



## The Re-evaluation of Golestan National Park Zoning with a Approach of Species Richness Hotspots, Iran

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### Abstract

In recent decades, the rate of extinction of species has been increased continually all over the world and lack of effective and efficient conservation strategies will lead to extinction of a large number of species. Determination of habitat suitability is an essential necessity for management and conservation of wildlife. Suitable habitats play a crucial role in the survival and reproduction of species; therefore, paying more attention to these areas in wildlife management and conservation will result in more effective conservation. In this study, the locations of presence of large carnivores and herbivores in Golestan National Park have been recorded during 2014- 2015 to predict the presence of the species and determine the environmental parameters affecting their presence, also to specify species richness hotspots in this area. For this purpose, the

modeling was performed by using the MaxEnt and Gap Analysis methods. The findings show that though the park's conservative zones do not adequately overlap with suitable habitats of some species such as gazelle and wolf, fortunately, these zones cover a significant proportion of the park's species richness hotspots. Certainly, modification and extension of the conservative coverage area of zones 1 and 2 to the park's areas of species richness hotspots containing a richness of 4 to 9 species, also modifying and extending the limits of these zones in favor of species whose habitat suitability has lower overlap with zones 1 and 2 will lead to more efficient conservation in Golestan National Park; therefore, as a result of revising the zoning of Golestan National Park, this goal can be approached in near future.

**Keywords:** MaxEnt, Gap Analysis, habitat modeling, species richness hotspots, Golestan National Park.

### Introduction

Conversion, fragmentation and destruction of habitat threaten the sustainable survival of wildlife, particularly carnivores, in a way that today protection of wildlife populations has become necessary and inevitable. Although preservation and protection of remaining populations in natural ecosystems is one of the most efficient means of protecting endangered species (Groves 2003, Rosenzweig 2003), However several studies show that current protected areas often fail to reflect the full range of a region's biodiversity and their coverage and inclusion level is lower than the desired global conservation goals. (Rodrigues *et al.* 1999, Margules and Pressey 2000). In fact, in the majority of cases, socio-economic,

aesthetic, or political criteria were given more weight in establishment of protected areas and this has reduced the protective value of these areas in many cases and there is an increasing necessity for protection of regions which are capable to provide a high level of protection for living organisms in an area.

Furthermore, evaluating the efficiency of current protected areas is a critical component of biodiversity conservation. In fact, in the first place, conservation planning and its performance evaluation will be possible by identification of areas containing the highest biodiversity (Maiorano *et al.* 2006, Brito *et al.* 2009). However, it is challenging to manage biodiversity when in many cases, the spatial distribution of species is hardly known.

For this reason, species distribution models serve as essential tools for management and conservation of biodiversity. Through using SDMs, field data and species' presence data, quantitative estimations of species' potential habitat and comparison of several areas in terms of their potential for presence of wildlife species can be provided.

On the other hand, having knowledge about factors which influence wildlife habitat selection is vital for proper management of species. Suitable habitat has substantial effect on survival and reproduction of wildlife and is thus given considerable attention.

Studying wildlife on large scale is difficult, or in many cases impossible. Therefore, the models which are able to link the geographical distribution of species and communities to their environment are needed to be used. Habitat suitability models can calculate the probability of a species occurrence in a particular location based on environmental conditions. Established more than 50 years ago, Golestan National Park (GNP) and Biosphere Reserve is the first national park in Iran and the Middle East, ranking among the top 10 national parks in the world in terms of biodiversity (encompassing 1360 species of plants, 71 species of mammals, 170 species of birds, as well as numerous reptilian and amphibian species) and ecosystem

diversity. In recent years, problems such as the road passing through the park (the Asian highway), the rise in poaching, intentional and accidental fires, grazing, and removal of shrubs, and opportunistic exploitation of the park (Hasanzadeh Kiabi *et al.* 1993) and its surrounding buffer zones has led to a severe decline in the populations of the dominant carnivores and herbivores in the park.

