



RESEARCH PAPER

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Study of seasonal changes in habitat suitability of *Caracal caracal schmitzi* (Maschie 1812) in the central desert of Iran

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Abstract

Caracal is one of 10 cat's species in Iran that lives in plain and desert. Major changes in natural ecosystems and increasing desertification, threatens the habitat of *Caracal* and its symbiotic. This research aim was to assess the suitability of *Caracal*'s habitat in different seasons to determine the most important factors that leads to seasonal selection of habitat. Presence data of *Caracal* were collected during 10 years and maps of effective environmental factors was prepared (slope, aspect, height, water resources, vegetation, land cover, prey and competitor's distribution map). Results showed best model with highest accuracy for seasonal distribution of *Caracal* belongs to summer (AUC= 0.835). Water and vegetation have the most participation in this model (54% and 21.5 %respectively). Also winter has the lowest efficiency compared with other models (AUC = 0.772) and its most effective variables are vegetation and competitors (27.4 % and 26.8 % respectively). This study suggests the importance of vegetation in different season as shelter and ambush for *Caracal* and its prey. *Caracal* depends on the water in the summer, but in other seasons it needs less and in winter is lowest (0%). Totally the area of *Caracal* habitat in different seasons is various due to changes in priority of affective variables. As a result, in the summer, according to limited water suitable habitat is minimized and in autumn, it is maximum (8.2% and 44.2% of total area respectively). Accordingly, efforts to the development of suitable habitat of *Caracal* can be focused on improving the limiting factors of water and vegetation in the Kavir National Park.

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Introduction

Caracal is one of 10 cat's species of Iran that lives in the most arid plains and desert of central and eastern areas of Iran (Ziaee, 2009). *Caracal* usually prefers to live in the dry steppes and deserts, Savannah and dry forest, scrub and short bushes or rocky area that prepares its adequate shelter for hunting and resting (Heptner *et al.*, 1992).

Even though *Caracal* is at least concern species on a global scale (IUCN, 2013), but the main threats to populations of *Caracal* in the world is human interference by habitat destruction and hunting, livestock's over grazing and reduce prey that are mentioned as the primary threats in Arabic countries (Digeronimo *et al.*, 2010).

In Iran, a few researches have been done in relation to ecological needs, habitat conditions and *Caracal*'s conservation. In most habitats, human impacts can be observed such as roads, towns, agriculture and animal husbandry and etc., Wildlife and their habitat selection are affected by these environmental stresses and these conditions lead to some abnormal behavior in wildlife species. In this situation, in an intact environments such as Kavir National Park of Iran, where there is no human conflict and wildlife lives without any influence of human activities, provides a good opportunity to study of the behavior, biology and ecology of this species. The *Caracal* is not emigrant animal, but based on observation, it has a displacement seasonally and locally in its habitat. *Caracal* usually has a joint habitat with huge carnivores like *Panthera pardus saxicolor*, *Acinonyx jubatus venaticus* and *hyena hyena*'s. In addition, despite its potential to hunt ungulates such as *Gazella bennettii* and *Gazella subgutturosa* which are larger than *Caracal*, but *Caracal* usually prefers to eat other food sources (Sunquist and Sunquist, 2002). Based on Mukherjee *et al.* (2004) studies, the most important resources of *Caracal* diet are mammals, rodents, reptiles, birds and invertebrates, respectively. Plant material and etc., are in the next place. In order to plan for appropriate management of

