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Modeling Habitat Requirements of Leopard (*Panthera pardus*) Using Genetic Algorithm in Golestan National Park

S. Abdollahi
Graduate of Environmental Science, Gorgan University of Agricultural Sciences and Natural Resources

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Abstract

Top predators are seen as keystone species of ecosystems. Knowledge of their habitat requirements is important for their conservation and for stability of the interacting wildlife communities. Recent environmental destructions have generally led to major habitat loss, so protection of the leopards' habitats is regarded as very important. As such, habitat management based on modeling is strongly recommended as a practical solution. The goal of this study was to model the habitat of leopard *Panthera pardus* in Golestan National Park, where it is endangered, and determine the most important parameters affecting its habitat. In this paper, I apply the technique ecological niche modeling using genetic algorithm for rule-set prediction (GARP) to predict the distributions of this species. The results of this study showed that the distribution of the leopard is affected by altitude, and prey density. This research also provides an algorithm for sample data management, which could be used in modeling habitats of the similar species.

Keywords: Leopard, Habitat modeling, GRAP, Golestan National Park

*Corresponding author; sabdollahi44@yahoo.com

1. Introduction

Conservationists recognize that the best way to save threatened species is to protect the places where they live. Identifying and protecting irreplaceable habitats in the context of local politics, economic stability and human needs is a key conservation objective in managing the species that their habitats. In efforts to protect or restore wildlife communities, top predators are seen as keystone species and indicators of the species richness of these communities (Gavashelishvili and Lukarevskiy, 2008). Each species has some requirements based on its behavioral, biological, genetic and evolutionary history to choose a habitat for survival and each habitat must provide these species requirements. By identifying species requirements within habitats we can define suitable areas for species survival (Nazeri *et al.,*, 2010). Prediction of species distribution is an important element of conservation biology. Management of endangered species for ecosystem restoration, species re-introduction, population viability analyses and human–wildlife conflicts often rely on habitat-suitability modeling (Hirzel *et al.,*, 2001). Models predicting the spatial distribution of species are sometimes called resource selection function or habitat suitability models – and are currently gaining interest. These models often help in understanding species niche requirements and predicting species potential distribution, and their use has been especially promoted to tackle conservation issues, such as managing species distribution, assessing ecological impacts of various factors (e.g. pollution, climate change), risk of biological invasions or endangered species management (Guisan and Thuiller, 2005). These models statistically relate field observations to a set of environmental variables, presumably reflecting some key factors of the niche, like climate, topography, geology or land-cover. They produce spatial predictions indicating suitability of locations for a target species, community or biodiversity. Different types of fit for various biological information in each modeling techniques are used to sample sites: (1) presence-only: occurrences of the target species are recorded; (2) presence/absence: each sample site is carefully monitored so as to assert with sufficient certainty whether the species is present or absent (Hirzel *et al.,* 2006).Presence-only modeling techniques are increasingly being used to study the distribution of many different organisms (Hirzel *et al.,* 2001).

The three presence-only techniques are Ecological Niche Factor Analysis (ENFA), Genetic Algorithm for Rule-set Prediction (GARP) and PCA-based approach. All three techniques are based on the ecological niche theory (Hutchinson, 1957) and use the environmental variables of locations where animals have been recorded as present to identify the niche occupied by a species. GARP differs from ENFA and PCA in that it is a machine-learning approach to modeling ecological niches of species. GARP develops a set of rules through an evolutionary refinement procedure by generating and testing a diverse range of possible solutions based on various rules from different statistical approaches including categorical and logistic regression models (Mandleberg, 2004). The canonical depiction of the species' niche relative to its environment allows one to evaluate which part of the available habitat is occupied and to assess to which extent the available habitat is utilized (Titeux *et al.,* 2006, Braunisch *et al.,* 2008). The leopard *Panthera pardus* is a top predator and the most adaptable, and hence the most widespread, wild representative of the family Felidae. Its range spreads from south Africa through the countries of sub-Saharan Africa, across the Middle East to south-east Asia and Java, and northwards to the Russian Far East (Nowell & Jackson, 1996). Leopards are found in a variety of habitats, from desert to rainforest and high mountains (Gavashelishvili & Lukarevskiy, 2008). According to the latest assessment of leopard status for the 2008 IUCN Red List of Threatened Species, the Persian leopard should be classified as 'endangered' under the category C2a(i) (Khorozyan 2008). Iran has been the stronghold of the Persian leopard population in the Middle East where a range of approximately 885,300 km^2 provides home for estimated 550-850 individuals. There are numerous current threats which could have a detrimental effect on Persian Leopard populations, including accidental and deliberate killing and habitat loss (Kiabi *et al.,* 2002). Previous research on the Persian leopard in Iran has focused on the species' population size and status (Kiabi *et al.,* 2002,), movement routing (Erfanian. 2011), genetic and phylogenetic analysis (Nassiri *et al.,* 2011), and habitat modeling (Omidi 2008). In this paper, we introduce GRAP (genetic algorithm for rule- set prediction) in order to: determine ranging patterns and habitat use by leopard, determine the most important requirements of Leopards' habitat and establish a management plan for leopards for Golestan National Park to ensure viable populations of the species are protected appropriately.

