: Software, Validation. **Kamran Almasieh and Alireza Mohammadi**: Writing- Reviewing and Editing.

ACKNOWLEDGMENTS

We would like to thank rangers and experts of the Department of Environment of Iran who provided occurrence points for this study. This study was supported by Research and Technology of Agricultural Sciences and Natural Resources University of Khuzestan (project number 1400/14). We also acknowledge Danial Nayeri for the editorial review of the manuscript.

CONFLICT OF INTEREST STATEMENT

The authors declare no potential conflicts of interest.

DATA AVAILABILITY STATEMENT

Relevant data used in this study are available as Supporting Information files. Moreover, data on habitat modeling in this study is available upon reasonable request from the authors.

ETHICS STATEMENT

All aspects of this study were approved by Agricultural Sciences and Natural Resources University of Khuzestan (project number 1400/14).

ORCID

Kamran Almasieh https://orcid.org/0000-0001-8735-8459
Alireza Mohammadi https://orcid.org/0000-0003-3701-6455

REFERENCES

Ahmadi, M., Farhadinia, M. S., Cushman, S. A., Hemami, M. R., Nezami Balouchi, B., Jowkar, H., & Macdonald, W. D. (2020). Species and space: A combined gap analysis to guide management planning of conservation areas. *Landscape Ecology*, *35*, 1505–1517.

Akbari, H., Moradi, H. V., Sarhangzadeh, J., & Shams-Esfandabad, B. (2014). Population status, distribution, and conservation of the chinkara, *Gazella bennettii*, in Iran (Mammalia: Bovidae). *Zoology in the Middle East*, *60*(3), 189–194.

Akbari, H., Varasteh Moradi, H., Rezaie, H.-R., & Baghestani, N. (2015). Seasonal changes in group size and composition of chinkara (*Gazella bennettii shikarii*) (Mammalia: Bovidae) in Central Iran. *Italian Journal of Zoology*, *82*(4), 609–615.

Almasieh, K., & Cheraghi, M. (2022). Habitat suitability, core habitats and diversity hotspots for the conservation of the mustelid species in Iran. *Global Ecology and Conservation*, *36*, e02120.

Almasieh, K., Mirghazanfari, S. M., & Mahmoodi, S. (2019). Biodiversity hotspots for modeled habitat patches and corridors of species richness and threatened species of reptiles in Central Iran. *European Journal of Wildlife Research*, *65*, 92.

Almasieh, K., Rouhi, H., & Hasti, F. (2023). Identifying core habitats and connectivity paths for theconservation of mouflon (*Ovis gmelini*) in Western Iran. *Global Ecology and Conservation*, *41*, e02377.

Almasieh, K., Rouhi, H., & Kaboodvandpour, S. (2019). Habitat suitability and connectivity for the brown bear (*Ursus arctos*) along the Iran-Iraq border. *European Journal of Wildlife Research*, *65*, 57.

Ashrafzadeh, M. R., Khosravi, R., Adibi, M. A., Taktehrani, A., Wan, H. Y., & Cushman, S. A. (2020). A multi-scale, multi-species approach for assessing the effectiveness of habitat and connectivity conservation for endangered felids. *Biological Conservation*, *245*, 108523.

Ashrafzadeh, M. R., Khosravi, R., Mohammadi, A., Naghipour, A. A., Khoshnamvand, H., Haidarian, M., & Penteriani, V. (2022). Modeling climate change impacts on the distribution of an endangered brown bear population in its critical habitat in Iran. *Science of the Total Environment*, *837*, 155753.

Barbet-Massin, M., Jiguet, F., Albert, C. H., & Thuiller, W. (2012). Selecting pseudo-absences for species distribution models: How, where and how many? *Methods in Ecology and Evolution*, *3*, 327–338.

Brito, J. C., Del Barrio, G., Stellmes, M., Pleguezuelos, J. M., & Saarinen, J. (2021). Drivers of change and conservation needs for vertebrates in drylands: An assessment from global scale to Sahara-Sahel wetlands. *The European Zoological Journal*, *88*(1), 1103–1129.