an animal and its related species and for conservation of their population, it is necessary to identify the habitat with higher suitability in the special environmental conditions and different seasons. (Dayton & Fitzgerald, 2006). During critical periods such as winter when the importance of intraspecific competition has reduced, species may be obviated their ecological needs by expanding its ecological nest, and utilization of rare nutritional resources is more efficiently compared to spring. These changes within the ecological nest, can indicate expanded or reduced of seasonal habitat and species distribution. With this explanation, more information is needed about suitable habitat in different seasons and it is essential to realize the seasonal displacement of species (Suarez *et al.*, 2008). Ecological preference of species and their needs are varies in different seasons, these will affect the distribution of animals (for example: Seonea *et al.*, 2008, Cincjak *et al.*, 1987). Also, Gaston (1996) suggests prediction and mapping of potentially suitable habitat for the species is necessary for monitoring and restoring the declined native population in their natural habitat, introducing an artificial habitat or selecting protection sites and management of critical habitats for native species. Many researchers have used different methods for modeling suitable habitat of species. These models determine the relationship between species distribution and environmental factors. Also MaxEnt is one of these software that is widely used in habitat suitability modeling for various species. (Sanei *et al.*, 2013, Sequeira *et al.*, 2012, Kalle *et al.*, 2013; wilting *et al.*, 2010). This study was performed to determine the spatio- temporal distribution of *Caracal* within the Kavir National Park and identify the main affecting factors on seasonal use of habitat and also for providing predictive maps of *Caracals*' suitable habitat during seasonal changes.

Materials and methods

Location and characteristics of the study area

The Kavir National Park is located between the 51° 58' to 53° 03' E longitude and 34° 17' 05" to 34° 53' 40" N latitude and in the south-west of Semnan province, Iran

that is between the central desert of Iran and salt lake. According to the divisions of the EPA (Environmental Protection Agency of Iran), central desert is composed of two parts: Kavir National Park and protected area. Extent of protected area and national park is 248,960 and 442,212 hectares respectively. This area characterized by special flora such as xerophyte, halophyte and psammophyte plants and also with particular fauna like *Vulpes rueppellii*, *Felis margarita* and *Acinonyx jubatus venaticus*. The range of height is from 750 (in the east) to 2000 meters (in the central area of the park) above the sea level (Atarodi, 2011). According to information of the Garmsar synoptic station that is the nearest station to the research area, average precipitation in 2011-2012 is 148.8 mm and average temperatures in this years` is 17.5 °C (Anonymous, 2012). About 205 plant species from 153 genus and 40 families in 8 vegetation types are found in this habitat. (Anonymous, 2002). Also, there are 31 mammal species from 28 genus, belonging to 15 families and 131 species of birds belonging to 35 families, 20 reptile species belonging to 9 families and two species of amphibians belonging to two families in this area.

Field measurements and methods of experiment

Presence data of target species

Presence data of *Caracal* were recorded in the Kavir national park over a period of 10 years (2002- 2012). Most of these points were recorded by the first author of the paper and with direct observation. Also camera trapping Technique was used and indirect observation made by game guards and footprint of *Caracal*. Totally 99 points was recorded that included 25 points for spring, 23 points for summer, 27 points for autumn and 24 points for the winter.

Habitat variables

Maps of topographical Variables (slope, aspect, height), land cover, distance from water resources, vegetation density, prey (*Capra aegagrus*, *Ovis orientalis*, *Gazella bennettii*, *Chlamydotis undulata*, *Alectoris chukar*, *Ammoperdix griseogularis*, *Pterocles coronatus*, *Lepus capensis*, *Meriones libycus* and *Allactaga elater*), and *Caracals*

competitors (*Panthera pardus saxicolor*, *Acinonyx jubatus venaticus*, *Canis lupus*, *Canis aureus* and *Felis margarita*) were produced in raster format using ArcGIS 9.3.

Modeling method

In the present research the maximum entropy distribution modeling methods or MaxEnt was used to predict the species occurrence with presence-only data and determine the contribution of each environment variables in seasonal habitat suitability map, the amount of the AUC and the Jack Nife curve (Elith *et al.*, 2006; Ortega-Huerta and Peterson, 2008; Kumar and Stohlgren, 2009). In the reliability of models based on the ROC¹ curve for all seasons, whatever area under the curve is closer to 1, the model can separate better the points of presence or absence from each other (Pearce and Ferrier, 2000).

Results

Fig. 1 shows habitat suitability for *Caracal* in four seasons, as indicated on these maps the area of *Caracal* ecological niche is varied in different seasons. According to the results accuracy of models for spring, summer, autumn and winter was in this order, respectively AUC=0.806, 0.835, 0.778 and 0.772.