The zoning of the park was performed in 2002 (Dehdar Dargahi & Makhdum 2002). The zoning divided the park into several zones including a safe zone (zone 1), a protective zone (zone 2), an extensive recreation zone, and an intensive recreation zone, with 49.43%, 35.05%, 4.58%, and 0.54% of the area of the park allocated to them, respectively. 9.91% of the park was set aside for restoration, 0.11% was devoted to special applications, and 0.38% was established for historical-cultural use. Lastly, 5.69% of GNP's area was assigned as a buffer zone, along borders of the safe zone and the protected zone (Dehdar Dargahi & Makhdum 2002). Regardless of the criteria that were used in primary zoning of GNP, the criterion of habitat suitability has not been taken into account in selection of several other protected areas. Certainly GNP has not been an exception in this regard, and accordingly there is an increasing necessity for identification of regions which are capable to provide a high level of protection for the most of living organisms of an area.

With more than 150 species, small mammals constitute the majority of mammals in Iran. However, most studies with a conservation or ecological approach have been focused on large mammals (Farhadinia *et al.* 2010) because that large mammals indeed act as umbrella species in the ecosystem.

Similarly, this study aims to investigate the distribution of large carnivores and herbivores in GNP, assess the degree of protection for these species, and perform gap analysis to determine the extent of their suitable habitats covered by GNP's conservation zones.

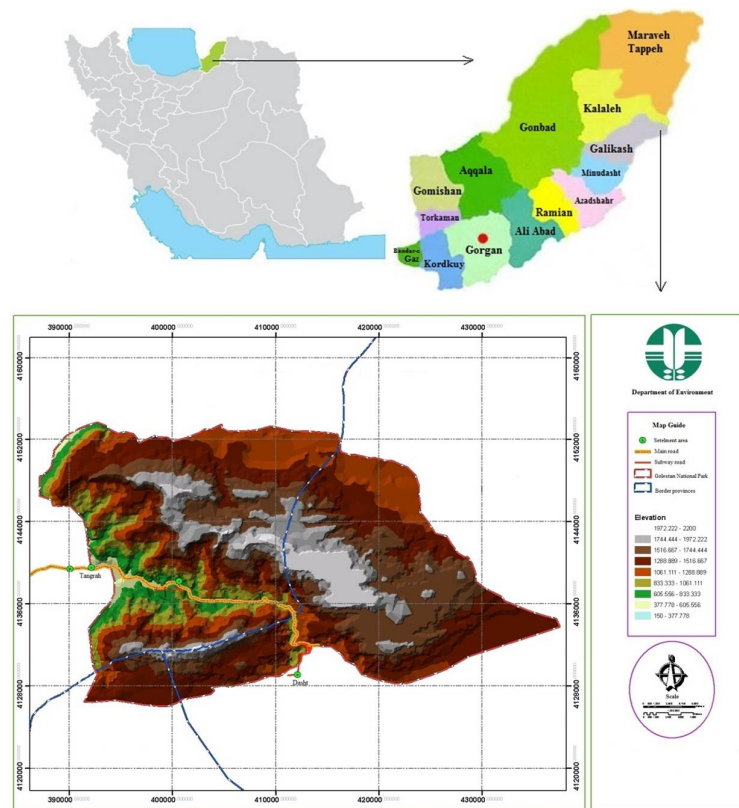
## Material and methods

### Study area and sampling

GNP covers 91,895 hectares at the intersection of three provinces (Golestan, North Khorasan, and Semnan). The park is located at the easternmost section of the Hyrcanian forests (Darvishsefat 2006), 120 km east of Bonjnourd along the Gorgan-Mashhad highway (Hasanzadeh Kiabi *et al.* 1993). GNP is located between 37° 16' to 37° 31' north and 55° 43' to 66° 17' east (Hasanzadeh Kiabi *et al.* 1993) (Fig. 1). It has a mountainous landscape with elevations ranging from 450 to 2411 m above sea level. GNP is the eastern terminus of the

Hyrcanian biome in Iran (Varaste Moradi 2004) and the last safe habitat for various wildlife species (Varasteh Moradi 2005).

