Zoology in the Middle East, 2016
http://dx.doi.org/10.1080/09397140.2016.1144286

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Prey of the Persian Leopard (*Panthera pardus saxicolor*) in a mixed forest-steppe landscape in northeastern Iran (Mammalia: Felidae)

Elmira Sharbafi[*a], Mohammad S. Farhadinia[a,b], Hamid R. Rezaie[c] and Alex Richard Braczkowski[b]

[a]*Iranian Cheetah Society (ICS), Tehran, Iran;* [b]*Wildlife Conservation Research Unit, Department of Zoology, University of Oxford, Recanti-Kaplan Centre, Oxford, U.K.;* [c]*Environmental Science Department, Gorgan University of Agriculture and Natural Resources*

(Received 15 June 2015; accepted 1 December 2015)

We carried out a dietary analysis of Persian Leopards, *Panthera pardus saxicolor*, in a temperate region in north-eastern Iran, where the largest population nucleus exists across the subspecies range. We investigated 113 faecal samples collected between February 2009 and March 2010 in Golestan National Park. Faecal analysis revealed that leopards predominantly preyed upon wild ungulates, with the Wild Boar, *Sus scrofa*, being the most important prey species in terms of frequency and biomass. Eleven different prey items were identified, 7 of which were ungulates, comprising 99% of the total food items. We also found a spatial pattern in the prey composition of leopards: cervids were predominantly found in forest landscapes, whereas Wild Sheep, *Ovis orientalis*, was mainly found in steppe habitats, revealing the leopards' predation on medium- to large-sized ungulates. Livestock remains were mainly extracted from steppe samples, but the overall contribution to the leopard diet pattern (approximately 8.5% of consumed biomass) suggested that conflict with human communities, at least within the investigated core parts of the National Park, is not a major concern. The study provides the first illustration of the Persian Leopard's dietary composition in a temperate area with a relatively high diversity of available prey, and can be a baseline for future investigation and human-leopard interaction monitoring.

Keywords: Leopard diet; Persian Leopard; Golestan; temperate zone; forest; human-wildlife conflict

Introduction

The Leopard, *Panthera pardus*, is the most widely distributed large cat in the world, occurring throughout many parts of sub-Saharan Africa and Asia (Stein & Hayssen, 2013). This is a result of its highly adaptable hunting and feeding behaviour (Bertram, 1999; Hayward et al., 2006) and its ability to persist near human settlements (Athreya et al., 2013). The leopard is catholic in its choice of prey and has been observed to feed on animals from the size of small beetles to adult male Eland *Taurotragus oryx* (Estes, 1999). However, its diet appears to correlate to prey abundance, with the most predominant species forming the principal prey in many areas (Karanth & Sunquist, 1995). Leopards at times also feed on livestock and may cause substantial financial losses, for which they are often persecuted (Inskip & Zimmerman, 2009; Wang & Macdonald, 2009). Investigating the diet of large carnivores such as leopards is important in further-

[*]Corresponding author. Email: elmirasharbafi@wildlife.ir

ing knowledge of their basic ecology. Understanding leopard diet may also aid their conservation, particularly in regions where conflict with livestock occurs or is perceived to be due to leopards.

The Persian Leopard *P. p. saxicolor* is one of the least-studied subspecies of leopards and occurs in Iran, Afghanistan, Turkmenistan and the broader Caucasus (Breitenmoser et al., 2010). Iran hosts the largest population of the Persian Leopard (Lukarevsky et al., 2007); however most of these are now confined to reserves located throughout the country. Approximately 550-850 Persian leopards are thought to inhabit Iran (Kiabi et al., 2002), but there is a paucity of data available, particularly on their feeding ecology (Farhadinia et al., 2014a). Diet studies to date suggest that Wild Sheep, *Ovis orientalis*, Wild Goat, *Capra aegagrus,* and Wild Boar, *Sus scrofa*, comprise the majority of the leopards' diet in various steppe and arid habitats of the country (Harrington & Dareshuri, 1976; Etemad, 1985; Ziaie, 2008; Farhadinia et al., 2014a) while our knowledge is still lacking across temperate zones where the prey spectrum is more diverse (Ziaie, 2008).

Accordingly, we carried out a study within the temperate zone of north-eastern Iran known to have an important population of leopards (Kiabi et al., 2002). We also attempted to assess the extent of livestock contribution to the diet of leopards in this area as this is likely to contribute to retaliatory killings of leopards by local pastoralist communities.