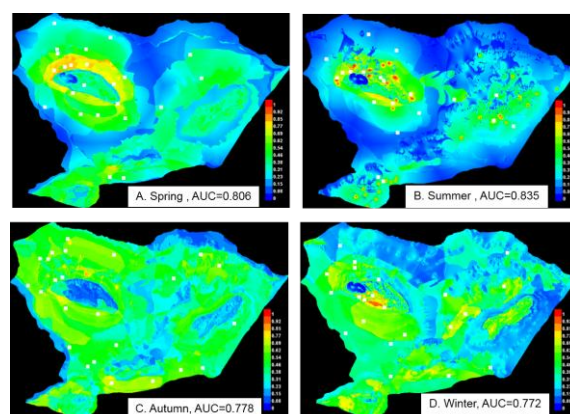


Fig. 1. prediction of *Caracal* suitable habitat in the different seasons as continuous variables, A- Spring. B- Summer. C- Autumn. D- Winter (warm colors indicate areas with higher presence probability and white point's demonstrates the places where *Caracal* has been observed.

¹ ROC= relative operating characteristic curve

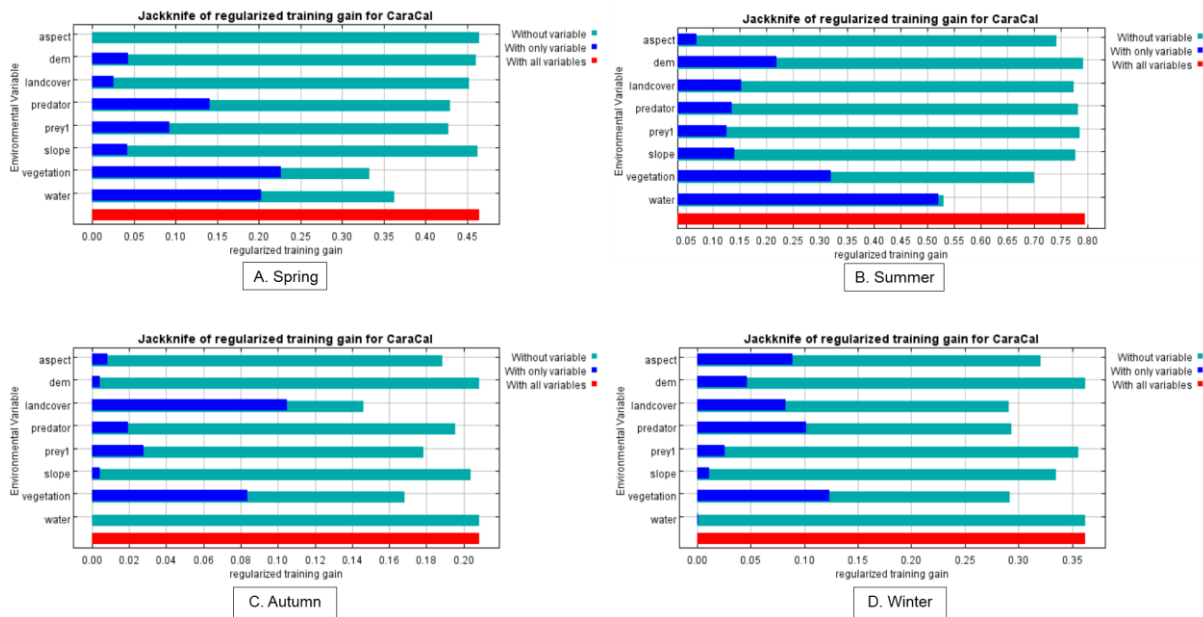


Fig. 2. Results of jackknife evaluations of relative importance of predictor variables for predicting potential seasonal suitable habitat of Caracal. A- Spring, B- Summer, C- Autumn, D-Winter.

In spring, vegetation and water are two main factors that affecting on *Caracal* habitat suitability model with 47.7% and 19.9% contribution respectively. And also predator and prey are in the next place with 16.6% and 12.5% respectively. Topographic factors

such as height, slope, aspect, have lower participation in this model respectively, with 0.5, 0.2 and 0% (table 1). Our findings indicate that suitable and unsuitable habitat of *Caracal* in spring is 11.74% and 88.26% of the total park area, respectively.