At first by performing field operation through direct observation method, signs of animals' presence (such as track, footprint and run way, and pellet or dropping for all species, scrape for leopard and brown bear, rubbing for roe deer and red deer, wallowing for wild boar, gnawing and quills for porcupine) as well as indexes and GNP experts' information the highest number of species presence points during one year (i.e. 1613 points) was recorded by using GPS technology (Table 1).



**Figure 1.** Geographic location, elevation and forest cover of GNP (GIS Department, Department of Environment of Golestan Province).

### Environmental variables

Type of vegetation cover determines the distribution patterns of animal species (Burton *et al.* 2012). Vegetation type variables have been used in modeling as indicators of habitat type, vegetation cover structure, and primary production (Mueller *et al.* 2008, Burton *et al.*

2012). Each vegetation type was extracted from the land-cover map of the area and the ratio of each type was calculated using neighborhood analysis in ArcGIS. Vegetation types included forest, shrub-grassland, forest-shrub, and Onobrichys-grass.

**Table 1.** Number of presence points recorded for each species in GNP.

Species	Threat's category	No. of observations
Goitered gazelle ( <i>Gazella subgutturosa</i> )	VU	64
Grey wolf ( <i>Canis lupus</i> )	LC	87
Wild sheep ( <i>Ovis orientalis</i> )	VU	154
Roe deer ( <i>Capreolus capreolus</i> )	LC	81
Red deer ( <i>Cervus elaphus</i> )	LC	195
Leopard ( <i>Panthera pardus</i> )	EN	200
Brown bear ( <i>Ursus arctos</i> )	LC	258
Porcupine ( <i>Hystrix indica</i> )	LC	237
Bezoar goat ( <i>Capra aegagrus</i> )	VU	100
Wild boar ( <i>Sus scrofa</i> )	LC	237

Farmlands are among the alterations made (by human) in natural environments which are located with varying distances from the park, some even have common borders with GNP. Ranger stations can also influence the distribution of species by providing protection against poachers. A map which shows the distance from ranger stations and farmlands was generated using the distance function in ArcGIS.

The landform and topography can influence prey availability, size of home range, and availability of movement corridors for carnivores. Topography can also affect distance from areas with high human activity and population density as such phenomena are less common on rough terrain (Salvatori and Linnell 2005, Gavashelishvili and Lukarevskiy 2008, Rich *et al.* 2012). We used a Digital Elevation Model (DEM) prepared by USGS to provide two variables of elevation and slope. Elevation by affecting temperature, vegetation cover, and access of carnivores and herbivores to different areas, and slope by affecting vegetation cover, soil depth, and access to the area, play important role in habitat preferences

of each species and for this reasons these two variables have been prepared. The elevation map was prepared using a contour map and slope was calculated using DEM and Surface function. The maps were generated in ArcGIS 9.3 at 30 m resolution.

Then variables related to human interferences and bio characteristics of landscape were prepared in ArcGIS 9.3 as raster layers, for determination of minimum habitat requirements and modeling of the areas which have potential. Overall, 10 information layers were used (table 2)).

#### Data analysis and modeling

In this study MaxEnt, a species distribution model which utilizes the principle of maximum entropy, was used to analyze data, generate models and prepare habitat suitability maps. MaxEnt is a presence-only model which eliminates many of the shortcomings and uncertainties arising from absence points (Phillips *et al.* 2006). As input, MaxEnt accepts raster layers of species presence data and environmental variables (all in ASCII format).

