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Food Habits of Large Carnivores (Leopard and Lion) in Gir National Park and Sanctuary (GNPS), Gujarat, India

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Abstract: Food habits of Leopard *(Panthera pardus fusca)* and Asiatic lion *(P. leo persica)* were investigated from 2009 to 2012 in the GNPS, Gujarat. A total of 951 scats were analyzed of which, 480 scats were of leopards and 471 scats were of lions. Diets of both carnivores emerged to be dominated by chital (*c.*38.57% and44.58%) followed by sambar (*c.* 21.42 and 25.59). Certainly, substantial contribution of smaller to small prey taxa was found with the high proportion of rodents (*c.*9.98%) in the leopard's diet and civet in the leopard's and lion's diet (*c.* 4.44 and1.91%). Non-wild prey constituted expectedly low proportions (*c.*4.86% leopard and 5.48% lion). Differences in the seasonal diets were non-significant. Pangolin (*c.*1.05%) was new to report in the leopard's diet. Sambar constituted relatively high biomass and ample rodents were consumed. High dietary niche overlap emerged (O = 0.95, s = 0.03) between leopards and lion with broader niche breadth (B = 0.32 and 0.30). Prey selection was significant for both carnivores. Leopard consumed chital, sambar, nilgai and langur more in proportion to their availabilities. Lions avoided chital and wild boar, however, selected sambar and nilgai in proportion to their availabilities. Our study revealed the potential and complexities of coexistence and certainly crucial role of smaller to small prey taxa. Hence, recommend managing the bulk of sufficient potential prey to manage these two sympatric large carnivores within administrative boundaries of the park for conservation purpose.

Key words: Large Carnivores · Scat Analysis · Diet Composition · Prey Selectivity · Niche Overlap · GNPS

INTRODUCTION

Food is a crucial resource to understand the ecology of an animal, however, its partitioning is sheer important for a sound understanding of interactions occur amid coexisting sympatric animals [1,2]. Leopard *(Panthera pardus* Linnaeus*)* is advantaged to coexist in multiple-carnivore system due to its generalist nature, catholic diet, high adaptability to survive from dense forest to fringe habitats and in human-dominated land [3-9]. The success of coexistence can vary with changes in prey diversity, abundance, size variability, habitats or in different geographical sites [1,8,10]. Large carnivores always pose enormous challenges as far as their long-term conservation is concerned [11,12]. If carnivore enlisted endangered by IUCN and coexisting with sympatric species of high profile conservation status, need extra attention [13,14, 68].

The two endangered large carnivore's leopard *(P.p. fusca* Meyer*)* and Asiatic lion *(P. leo persica* Linnaeus*)* uniquely coexist in GNPS, Gujarat, India. Although food habits of leopard have been studied well in Indian tropical ecosystem either alone or in coexistence, reveals recent studies [1,18,19,21], but our knowledge still lacks in case of GNPS where interspecific competition between leopard and lion sounds more complex [unpublished data, 20]. Hence, it becomes perilously essential to scan comparative food habits of leopard and lion to understand the level of their coexistence in terms of niche partitioning or overlap and to assure that the facilitating key prey of coexistence exists adequately or in case need management alteration. This information would be of much use in tropical dry deciduous and thorn forest of western India [22] for conservation and management of these two large carnivores [24]

Study Area: The study was carried out in the intensive study area (200km^2) lies in western part of Gir National Park and Sanctuary (henceforth GNPS) covering an area over 1412.13 km^2 (Figure 1).

