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Desert Fox (*Vulpes vulpes pusilla*) a Generalist or Opportunistic Specialist: Insight into the Feeding Habit in Thar Desert of Rajasthan, India

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ABSTRACT

Desert fox is a medium sized meso-carnivore, found in variety of habitats. For understanding its role in ecosystem, as a carnivore, an insight in feeding ecology is explored in Thar Desert of Rajasthan. However, the available information on the same for Desert fox (a sub-species of Red fox) is insufficient. The present study was undertaken to understand the dietary pattern of Desert fox and variation between the seasons in resource constrained environment of Thar Desert of Rajasthan. A total of 699 scats were collected for a period of around two years, covering all seasons between year 2015 and 2017 and analyzed using standard methods. It was found that fruits (28.05%) were identified as the major category followed by insects (18.94%), mammals (17.32%), reptiles (6.72%), birds (3.17%) and Arachnida (0.45%), in the diet of Desert fox. Interestingly, remains of many large domestic animals were found in the scat, suggests that upon availability, occasionally it also scavenge. The dietary pattern from the results suggested that, as opportunistic feeders, Desert foxes may have adapted to survive in one of the densily population desert landscape with changing land-tenure system and behavior to suit local circumstances, using alternative sources of prey and anthropogenic food.

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INTRODUCTION

The Red fox is the most widespread of all wild canids and has the largest natural distribution of any non-human land mammal. The distribution includes a diverse array of habitats from deserts to Arctic tundra and can be summarized as being Holarctic, Oriental, Australasian, Northern Neotropical and African (Sillero-Zubiri et al. 2004). Red fox is considered to be the most adaptable mammals surviving in wide variety of habitat. Its adaptability is manifested in its feeding ability on a wide range of different items. Desert fox *Vulpes vulpes pusilla* (Order Carnivora, Family Canidae) is a sub-species of Red fox found in arid and semi-arid region of Thar Desert of Western Rajasthan and Kutch region of Gujarat, India. Although Red foxes (*Vulpes vulpes*) are the most widely distributed carnivore in the world which makes their status as Least Concern (IUCN Red Data List), role of Desert fox in desert ecosystem is still not studied and information regarding this sub-species of Red fox is meager. The Desert fox is also included in Schedule I of Wildlife (Protection) Act, 1972 in India as well as in Appendix III of CITES with full protection. So far, only a handful of studies have been conducted on this animal, that too regarding its distribution and status in various regions of Thar Desert, Rajasthan. Recent studies have indicated that its present distribution is reduced (Rahmani 1997, Kankane 2000, Dookia and Wilson 2016) thereby implicating regional threat to

Desert fox (Prakash 1997, Sharma 2013, Khan et al. 2015). Feeding pattern is an important aspect in the study of carnivore ecology, since trophic resources dominate several aspects of their biology ((Macdonald 1983, Bekoff et al. 1984) and is the prime aspect to influence the activity pattern of Red foxes (Cavallini and Lovari 1991). On one hand, a study on Red foxes (*Vulpes vulpes*) in China has shown that they have a generalist dietary pattern (Tsukada et al. 2014) whereas, on the other hand various studies have revealed that Red foxes are not only opportunists but also facultative specialists (Vlasseva et al. 2017, Balestrieri et al. 2011, Lanszki and Heltai 2010, Lanszki et al. 2006, Serafini and Lovari 1993, Hockman and Chapman 1983). Diet composition of Red fox is mainly estimated using non-invasive method like scat analysis (Korschegen 1980, Putman 1984, Pierce and Boyle 1991, Litivaitis 2000, Iverson et al. 2004), where the food remains are examined and identified. Most available information about the food habits and diet of foxes found in India are not on Red fox but on its sympatric Indian Fox, *Vulpes bengalensis* (Dookia et al. 2012, Kumara and Singh 2012, Home and Jhala 2009). Whereas very little information is available on the feeding pattern of the Desert fox in the Thar Desert, Dookia and Wilson (2016) stated that the diet of this opportunistic omnivore consists a wide range of food items like insects, birds, rodents, fruits, arthropods and mammals. In general, arid habitats impose challenging conditions to survival of its inhabitants, since diet and resource availability varies largely from season to season (Louw and Seely 1982). Also, a reliable knowledge of diet is of paramount interest in understanding the species overall biology. Keeping this in mind, the current study was undertaken to determine the dietary pattern feeding choice of Desert fox in Thar Desert of Rajasthan, India.