Table 1. contribution of each variable in prediction of seasonal Caracal's suitable habitat.

Variable	Spring		Summer		Autumn		Winter	
	grade	Percent contribution	grade	Percent contribution	grade	Percent contribution	grade	Percent contribution
vegetation	1	47.7	2	21.5	2	23.6	1	27.4
water	2	19.9	1	54	7	0.1	0	0
predator	3	16.1	5	4.7	4	8	2	26.8
prey	4	12.5	6	2.5	3	14.3	6	2.8
land cover	5	3.1	3	7.8	1	44.5	3	24.5
Dem (elevation)	6	0.5	8	0.6	8	0	0	0
slope	7	0.2	7	1.9	6	3.4	5	3
aspect	8	0	4	7.1	5	6.1	4	15.4

In summer, water with more than 50% contribution in model is the first priority and is the most important, and then vegetation, land cover and aspect with 21.5, 7.8, 7.1 are the most effective factors in determine *Caracal*'s suitable habitat in summer respectively. Other factors have contributed less than 5% in the summer model. Height has the lowest proportion with 0.6%.

The suitable habitat of *Caracal* in summer constitutes 8.2 percent of the total area of the National Park and unsuitable habitat has 91.8% of the total area.

In autumn, land cover, vegetation, prey and predator have higher priority with 44.5, 23.6, 14.3 and 8 percent, respectively. Other factors have contributed less than 6% and height has not proportion in this model. The area of Suitable habitat for *Caracal* in

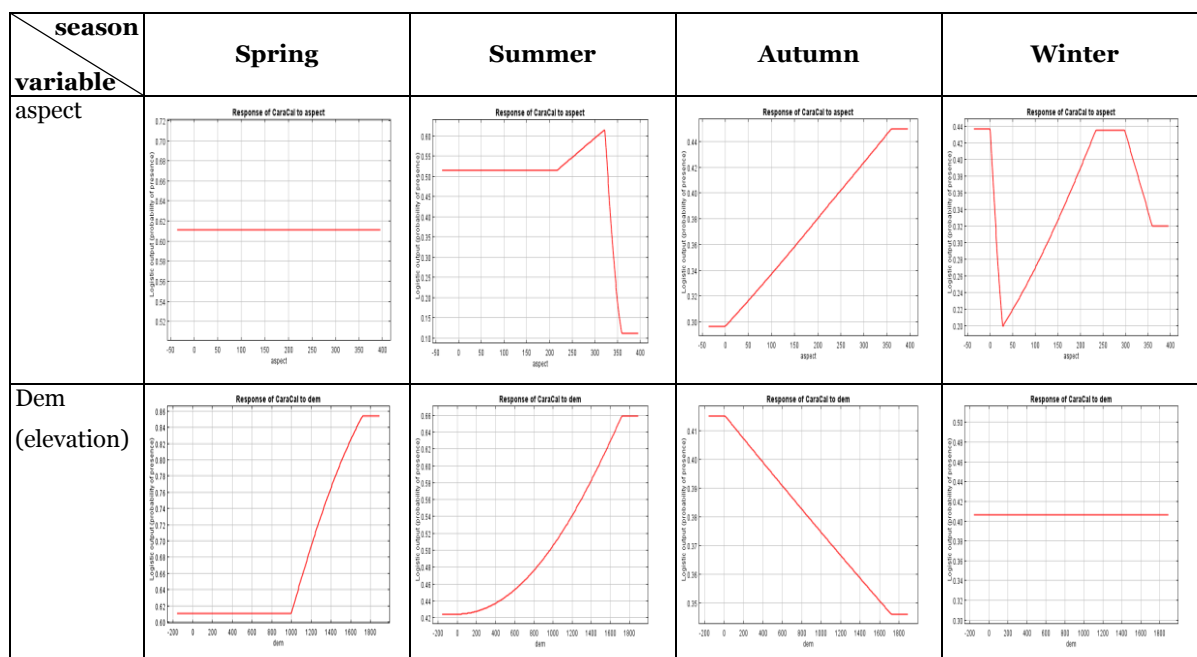
autumn is highest among other season and it is 44.28% and unsuitable habitat comprises 55.72% of whole area of National Park.