**Table 2.** Input variables for MaxEnt model.

Variable	Abbreviation
Distance from agricultural land	agri
Elevation	Dem
Distance from Forest	Forest
Distance from Ranger Station	Gurad_dis
Distance from Residential areas	Setl_dis
Distance from shrub-forest vegetation Type	Shrub_forest
Distance from shrub-grassland vegetation Type	Shrub_grass
Distance from Onobrichys-grass vegetation Type	Sprs_grass
Slope	Vrm
Distance from Water	Water_dis

MaxEnt method is based on machine learning response. It is designed for making predictions using incomplete data. This method estimates the distribution with maximum entropy (closest to uniform) from sampling points in comparison with background and considering limitations inferred from input data (Grenard 2001, Phillipps *et al.* 2004, 2006). Therefore, the output indicates the goodness of fit between the predictions of the model and presence points, compared to a uniform distribution. In this study, the correlation between environmental variables and species' presence points was calculated. This correlation was compared with the correlation between environmental variables and 10,000 random points (background or pseudo-absence points) in the study area. In this manner, the relative entropy between presence points and random points was reduced. Finally, a model was formulated with the best predictive power which is capable to specify species' suitable habitat in its accessible range (Phillips *et al.* 2006, Elith *et al.* 2011, Libal *et al.* 2012).

The maximum entropy method in MaxEnt by applying the jackknife test is capable to detect the most important variables in determining habitat suitability and to evaluate their contribution in prediction of suitable areas. The area under the Receiver Operating Characteristic curve (AUC) was used to evaluate the predictive power of the model. AUC is the most prominent threshold-value-independent metric for evaluating model performance (Palialexis *et al.* 2009). AUC equals the probability that the model would

discriminate between points where a species is present and points where the species is absent (Phillips *et al.* 2006).

Using the aforementioned methods, 545 and 1068 presence points were recorded for carnivores and herbivores in GNP, respectively. Information layers, including presence points and environmental variables, were prepared and entered into MaxEnt. Finally the habitat suitability layers have been overlapped in order to determine the species richness hotspots in GNP and by comparing these hotspots and current zoning of the park the conservation gaps can be detected (areas with the highest number of suitability resulting from the accumulation of overlapping considered as hotspots) (Rodrigues *et al.* 2004, Catulloa *et al.* 2008, Brito *et al.* 2009, Wilting *et al.* 2010, Pous *et al.* 2011, Kalle *et al.* 2013, Almasieh *et al.* 2016, Naderi *et al.* 2018).

## Results

A comparison between map of hotspots of species richness and the current zoning scheme exposed the gaps in protection.

### Overlap between species suitable habitats with zones 1 and 2 in GNP

Table 3 illustrates the degree of overlap between suitable habitat for the studied species and GNP's zone 1 (safe zone) and zone 2 (protective zone). The two zones respectively cover 423.15089 and 282.000299 km<sup>2</sup> of the park.

**Table 3.** Overlap between suitable habitat and conservation zones

Species	Suitable habitat in zone 1 (km <sup>2</sup> )	Suitable habitat in zone 2 (km <sup>2</sup> )	Suitable habitat in zone 1 (%)	Suitable habitat in zone 2 (%)
Goitered gazelle	1.439	3.858	0.3	1.3
Red deer	109.438	50.3453	25.8	17.8
Roe deer	105.066	58.993	24.8	20.9
Wild sheep	61.068	43.761	14.4	15.5
Bezoar goat	101.345	63.63	23.9	22.5
Wild boar	114.130	70.815	26.9	25.1
Porcupine	107.293	75.601	25.3	26.8
Grey wolf	27.007	39.787	6.3	14.1
Brown bear	134.702	193.268	31.8	68.5
Leopard	119.110	80.393	28.1	28.5
Average			20.8	24.1

According to Table 3, the largest overlap between zones 1 and 2 and suitable habitat is predicted for brown bears (*Ursus arctos*) with 31.8% and 68.5% of their suitable habitat situated in zones 1 and 2, respectively. Overall, a large percentage of conservation zones in the park protect brown bears' suitable habitat. This can be due to omnivorous diet of this species and as a result its distribution in a wide range area. The smallest overlap was observed for goitered gazelles (*Gazella subgutturosa*) with a mere 0.3% overlap with zone 1 and only 1.3% overlap with zone 2. This poor overlap may be due to the fact that the habitat of this species is limited to the marginal regions of the Park.