MATERIALS AND METHODS

Study area

The study area was selected covering all habitats (shrubland, grassland and the agricultural fields) in arid region of Thar Desert along with Desert National Park and its peripheral mix land use area including agriculture fields and wastelands. The Desert National Park is one of the largest protected area of Thar Desert and falls in arid regions of the Desert in Rajasthan (26º 01′ 00′′ N and 28º 02′ 12′′ N latitudes and 69º 30′ 00′′ E to 72º 21′30′′ E longitudes). The region has undulating terrain covered by various land features like sand dunes, shrubland, stony and gravelly wasteland, natural grassland and agricultural land with sparse and xerophytic natural vegetation.

Sampling period : The sampling for the collection of scats was conducted for a period of around two years, covering all seasons of the year between 2015 to 2017.

Diet composition

Collection of scats : A total of 699 scats were collected during the sampling period. Each scat was stored individually in numbered paper bag with additional cover of polythene zip lock bag that was labeled with date, time, GPS coordinates and place of collection. Scats were mostly collected from the surroundings of confirmed active Desert foxden sites to avoid confusion with similar sized scats of sympatric meso-carnivores like Desert cat (*Felis sylvestris ornata*) and Indian fox (*Vulpes bengalensis*).

Scat analysis for diet estimation : Scat analysis is a non-invasive and reliable method used to study carnivore diet spectrum (Korschgen 1980, Sankar and Johnsingh 2002, Mukherjee et al. 2004, Edgaonkar 2008). All 699 scats were sun dried, washed and strained in water through a 0.5 mm mesh sieve to discard unwanted items, dismembered with forceps and finally oven dried for 3 h at 60ºC in the laboratory. The processed scats were then analyzed for the presence of various indigestible items like hair, scale, bones, chitin, claws and seeds (Fig. 1). These items were identified by different methods suitable for each category of food item. Insects were identified on basis of their undigested exoskeleton compared to reference samples. Fruits were identified on the basis of undigested seeds found in scats that were compared with a reference collection of seeds from the study area. Reptiles and birds were identified only upto class level on basis of their scales, claws and feathers, respectively. Arachnids were identified on the basis of their size, texture and pattern of exoskeleton and later compared with samples collected

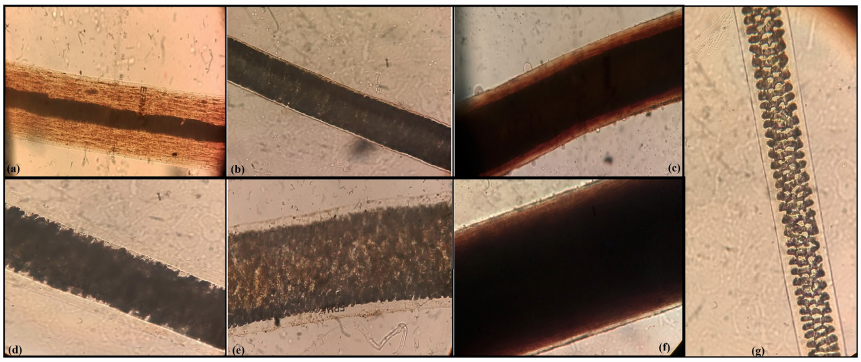

Fig. 1. Photo-micrographs of various selected hair sample (a) Camel hair, (b) Chinkara hair, (c) Goat hair, (d) Cow hair, (e) Sheep hair, (f) Pig hair and (g) Rodent hair.

from the study area. Mammalian food items were identified following standard protocol (Mukherjee et al. 1994, Bahuguna et al. 2010).

Those items that can't be understood beyond the class level were labeled as unidentified under their respective category whereas, grasses, debris, pebbles and plastics that were identifiable with direct observations were labeled as others as a separate category.

Determination of sample size adequacy for number of scats **:** In every season, the scats collected were analyzed for standardization of minimum adequate number of scats that could represent the detection of all possible food items in the diet of Desert fox for that

Table 1. Season-wise food items identified in Desert fox scats.