2. Materials and methods

2.1. Study area

Golestan National Park is located in the northeastern part of Iran near the border with Turkmenistan and covers an area of about 91895 hectares. The park is located east of the Caspian Sea between 37.40' N and 37.82'N and 55.85' E and 55.97' E (Madjnoonian *et al.,* 1999) shown in fig 1. The vegetation of the park can be divided into two zones: the Hyrcanian forest in east Alborz (the western section of the park with a high humidity) and the Iran-Turanian vegetation (the eastern section of the park where it is dry (Javanshir, 1976). The altitude varies from 400 m in Tang-e Rah to 2411 m at the summit of Divar Kaji Mountain, respectively. The park includes mountainous areas, hills and plains. The mountainous areas of the park are mostly located in the northern and western parts, with altitudes reducing gradually towards the steppes in the east. The average annual precipitation is 400 mm and the annual average temperature is 11.98^{o}C from April to October with 10.58^{o}C from December to March. Golestan National Park is the most important protected area of Iran with great habitats for Persian leopards because of its unique natural situation and the well-chosen location (Agili, 2005).

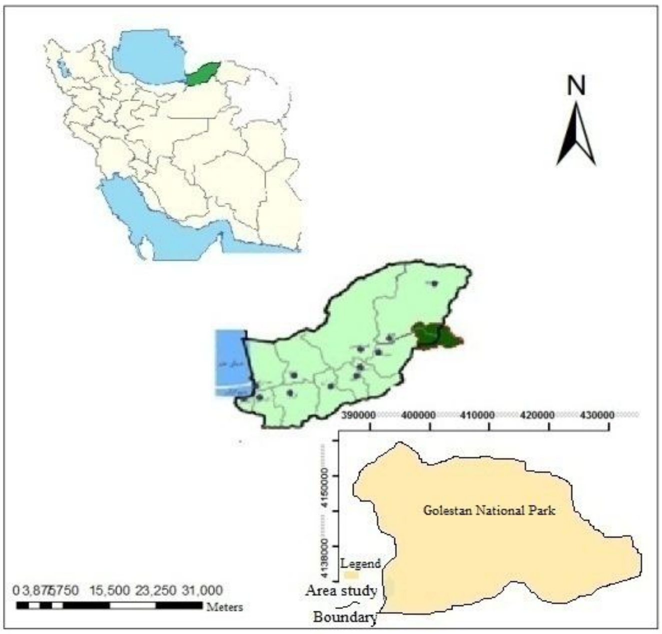

Figure 1. Geographical location of the study area

2.2. Data collection

Leopard distribution data used for the model analysis were collected from field observations and interviews with biologists and park managers from regional environmental agencies. Prey species distribution data were also obtained by means of field observations using GPS and map-based interviews with rangers and staff from the environmental office in Golestan National Park. Environmental data set used for this research were topographical features (e.g. altitude and slope), ecological data (e.g. frequency of forests and preys), and human infrastructures (e.g. distance to villages and road density). An ArcInfo Geographic Information System (GIS) was used to convert data from each variable to a grid with a 30×30 m cell size.

2.3. Genetic Algorithm for Rule-set Prediction – GARP Modelling System

In our study, the GRAP method was used to predict leopard distribution. GARP is a machine learning-based analytical package developed by Stockwell and Noble 1991 (Pouteau *et al.*, 2011). Genetic algorithms belong to a class of stochastic, machine learning, global search algorithms that use strategies mimicking biological evolution to generate vectors, each containing a sequence of environmental parameters, which can be modified to produce a model that satisfies a data set by the evolutionary refinement of a set of rules. Desktop GARP (DK-GARP v. 1.1.6) operates through using an iterative process of rule selection, testing, evaluation and incorporation or rejection (Anderson *et al.,*, 2003). The simplest rule is based on a single value of a variable (e.g. if temperature=7 °C and slope=30° then the species is predicted to be present). A second type, the BIOCLIM rule operates by enclosing the range of environmental values coinciding with the species locality records in a statistically defined envelope; the distribution of the species is predicted at those points that fall within the envelope (e.g. if temperature lies between 7 °C and 10°C, slope lies between 15° and 30° and aspect lies between 120° and 270°, then the species is predicted to be present). Other rules include the range rule, a generalization of the BIOCLIM rule, and the logit rule, useful when species are known to respond to environmental gradients. During model generation, each rule evolves through processes, such as mutation and cross-over, similar to those involved in the evolution of DNA. The accuracy of a model prediction, roughly defined by the proportion of species location data predicted correctly by the model, varies from one rule-set to the next. It is used to evaluate whether a particular rule is incorporated or rejected into the model (Guinan *et al.*, 2009).