Material and Methods

Study Area. Our study was conducted in Golestan National Park (hereafter GNP) in north-eastern Iran covering an area of approximately 919 km^2, (37°16', 37°31'N) to (55°31', 56°17'E). Under official protection since 1957, Golestan consists of various biomes, from Irano-Turanian landscapes to highland Alpine scrublands and extending to deep Hyrcanian forests. Altitudes range from 450 to 2411 m a.s.l. and mean annual precipitation ranges between 150 and 750 mm. Mean annual temperature ranges between 11.5 and 17.5°C (Kiabi et al., 1994). A heavily used transport route termed the "Asian road", which connects central Iran to the North, passes through the park. The main vegetation units of the park include closed forests, open woodlands, scrubland, mountain meadows, steppes, halophytic and fern communities (Akhani, 2005; Darvishsefat, 2006).

Golestan is well-known as an important habitat for the Persian Leopard in north-eastern Iran (Kiabi et al., 2002), together with a diverse fauna that includes a number of large Iranian mammal species such as Wild Goat, Wild Sheep, Maral Red Deer, *Cervus elaphus*, and Roe Deer, *Capreolus capreolus*, Brown Bear, *Ursus arctos*, Grey Wolf, *Canis lupus* and Wild Cat, *Felis sylvestris ornata*, which are the main carnivores in the area (Kiabi et al., 1994; Darvishsefat, 2006).

Our sampling effort was concentrated in two different habitat types in GNP, both outside of village areas and which had been granted high levels of anti-poaching control to protect leopards and their prey. The two main habitat types surveyed were the Tange Gol (forest) comprising a 120 km^2 area and Degarmanli (steppe) with an area of 160 km^2.

Scat collection and analysis. We used scat analysis to determine the diet of the leopards in both areas. Surveys were carried out between February 2009 and March 2010, mainly along single path trails which leopards prefer to use as travel routes and where scats are deposited as a social communication mechanism (Henschel & Ray, 2003).

Leopard scats were identified based on their size, shape and the presence of leopard signs, e.g. scrapes (Henschel, Abernethy, & White, 2005; Martins, Horsnell, Titus, Rautenbach, & Harris, 2011). The majority of previous authors (Ott, Kerley, & Boshoff, 2007; Martins et al., 2011) used a 20 mm scat diameter (Norton, Lawson, Henley, & Avery, 1986) in order to differentiate leopard scats from other sympatric predators; however since those studies were done on leopards with smaller body masses (Stein & Hayssen, 2013), we adopted a more cautious approach using only scats in excess of 25 mm in the analysis. The Grey Wolf is the only other large carnivore species in our study area which has a similar scat to the leopard, but wolf tracks were only encountered

Table 1. Frequency of food items in scats of the Persian Leopard in Golestan. F% = Frequency of occurrence; P% = Percentage of occurrence.

	N	F%	P%
Common Fox (*Vulpes vulpes*)	2	1.8	1.6
Domestic dog (*Canis familiaris*)	1	0.9	0.8
Domestic Sheep (*Ovis aries*)	11	9.7	9
Goitered Gazelle (*Gazella subgutturosa*)	7	6.2	5.7
Maral Red Deer (*Cervus elaphus maral*)	2	1.8	1.6
Reptile	1	0.9	0.8
Rodents	2	1.8	1.6
Roe Deer (*Capreolus capreolus*)	5	4.4	4.1
Wild Boar (*Sus scrofa*)	57	50.4	46.7
Wild Goat (*Capra aegagrus*)	11	9.7	9
Wild Sheep (*Ovis orientalis*)	23	20.3	18.9
No. of food items	**122**		
No. of scats	**113**		
No. of food items/scat	**1.08**		

four times in Golestan, suggesting low densities of this predator in the reserve, while leopard tracks were encountered on average three times on each trail.

Collected scats were sealed in plastic bags and later washed in water, using a 1.5 mm sieve to separate the hair from other organic matter, and air dried. We used the laboratory procedure of Ott et al. (2007) in order to prepare scats for analysis.

Prey remains were identified using a combination of macroscopic analysis, cuticular hair scale patterns and medullary cross sections (Norton et al., 1986; Bothma & LeRiche, 1994). To ensure accurate sampling of prey species in scats, we randomly chose twenty hairs (Mukherjee et al., 1994) per scat. All hair analyses were made using a printed key of the local prey species (Sharbafi, unpubl.) that we prepared prior to the analyses.

Data analysis. We present frequency of occurrence (FO) (percentage of total scats in which an item was found) and percentage of occurrence (number of times a specific item was found as a percentage of all items found) as indices of leopard diet (Ackerman et al., 1984). However, as the body sizes of different prey items are highly variable, the frequency of occurrence and percent occurrence indices can considerably overestimate the importance of smaller prey species (Klare et al., 2011). We therefore followed other authors (e.g. Karanth & Sunquist, 1995; Henschel et al., 2005) in applying a correction factor developed by Ackerman et al. (1984) for the ecologically analogous Puma *Puma concolor* and derived from feeding trials. By using the regression equation: $y=1.98+0.035x$, where x is the live weight of prey consumed, y may be applied in the form of a correction factor that when multiplied by the observed frequency of occurrence may produce the relative biomass consumed by leopards. The correction factor was not applied for small prey species with <2 kg body weight (Ackerman et al., 1984). The relative biomass estimate was obtained using the average live weight of each species and for each sex from available publications (Valdez, Alamia, Bunch, & Mowlavi, 1977; Goshtasb, 2001; Ansorge, Kluth, & Hahne, 2006).