		Winter N=363		Summer N=186		Monsoon N=150	
Category	Food Items	No. of occur-rences	(Fo%)	No. of occur-rences	(Fo%)	No. of occur-rences	(Fo%)
Insects	Beetles	101	14.05	94	20.00	78	21.79
	Grasshopper	5	0.70	10	2.13	5	1.40
Fruits	Zizyphus	290	40.33	6	1.28	10	2.79
	Cucumis melo	36	5.01	53	11.28	12	3.35
	Unidentified seed	15	2.09	2	0.43	0	0.00
	Unidentified seed 2	10	1.39	0	0.00	0	0.00
Reptiles	STL	2	0.28	5	1.06	6	1.68
	Unidentified scales	22	3.06	36	7.66	24	6.70
	Reptile claws	2	0.28	1	0.21	6	1.68
Birds	Birds	15	2.09	22	4.68	9	2.51
	Egg shell	2	0.28	1	0.21	0	0.00
Mammals	Wild mammals	9	1.25	33	7.02	27	7.54
	Domestic mammals	43	5.98	62	13.19	61	17.04
	Unidentified Bones	7	0.97	11	2.34	15	4.19
Arachnida	Scorpion	0	0.00	2	0.43	5	1.40
Others	Grasses	66	8.18	82	17.45	64	17.88
	Debris	80	11.13	40	8.51	31	8.66
	Pebbles	13	1.81	10	2.13	5	1.40
	Plastic	1	0.14	0	0.00	0	0.00
	Total items	719		470		358	

particular season. For this purpose, all scats of every season were randomized and percentage frequency of each item in the diet was plotted cumulatively, at an interval of 10 scats. This was continued until all scats were included and the cumulative frequency of occurrences of different food categories was used to test the effect of sample size on the results. An asymptote of the frequencies of scats was considered sufficient to quantify the food category in the diet reliably (Jethva and Jhala 2003, Home 2005).

Data analysis

Estimation of dietary items : The identified items were classified into various categories and calculated for percent frequency of occurrence of an item / total items (% F_o / Item) (Maurya et al. 2011). Seasonal variation in diet (variation among the components that occurred in winter, summer and monsoon) was computed by analyzing scats of each season separately as percentage frequency of occurrence of an item/ total items (% F_o /Item), adding the values of both the seasons together. Finally, Chi-square test for statistical analysis was used to observed any significant difference in dietary pattern of Desert fox among seasons. The statistical analysis was done using SPSS 16.

RESULTS AND DISCUSSION

The dietary choice, feeding pattern and food spectrum of Desert foxes were estimated through non-invasive procedure, i.e., scat analysis. For determining minimum number of scats to be analyzed to understand dietary composition in Desert fox, cumulative percent frequency of the different food items was calculated at each increment for 10 scats and it was plotted against the total number of scats of each season. It was observed that the cumulative frequency for food items stabilized at 115 scat samples for winter, 80 for summer and 60 for monsoon season, approximately. In overall analysis of 699 scats (total of all the scats collected in 2 years covering all seasons of sampling period), it was found that Fruits (*Zizyphus* sps., *Cucumis* sps. and few others) were identified as the major category (28.05%) followed by Insects (Beetles and Grasshoppers) (18.94%), Mammals (among wild mammals are Rodents, Hedgehog, Hare and Chinkara, whereas among domestic mammals are Sheep, Goat, Pig, Cow and Camel) (17.32%), Reptiles (6.72%), Birds (3.17%) and Arachnida (0.45%). The items that comprised the other category was grasses, pebbles, debris that was found substantially in all the scats except plastic which was found only in one scat. Reptiles were identified through remnants of scales, birds through undigested feathers and mammals were identified through hair analysis (Photo-micrographs plate provided as Annexure-I).

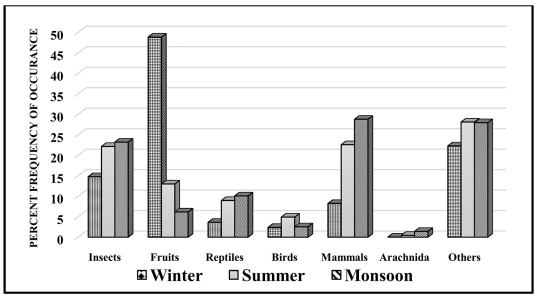

Fig. 2. Seasonal comparison of relative frequency of occurrence of major food items.