2.3.1. Model generation

After the preparation of environmental variables, these layers were converted to Ascii format using ARC GIS software, also species presence layer was prepared in excel format including 119 presence points. To identify the most important parameters on leopard geographical distribution, environmental variables were prepared to eleven data set using data set manager. The model runs for each data set separately and results of models were evaluated to determine the most important parameters on leopard distribution. Then the occurrence data and the fourteen eco-geographic variables were imported into the GARP software. The percentage of the points to be used for 'training' i.e. model construction was specified as 67%. These points were randomly selected by GARP leaving the remaining test points for subsequent model evaluation. Test points (33%) were withheld completely from GARP's model building process and were only used for the internal evaluation process. Then, other combinations of the variables (other data set) were tested. This created models for eleven different data sets with twenty runs for each model. Each model was run twenty times, to reduce the impact of a chance relationship. Outputs of the model contained: predictive map of species presence and non-presence and excel file of results containing model evaluation, rules used for each predictive map and other cases related to the model. The model with the highest mean predictive accuracy out of the ten models was selected using the evaluation procedure described below. Another model was constructed using all of the variables to investigate whether including all fourteen variables produced a more accurate model.

2.3.2. GARP Intra-model evaluation

The presence data points set aside for model evaluation (33%) were used to test the model predictions automatically in the GARP software. To assess model performance, the model with the lowest omission error was selected. Omission error is the proportion of test points falling outside the predicted area (outtest/ntest), where outtest = the number of test points falling outside predicted areas and ntest = the number of test points. The commission index is the proportion of the study area predicted as presence. The mean omission error and mean commission indices were plotted for all eleven combinations of variables and the combination of variables with the lowest mean omission error was selected as the best model. The mean omission error was also calculated for the models constructed using all variables. A map of predicted occurrence was produced for the model with the lowest omission error. A composite map was produced by summing all twenty runs for each model, using a value of 1 for grid cells with predicted presence, and 0 for predicted absence. The resulting map of occurrence contained grid cells with values ranging from 0-20, representing the number of runs predicting leopard presence (20 in cells where all runs of the model predicted occurrence and zero where no runs predicted occurrence).

3. Results

Out of the eleven combinations of variables, topographical variables and preys had the lowest mean omission error (Table 1 and Figure 2). The other GARP models did not exceed the performance of this GARP model in terms of omission error. These models had a higher mean omission error (Table 1). After topographical variables and preys, preys and watercourses combination had the lowest mean omission error (Figure 3). The map of predicted occurrence for the model with the lowest mean omission error highlighted all areas where leopards are expected to occur. Summing all twenty runs from this model produced a composite map which revealed consistent patterns of leopard presence, with a high agreement between the suite runs (>18) in most areas (Figure 4).

Table 1. Mean omission/commission values for all GARP models

Model	Mean omission error	Mean commission error
all variables	13.24	27.69
Topographical variables+ preys	7.89	21.13
Topographical variables+ human infrastructures	25.72	37.62
Topographical variables+ watercourses	9.48	25.18
Topographical variables+ NDVI	11.76	41.52
Preys+ human infrastructures	14.01	31.37
Preys+ watercourses	8.19	18.94
Preys+ NDVI	11.23	23.73
human infrastructures+ watercourses	17.76	42.45
human infrastructures+ NDVI	21.84	34.4
watercourses + NDVI	12.18	29.36

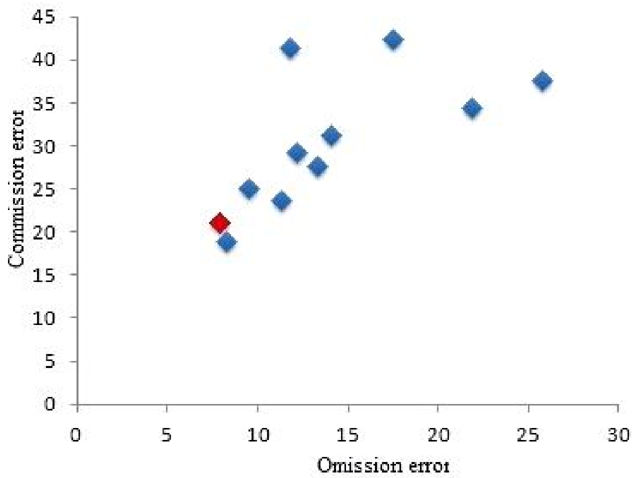

Figure 2. Mean omission/commission values for all eleven combinations of variables. The combination with the lowest mean omission error is highlighted in red.