Results

We analysed a total of 113 leopard scats accounting for 123 food items, yielding a proportion of 1.06 food items per scat (Table 1). Most of the scats contained only one prey item (n=113, 91.1%), while the remainder contained two food items.

Table 2. Comparison of food composition (%) of diet of the Persian Leopard in steppes (N=78) and forests (M=35) in Golestan.

Prey	Steppe (FO)	Forest (FO)
Large-size prey		
Maral Red Deer	-	5.71
Wild Boar	43.58	65.71
Medium-size prey		
Domestic Dog	1.28	-
Domestic Sheep	12.82	2.85
Goitered Gazelle	8.97	-
Roe Deer	2.56	8.57
Wild Goat	6.41	17.14
Wild Sheep	26.92	5.71
Small-size prey		
Common Fox	2.56	-
Reptiles	-	2.85
Rodents	1.28	2.85

Table 3. Relative biomass consumed and relative number of prey items consumed by the leopard in Golestan. F% was corrected for the occurrence of multiple prey items; body weight is the estimated mean live weight in kg; correction factor: estimated weight of prey consumed per collectible scat (C = 1.98 + 0.035B); relative biomass consumed: (A×C)/∑〖(A×C).〗.

Prey	A: F% (corrected)	B: Body weight (kg)	C: Correction factor (kg/scat)	D: Rel. biomass consumed (%)
Domestic Dog	4.4	20	2.7	0.38
Domestic Sheep	9.2	35	3.21	8.46
Fox	1.8	5	2.2	1.19
Goitered Gazelle	5.3	20.6	2.70	4.50
Maral Red Deer	1.8	65	4.26	2.36
Reptiles	0.9	0.1	0.1	0.02
Rodents	1.3	0.1	0.1	0.04
Roe Deer	3.5	15	2.5	2.08
Wild Boar	48.7	45	3.56	54.32
Wild Goat	8.9	36	3.24	9.00
Wild Sheep	18.1	34	3.17	18.05

A total of at least 11 species was found in 113 leopard scats with Wild Boar comprising the highest proportion (50.4%), followed by Wild Sheep (20.3%), Wild Goat (9.7%) and livestock (9.7%). Ungulates comprised 51.6% of the total food items and, with the exception of Red Deer and Wild Boar, the rest of the ungulates were medium-sized and most of them were wild species (Table 1).

Suids and bovids were both taken with a similar frequency while Red Fox, *Vulpes vulpes*, domestic dog, rodents and reptiles were preyed on only occasionally (we failed

to identify the latter two items to species level). Leopard hairs were found in three scats which, in view of the lack of claws or bones, were suspected to be from grooming.

35 samples were collected in the forest habitat (30.9%) and 78 in the steppe area (69%). Red Deer and reptiles were found exclusively in forest samples while Goitered Gazelle, *Gazella subgutturosa*, Common Fox and domestic dog were only detected in scats collected in the steppe. Furthermore, we observed a significant difference in the occurrence of Wild Sheep (X^2=15.696, p<0.0001) and livestock (X^2=7.364, p<0.007) between two habitat types in GNP. Wild Boar frequency was higher in the forest compared to the steppe (FO: 65.7% and 43.5%, respectively). By contrast, Wild Sheep was more frequent in the steppe areas (Table 2).

Of the 57 scats with Wild Boar remains, 14 contained bones and hairs that permitted separation into juveniles and adults. Thirteen of them were from juvenile individuals. Remains of Wild Sheep were found in scats 23 times and identification between juvenile and adult was possible for 12 scats. Nine individuals consumed were juvenile and three were adult.

In terms of the relative biomass consumed by leopards, the Wild Boar was the main prey in GNP, comprising 54.3% of the total biomass (Table 3). Wild Sheep, Wild Goat and livestock were also important with 18.1%, 9% and 8.5%, respectively. Ungulates were the most important prey for the Persian Leopards in GNP, constituting 98.8% of relative biomass consumed.

During the survey period, two leopards were found dead in road accidents in Golestan, both females (one cub and one adolescent). The stomach contents of these revealed the remains of an Indian Crested Porcupine *Hystrix indica*.

