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Prey selection by the critically endangered Asiatic cheetah in central Iran

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The presence of the critically endangered Asiatic cheetah (*Acinonyx jubatus venaticus*) has been verified in several protected areas in central Iran. Prey selection by the Asiatic cheetah was studied in Dare-Anjir Wildlife Refuge, one of its typical habitats in central Iran where there are no carnivorous competitors. The frequency of cheetah kills was compared with the relative abundance of each of its primary prey species obtained through two independent surveys. Jebeer gazelle (*Gazella bennettii*) was least abundant, but was the preferred prey of cheetah, whereas wild sheep (*Ovis orientalis*) followed by Persian ibex (*Capra aegagrus*) were the most frequently killed prey. Cheetahs selectively preyed on males of the three prey species. Our data suggest that Asiatic cheetahs prey mainly on mountain ungulates (wild sheep and Persian ibex), which has management implications for effective conservation of this taxon in Iran.

Keywords: *Acinonyx jubatus venaticus*; Asiatic cheetah; prey selection; Dare-Anjir Wildlife Refuge; Iran

Introduction

The conservation of the Asiatic cheetah (*Acinonyx jubatus venaticus* Griffith, 1821), a critically endangered subspecies (IUCN 2008), has been of international concern over the last decade. The Asiatic cheetah has declined both in area of occupancy and abundance over the last century (Nowell and Jackson 1996). The historical distribution of *A. j. venaticus* encompasses the Indian subcontinent, Afghanistan, Turkmenistan and Iran to the Arabian Peninsula and Syria (Ellerman and Morrison-Scott 1966). Scattered reports of cheetahs or their signs over the last few decades suggest that the population of Asiatic cheetahs has fallen by two-thirds during this period (Hemami 2005). Over the past 20 years, the eastern half of Iran has been the last stronghold for a few dozen Asiatic cheetahs occurring within several verified areas, including Dare-Anjir Wildlife Refuge (Farhadinia 2004).

Food habits are an important aspect of the ecological niche of carnivores, incorporating both the availability and abundance of their potential prey (Stander 1991; Caro 1994) as well as the morphological, behavioural and physiological adaptations of the predator that enables it to prey upon a variety of species (Kok and Nel 2004). Food habits, therefore, are important considerations when developing species and ecosystem management strategies for a species (Mills 1992). There have been many studies on the food habits of the African cheetah (e.g. Schaller 1972; Caro 1994;

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Marker-Kraus et al. 2003; Mills et al. 2004), but our knowledge of its Asiatic counterpart is largely lacking. In Africa, the main prey species of cheetahs are medium-sized herbivores. However, cheetah prey varies from small birds and mammals to ungulates as large as wildebeest and zebra (Eaton 1974; Marker-Kraus et al. 2003; Bisset and Bernard 2007). The frequency of predation on each species depends primarily on availability of prey, as well as the suitability of the habitat structure in which the predator must hunt (Mills et al. 2004). In areas where the structure of the habitat, and the number and composition of prey species has been greatly changed by human activities, cheetahs have to switch to other prey if they are to optimize their net energy gain.

Recent studies show that cheetahs are more flexible than was previously thought in their use of different habitats and predation patterns (e.g. Jourabchian 1999; Mills et al. 2004; Bisset and Bernard 2007). The current populations of Asiatic cheetah are distributed in dry land steppes with cold winters, which are very different from the African savannas and grasslands in which most cheetah studies have been conducted. Historically, the distribution of cheetahs in Iran and other Asian countries broadly overlapped with the distribution of gazelles and it has been widely accepted that gazelles are the main prey species of Asiatic cheetahs (e.g. Heptner and Sludskii 1972; Harrington 1977; Harrison and Bates 1991). However, Iranian cheetahs have been observed in mountainous areas, where gazelles are less frequent, preying on wild sheep (*Ovis orientalis* Gmelin, 1774) and Persian ibex (*Capra aegagrus* Erxleben, 1777) (e.g. Harrington 1977; Farhadinia 2004; Hunter et al. 2007). The aim of this study was to determine prey selection by the Asiatic cheetah using cheetah kills collected in an area where kleptoparasites were absent. This is the first attempt to illustrate food habits of this species in Asia. We used our findings to suggest management strategies for effective conservation of the critically endangered Asiatic cheetah.