Table 4 presents species richness of large mammals in the protective zone and safe zone (conservative zones) in GNP and Table 5 illustrates area of regions with different levels of species richness in conservative and non-conservative zones in the park.

#### Hotspots of species richness for large mammals in GNP

Figure 2 depicts hotspots of species richness in GNP. The map is produced by overlaying habitat suitability maps for 10 studied species.

Figure 3 shows Location of hotspots of species richness for large mammals in relation to conservation zones in GNP.

**Table 4.** species richness of large mammals in the protective zone and safe zone in GNP

	With a richness of 1 to 3	With a richness of 4 to 6	With a richness of 7 to 9
Area of zone 1 (km <sup>2</sup> )	263.557	143.441	15.831
Area of zone 2 (km <sup>2</sup> )	192.915	76.519	12.564
Area of zone 1 (%)	62.2	33.8	3.7
Area of zone 2 (%)	68.4	27.1	4.4

**Table 5.** Area of regions with different levels of species richness in conservation and non-conservation zones in the park

Regions	Surface (km <sup>2</sup> )	Matched with zone 1 (km <sup>2</sup> )	Matched with zone 2 (km <sup>2</sup> )	Matched with zone 1 (%)	Matched with zone 2 (%)	Matched with other zone (%)
1 to 3 species	573.679	263.31	192.756	45.9	33.6	20.5
4 to 6 species	296.194	143.35	76.418	48.4	25.8	25.8
7 to 9 species	39.434	15.813	12.540	40.1	31.8	28.1

## Discussion

A range of methods have been proposed for prioritizing species for conservation, each of them with a different approach has been focused on endangered, native, endemic, flagship, key, indicator, umbrella species and species with economic, ecological, scientific, or cultural significance.

In this study, we attempted to revise and modify the current zoning in GNP based on maximizing the overlap between coverage of

hotspots of species richness and species' suitable habitats and conservation zones. Therefore, by selecting focal species, we tried to select areas with the highest animal diversity possible, so that in future revisions of the zoning of the Park these areas can be added to or cut from the current zoning. Table 3 presents the degree of overlap between each species' suitable habitat and zones 1 and 2 in the park. Average overlap of suitable habitats with zone 1 and zone 2 was respectively about 20% and

25% for goitered gazelle (*Gazella subgutturosa*), roe deer (*Capreolus capreolus*), Caspian red deer (*Cervus elaphus maral*), bezoar goat (*Capra aegagrus*), wild sheep (*Ovis orientalis*), porcupine (*Hystrix indica*), wild boar (*Sus scrofa*), grey wolf (*Canis lupus*), brown bear (*Ursus arctos*), and leopard (*Panthera pardus*). The current coverage demonstrates the inadequacy of the current zoning and highlights the need to revise current conservation zones, particularly for species whose suitable habitats have less than 50% combined overlap with zones 1 and 2 and shows previous criteria used for selecting and bordering of the conservative zones have not been sufficient to provide maximum protection for focal species in GNP. These gaps are larger for roe deer (45.7% total overlap), bezoar goat (46.4%), grey wolf (20.4%), and wild sheep (29.9%). The largest gap is particularly related to *G. subgutturosa* with only 1.64% of its suitable habitat included in conservation zones.

Very limited inclusion of the suitable habitat of *G. subgutturosa* in zone 1 and zone 2 (with 0.3% and 1.3% coverage, respectively) could be due to the fact that limited habitat of this species is located in the marginal areas of GNP and accordingly for better protection of this species a revision in zoning, especially in the eastern limits of GNP seems necessary.