Brown, J. L. (2014). SDMtoolbox: A python-based GIS toolkit for landscape genetic, biogeographic, and species distribution model analyses. *Methods in Ecology and Evolution*, *5*(7), 694–700.

Calambás-Trochez, L. F., Velazco, S. J. E., Hoffmann, P. M., Gurski, E. M., Brum, F. T., & Carlucci, M. B. (2021). Climate and land-use changes coupled with low coverage of protected areas threaten palm species in south Brazilian grasslands. *Perspectives in Ecology and Conservation*, *19*(3), 345–353.

Carter, N., Killion, A., Easter, T., Brandt, J., & Ford, A. (2020). Road development in Asia: Assessing the range-wide risks to tigers. *Science Advances*, *6*, eaaz9619.

Carter, N. H., & Linnell, J. D. C. (2016). Co-adaptation is key to coexisting with large carnivores. *Trends in Ecology and Evolution*, *31*, 575–578.

Chenoweth, J., Hadjinicolaou, P., Bruggeman, A., Lelieveld, J., Levin, Z., Lange, M. A., & Hadjikakou, M. (2011). Impact of climate change on the water resources of the eastern Mediterranean and Middle East region: Modeled 21st century changes and implications. *Water Resources Research*, *47*(6), 1–18.

Cushman, S. A., Landguth, E. L., & Flather, C. H. (2013). Evaluating population connectivity for species of conservation concern in the American Great Plains. *Biodiversity and Conservation*, *22*, 2583–2605.

DeFries, R., Hansen, A., Turner, B. L., Reid, R., & Liu, J. (2007). Land use change around protected areas: Management to balance human needs and ecological function. *Ecological Applications*, *17*(4), 1031–1038.

DoE (Department of the Environment of Iran). (2022). Department of the Environment of Iran. www.doe.ir Accessed 1 April 2021.

Durmus, M. (2010). Determination of home range size and habitat selection of gazelles (*Gazella subgutturosa*) by GPS telemetry in Şanliurfa. (doctoral dissertation, Middle East Technical University).

Ebrahimi, E., Sayahnia, R., Ranjbaran, Y., Vaissi, S., & Ahmadzadeh, F. (2021). Dynamics of threatened mammalian distribution in Iran's protected areas under climate change. *Mammalian Biology*, *101*(6), 759–774.

Emadodin, I., Reinsch, T., & Taube, F. (2019). Drought and desertification in Iran. *Hydrology*, *6*(3), 66.

Erasmus, B. F., van Jaarsveld, A. S., Chown, S. L., Kshatriya, M., & Wessels, K. J. (2002). Vulnerability of south African animal taxa to climate change. *Global Change Biology*, *8*(7), 679–693.

Eskildsen, A., Roux, P. C., Heikkinen, R. K., Høye, T. T., Kissling, W. D., Pöyry, J., Wisz, M. S., & Luoto, M. (2013). Testing species distribution models across space and time: High latitude butterflies and recent warming. *Global Ecology and Biogeography*, *22*, 1293–1303.

Evans, J. P. (2009). 21st century climate change in the Middle East. *Climatic Change*, *92*(3), 417–432.

Fadakar, D., Bärmann, E. V., Lerp, H., Mirzakhah, M., Naseri Nasari, M., & Rezaei, H. R. (2020). Diversification and subspecies patterning of the goitered gazelle (*Gazella subgutturosa*) in Iran. *Ecology and Evolution*, *10*(12), 5877–5891.

Fadakar, D., Mirzakhah, M., Naderi, S., Barmann, E. V., Nasari, M. N., Gorji, F. M., & Rezaei, H. R. (2019). The first record of mitochondrial haplotypes of *Gazella marica* (Artiodactyla, Bovidae) in wild populations in Iran. *Mammalian Biology*, *95*, 181–187.