Materials and methods

Study area

The study was conducted in Dare-Anjir Wildlife Refuge (32°11′ to 32°37′ N, 54°49′ to 55°32′ E), an area of about 175,000 ha (Figure 1). Dare-Anjir is a hyper-arid hilly–mountainous area with vast expanses of plains surrounding a few main rolling mountains. Altitude ranges from 850 to 2200 m. The mean annual temperature and precipitation are 15.5°C and 75 mm, respectively. As a result of the variability in topography and distribution of precipitation, the composition and structure of the plant communities is not uniform within the area. The vegetation consists of different perennial, shrub and tree species such as fig (*Ficus carica* Linnaeus, 1753), mountain almond (*Amygdalus horrida* Spach, 1843) and Turk terebinth pistache (*Pistacia atlantica* Desfontaines, 1799) (Darvishsefat 2006). Dare-Anjir is located between a complex of cheetah habitats (Figure 1), serving as a migration corridor for the species from the farthest parts of Kalmand and Bafq protected areas in south, Siahkuh protected area in northwest and Saqand and Naybandan Wildlife Refuge in the east. Large herbivore species of the area include Jebeer gazelle (*Gazella bennettii* Sykes, 1831), wild sheep (*Ovis orientalis*), Persian ibex (*Capra aegagrus*) and Cape hare (*Lepus capensis* Linnaeus, 1758). Cheetah is the dominant predator in the study area with an estimated population size of 7–10 individuals (Farhadinia 2004).

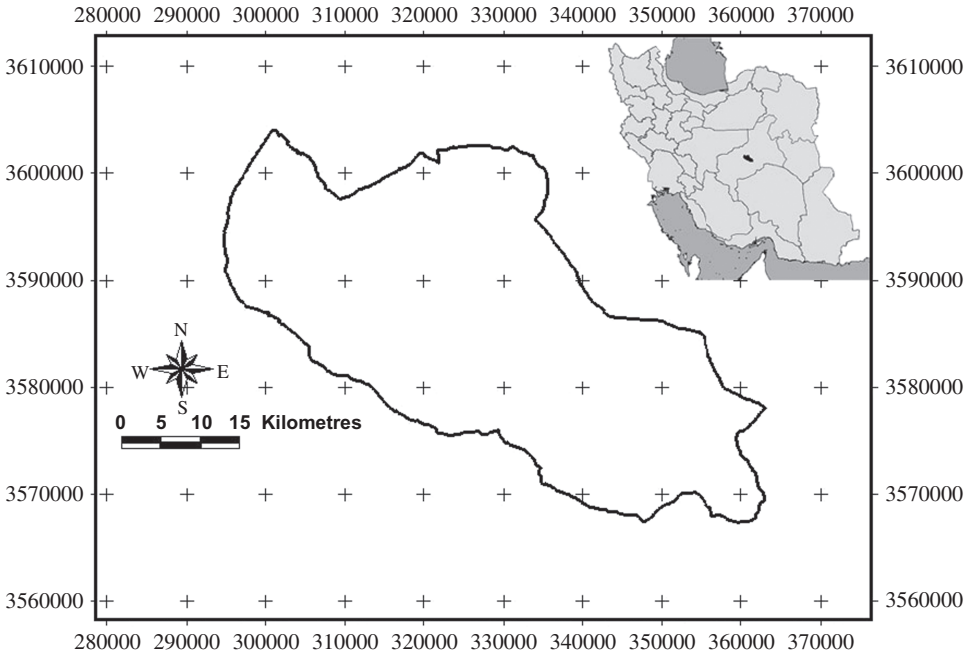

Figure 1. Map of Dare-Anjir Wildlife Refuge and its location in Iran.

Data collection

The study was carried out between April 2002 and March 2003, across the cheetahs' range in Dare-Anjir Wildlife Refuge. To study the food habits of cheetahs in the area, we looked for remains of ungulates killed by cheetahs. Kills were known to be by cheetahs because no other large carnivores are known to exist in the study area based on previous extensive camera-trapping surveys (Ali Jourabchian, Manager of the Conservation of the Asiatic Cheetah Project, personal communication). Moreover, whenever the detected prey carcasses were still fresh, skin lacerations associated with cheetah attacks or cheetah tracks were visible. We are therefore confident that cheetahs had caused all kills found throughout the reserve.