In winter vegetation, predator, land cover and aspect with 27.4, 26.8, 24.5 and 15.4 are the most important variables in *Caracal* suitable habitat model, respectively. Other factors have contributed less than 3%. Water and height are two variable that no take part in winter model (table 1). In winter, the area of *Caracal* suitable habitat is 22.53% and unsuitable habitat area is 77.47% of the total area of the Kavir National Park.

Results of jackknife evaluations for all season indicates the relative importance of predictor variables for *Caracal* suitable habitat and the accuracy of running model by one variable comparing with other variables. This is important, hence that will determine which of the variables play greater role in the implementation of the model lonely. As is shown in the following chart, vegetation in spring, water in summer, ground cover in autumn and vegetation in winter, plays important role alone in the

implementation of the seasonal suitable habitat models for *Caracal*.

The results of this study showed that vegetation is the first important variable in spring and winter but in the summer and autumn it is on the second placed. And plays a crucial role in determining the suitability of seasonal habitat for *Caracal* compare with other factors. *Caracal* has mostly attended in vegetation type 2 (*Artemisia sieberi-Dendrostellera lesseri*) in the spring, summer and autumn in and in winter they are often seen in the type 5 (*Artemisia sieberi-Zygophyllum eurypterum- Seidlitzia rosmarinus*) that are bush shrub plants (Fig. 3). Generally, topographical factors such as height, slope and aspect in this area don't have an effect on these models and entering to the model lastly. Along with decreasing temperature in autumn and winter, the probability of *Caracal* presence is increasing in the lowlands (Fig. 3) and also in winter *Caracal* often seen in western and southern slopes.