Farashi, A., Shariati, M., & Hosseini, M. (2017). Identifying biodiversity hotspots for threatened mammal species in Iran. *Mammalian Biology*, *87*, 71–88.

Farr, M. T., Green, D. S., Holekamp, K. E., Roloff, G. J., & Zipkin, E. F. (2019). Multispecies hierarchical modeling reveals variable responses of African carnivores to management alternatives. *Ecological Applications*, *29*, e01845.

Fick, S. E., & Hijmans, R. J. (2017). Worldclim 2: New 1-km spatial resolution climate surfaces for global land areas. *International Journal of Climatology.*, *37*(12), 4302–4315.

FRWMO (Forest, Range and Watershed Management Organization of Iran). (2010). Iranian forests, Range and Watershed Management Organization National Land use/Land cover map.

Ghoddousi, A., Bleyhl, B., Sichau, C., Ashayeri, D., Moghadas, P., Sepahvand, P. K., Hamidi, A., Soofi, M., & Kuemmerle, T. (2020). Mapping connectivity and conflict risk to identify safe corridors for the Persian leopard. *Landscape Ecology*, *35*(8), 1809–1825.

Ghoddousi, A., Soofi, M., Hamidi, A. K., Ashayeri, S., Egli, L., Ghoddousi, S., Speicher, J., Khorozyan, I., Kiabi, B., & Waltert, M. (2019). The decline of ungulate populations in Iranian protected areas calls for urgent action against poaching. *Oryx*, *53*(1), 151–158.

Heffelfinger, L. J., Stewart, K. M., Bush, A. P., Sedinger, J. S., Darby, N. W., & Bleich, V. C. (2018). Timing of precipitation in an arid environment: Effects on population performance of a large herbivore. *Ecology and Evolution*, *8*(6), 3354–3366.

Hemami, M. R., & Groves, C. P. (2001). Iran. In D. P. Mallon & S. C. Kingswood (Eds.), compilers *Antelopes. Part 4: North Africa, the Middle East, and Asia. Global survey and regional action plans, Middle East* (pp. 114–118). IUCN/SSC Antelope Specialist Group.

Hosseini, M., Farashi, A., Khani, A., & Farhadinia, M. S. (2019). Landscape connectivity for mammalian megafauna along the Iran-Turkmenistan-Afghanistan borderland. *Journal for Nature Conservation*, *52*, 125735.

IUCN SSC Antelope Specialist Group. (2017a). *Gazella subgutturosa*. The IUCN Red List of Threatened Species 2017: e.T8976A50187422. https://doi.org/10.2305/IUCN.UK.2017-2.RLTS.T8976A50187422.en

IUCN SSC Antelope Specialist Group. (2017b). *Gazella bennettii*. The IUCN Red List of Threatened Species 2017: e.T8978A50187762. https://doi.org/10.2305/IUCN.UK.2017-2.RLTS.T8978A50187762.en

Jorgensen, N., Leary, J., Renz, M., & Mahnken, B. (2021). Characterizing the suitable habitat of *Miconia calvescens* in the east Maui watershed. *Management of Biological Invasions*, *12*(2), 313–330.

Kaboodvandpour, S., Almasieh, K., & Zamani, N. (2021). Habitat suitability and connectivity implications for the conservation of the Persian leopard along the Iran–Iraq border. *Ecology and Evolution*, *11*, 13464–13474.

Kaky, E., Nolan, V., Khalil, M. I., Mohammed, A. M. A., Jaf, A. A. A., Mohammed-Amin, S. M., Mahmood, Y. A., & Gilbert, F. (2023). Conservation of the Goitered gazelle (*Gazella subgutturosa*) under climate changes in Iraq. *Heliyon*, *9*(2), e12501.

Karami, M., Ghadirian, T., & Faizolahi, K. (2016). *The atlas of the mammals of Iran*. Department of the Environment of Iran.