Adult mortality for ungulate populations with no large predators is estimated to be about 8–10% (Loison et al. 1999; Gaillard et al. 2000). Nevertheless, large predators are known to affect the adult mortality rate of ungulate populations (Owen-Smith and Mason 2005) in a compensatory manner (Kruuk 1972). We considered therefore negligible natural mortality causes for adult cheetah prey species because of the absence of other large predators. For similar reasons, juveniles were not considered in this study. The entire Jebeer and mountain ungulate habitats, excluding areas with slopes more than c. 35%, was regularly searched for carcasses of ungulates. The search was aided by game guards using motorbikes or on foot throughout the year. Carcasses were sexed and aged into two age classes (juvenile: < 1 year old and adult: > 1 year old) based on the presence/absence of horns, size of the body/skull and or tooth eruption patterns.

Prey availability was assessed a year later through a census made by Yazd Provincial Office of the Department of the Environment (DoE) in October 2004. As there

were no changes in the environmental conditions of the area between the two years, it was assumed that prey availability had also remained the same. The census was aided by teams of game guards searching blocks of the study area on predetermined routes. A point-count survey was conducted by the Conservation of the Asiatic Cheetah Project (CACP) throughout the mountainous part of the study area in July 2005 from 13 randomly selected points (Hemami 2005). Counts were carried out over a 3-day period from 07.00 to 11.00 h from each of the census points. In both surveys, sighted groups of ungulates were sexed and classified as juveniles or adults at the time of detection. The probable changes in relative abundance of the two species and population sex structure of each prey species over this period (2004–2005) was examined using the two sets of data.

The proportion of wild sheep to Persian ibex in the two surveys was nearly equal ($\chi^2 = 0.36$, df = 1, $p = 0.55$). Moreover, the sex ratio of wild sheep and Persian ibex obtained by the CACP survey through point-counts did not differ significantly from those extracted from DoE data (wild sheep: $\chi^2 = 3.30$, df = 1, $p = 0.07$; Persian ibex: $\chi^2 = 2.46$, df = 1, $p = 0.12$). Therefore, we used the results of both surveys for assessing the prey selection by cheetah. Unlike the CACP survey, the DoE data incorporated Jebeer gazelle numbers.

Analysis

Selectivity of cheetah predation for prey species and for a particular sex class of a specified prey species was assessed by Jacobs selectivity index *D* (Jacobs 1974):

$$D = (r - p) / (r + p - 2rp)$$

where r is the proportion of a given prey species (or a given sex class) in cheetah kills, and p is its proportion in the free-living population. Jacobs selectivity index ranges from – 1 (total avoidance) to + 1 (restricted to that habit).

Prey selectivity analysis was conducted in two ways: (1) using only wild sheep and Persian ibex data obtained through point-count surveys and excluding Jebeer gazelle from cheetah kills, and (2) considering the three main cheetah prey applying the DoE census data.

The frequency of each prey species as well as each sex class in cheetah kills was compared with their relative abundance in the free-ranging population by means of a χ^2 goodness of fit test (Zar 1999).

Results

Ungulate surveys

A total of 31 adult cheetah kills, including 18 wild sheep, 10 Persian ibex (Table 1) and three Jebeer gazelle were detected within the study area over 1 year.

During the point-count survey, a total of 110 prey individuals in 32 groups consisting of both wild sheep and Persian ibex were sighted. According to the point-count data, the average group sizes ± SD for female (including juveniles) and male herds of wild sheep were 4.7 ± 1.5 versus 1.5 ± 0.6 and of Persian ibex were 3.0 ± 1.3 versus 2.0 ± 1.0, respectively. Numbers of adult males and females seen in both surveys are given in Table 1. We collected only one lamb skull among the cheetah kills.

Table 1. Number of detected adult cheetah kills and observed frequency of primary prey species of cheetahs in Dare-Anjir Wildlife Refuge.

	Cheetah kills		
	Wild sheep	Persian ibex	Jebeer gazelle
Males	10	8	3
Females	8	2	0
Cheetah adult prey observed (DoE census, 2004)			
Males	94	85	14
Females	164	163	20
Cheetah adult prey observed (point-counts, 2005)			
Males	7	9	–
Females	26	31	–

Skulls of juveniles usually do not persist for long in nature (Caro 1994). As we had no other data to correct the underestimation in the relative abundance of juveniles among cheetah kills and had not measured natural mortality of juveniles, we did not compare selection for juveniles versus adults by cheetahs in this study. The sex ratios (male : female) of free-ranging wild sheep and Persian ibex based on direct observations (point-counts) were 1 : 2.7 and 1 : 3.0 respectively.

Prey selection

The proportion of wild sheep in the diet of cheetahs was nearly twice that of Persian ibex, whereas the proportion of the two species in the population was more or less the same (Figure 2). This implies that the frequency of cheetah predation on these two species does not follow their abundance (point count data: $\chi^2 = 2.76$, df = 1, $p = 0.10$).