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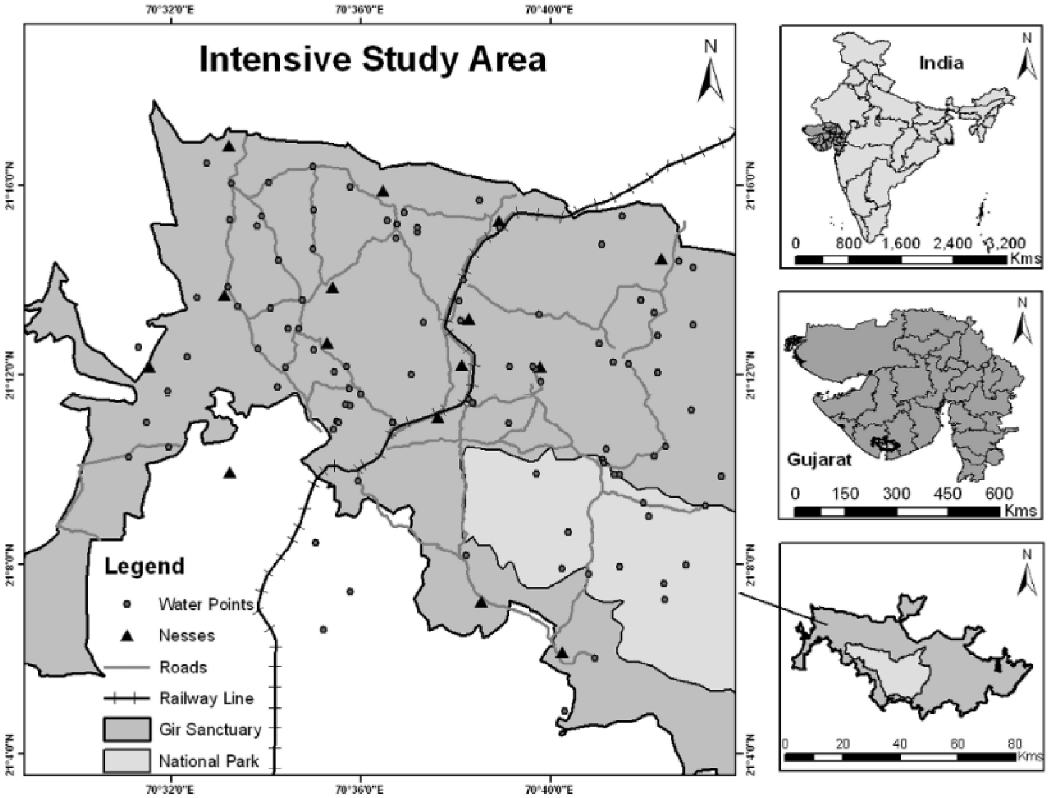

Fig. 1: Map of the Gir National Park and Sanctuary (GNPS) showing boundaries and interiors of the roads and Intensive Study Area (ISA).

It (Latitude 21 55’ to 21 20’N and Longitude 70 25’ to 71 15’E) comprises a National Park 250 km^2 and Sanctuary 1154 km^2, the rest of the area falls under protected and un-classed forests [22]. The western border is limited by the Arabian Sea and the region is clutched by the gulf of Khambat and Gulf of Kachch. The hills are of volcanic origin with an altitudinal range of 83-524msl. Typical soil types in the area are black cotton soil and reddish brown sandy loam soil. GNPS lies in the Afro-tropical Realm and has the biome of Dry Deciduous Thorn Forest and Scrub Land, with the Western Gir dominated by *Tectona grandis* (L.) in combination with *Acacia* and *Zizyphus* spp. and Eastern Gir dominated by *Anogeissus latifolia* (Roxb.) [23,24]. The temperature varies from the peak in summer at 45°C, dropping below 10°C on cold winter nights. The rains bring some relief from the heat during the monsoon period remains from June to September. The average rainfall was recorded 1000 mm/year on the Western Gir and 650mm/year in Eastern Gir [22]. The prey list includes chital *(Axis axis* Erxleben*),* sambar *(Rusa unicolor* Kerr*),* nilgai *(Boselaphus tragocamelus* Pallas*),* chinkara (*Gazella bennetti* Sykes)*,* chousingha (*Tetracerus quadricornis* de Blainville*),* wild boar (*Sus scrofa* Linnaeus)*,* langur (*Presbytes entellus,*Pocock*),* peafowl (*Pavo cristatus* Linnaeus), black napped hare (*Lepus nigricollis* F. Curler) and several rodent spp.