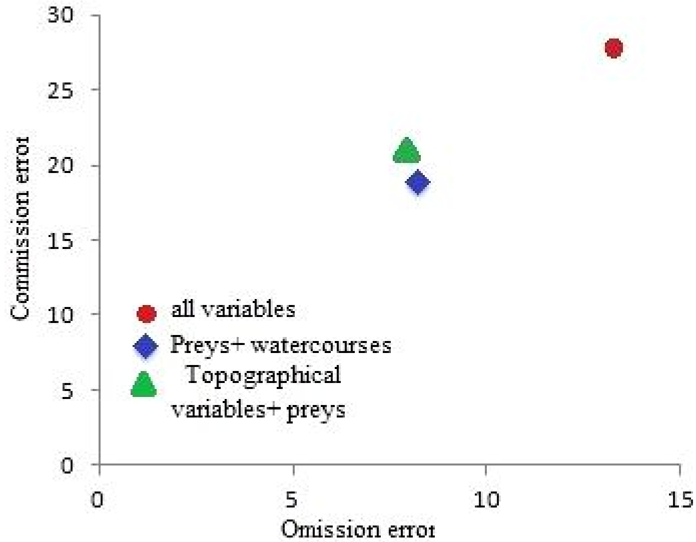

Figure 3. Mean omission/commission values for three models

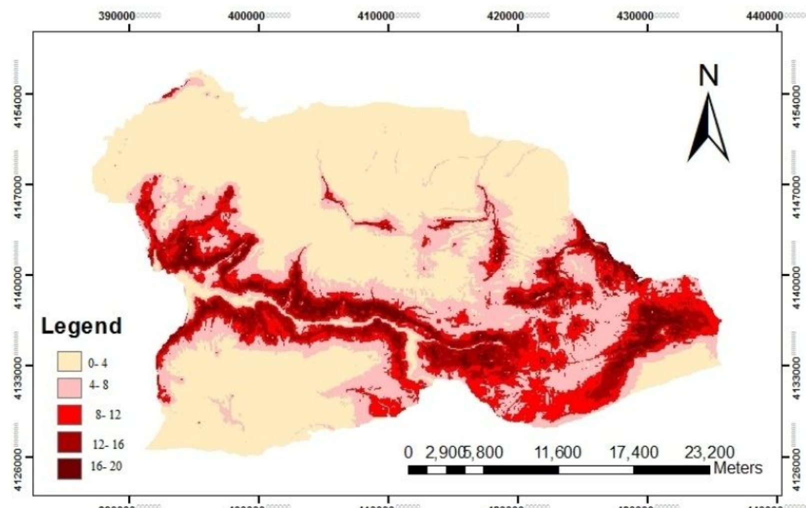

Figure 4. GARP model prediction of leopard occurrence (constructed using topographical variables and preys location)

4. Discussion and Conclusions

Effective conservation of wild populations requires an understanding of the relationship between populations and their habitats, preferably with predictive ability. A first step towards this is to determine which habitats are used with higher frequency (Canadas *et al.,* 2005). The objective of this study was to provide an accurate approach to quantifying habitat requirements for leopard in Golestan National Park. The results of this study showed that the distribution of the species is affected by altitude, preys density and watercourses (i.e. springs and rivers). Overall, the habitat suitability map represents an overlap between the best habitat for leopard, its preys' habitat (goitered gazelle, red deer, wild boar, wild goat and wild sheep). On the other hand, other parameters such as aspect, NDVI, and agricultural lands are the less important parameters to leopard habitat suitability. There are many studies that emphasize the importance of altitude and slope on leopard's habitat modeling (Mobargha, 2007; Omidi, 2008; Erfanian, 2011; Abdollahi, 2012). The results of this study show that the habitat suitable for leopard comprises 22% of the regions' area, averaging 1,200 m in altitude and a slope between 30 and 35% encompassing the western, central and southeastern parts of the Golestan National Park. This paper gives insights on the domains of GRAP application. It appears that the robustness of GRAP makes it particularly suitable and efficient when the quality of data is either poor (the absence data are unreliable) or unknown. The model we have constructed provides a tool for effective identification of potential leopard populations and habitats in the Golestan National Park for successful conservation and management of the species. Finally, understanding the habitat selection processes of wide-ranging large carnivores such as leopard is essential for developing conservation strategies to improve long-term viability. This study demonstrates that GRAP is a useful tool to explore the characteristics of the leopard's niche as well as to produce habitat suitability maps that can aid in conservation management.

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