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Wild Bezoar Goat (*Capra aegagrus* Erxleben, 1777) in Agh-Dagh Protected Area, Ardabil, Iran: Habitat Suitability Modelling by Ecological Niche Factor Analysis

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Abstract: We used Ecological Niche Factor Analysis (ENFA) to describe the niche of Wild Bezoar Goat (*Capra aegagrus* Erxleben, 1777) in the Agh-Dagh Protected Area and to identify key factors that shape its distribution. The habitat suitability modelling showed that the species distribution is restricted to the marginal habitats, principally because of some repulsive factors, such as the human settlements and road networks. Furthermore, we found that the occurrence of the species is positively correlated with variables related to the topographical features, including elevation, scape terrain and slope characteristics. Since this area is the most important protected area in the province, immediate conservational actions should be undertaken for managing the repulsive factors.

Keywords: Conservation, habitat use, ecological niche, ENFA, marginality, specialisation.

Introduction

The Agh-Dagh Protected Area is the only main protected territory in Ardabil Province, which has been declared for conservation of the Wild Bezoar Goats (*Capra aegagrus*) population. One of the major threats to the species in the area is knowledge deficiency about the core suitable area and its periphery in order to concentrate the conservational actions. For this reason, we used the Ecological Niche Factor Analysis (ENFA) (Hirzel *et al.* 2002) for modelling the habitat suitability of the Wild Bezoar Goats. The ENFA is a widely used method that has a key advantage of requiring only species presence data, which is frequently the only type of data available. By using the ENFA, it is also possible to assess the contribution of each environmental variable to the final model allowing an extra validation of the results by an ecologist; in contrast, this cannot always be done, at least in a straightforward manner, with other ecological niche modelling methods (Sergio *et al.* 2007). Habitat suitability modelling for the studied species was previously developed by Farashi *et al.* (2010) in the Kolah Ghazi National Park, Isfahan Province. Based on the habitat suitability map, they concluded that the distribution of the plant communities, such as *Stipa* spp., *Ebenus stellata* and *Convolvulus leiocalycinus,* completely affect the habitat selection of the Wild Bezoar Goat. At the same time, the species has a narrow ecological niche and tends to marginal habitats (scores of global marginality, specialisation and tolerance range were 1.34, 1.94 and 0.51, respectively). Naderi *et al.* (2013) reported that the topographic features are the main factors that affect the wild goats' habitat selection in the Agh Dagh Protected Area.

The aim of the present study is to identify suitable habitats for the Wild Bezoar Goats in the area in order to be used by the responsible authorities for conservational actions.

Material and Methods

Study area

The markedly Mediterranean climate with a pro-

longed cold winter and considerable rain and snow precipitation especially makes the study area an excellent habitat for diverse wild species. This area is located in the south of Ardabil, with altitude c.1900 m a.s.l. The Agh-Dagh Protected Area (37°37'N, 48°31'E) is mainly a mountainous region with suitable water resources in the form of seasonal springs. The main reason for declaring the area as a protected territory is the presence of *Capra aegagrus*, which unfortunately has shown a decreasing trend from 1990s (Personal communication, Department of Environment, Ardabil, 2012). The mismanagement as well as the illegal hunting and existence of human activities, such as ranching, traffic, group mountaineering, especially in the breeding season (personal observation), are the main threatening factors for the species conservation.

Ecological niche factor analysis

The ENFA quantifies the niche that a species occupies by comparing its distribution in an ecological space defined by one or more variables (known as ecogeographical variables, EGVs), with the distribution of all cells in that space, focusing on the marginality (the species niche position) and specialisation of the species (Hirzel *et al.* 2002, Elith, Burgman 2003). The ENFA uses only data on the presence of the target species and requires a raster map that describes the species occurrence and is encoded in Boolean format. In this method, the environmental variables are categorised into two types of uncorrelated factors: marginality (representing the deviation of a species mean distribution from the global mean, which can be + or –) and specialisation (a ratio comparing the range of the global distribution to that of the species). Together, these define a hyper-volume of space corresponding to the ecological niche of the species (Hirzel *et al.* 2002, Zaniewski *et al.* 2002). Habitat suitability indices (scaled to range between 0 and 100) are computed by comparing the above-mentioned factors for the observed species distribution, with the distribution of the environmental variables in the whole area (Hirzel *et al.* 2002, Zaniewski *et al.* 2002). A median of an axis neighbourhood cell will be given 100 and the outside cell from the species distribution would have zero score (Hirzel *et al*. 2002, 2006). Biomapper software was used for the analyses.