MATERIALS AND METHODS

Food habits of leopard and lion were estimated using scat analysis since it allows determination of complete diet [25]. Scats of both large carnivores were collected from temporary trails, established roads and prey kill sites on a seasonal basis. Encountered scats were identified on the basis of field expertise, with help of field assistants, morphological evidence of scats i.e. quantity, size, end points, lobs etc. and sometimes the presence of spoor and scrapes found marked on the sites [26] respectively. Only one sample of scat was collected when more than one scats found at a single spot. Of that a portion containing an adequate amount of prey remains was collected in a Ziploc bag from the site and belonging carnivore name, scat number, date andtime, GPS location were marked by a waterproof marker. The survey was terminated when a maximum of 150 scats was collected in each season. Liquid scats, which only contain protein and a small amount of hair, were unsuitable and the same avoided from the collection. Scats were properly either sun-dried or oven dried at the same time. Scats analysis was carried out following standard method [25], also used in GNPS earlier and recommended a sample of 80 scats to scan complete dietary profile [20]. Thus, all collected scats were randomly mixed and a sample of 80 scats was sorted out for each season. First, these scats were soaked individually in a shallow container for 10-12 hr, completely fragmented and filtered over a sieve (1mm) thoroughly under running water several times. It removed the dust, soil particles and calcium layering from the remaining indigestible food items i.e. hairs, hooves, bones and teeth and desiccated through the soaking paper [26].

Slides were prepared using 20 hairs per scat to make five slides for identifying possible all consumed prey items as reported that the prey items may be missed, if less than 20 hairs imprints per scat are used [20]. Washed hairs were kept in Xylene for 24 hr. Later these hair samples were mounted on the slide from roots with the help of DPX reagent and packed by square or circular cover slip (22mm), left over for a night to properly fix. These slides were examined macroscopically and microscopically (Olympus microscope, model CH2oi) to identify prey item using features like length, colour, width, outer or inner cuticle pattern, medulla and scaling pattern, thickness, basal configuration and cortex pigmentation etc. All these characters matched with reference slides prepared from known species (hair samples were collected either from kills or obtained from Sakkar Bagh Zoo by Nazneen Zehra) and with available literature [27]. Other undigested recognizable parts of prey passed through their digestive systems were also recognized in the form of hooves, bones, teeth and nails (Figure 6).

Analysis

Estimation of Frequency of Occurrence, Percent Occurrence, Relative Biomass and Number of Prey Individuals Consumed: Scats contained remains presented in the frequency of occurrence *(number of particular prey item in total scats = n/N)* and percent occurrence (*number of prey item found as percentage of a total prey items)*. A corrected frequency of occurrence was needed cause of more than one prey items were found in the scats of both large carnivores (leopard and lion). The linear regression ($y = 1.98 + 0.035x$) developed for cougar *(Puma concolor)* was used purposely [28]. If two items occurred in a scat, each was counted as 0.5 [29]. All feasible attempts were made to convert the frequency of occurrence (foO) into relative biomass = $\frac{foO \times Y}{\sum(foO \times Y)} \times 100$, where Y = No. of per field collectible scats and the relative number of each prey species consumed (E) = $\frac{D/x}{\sum\left(D/x\right)} \times 100$, where D = Biomass, x = avg. body mass of the prey species. The body mass of various prey species killed by leopard and lion were obtained from relevant publications [24,30]. Prey species were classified viz. medium size (60-30kg), small size (5-30kg) and smaller taxa (0-5kg) considering their body weights. The mean prey weights of leopard and lion were measured using difference test.

The prey selectivity was assessed by comparing observed prey items in the scats from the estimated prey availability [32,33]. The program SCATMAN was used to assess the prey selectivity using multinomial likelihood ratio test [33]. Seasonal diet differences were measured using Wilcoxon test. The extent of food niche overlap between leopard and lion was calculated using Pianka index [34]. The calculated index can take values from 0 to 1, where 1 stands for identical food habits or complete overlap and 0 indicates completely different food habits, or no overlap. Statistical program STATISTICA (Ver. 10.0) was used for analysis purpose.

RESULTS

Diet Compositions of Leopard and Lion: An average of 60 km of temporarily established trails and 8 roads with total a length of 156 km were searched carefully on the seasonal basis. These efforts resulted in collection of almost 45% scat from trails, about 20% scats from kill sites and 35% scats from road sides respectively. A total of 951 scats were analyzed of which, 480 scats were of leopards and 471 scats were of lions. About 17 and 14 prey items were scanned from the scats of leopard and lion in the form of different mammalian prey species viz. chital, sambar, nilgai, wild boar, chinkara, chousingha, civet, pangolin, porcupine, mongoose, rodents, squirrel, black napped hare, langur and small unidentified birds (Figure 5). The per scat prey items detected were ranging