Seasonal comparison of diet composition of Desert fox

The categories and their respective food items identified in scats varied in terms of relative frequency of occurrence (F_o / Item) among seasons (Fig. 2) (Table 1). It was found that during winter season fruits (48.82%) were identified as the major category followed by insects (14.05%), mammals (8.2%), reptiles (3.62%), birds (2.37%) and other components (Grass, Debris, Pebbles and Plastic) comprised (22.26%). During summer season, major components identified were mammals (22.55%) followed by insects (22.13%), fruits (12.99%), reptiles (8.93%), birds (4.89%), arachnida (0.43%) and others (28.09%) ; for monsoon season, major components identified were mammals (28.77%), insects (23.19%), reptiles (10.06%), fruits (6.14%), birds (2.51%) arachnida (1.40%) and other (27.94%). Season-wise, frequency of occurrence of fruit items in Desert fox's scat was recorded higher in winter season (48.82%) than in summer (12.98%) and monsoon (6.15%) season. Higher frequency of occurrence of mammals (28.77%), insects (23.18%), reptiles (10.06%) and arachnida (1.40%) items was observed in monsoon season relative to summer

and winter. However, arachnida was completely absent in winter scats. Frequency of occurrence of bird (4.89%) items was observed higher for summer season relative to other seasons i.e. winter (2.36%) and monsoon (2.51%). Also, there was a significant difference between food items of Winter and Summer $\{\chi^2 = 188, df = 6, P (\chi^2 > 188) = 0.000\}$; between food items of Summer and Monsoon $\{\chi^2 = 18.2, df = 6, P (\chi^2 > 18.2) = 0.006\}$ and between food items of Monsoon and Winter $\{\chi^2 = 238, df = 6, P (\chi^2 > 238) = 0.000\}$. Domestic mammals (5.98%) in winter, (13.19%) in summer and (17.14%) in monsoon were observed more than the wild mammals (1.25%) in winter (7.02%) in summer and (7.54%) for monsoon seasons in the scats.

Food habit is one of the important aspects of the animal ecology. The Desert fox (a sub-species of Red fox) is one of the important meso-carnivores of Thar Desert ecosystem, but very little is known about its feeding ecology. Evidences from various studies on different species of Red foxes showed that their diet is correlated to the availability of the food resources which again is connected towards the metrological factors (Cavallini and Lovari 1991). Studies conducted by Bakaloudis et al. (2015) in heterogenous Mediterranean landscape on gut content of Red fox suggested food categories like mammals 20.81%, birds 3.22%, reptiles 1.65%, amphibians 0.15%, fishes 0.15%, arthropods 34.73%, fungi 0.52%, mollusks 0.07%, plants 30.39% and various components 7.26% like plastic, gravel and paper. Similar results were observed from regions of Strzelecki Desert and Simpson Desert by Cupples et al. (2011) with high composition of mammals, reptiles and comparatively low in aves and vegetative components in their diets. In the present study, Desert fox show — Opportunistic behavior especially in regards with scavenging large prey rather than predating and Facultative specialist behavior in feeding habits with respect to the available resource that enables them to sustain in difficult and harsh environment of Thar Desert. Overall dietary spectrum of Desert fox in and around the study area consisted of 6 categories such as : Fruits (*Zizyphus* and *Cucumis* melo) > Insects (beetles, grasshoppers) > Mammals (sheep, goat, camel, cow chinkara, pig and rodents) > Reptiles (spiny-tailed lizard, other reptiles) > Birds (terrestrial birds) > Arachnida (scorpion). This dietary spectrum of Desert fox consisting of diverse food items in-turn depicts a generalist feeding habits of Red fox. Similar patterns with diverse items were identified for research conducted on other sub-species of Red fox as well as other meso-carnivores in India. Studies done by Reshamwala et al. (2018) in India on another sub-species of Red fox, concluded that foxes consumed less wild prey where there was abundant supply of human sub-sidies (55.87%). Its diet included wild carrion, rodents, lagomorphs, birds, wild seeds, grasses, plant materials, eggs, insects and human sub-sidies. Results from Aryal et al. (2010) stated Lagamorphs (29.88%), wild mammals (21.53%), vegetation components (24.76%), non-food items (13.00%), insects (5.41%), domestic mammals (2.82%) and birds (2.59%) in Red fox diet from Nepal. According to finding from Kumara and Singh (2012) on Indian fox diet undigested plant remains, seeds and fruits occurred in 81%, rodents occurred in 80% and reptiles occurred in 12% of the scats. Other mammals, birds, egg shells and frogs collectively occurred in < 10% of the scats. Similar studies were conducted by Gompper and Vanak (2006), Home and Jhala (2009), Kidawa and Kowalczyk (2011), Maurya et al. (2011), Singh et al. (2016). Relative frequency of occurrence of one item/category with respect to total items/categories revealed that the Desert fox diet comprised of fruits and insects as well as both small and large mammals as the major items whose occurrence may change according to the food availability. Due to its small size, it is not possible for this animal to hunt large mammals, therefore, presence of large and domestic mammals components in scats is solely due to scavenging. Similar inferences on its scavenging behavior is reported by Amy et al. (2018), Bassi et al. (2018), Reshamwala et al. (2018), Young et al. (2015), Aryal et al. (2010). Also, prey like reptiles, birds and scorpion seem to contribute relatively less in their diet. However, their remains were difficult to identify at species level. It must be noted that if the frequency of occurrence of one item is related to the number of all items found, instead to the scat number, the results can be interpreted as an approximation of the volumetric importance of items in the diet (Loveridge and Macdonald 2002). However, this assumption was not supported in this study. Small food items (e.g. different insect species) May occur in great numbers