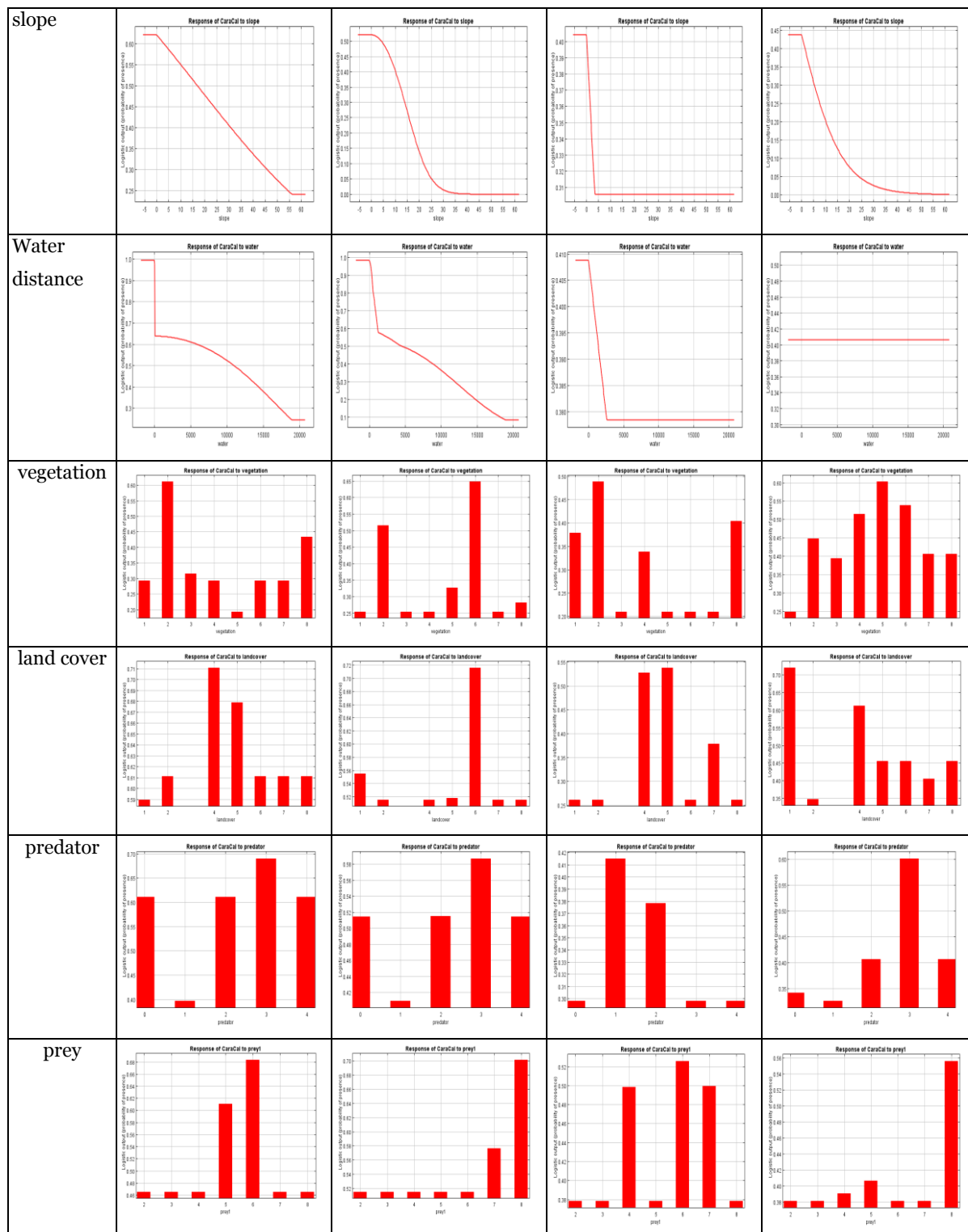


Fig. 3. In land cover response curves class 1 is: rock lands, 2: salt lands, 3: mixed of salt lands and very poor rangelands, 4: mixed of poor rangelands, 5: poor rangelands, 6: moderate rangelands, 7: bare lands, 8: salt lake. In vegetation type response curves class 1 is: *Artemisia sieberi* -*Seidlitzia rosmarinus*, 2: *Ar.sieberi*-*Dendrostellera lessertii*, 3: *Ar.sieberi*-*Stipa arabica*, 4: *Ar.sieberi*-*Zygophyllum eurypterum*, 5: *Ar.sieberi*-*Zygophyllum eurypterum*-*Seidlitzia rosmarinus*, 6: bare lands, 7: helophytes, 8: *Haloxylon persicum*-*Stipagrostis plumose*. In prey and predator response curves horizontal axes are presented number of prey or predator.

Discussion and conclusions

On all maps that have presented for potential suitable habitat in different seasons of *Caracal*, central parts of maps have marked as blue spots that are regions without any vegetation so the presence of *Caracal* is least in these areas.

In ecological condition of kavar national park, plants can provide shelter, den and suitable canopy for hunting or the rest of the wildlife. Also, many of *Caracal* *Caracal*'s prey such as rodents, birds, and rabbits live under bushes and shrubs. Results of other studies have confirmed this content (Bothma & Walker, (1999); Farhadinia *et al.*, (2007)). In spring, with beginning the plant growth, activity and the presence of prey, like rodents in the plains and slopes will become greater. Also, *Capra aegagrus* and *Ovis orientalis* after their breeding season in spring, spend more time for grazing in low plains areas for grazing so presence of them become greater, As a result, *Caracal* and other predator in these areas have seen more. From mid spring to late spring, with warming the weather gradually, the preys become closer to the water resources, and it is highlighted the importance of water and water sources. As, water from the second position in the spring model goes to the first position in the summer model, and in summer season due to the extreme heat and drought, water is the most influential factor in seasonal modeling. Therefore, Probability of *Caracal* presences around the water resources is highest. Kok & Nel studies (1996) determined water is the most important habitat requirements of this species. This can be investigated from two aspects: Whether is *Caracal* depending on water source because of its ecological needs, or another reason is because of its preys are depending on water, *Caracal* presents in the areas of water resources for hunting its prey. Also Sunquist & Sunquist (2002) expressed that *Caracal* is adapted for living in arid areas. Low drinking water and provides his water need from the blood of its prey, thus, it can be stated that regards water is the most important needs of any lives and due to the limitations of water resources in the Kavir National

Park, so the importance of water in *Caracal*'s suitable habitat models, is because of the high dependence of its prey in the water. The *Caracal* is present near the water resources in summer, not only due to its water needs, but also it is because of aggregation the preys around the water resources. Other researches confirm these findings, which *Caracals* could be spent a lot of time without drinking water, and they can provide their water needs from existing water of their prey bodies (Ziaee, 2009).