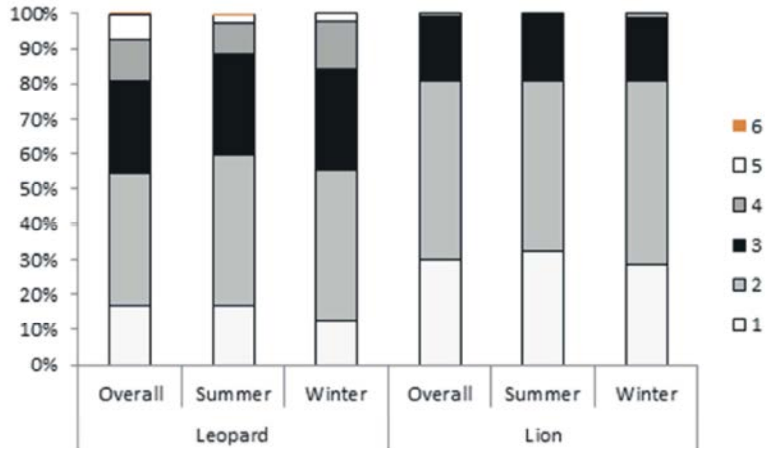

Fig. 2: Number of food prey items detected per scat (percent) of leopard and Asiatic lion in GNPS, Gujarat.

Table 1: Prey species found during analysis of scats in GNPS, Gujarat. Average unit weight (X) of prey species were taken from published data (26,33), number of per field collectible scats per kill (Y) derived using regressions equation (31) (Y = 1.980 + 0.035X) developed for cougar.

Prey species	Prey weight (Kg) (X)	Per field collectible scats (Y)
Chital	45	3.56
Sambar	166	7.79
Nilgai	184	8.42
Peafowl	4	2.12
Langur	8	2.26
Bird	0.25	1.99
Buffalo	273	11.54
Cow	180	8.28
Chousingha	21	2.72
Chinkara	12	2.40
Porcupine	8	2.26
Pangolin	11.5	2.38
Rodents	0.11	1.98
Squirrel	0.11	1.98
Wild boar	32	3.1
Civet	8	2.26
Black N. hare	3	2.09
Mongoose	0.28	1.99

from 1 to 6 in leopard's scats and 1 to 4 in lion's scats (Figure 2). Detected prey species were ranging from 0.11 to 184kg body weight in case of wild prey and 45 to >273kg in case of non-wild prey (buffalo, cow) (Table 1). Mean prey weight was 28.74±10.56kg for leopards and 53.12±19.93kg for lions. There was found a significant difference in the mean prey weights of leopard and lion ($p<0.01$).

The proportional composition of leopard and lion's diets are listed in Tables 2-4. The diet composition was scanned in order of proportional contribution of large to medium-sized prey or ungulates (chital, sambar, nilgai and wild boar), small sized prey (chousingha, chinkara, langur, porcupine, pangolin and civet) and smaller prey taxa (peafowl, black napped hare, rodents, mongoose, small birds and squirrel). Ungulates constituted the biggest portion of the leopard and lion's diets (*c.*69.12% and 90.39%). Ungulates proportions were highest contributed by chital (*c.*38.57% and44.58%). Smaller prey taxa appeared to be a second most important food resource by constituting *c.* 17.32% of leopard's diet with high contribution of rodents (*c.* 9.98%). It followed by small-sized prey constituted *c.*8.71% of the total leopard's diet with a maximum contribution of civet (*c.* 4.44%). In case of lion, small sized prey appeared to be the second important food resource by constituting *c.*2.35%, followed by smaller prey taxa (*c.*1.79%). However non-wild prey constituted *c.*4.86% of the leopard's diet and *c.*5.48% of the lion's diet respectively.

Seasonality reflected non-significant in the prey composition of leopard ($Z = 0.49$, $p < 0.05$, $n=17$) and lion's diets ($Z = 0.27$, $p < 0.05$, $n=11$), where all detected prey species emerged with negligible differences. For leopard, the difference occurred in the proportional contribution of sambar and squirrel found slightly high in winter season diet compared to summer. In other prey taxa, peafowl, langur, porcupine, rodents and wild boar constituted high proportions of summer season diet compared to winter. Summer diet also enlisted one new prey item "pangolin" with *c.* 1.05% (Table 3). Non-wild prey constituted slightly high proportion (*c.* 5.24%) during summer season diet compared to winter (*c.*4.5%)

Table 2: Diet composition of leopard and Asiatic lion derived from 480 and 471 scats during study period (2009-2012) in GNPS, Gujarat.