Karami, M., Hemami, M. R., & Groves, C. P. (2002). Taxonomic, distributional and ecological data on gazelles in Iran. *Zoology in the Middle East*, *26*, 29–36.

Karami, M., Hutterer, R., Benda, P., Siahsarvie, R., & Kryštufek, B. (2008). Annotated check-list of the mammals of Iran. *Lynx (Praha)*, *39*, 63–102.

Khosravi, R., Hemami, M. R., Malekian, M., Silva, T. L., Rezaei, H. R., & Brito, J. C. (2018). Effect of landscape features on genetic structure of the goitered gazelle (*Gazella subgutturosa*) in Central Iran. *Conservation Genetics*, *19*, 323–336.

Khosravi, R., Hemami, M. R., Malekian, M., et al. (2016). Maxent modeling for predicting potential distribution of goitered gazelle in Central Iran: The effect of extent and grain size on performance of the model. *Turkish Journal of Zoology*, *40*, 574–585.

Kuemmerle, T., Radeloff, V. C., Perzanowski, K., Kozlo, P., Sipko, T., Khoyetskyy, P., Bashta, A.-T., Chikurova, E., Parnikoza, I., Baskin, L., Angelstam, P., & Waller, D. M. (2011). Predicting potential European bison habitat across its former range. *Ecological Applications*, *21*(3), 830–843.

Landguth, E. L., Hand, B. K., Glassy, J., & Cushman, S. A. (2012). UNICOR: A species connectivity and corridor network simulator. *Ecography*, *35*, 9–14.

Lelieveld, J., Hadjinicolaou, P., Kostopoulou, E., Chenoweth, J., El Maayar, M., Giannakopoulos, C., & Xoplaki, E. (2012). Climate change and impacts in the eastern Mediterranean and the Middle East. *Climatic Change*, *114*(3), 667–687.

Liang, J., Ding, Z., Jiang, Z., Yang, X., Xiao, R., Singh, P. B., Hu, Y., Guo, K., Zhixiang Zhang, Z., & Hu, H. (2021). Climate change, habitat connectivity, and conservation gaps: A case study of four ungulate species endemic to the Tibetan plateau. *Landscape Ecology*, *36*, 1071–1087.

Lundgren, E. J., Ramp, D., Stromberg, J. C., Wu, J., Nieto, N. C., Sluk, M., Moeller, K. T., & Wallach, A. D. (2021). Equids engineer desert water availability. *Science*, *372*(6541), 491–495.

Macdonald, D. W., Bothwell, H. M., Kaszta, Ż., Ash, E., Bolongon, G., Burnham, D., Can, E. Ö., Campos-Arceiz, A., Channa, P., Clements, G. R., Hearn, A. J., Hedges, L., Htun, S., Kamler, J. F., Kawanishi, K., Macdonald, E. A., Mohamad, S. W., Moore, J., Naing, H., … Cushman, S. A. (2019). Multi-scale habitat modelling identifies spatial conservation priorities for mainland clouded leopards (*Neofelis nebulosa*). *Diversity and Distributions*, *25*(10), 1639–1654.

Majka, D., Jennes, J., & Beier, P. (2007). CorridorDesigner: ArcGIS tools for designing and evaluating corridors. http://www.corridordesign.org/

Malakoutikhah, S., Fakheran, S., Hemami, M. R., Tarkesh, M., & Senn, J. (2020). Assessing future distribution, suitability of corridors and efficiency of protected areas to conserve vulnerable ungulates under climate change. *Diversity and Distributions*, *26*(10), 1383–1396.

Mansouri Daneshvar, M. R., Ebrahimi, M., & Nejadsoleymani, H. (2019). An overview of climate change in Iran: Facts and statistics. *Environmental Systems Research*, *8*(1), 1–10.

Mateo-Sánchez, M. C., Balkenhol, N., Cushman, S., Pérez, T., Domínguez, A., & Saura, S. (2015). A comparative framework to infer landscape effects on population genetic structure: Are habitat suitability models effective in explaining gene flow? *Landscape Ecology*, *30*(8), 1405–1420.