The continuous Boyce Index (Hirzel *et al*. 2002, 2006) was used for evaluating the robustness and the predictive power of the habitat suitability, which the model ranges from 0 to 1. This index assesses the relation between the observed and expected number of validation points in different habitat suitability values and give us some guidelines for classifying the habitat suitability values. A K-fold cross validation method was applied to evaluate the central tendency and variance of the Boyce Index (Boyce *et al.* 2002).

Environmental data

The study area was modelled as a raster map (1 km^2 per pixel) overlaid on the UTM Coordinate System by IDRISI software. By classifying environmental variables, totally eight ecogeographical variables (EGVs) were used in the analysis: (1) topographic variables, including the altitude (in meters), slope (derived from the digital elevation model) and the aspect (derived from the slope data); (2) Water resources' distribution (springs) (computed as a quantitative raster layer, attributing to each pixel its minimum distance to the springs). Each layer was formatted in a quantitative raster format. This was achieved using the *Spatial Analyst* extension in *ArcGIS v9.2*; (3) Repulsive factors (variables related to the human population pressure on the environment) including road's network (in m) and distance to the human settlements (in m); (4) Habitat variables, including vegetation community patches and a predator distribution map. Each land cover type constituted a separate layer that was encoded in Boolean format. The distribution of each EGV was normalised by the Box-Cox algorithm (Sokal, Rohlf 1981). All layers were smoothed using the median index calculated over the 10×10 neighbouring spatial units of a focal cell and exported as IDRISI files into the software *Biomapper 4.0.*

Fig. 1. Study area in North-western Iran, Ardabil Province

Results and Discussion

Our analysis showed a high global marginality value (1.98), which indicated that the species occupied a relatively small portion of the available environment as defined by the EGVs in the study area. The global tolerance index was generally low (0.23) and indicated low tolerance towards deviations from the species optimal conditions (Table 1). The combination of all EGVs was represented ideally by the marginality factor characterising the ecological niche at the geographical scale. Alone, the marginality factor accounted for 72.1% of the total model variance. Wild goats preferentially used habitats at higher slopes than available and positively correlated with variables related to other topographical features, including the elevation and the scape terrain. The Geometric Algorithm proposed by Hirzel *et al. (2002, 2006)* was used to derive the habitat suitability (HS) values for each cell in the reference area (Table 2). The resulting reclassified maps showed four HS classes (highly suitable, suitable, intermediate and unsuitable) for the species in the study area (Fig. 2). The accuracy of the habitat suitability maps was evaluated by cross validation methods and since AVI and CVI (the presence only evaluators) was around 0.5. It could be concluded that the model was able to distinguish suitable and unsuitable habitats, and the set of EGVs allowed to distinguish the specific habitats preferred by the species from the overall available habitats.

However, the high standard deviations indicated rather low robustness. The Boyce indices provided a more continuous assessment of the model and predictive map accuracy. The values of these indices were positive and high. The large standard deviation around the most estimates reflected a low robustness, especially in the case of the continuous model. Nevertheless, the reclassified HS maps were reliable to predict the distribution of HS throughout the protected area as indicated by the high and positive values of the Boyce *index*.