Despite the severe bias in sex ratio toward females in both species, cheetahs selectively preyed on males (wild sheep: $\chi^2 = 5.41$, df = 1, $p = 0.02$; Persian ibex: $\chi^2 = 11.79$, df = 1, $p = 0.001$). Considering only wild sheep and Persian ibex as cheetah prey (using point-count data), Jacobs selectivity index was positive for males and negative for females of both species (Figure 3A). This suggests that cheetahs prey mostly on males and that wild sheep are preferred to Persian ibex. When all three primary prey species are considered, cheetahs selected males and avoided females. Jebeer gazelle had the highest score of selectivity among males of the three prey species (Figure 3B).

The frequency of Jebeer gazelle and wild sheep in cheetah diet is consistent with their relative abundance in the study area ($\chi^2 = 0.14$, df = 1, $p = 0.71$).

Discussion

Feeding ecology

Data collected by the two surveys (DoE census and point-counts) suggests that the relative abundance and population structure of wild sheep and Persian ibex was stable over the 2-year period.

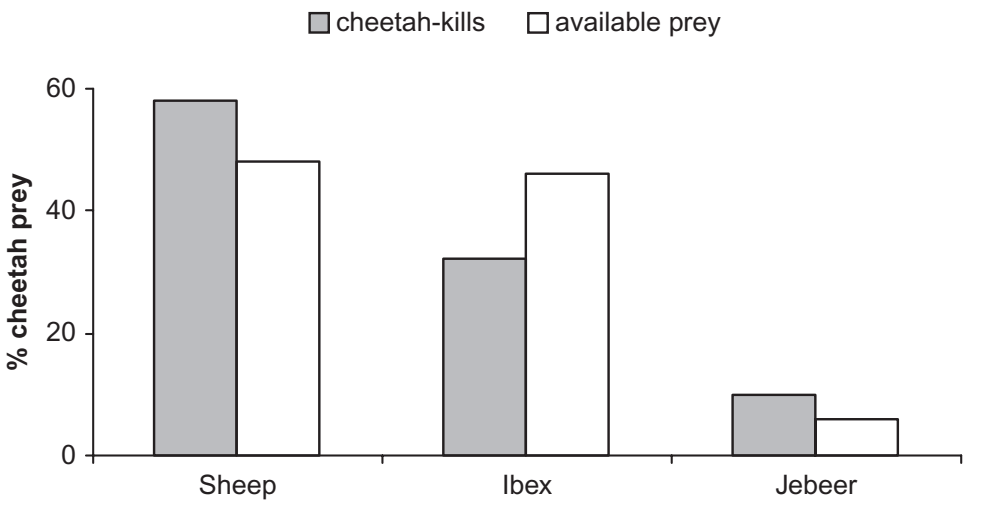

Figure 2. Proportion of cheetah primary prey species in its diet and in the study area. Number of prey as cheetah kills by species: wild sheep = 18; Persian ibex = 10; Jebeer gazelle = 3. Number of ungulates available as prey by species: wild sheep = 258; Persian ibex = 248; Jebeer gazelle = 34.

The sample size used in this study is very small for the Jebeer gazelle. This means that the results for this species may have been biased. However, as the population density of Jebeer gazelle in all cheetah habitats in Iran is currently very low and there is a paucity of information on feeding biology of Asiatic cheetah, we present our findings on this species too. Our results suggest that male Jebeer gazelle is the most preferred cheetah prey followed by male wild sheep. As stated before, the frequency of these two species in cheetah food is in accordance with their relative abundance in the study area. However, this conclusion is not applicable to Persian ibex, which spend most of their time on rocky high elevations and are less frequently seen in cheetah habitat. Water resources in the foothills may be the main attraction for ibex to use this habitat. We conclude that the unavailability of ibex in cheetah habitat is likely to be the main reason for less predation on them.

Hilly terrain and foothills where fringes of mountains coalesce into the surrounding plains is a common habitat at least for Jebeer gazelle and wild sheep (Ziaie 2008). Therefore, we suggest that such habitat may be a suitable hunting terrain for cheetahs compared with the vast plains with low density of prey. Moreover, foothills provide enough cover for stalking prey. Cover is considered to reduce chase distance (Caro 1994), as it enables cheetahs to stalk closer to the quarry before initiating the chase (Eaton 1974; Mills et al. 2004).