Meliane, M. K., Saidi, A., Petretto, M., Gilbert, T., & Nasri-Ammar, K. (2023). Temporal and spatial distribution of dorcas and slender-horned gazelles in a Saharan habitat. *The Journal of Wildlife Management*, *87*(5), e22408.

Mohammadi, A., Almasieh, K., Clevenger, A. P., Fatemizadeh, F., Rezaei, A., Jowkar, H., & Kaboli, M. (2018). Road expansion: A challenge to conservation of mammals, with particular emphasis on the endangered Asiatic cheetah in Iran. *Journal for Nature Conservation*, *43*, 8–18.

Mohammadi, A., Almasieh, K., Nayeri, D., Adibi, M. A., & Wan, H. Y. (2022). Comparison of habitat suitability and connectivity modelling for three carnivores of conservation concern in an Iranian montane landscape. *Landscape Ecology*, *37*, 411–430.

Mohammadi, A., Almasieh, K., Nayeri, D., Ataei, F., Khani, A., López-Bao, J. V., Penteriani, V., & Cushman, S. A. (2021). Identifying priority core habitats and corridors for effective conservation of brown bears in Iran. *Scientific Reports*, *11*, 1044.

Mohammadi, A., Almasieh, K., Wan, H. Y., Nayeri, D., Alambeigi, A., Ransom, J. I., & Cushman, S. A. (2021). Integrating spatial analysis and questionnaire survey to better understand human-onager conflict in southern Iran. *Scientific Reports*, *11*, 12423.

Mohammadi, A., Lunnon, C., Moll, R. J., Tan, C. K. W., Hobeali, K., Behnoud, P., Moghadas, P., Macdonald, D. W., & Farhadinia, M. S. (2021). Contrasting responses of large carnivores to land use management across an Asian montane landscape in Iran. *Biodiversity and Conservation*, *30*(13), 4023–4037.

Noroozi, J., Akhani, H., & Breckle, S. W. (2008). Biodiversity and phytogeography of the alpine flora of Iran. *Biodiversity and Conservation*, *17*(3), 493–521.

Ogutu, J. O., & Owen-Smith, N. (2005). Oscillations in large mammal populations: Are they related to predation or rainfall? *African Journal of Ecology*, *43*(4), 332–339.

Payne, B. L., & Bro-Jørgensen, J. (2016). Disproportionate climate-induced range loss forecast for the most threatened African antelopes. *Current Biology*, *26*(9), 1200–1205.

Puddu, G., & Maiorano, L. (2016). Combining multiple tools to provide realistic potential distributions for the mouflon in Sardinia: Species distribution models, spatial pattern analysis and circuit theory. *Hystrix*, *27*(1), 1–6.

Qadir, M., Qureshi, A. S., & Cheraghi, S. A. M. (2008). Extent and characterization of salt-a_ected soils in Iran and strategies for their amelioration and management. *Land Degradation and Development*, *19*, 214–227.

Rezaei, S., Mohammadi, A., Malakoutikhah, S., & Khosravi, R. (2022). Combining multiscale niche modeling, landscape connectivity, and gap analysis to prioritize habitats for conservation of striped hyaena (*Hyaena hyaena*). *PLoS One*, *17*(2), e0260807.

Ripple, W. J., Newsome, T. M., Wolf, C., Dirzo, R., Everatt, K. T., Galetti, M., Hayward, M. W., Kerley, G. I. H., Levi, T., Lindsey, P. A., Macdonald, D. W., Malhi, Y., Painter, E. L., Sandom, C. J., Terborgh, J., & van Valkenburgh, B. (2015). Collapse of the world's largest herbivores. *Science Advances*, *1*(4), e1400103.

Shams-Esfandabad, B., Ahmadi, A., & Yusefi, T. (2019). Seasonal changes in the distribution of suitable habitats for the Persian goitered gazelle (*Gazella subgutturosa*) in Isfahan province. *Journal of Wildlife and Biodiversity*, *3*(1), 58–65.