The produced HS map showed a core favourable habitat in the area with the highest distances from human settlements and lower distance from some habitat variables such as topographic features and seasonal springs. The habitat suitability decreased with moving from the north-west to the west because of the increase in the repulsive factors such as the presence of villages, roads and gardens. These findings were in agreement with the previous study that showed the optimal habitat tends to the marginal habitats (Naderi *et al*. 2013). This trend had not been reported in the Kolah Ghazi National Park where rural community was lacking and therefore similar repulsive

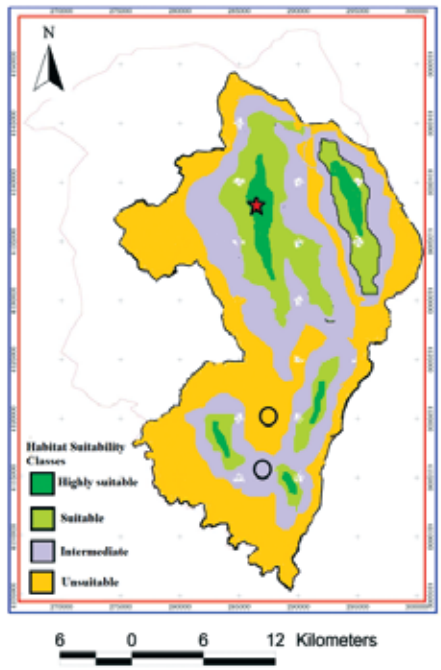

Fig. 2. Habitat suitability map for the Wild Bezoar Goats based on the Ecological Niche Factor Analysis and indicating areas of high and marginal suitability. The locations of mountaineer activity (asterisks) as well as the location of the posts of duty (circles) are shown

factors were lacking in that national park (Farashi *et al*. 2010). Some patches of highly suitable habitats, however, were also found in areas where the group mountaineering activity was carried out each year. We observed that hundreds of people were involved in such a yearly activity organised by the governmental agencies. A fact of greater concern was that these activities were organised each year during the autumn season when the rutting season was ongoing. Patches of suitable habitats that cover both water and food resources as well as some very steep areas were also found at the edge of the western south parts located at about 4 km from certain local factories.

The avoidance of trail densities related to a high human population pressure as demonstrated by the species, implies avoidance of rural and nomadic societies by the Wild Bezoar Goats. Consequently, the human presence was recommended to move away from suitable core areas into more marginal areas containing less suitable habitats. Apparently, the dispersed shrub communities retain their considerable influence on the suitable habitats and, accordingly, the destruction of the Wild Bezoar Goats' habitat is more common in areas with high HS. Therefore, if the encroachment by these communities continues at its current rate, the wild goats will be shifted further to the intermediate habitat conditions at the margins of

Table 1. Scores of the Ecological Niche Factor Analysis. The marginality scores indicate the average distance between the ecological conditions in which the wild goats were found and the average conditions in the study area. High values (> 0.5) indicate higher use by the species than expected on availability. Specialisation scores indicate the proportion of the ecological conditions in the study area, under which the species was found

	Marginality (72.1%)	**Specialisation 1 (19%)**	**Specialisation 2 (10%)**
Distance to the water resources	0.212	- 0.032	0.67
Distance to the roads	-0.68	0.034	-0.032
Distance to the human settlements	-0.845	0.462	-0.31
Scape terrain	-0.243	- 0.312	0.29
Elevation	0.561	0.51	0.043
Aspect	0.385	0.21	0.09
Slope	0.945	-0.25	-0.31
Vegetation patches	0.131	-0.024	0.04
Predator distribution	-0.651	0.038	0.07
Global tolerance: 0.237			

Table 2. Boyce indices for the selection of the best algorithm

	Algorithm	SD ± Boyce Index
1	Median	0.476 ± 0.656
2	Harmonic	0.120 ± 0.897
3	Geometric	0.034 ± 0.890
4	Minimal Distance	0.065 ± 0.798

their niche. We believe that the effect of anthropogenic influences on wildlife distributions is that habitat alterations is the biggest threat to the survival of wildlife today (Achard *et al*. 2002, Brook *et al*. 2003).

On the grounds of the HS map, we strongly recommend that the mountaineering activity be relocated to the outside parts of the highly suitable area and a post of duty should be stabilised in the north-west parts of the territory. More control must be exerted over the native illegal hunting and deforestation.

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