in one scat, whereas large food items do not. Thus, frequency per item could have further increased the importance of small food items (Klare et al. 2010).

Also, suggestive differences were found in the dietary items of Desert fox diet seasonally (especially winter and monsoon) that may be attributed to the difference in preference or possibility of food items. The possibility could be due to seasonal habitat change or breeding season of prey species. The seasonal changes in diet items is in corroboration with results of other studies showing that the diet of Red foxes varies seasonally (Lin 2010, Murdoch et al. 2010, Xuanlong 2010). Fruits were the significant and more preferred component of Desert fox diet during winters due to their high seasonal availability in this season and also because finding other prey items in winter is scarce, due to low temperature. Although fruits have relatively low protein content but they can be procured with great ease relative to the time and effort invested, allow meeting at least minimal protein requirement (Rode and Robbins 2000). Though the choice of fruit species in Desert fox diet was mostly limited to *Zizyphus* during winters and because it may not have fulfilled optimum nutritional requirement that could have prompted foraging even on insects especially beetles as observed in the remains of winter scats. Remaining items in scats revealed the opportunistic feeding habit of Desert fox via scavenging on large livestock (camel, cow, sheep, goat, pig) carrions and hunting of rodents, small mammals and reptiles by digging them out of their burrows. On the other hand, due to low availability of *Zizyphus* in summer and monsoon season, the most significant items of Desert fox diet were mammals and insects indicating that it prefers protein rich food sources in a given amount of available habitat. Also, relationships between frequency of occurrence of mammal remains and insects in individual summer and monsoon scat samples in the present study suggest that when Desert fox was able to feed on rodents or scavenge on ungulates carcasses, insects becomes the secondary diet. In addition to this, another fruits *Citrullus* sps. and *Cucumis* sps. were also taken in proportion to its availability in summer and monsoon season. Presence of *Citrullus* sps. and *Cucumis* sps. fruit parts in scats again demonstrates the opportunistic aspect of their foraging behavior. The presence of seeds in the scat is consistent with other studies, mostly concluding a possible role in scouring the intestine during digestion (Kalle et al. 2012). Further, it must be noted that the category of food items was approximately similar between both the winter, both summer and both monsoon seasons, it indicates that Desert fox is not only generalist as mentioned above but it may also be considered as facultative specialist (Petrov et al. 2016).

CONCLUSION

Desert Fox is one of the important meso-carnivores of desert ecosystem. It was found that the diet changes seasonally as well as depending upon availability. The results indicate that Desert foxes have a generalist dietary spectrum wherein ungulates, rodents, insects and fruits contribute significantly in terms of proportions based on their availability. Remains of large ungulates as well as domestic animals found in fox feces symbolize scavenging behavior on carrion rather than hunting. Also, apart from vultures and feral dogs, there is no known presence of top predators such as wolves and hyena in the study area, which makes carrion, available for longer duration. The significant difference in the frequency of occurrence of different food items and between the diet compositions among season in study area is mainly due the increased availability and use of *Zizyphus* fruit during winter. In our present study, the dietary pattern suggested that, as opportunistic feeders, Desert foxes may have adapted to the land - tenure system and behavior to suit local circumstances, using alternative sources of prey and anthropogenic food. Therefore, we comprehend that Desert fox as a scavenger and an opportunistic specialist along with generalist feedings characteristics.

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