Table 4 presents 69% of the area of conservation zones safeguards the suitable habitat for over 40% of large species (4-9 species). Meanwhile, only 8.1 percent of conservation zones encompass the suitable habitat for 7-9 species (between 70 to 90 percent of species). As a result, adjusting the borders of zones 1 and 2 to include a larger portion of suitable habitats for 7-9 species will improve protection efficiency and biodiversity conservation.

Table 5 shows that 74.2% of sites with average species richness (4-6 species) and 71.9% of sites with the highest species richness of large mammals (7-9 species) are covered under the conservation zones in GNP. Shifting the borders of zones 1 and 2 to include 100% of areas that are suitable habitats for 7-9 species would be ideal.

Figure 2 depicts hotspots of species richness in GNP. Although significant portions of hotspots

fall within conservation zones, there are large patches with high biodiversity that are not covered with conservative zones. These patches are circled and indicated with arrows in Figure 3. In the future, and in the absence of conflicts, these patches should be added to current conservation zones.

Pous *et al.* (2011) used MaxEnt to prioritize and assess the efficiency of Morocco's network of protected areas to support and conserve reptiles and amphibians. After preparing species richness maps for reptiles and amphibians in Morocco and distribution patterns for each species, they concluded that a significant expansion of protected areas is needed to meet the global goal of at least 10-percent representation in order to guarantee the sustainability and survival of each individual reptilian and amphibian species. Although it merely uses mammalian species as pattern, this study indicates as well that a 54-percent gap in habitats with an average or higher richness (4-9 species), and a 28-percent gap in habitats with the highest richness (7-9 species) were observed which shows the need for inclusion of other key and indicator vertebrate species of GNP in researches and making new decisions based on other species richness areas in order to have protected areas with the highest species richness and the smallest conservative gap. In this regard, species from other taxonomic classes and their respective richness areas should also be taken into account. Therefore, considering the aforementioned explanations, the safe zone in GNP, subject to attachment of some mentioned patches as per Figure 4, covers the areas having the highest biodiversity.

## Conclusion

Although the conservation zones of the park lack sufficient overlap with suitable habitats of some studied species, particularly *C. lupus* and *G. subgutturosa*, however, zones 1 and 2 cover a significant portion of hotspots of species richness in the park. Certainly, adjusting and expanding the protective coverage of zones 1 and 2 to include hotspots of species richness (suitable habitats for 4-9 species), as well as extending these zones to species whose suitable habitats have less overlap with