	Leopard				Lion			
Prey species	Frequency of Occurrence	Percent Occurrence	Relative Biomass	Relative no. of prey consumed	Frequency of Occurrence	Percent Occurrence	Relative Biomass	Relative no. of prey consumed
Chital	94.17	38.57	28.23	1.41	84.71	44.58	26.94	16.81
Sambar	52.29	21.42	34.31	0.47	48.62	25.59	33.89	5.73
Nilgai	20.21	8.28	14.33	0.18	34.61	18.21	26.7	3.98
Peafowl	1.25	0.51	0.22	0.13	0.64	0.34	0.12	0.85
Langur	7.08	2.9	1.35	0.38	1.06	0.56	0.21	0.75
Bird	0.63	0.26	0.11	0.95	-	-	-	-
Livestock	11.87	4.86	11.31	0.1	10.4	5.48	10.49	1.11
Chousingha	0.83	0.34	0.58	0.02	0.42	0.22	0.1	0.14
Chinkara	0.63	0.26	0.19	0.02	0.21	0.11	0.05	0.11
Porcupine	0.63	0.26	0.13	0.03	-	-	-	-
Pangolin	1.25	0.51	0.12	0.05	0.85	0.45	0.18	0.44
Rodents	24.38	9.98	0.25	83.22	1.49	0.78	0.26	65.56
Squirrel	2.29	0.94	4.07	7.82	-	-	-	-
Wild boar	2.08	0.85	0.38	0.04	3.82	2.01	1.06	0.93
Civet	10.83	4.44	0.54	0.58	1.91	1.01	0.39	1.36
Black N. hare	11.46	4.69	2.06	1.51	1.27	0.67	0.24	2.22
Mongoose	2.29	0.94	2.02	3.09	-	-	-	-

Note: Non-wild prey like buffalo and cow has been merged as livestock.

Table 3: Seasonal diet composition of leopard derived using 240 scats for each season (summer and winter) during study period (2009-2012) in GNPS, Gujarat.

	Summer				Winter			
Prey species	Frequency of Occurrence	Percent Occurrence	Relative Biomass	Relative no. of prey consumed	Frequency of Occurrence	Percent Occurrence	Relative Biomass	Relative no. of prey consumed
Chital	91.67	38.5	20.91	0.97	96.67	38.7	20.61	0.96
Sambar	71.25	19.9	35.62	0.45	85.63	22.8	39.99	0.51
Nilgai	28.75	8.04	15.54	0.18	31.88	8.5	16.09	0.18
Peafowl	3.13	0.87	0.43	0.22	0.63	0.17	0.08	0.04
Langur	13.13	3.67	1.9	0.5	8.13	2.17	1.1	0.29
Bird	0.63	0.17	0.08	0.67	1.25	0.33	0.15	1.24
Livestock	18.75	5.24	13.88	0.11	16.88	4.5	11.18	0.09
Chousingha	0.63	0.17	0.11	0.01	1.88	0.5	0.31	0.03
Chinkara	0.63	0.17	0.1	0.02	1.25	0.33	0.18	0.03
Porcupine	1.25	0.35	0.18	0.05	0.63	0.17	0.08	0.02
Pangolin	3.75	1.05	0.57	0.1	-	-	-	-
Rodents	36.88	10.3	4.7	87.15	36.25	9.67	4.31	80
Squirrel	1.88	0.52	0.24	4.43	5	1.33	0.59	11.03
Wild boar	5	1.4	0.99	0.07	1.25	0.33	0.23	0.02
Civet	15	4.2	2.18	0.57	17.5	4.67	2.37	0.62
Black N. hare	16.25	4.55	2.17	1.52	18.13	4.83	2.27	1.58
Mongoose	3.13	0.87	0.4	2.99	3.75	1	0.45	3.35

Note: Non-wild prey like buffalo and cow has been merged as livestock.

Table 4: Seasonal diet composition of Asiatic lion derived using 240 scats for summer and 231 scats for winter season during study period (2009-2012) in GNPS, Gujarat.