Discussion

The Persian Leopards in our study site preyed on the entire range of ungulates known in GNP, with some differences in various habitat types. This dietary diversity accords with temperate ecosystems elsewhere (Johnson et al., 1993; Braczkowski et al., 2012). Leopards predominantly relied on wild ungulates and Wild Boar as the most important prey species in frequency and biomass. This correlated with the high relative abundance observed from a recent camera trap study (Hamidi et al., 2014), supporting the general conclusion that the leopard's diet appears to track the relative densities of ungulate prey in most areas (Karanth & Sunquist, 1995; Sunquist & Sunquist, 2002; Henschel et al., 2005; Farhadinia et al., 2014a). Field efforts from 1973 through 1976 in Golestan National Park led Joslin (unpubl. report 1990) to suggest that the high abundance of leopards was related to the high density of Wild Boar.

Leopards in GNP appeared to rely heavily on wild ungulates (predominantly Wild Boar). The high incidence of Wild Boar in the leopard diet in GNP contrasted with Hayward et al. (2006) who found that suids were largely avoided by leopards in several parts of their range. However, leopards in northern Iran are amongst the largest in the world (Sunquist & Sunquist, 2002) and individual males weigh on average nearly 70 kg (Farhadinia et al., 2014b). It is therefore possible that leopards in this region are not as constrained by suid anti-predator strategies as in other parts of their range (e.g. the Cape, Braczkowski et al., 2012). Henschel et al. (2005) also found suids in Gabon to be the single most important prey in biomass for leopards.

More than half of the consumed biomass consisted of Wild Boar which is most likely due to their high abundance in GNP, based on direct observations and camera trap survey (Hamidi et al., 2014). The higher frequency of leopards feeding on Wild Boar in the forest compared to steppes in GNP could be attributed to the greater accessibility of

Wild Boar due to stalking cover for leopards. Both species of deer occur in low density and small groups within the forests (Hamidi et al., 2014) and form the lowest proportion of the leopard's diet in these areas.

The higher detection of each prey species in the habitat type where it is more expected can explain the spatial pattern of prey composition in GNP. Therefore, the higher occurrences of Wild Sheep and livestock in the steppe habitat as well as the cervids' predominant presence in the forest area support their higher occurrence in scat samples collected from each habitat type, which is in accordance with Ott et al. (2007) who suggested kill and defaecation sites are often spatially explicit. However, the presence of Roe Deer in scat samples from the steppe habitat as well as Wild Sheep detected in the forest samples showed that such a relationship can sometimes be contradicted. Moreover, it generates a hypothesis that the leopards are not constrained to a specific landscape type in their ranging patterns.

The greater occurrence of Wild Sheep compared to Wild Goat among scats in this habitat is likely due to the lower abundance of the latter in the area, based on annual censuses made by the Golestan Department of Environment. As the largest prey of leopard in GNP, Maral Red Deer was detected only in two scat samples, showing non-frequent predation by the leopards. They are usually observed in herds on forest edges (Kiabi, Ghaemi, Jahanshani, & Sassani, 2004), but numbers have been depleted due to poaching, which suggests large body size combined with scarcity has affected their low predation level by leopards.

Domestic animals apparently do not contribute significantly to the leopard diet in GNP. However, since our scat samples were mainly collected in the core of the National Park, more surveys are required in the buffer zones around the National Park and beyond its borders. Similarly, Farhadinia et al. (2014a) reported around 15% of livestock were found in the leopard diet in Sarigol National Park, north-eastern Iran. Higher levels of livestock in the diet of leopards have been reported in other areas, and even half of the diet consisted of livestock remains, particularly in the western Himalayas and Bhutan (Mukherjee & Mishra 2001; Wang & MacDonald, 2009). Domestic animals are not allowed to graze in the National Park and their absence has probably contributed to their low occurrence in leopard diet in the area.

Our study has provided updated information about the food habits of the Persian Leopard within one of the most important sites for the species in north-eastern Iran and may serve as a reference point for future monitoring. Our work can also serve as a baseline for future researchers who may investigate future dietary shifts due to anthropogenic pressures being exerted on the prey base. We recommend that future studies should consider marginal habitats of GNP for faecal sampling, preferably with genetic fingerprinting to identify predator species to reflect an updated picture of the leopard feeding ecology in GNP as well as in adjacent reserves. However, there is no doubt that the future of the Persian Leopard populations relies heavily on prey abundance, and this should be one of the main conservation concerns for the region.

Acknowledgements

We would like to thank the Golestan Provincial Office of the Department of Environment, which provided logistic support for field surveys. Also, we wish to record our respect for the game guards, for their kind cooperation in field surveys. Finally, we have to thank Bahram Kiabi and Mansour Mesdaghi for their advice during the survey and Quinton Martins, Gus Mills and two anonymous reviewers for their comments on an earlier version of this paper.

Disclosure Statement

No potential conflict of interest was reported by the authors.

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