Despite the higher selectivity of Jebeer gazelle by cheetahs (Jacobs selectivity index for males, 0.60), our data suggest that in Dare-Anjir Wildlife Refuge, cheetahs mainly prey on mountain ungulates (wild sheep and Persian ibex). Lower frequency of Jebeer gazelle in cheetah kills was in compliance with their relative abundance among cheetah prey in the study area.

Although smaller prey was not detected in this study, Farhadinia (2007) has suggested that Asiatic cheetahs in Miandasht Wildlfe Refuge prey to some extent on Cape hare as well as rodents.

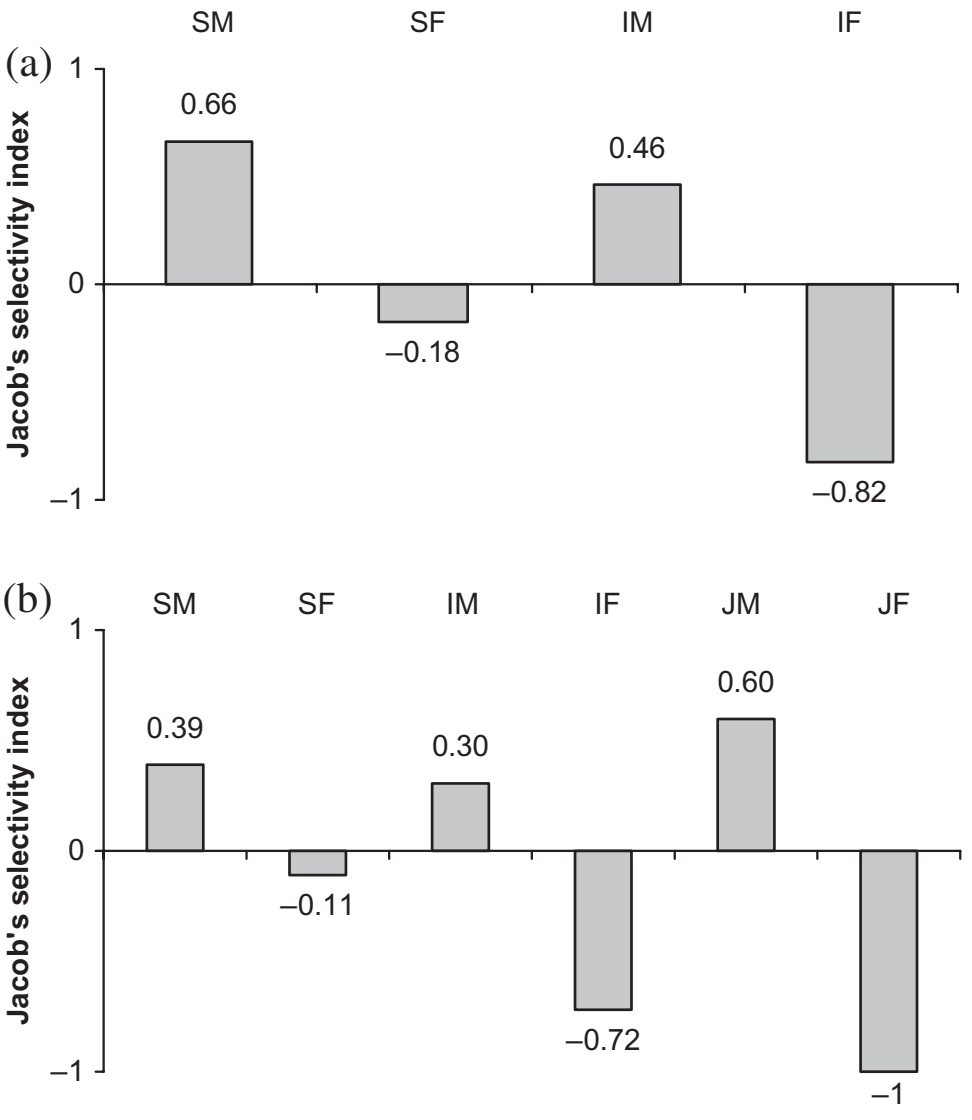

Figure 3. Jacobs selectivity index for (A) the cheetahs' two mountain preys and (B) all three preys in Dare-Anjir Wildlife Refuge. SM, male wild sheep; SF, female wild sheep; IM, male ibex; IF, female ibex; JM, male Jebeer; JF, female Jebeer.