	Summer				Winter			
Prey species	Frequency of Occurrence	Percent Occurrence	Relative Biomass	Relative no. of prey consumed	Frequency of Occurrence	Percent Occurrence	Relative Biomass	Relative no. of prey consumed
Chital	199	44.32	27.08	32.01	84.85	43.95	26.66	11.22
Sambar	129	28.73	38.46	12.32	48.92	25.34	33.68	3.84
Nilgai	79	17.59	25.46	7.36	37.23	19.28	27.71	2.85
Peafowl	2	0.45	0.16	2.16	0.43	0.22	0.08	0.38
Langur	1	0.22	0.09	0.58	0.43	0.22	0.09	0.2
Livestock	15	3.34	6.25	1.31	9.09	4.7	9.15	0.64
Chousingha	1	0.22	0.1	0.26	0.43	0.22	0.1	0.09
Chinkara	-	-	-	-	0.43	0.22	0.09	0.14
Pangolin	2	0.45	0.18	0.84	0.43	0.22	0.09	0.15
Rodents	1	0.22	0.08	35.74	2.6	1.35	0.46	76.34
Wild boar	13	2.9	1.54	2.56	3.9	2.02	1.07	0.63
Civet	6	1.34	0.52	3.45	2.16	1.12	0.43	1.02
Black N. hare	1	0.22	0.08	1.41	2.16	1.12	0.4	2.52

Note: Non-wild prey like buffalo and cow has been merged as livestock.

respectively. In case of lion, prey species like chital and langur constituted almost similar proportions of both seasonal diets (summer and winter), however, species like nilgai, rodents and black napped hare found to constitute slightly high proportions of winter season diet compared to summer. In other prey taxa, sambar, peafowl and pangolin constituted slightly high proportions of summer diet compared to winter season respectively. Chinkara was found only in winter season diet. Non-wild prey constituted slightly high proportion (*c.* 4.7%) of winter season diet compared to summer season (*c.*3.34%) respectively (Table 4).

Relative Consumption of Prey Biomass and Individuals: As ungulates emerged as the most important prey taxa for both carnivores by constituting the bulk of their diets, constituted *c.*77.25kg relative biomass (RB) of leopard's diet and *c.*90.39kg RB of lion's diet respectively. These biomasses were highly contributed by sambar (*c.*34.31kg for leopard and 33.89kg for lion). Smaller prey taxa constituted *c.*8.73kg and small-sized prey constituted *c.*2.91kg RB of leopard's diet. However, RB of lion's diet constituted by these two taxa of prey was found <1kg. Non-wild prey constituted *c.*13.94kg and 10.49kg RB of leopard and lions diets (Table 2). We calculated per field collectible scats (Y) produced high for nilgai (*c.*8.42) and sambar (*c.*7.79) followed by chital (*c.*3.56) and wild boar (*c.*3.1) respectively. The other prey of small to smaller size produced per field collectible scats ranging from *c.*1.98 to 2.72. Non-wild prey produced per field collectible scats highest to be ranging from *c.*8.28 to 11.54 (Table 1). The relative number of prey individuals consumed by leopard to construct a complete diet comprised maximum rodents (83.22 individuals) and lowest chital (1.41 individuals). The remaining prey consumed were =1 individuals. Lions also consumed maximum rodents (65.56 individuals) in smaller prey taxa, lowest nilgai (3.98 individuals) in large sized prey. The prey consumed =1 comprised wild boar, langur, pangolin, chousingha, chinkara and peafowl in decreasing order (Table 2).

On a seasonal basis, all detected prey species contributed in RB of leopard in a simultaneous order excluding sambar which constituted large RB of winter season diet compared to summer (Table 3). For the construction of a complete diet, rodents outnumbered in the summer season diet, squirrel, mongoose and small bird outnumbered in the winter season diet respectively. For lion, simultaneous to leopard, all detected prey species contributed equally during both seasonal diets, excluding sambar constituted high RB of summer season diet compared to winter. However, livestock contribution to RB was found high in winter season diet compared to summer season respectively (Table 4).

Diet Diversity and Niche Overlap: Scat analysis revealed the presence of maximum 5-6 prey items per scat for leopards and 3-4 prey items per scat for lions (Figure 2).