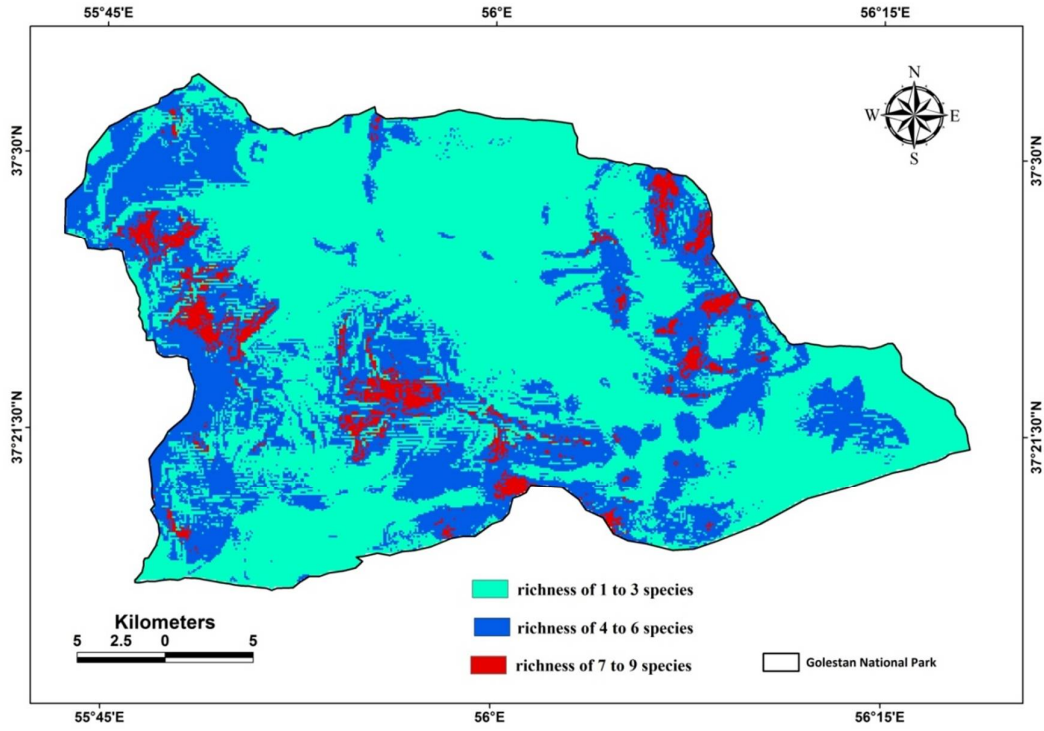


Figure 2. Hotspots of species richness for large mammals.

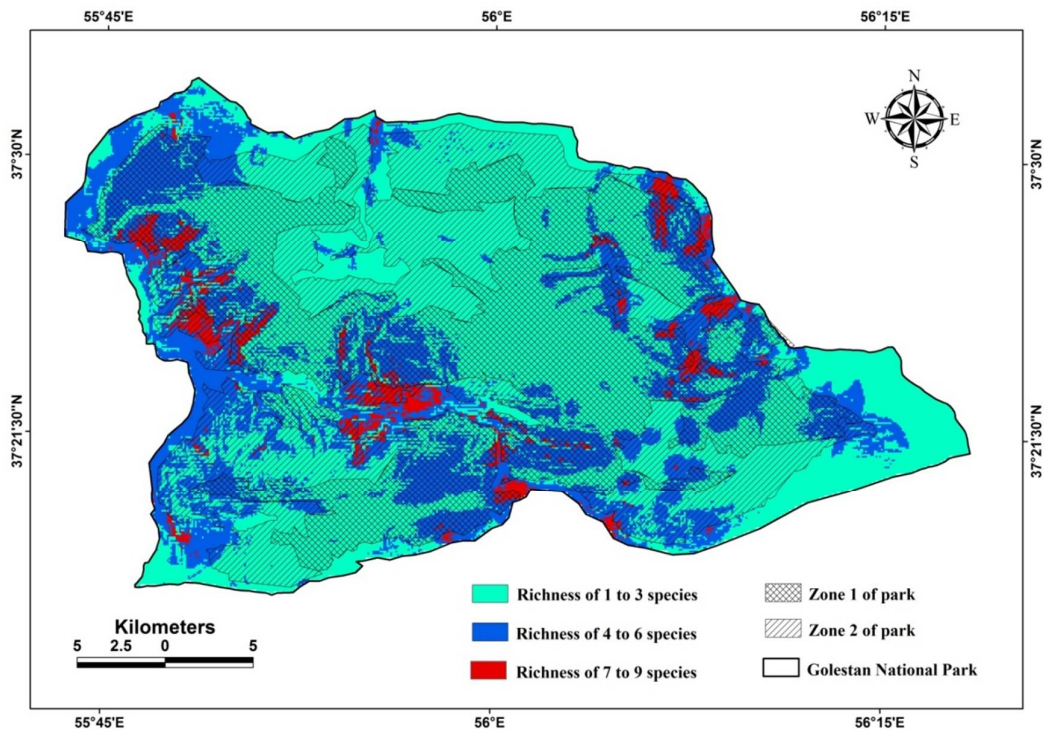


Figure 3. Location of hotspots of species richness for large mammals in relation to conservation zones in GNP.