Several authors have suggested that smaller prey (e.g. hares, rodents and juvenile ungulates) are usually under-represented in the cheetah menu when studies of food preferences are based on kills (e.g. Stander 1991; Mills 1992; Caro 1994). In Etosha National Park, Phillips (1993) found that cheetahs consume all bones, except the skull of prey weighing more than 10 kg. Correspondingly, it is likely that our study has underrepresented the importance of female Jebeer gazelles because the slender skulls of this species may not persist for long in nature. All the studies on feeding ecology of cheetahs have been carried out in areas where cheetah competitors, or

kleptoparasites, were present. Therefore, prey selection and food intake of cheetahs is influenced by their competitors (e.g. Durant 1998; Cooper et al. 2007). In open habitats, cheetah hunting success is higher, but cheetahs have to perform longer chases to catch their prey (Mills et al. 2004). Therefore, in areas where prey density in open habitats is very low, it is expected that cheetahs change their hunting strategy, switching to more abundant prey occurring in habitats with different, less suitable structure.

The mean body mass of preferred cheetah prey in Africa is 27.3 ± 4.8 kg (range 23–56 kg) (Hayward et al. 2006). The primary prey species of cheetah in Iran fall within this range although the weight of female Jebeer gazelle (15–18 kg) (Hemami 1994) is well under the minimum suggested range. However, since our sample size for Jebeer gazelle is too low, it is not possible to relate the lack of female Jebeer gazelle in the detected cheetah kills to its body mass.

Studies on prey selection of cheetah in Africa [e.g. Thomson's gazelle (*Gazella thomsoni* Gunther, 1884) in Serengeti National Park (Fitzgibbon 1990); springbok (*Antidorcas marsupialis* Zimmermann, 1780) in Kalahari (Mills 1990) and impala (*Aepyceros melampus* Lichtenstein, 1812) in Kruger National Park (Mills et al. 2004)] have also revealed the selection of male, medium-sized prey species compared with the smaller females. Hayward et al. (2006) suggested that in the presence of kleptoparasites, cheetahs may select smaller prey because they cannot consume the whole larger prey quickly and kleptoparasites will eventually take them. However, in Dare-Anjir area, in the absence of kleptoparasites, there seems to be no reason for selecting smaller prey (females), when larger ones (males) are available. Although we did not analyse juveniles as cheetah prey, because of the probable underestimation of their numbers in cheetah kills, their avoidance by cheetah is expected because of their low body mass.

On the other hand, the positive selectivity of cheetahs on male prey may partly be related to possible behavioural differences between the sexes of each species. Male wild sheep and Persian ibex seem less vigilant, particularly during the rutting season, and their heavy horns make them less agile compared with ewes. According to the point-count data, the average group sizes of female wild sheep and Persian ibex were threefold and 1.5-fold those of males of the same species, respectively (see Results). Studies on wild sheep and Persian ibex in other habitats in Iran support our findings that males of both species are found in smaller groups compared with females (e.g. Safiyan-Boldaji 2001; Tohidi 2001). Conversely, group size may be considered an index of predator avoidance (Ruckstuhl and Festa-Bianchet 2001) when comparing the sexes of each species. In this case, females of both species seem more gregarious and hence less vulnerable to predation.

Management implications

The composition of cheetahs' diet suggests that they select habitats consisting of hilly and light mountainous terrains surrounded by open plain for hunting. In such areas, Jebeer gazelle and wild sheep normally occur and ibex is an occasional visitor. Therefore, it is highly important to pay special attention to these "ecotone habitats" when developing conservation plans for cheetah habitats in Iran.

It is worth remembering that all four primary prey species of Asiatic cheetah are currently listed as Vulnerable by IUCN either at international scale (Wild sheep,

Persian ibex and Persian gazelle) (IUCN 2008) or national scale (Jebeer gazelle) (Hemami and Groves 2001). Hemami and Groves (2001) presented data on the extinction of gazelle populations within the network of protected areas of Iran; of the 32 populations of gazelles occurring in protected areas of Iran, 12 have become extinct over the last three decades. Considering the high selection of gazelles by cheetah and their low frequency in cheetah kills, special conservation programmes for gazelles in cheetah habitats are recommended. For instance, according to the historical distribution of gazelles in Iran, an evaluation of the suitability of residual natural habitats should be performed to form a base for habitat rehabilitation programmes. Selection of transitional areas for protection would provide the possibility of re-establishing metapopulations of cheetahs and their prey. It should also be considered a necessity to regularly assess the population status of both cheetahs and their prey to provide a base for their adaptive management.

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