Table 5: Interspecific and intra-specific niche overlap and breadth in GNPS, Gujarat

Study period	Carnivores	Niche overlap	Niche breadth	Variance
Intra-specific				
Overall	Leopard-lion	0.95	-	0.03
Summer	,,	0.92	-	0.03
Winter	,,	0.97	-	0.06
Seasonal	**Inter-specific**			
Summer-winter	Leopard	0.99	0.32	0.05
Summer-winter	Lion	0.96	0.30	0.07

Note: not calculated (-).

A total of 1172 prey items (2.44 prey items/scat) found in leopard scats on the overall account, 572 prey items (2.38 prey items/scat) and 600 prey items (2.5 prey items/scat) found in seasonal diets (summer and winter). In case of lion, the prey species composition was containing 895 prey items (1.86 prey items/scat) on overall account. On a seasonal basis, it was found to be containing 449 prey items (1.87 prey items/scat) and 446 prey items (1.93 prey items/scat) respectively. Consequently, prey diversity resulted significantly high (H'= 1.95), for leopards (at 95% confidence limit). The prey diversity in lion's diet was found (H'=1.48). The dietary niche overlap between leopard and lion was found expectedly high (O = 0.95, s = 0.03). Seasonally, it was found high but non-significant (O = 0.97, s = 0.06) in winter season compared to summer season (O = 0.92, s = 0.03). Dietary niche breadth of leopards was found to be broad (B = 0.32), for lions it was unexpectedly broad (B = 0.30). Although seasonal diets of leopards and lions at inter-specific level overlapped too; for leopard (O = 0.96, s = 0.07) and for lion (O = 0.99, s = 0.05) (Table 5).

Prey Selection by Leopard and Lion: Prey selectivity was tested using both individuals and cluster densities of potential prey species, but we considered cluster densities. Since, there was found a significant evidence of prey selectivity by leopards (X^2_5= 107.02, p< 0.05), further information of the analysis was examined to conclude the selectivity pattern at each prey species level. Chital was found to be consumed by leopards proportionally equal to its availability (X^2= 0.09, p <0.05), however sambar was found to be consumed more than its proportional availability (X^2= 75.71, p <0.05). Nilgai, peafowl and wild boar were found to be consumed less than their proportional availability (X^2= 0.24, p <0.05), (X^2= 47.61, p <0.05) and (X^2= 0.38, p < 0.05). Langur was consumed more than its proportional availability (X^2= 8.62, p <0.05) (Figure 3a). On seasonal basis, a significant prey selectivity patterns were emerged; for summer season (X^2_5= 137.68, p <0.05) and for winter season (X^2_5= 174.01, p <0.05) respectively. Herewith chital was consumed