Farhadinia *et al.*, (2007), also expressed sometimes, when *Gazella bennettii* are come down from hills to drinking water, are being hunted by *Caracal*, this confirms that *Caracal*'s dependent on water because of its prey and hunting them.

Also, in the north of the Kavir National Park, that can be seen more in mounds that the effect of solar radiation in this area is lower, soil moisture is greater and denser of vegetation is more than other areas, and due to the *Caracal* needs to shade and shelter more in the hot season, the importance of vegetation and hills on the north slopes is becoming greater. *Caracal* and other predators search less for prey in the northern slopes because of aggregation of prey around the water sources. It leads less competition of *Caracal* with other predator to get the prey. In this result, next places are belong to the prey and predator in summer (table1). In autumn due to the reduced temperature, dependence of *Caracal* and other predators and preys to water resources become lower, Prey go away from water sources and hillsides and spend more time in the lowlands and plain areas with better vegetation (Fig. 3).

In these areas, vegetation and gentle slopes are best refuge and shelter for this species living so *Caracal* and other predator can close to prey easily. The presence of prey and predators are the next priorities. In autumn, during temperature reduces, *Caracal* depending on water resources decreases, and vegetation and prey get more Importance (table 1).

In winter, predator and prey dependence to the water is greatly reduced and it is placed on the last priority in model therefor most of prey can be seen in the surrounding areas that have more and better vegetation. Since most prey for feeding and refuge are dependent on vegetation. And also, whole predator such as *Caracal* for its prey are related to vegetation as dens, too. Additionally in winter, vegetation cover of plain and desert plays role of windbreak for animals. According to that water in winter is not a limiting factor, Preys are separated in the park to find better vegetation. Subsequently, the predators are distributed widely so *Caracal* presence in Kavir Park will be more expanded. In winter, there is more competition between *Caracal* with other predators to get food sources. For this reason, predator variable is more important to winter suitability habitat model and it becomes in the second place for this model. As also is evident in Fig. 3, the *Caracal* presenting is more in southern and western slope, in winter where are warmer.

Competitors in the winter's model are in the second place after vegetation. In this season when the weather is being cooler, animal water requirement is reduced so they get away from water resources. And on the other hand due to reduction of rodent activity and their abundance and with regard to widely disperse of them in the park, also according to the migration of *Pterocles coronatus* and *Chlamydotis undulata* to warmer places (outside the park) competition among predators in winter increases. Whereas, as mentioned before in summer competition between predators is reduced due to prey colonies and abundance of prey around water sources. Melville & Bothma (2006) expressed that search of prey by *Caracal* take place of prey colonies in the summer, but in winter due to lack of prey searching was done randomly. Sunquist & Sunquist (2002) also were stated that *Caracal* has a joint habitat with huge carnivores such as leopard, Cheetah, Hyaena. Kavir National Park includes wide ranges of habitats of *Acinonyx jubatus venaticus*, *Canis lupus*, *Felis margarita* that these animals

prefer sandy desert and plain so considerable area of this region is shared with *Caracal* habitat. Some parts of *Caracal* habitat have overlap with *Panthera pardus saxicolor* habitat where is in the mountainous area with high elevations of the park. Since habitat of *Canis aureus* is a small part of the northern plain of the park, *Caracal* has less overlap with its habitat.