zones 1 and 2 will improve protection efficiency in GNP and enhance representation. A revision in zoning, particularly the extent of

each zone, may contribute in realization of this goal. It should be noted that as the total area for each zone is proper, a revision in the borders,

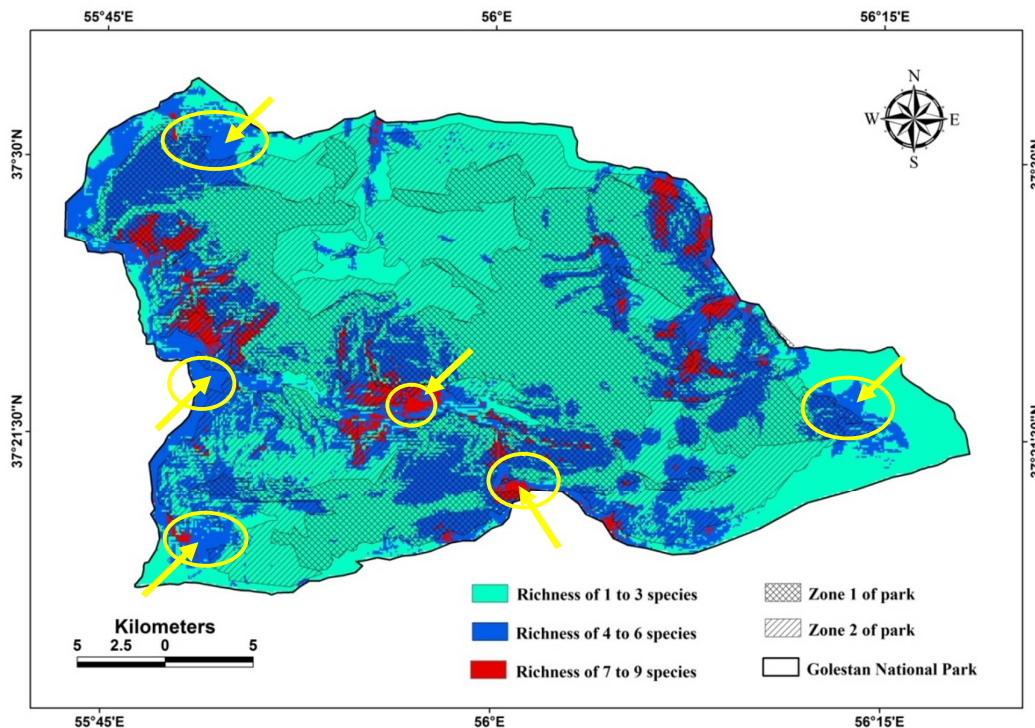


without expansion or restriction of area, seems more appropriate. Through developments in habitat suitability modeling methods and considering biodiversity hotspots maps in establishment of future protected areas, and revision in the borders and zoning of the current protected areas in order to fill conservation gaps, one can hope that selection of protected areas will not be merely based on attainment to quantitative results and fulfillment of 10-percent protection level and beside that, achievement to maximum efficiency in conservation and qualitative objectives of protection through using species distribution modeling and biodiversity hotspots will be taken in to account by decision makers in establishment of new protected areas. As other species have different habitat requirements, ideal conditions may only be reached when habitat suitability modeling is performed for other classes of vertebrates, in particular birds and reptiles, in order to supplement the findings of this study. Only

under such conditions comprehensive and correct decisions regarding the zoning within GNP and selection of new protected areas to complement the current network of protected areas can be made. Such an approach will pave the way for accomplishing the best possible level of conservation and eliminating gaps in protection.

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**Figure 4.** Hotspots of species richness in GNP which are not included in zones 1 and 2.

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