Shams-Esfandabad, B., karami, M., Hemami, M., Riazi, B., & Sadough, M. (2010). Habitat associations of wild goat in Central Iran: Implications for conservation. *European Journal of Wildlife Research*, *56*, 883–894.

Soofi, M., Ghoddousi, A., Zeppenfeld, T., Shokri, S., Soufi, M., Egli, L., Jafari, A., Ahmadpour, M., Qashqaei, A., Ghadirian, T., & Filla, M. (2019). Assessing the relationship between illegal hunting of ungulates, wild prey occurrence and livestock depredation rate by large carnivores. *Journal of Applied Ecology*, *56*, 365–374.

Soofi, M., Qashqaei, A. T., Trei, J.-N., Shokri, S., Selyari, J., Ghasemi, B., Sepahvand, P., Egli, L., Nezami, B., Zamani, N., Yusefi, G. H., Kiabi, B. H., Balkenhol, N., Royle, A., Pavey, C. R., Redpath, S. M., & Waltert, M. (2022). A novel application of hierarchical modelling to decouple sampling artifacts from socio-ecological effects on poaching intensity. *Biological Conservation*, *267*, 109488.

Thuiller, W., Georges, D., Engler, R., & Breiner, F. (2016). Biomod2: Ensemble platform for species distribution modeling. R Package Version 3.4.6. http://CRAN.R-project.org/package/biomod2

Torabian, S., Mehrdad Ranaie, M., Akbari Feizabadi, H., & Chisholm, L. (2021). Integrating gap analysis and corridor design with less used species distribution models to improve conservation network for two rare mammal species (*Gazella bennettii* and *Vulpes cana*) in Central Iran. *Contemporary Problems of Ecology*, *14*(5), 550–563.

Wan, H. Y., Cushman, S. A., & Ganey, J. L. (2019). Improving habitat and connectivity model predictions with multi-scale resource selection functions from two geographic areas. *Landscape Ecology*, *34*(3), 503–519.

Wu, X., Dong, S., Liu, S., Su, X., Han, Y., Shi, J., Zhang, Y., Zhao, Z., Sha, W., Zhang, X., Gao, F., & Xu, D. (2017). Predicting the shift of threatened ungulates' habitats with climate change in Altun Mountain National Nature Reserve of the northwestern Qinghai-Tibetan plateau. *Climatic Change*, *142*, 331–344.

Yusefi, G. H., Faizolahi, K., Darvish, J., Safi, K., & Brito, J. C. (2019). The species diversity, distribution and conservation status of the terrestrial mammals of Iran. *Journal of Mammalogy*, *100*, 55–71.

Yusefi, G. H., Safi, K., Tarroso, P., & Brito, J. C. (2021). The impacts of extreme climate change on mammals differ among functional groups at regional scale: The case of Iranian terrestrial mammals. *Diversity and Distributions*, *27*(9), 1634–1647.

Zhang, J., Jiang, F., Cai, Z., Dai, Y., Liu, D., Song, P., Hou, Y., Gao, H., & Zhang, T. (2021). Resistance-based connectivity model to construct corridors of the Przewalski's gazelle (*Procapra przewalskii*) in fragmented landscape. *Sustainability*, *13*(4), 1656.

Zhang, J., Jiang, F., Li, G., Qin, W., Wu, T., Xu, F., Hou, Y., Song, P., Cai, Z., & Zhang, T. (2021). The four antelope species on the Qinghai-Tibet plateau face habitat loss and redistribution to higher latitudes under climate change. *Ecological Indicators*, *123*, 107337.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Almasieh, K., & Mohammadi, A. (2023). Assessing landscape suitability and connectivity for effective conservation of two semi-desert ungulates in Iran. *Conservation Science and Practice*, *5*(12), e13047. https://doi.org/10.1111/csp2.13047