Based on the results and observation, *Lepus capensis* habitat and *Pterocles coronatus* have more overlap with *Caracal* habitat compare with other preys also as Farhadinia *et al.*, (2007) expressed rabbits, rodents and ground birds have an important role in the diet of *Caracal*. The main habitat of *Lepus capensis* and *Pterocles coronatus* is desert and plain area, and because these lands constituted a large part of Kavir National Park, therefore, has very joint area with *Caracal* suitability habitat. The most density of *Zygophyllum*, *Seidlitzia* and other shrub vegetation in the Kavir National Park is in the plain area where, most of the *Lepus capensis* and *Pterocles coronatus* are hiding in these shrub land that this situation provides an opportunity for *Caracal* to hunt them. Smaller animals such as *Pterocles coronatus*, *Meriones libycus* and bird like *Pterocles coronatus*, *Ammoperdix griseogularis*, *Alectoris chukar* have more frequency than other preys in the Kavir National Park. Thus, prey with higher frequency, have a greater contribution in *Caracal* diet. (Farhainia *et al.*, 2007).

Mukherjee *et al.*, (2004) stated that a *Caracal* feeds 2990 to 3285 rabbits annually and about 70% of its metabolic energy requirements obtained from rodents.

Some of *Chlamydotis undulata* in the Kavir National Park are native and others are emigrating. *Chlamydotis undulata* often lives near the short bushes & shrubs where these areas has overlap with *Caracal*'s habitat. *Chlamydotis undulata* lives among the low height scrub and bushes and these plants provide *Caracal*'s ambushes for hunting *Chlamydotis undulata*.

The habitat of *Capra aegagrus* and *Alectoris chukar* are mountain areas of the park and these species come to foothills for drinking water or for grazing and feeding, which these areas, around water sources and vegetation, provide good opportunities for *Caracal* to hunt them. Also *Ammoperdix griseogularis* lives in such habitats too. Because the mountainous area constitutes smaller part of national park therefore the animals that lives in these areas may have lower joint habitat with *Caracal* such as three species that mentioned above. It seems the importance of prey has been overshadowed and affected by the hidden correlated relation between environmental variables such as vegetation and water and presence of prey. Because prey is often seen in places with good vegetation canopies and water resources. Therefore, the correlation between three factors (prey, vegetation & water) cannot be ignored.

Land cover in autumn is in first place for modeling of *Caracal's* suitable habitat. These lands include foothills. They have a wide range of poor or medium rangeland cover or sometimes they are bare and without vegetation. But in valley and bed of the stream, vegetation has a better condition and *Caracal's* have seen in marginal vegetation of these waterways because of looking for food. In spring and summer *Caracal* usually can be seen in the foot hill area and high height. But In autumn and winter when the weather becomes cold, presence of prey and predators are more in the lowlands and plains.

Generally, selection of prey by *Caracals* depends on habitat types, the land form, availability and distribution of prey. Also, in this region during Bovidae species breeding season, (*Capra aegagrus* and *Ovis orientalis* and *Gazella bennettii*) their lambs and kids suitable prey *Caracal*. Although *Caracal* has joint habitat with large predator such as *Panthera pardus saxicolor*, *Acinonyx jubatus venaticus*, *Canis lupus* and *Canis aureus*, but the presence of these predators and their food commonalities is not considered as a threat for *Caracal* in Kavir national park although Digeronimo *et al.*, (2010) stated

habitat destruction and hunting are the most common threats. For *Caracal's* population, and in Arabic countries human interference, destruction of habitat and overgrazing and loss of prey are considered as a primary threat to this species.

But, due to protection of the Kavir National Park there are no human commuting and no livestock grazing and no sheepdogs, so any special thing does not threaten the habitat of *Caracal*. But, as Ray *et al.*, (2005) expressed desertification is considered as a great threats to *Caracal*. In Kavir national park, lack of precipitation, drought, desertification and reduce the water resources have direct impacts on vegetation that is the most important parameter in spring & winter and second priority in summer and autumn models. In addition, reduction of water resources, especially in the summer has an effect on the distribution of *Caracal*. Also, these change, affected on regeneration of rodent and small birds and other *Caracal's* prey.

And in the long time it could be considered as an effective factor on population of *Caracal*. According to the present research, vegetation and water resources had an important role in habitat of *Caracal* and, also the factor is very effective in the presence of *Caracal's* prey. Therefore, management of vegetation and water, protected them, dredging on time the water resources are considerable issues in management and protection of *Caracal* habitat in all seasons.

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