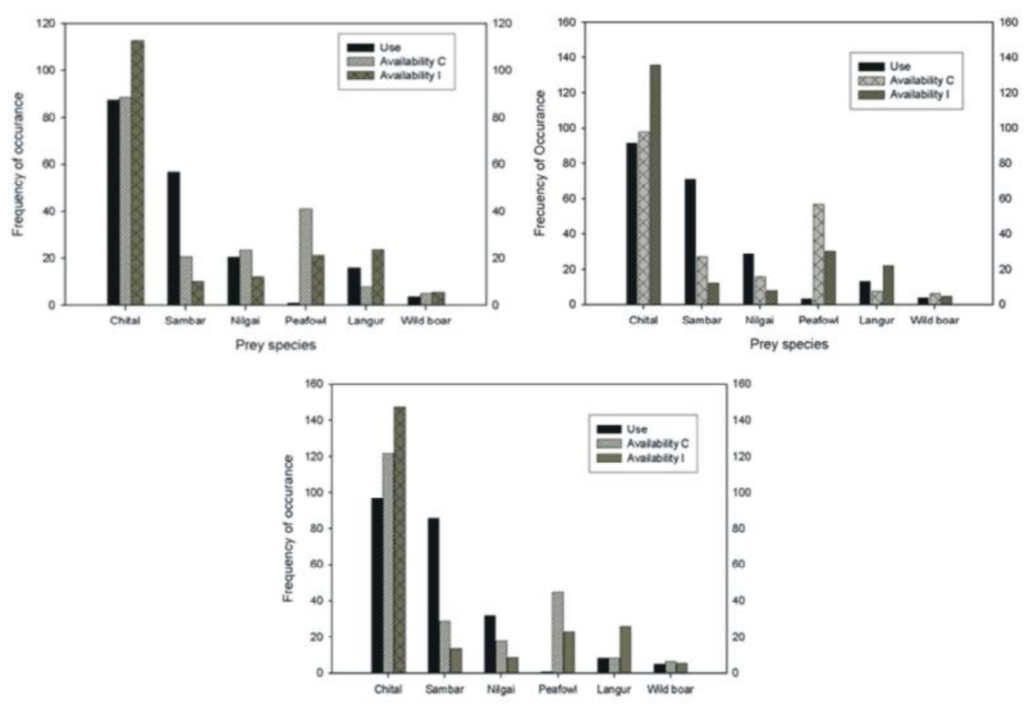

Fig. 3: Comparison of observed vs. expected proportions of prey use by leopard using scats analysis based on cluster and individual densities of prey species in GNPS, Gujarat. a) Overall, b) summer, c) winter season (left to right).

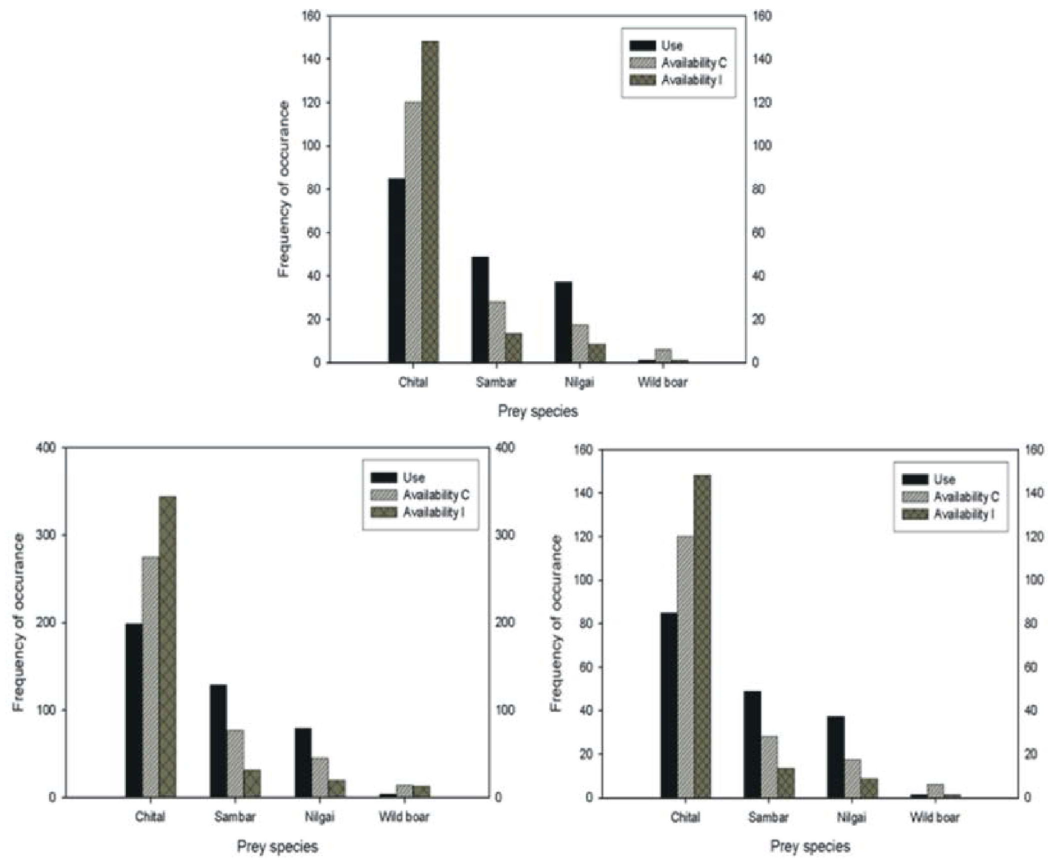

Fig. 4: Comparison of observed vs. expected proportions of prey use by Asiatic lion using scats analysis based on cluster and individual densities of prey species GNPS, Gujarat. a) Overall, b) summer, c) winter season (left to right).

proportionally low ($X^2 = 0.77$, $p > 0.05$) than its availability during summer season. However chital was consumed proportionally lowest ($X^2 = 11.19$, $p < 0.05$) than its availability during winter season. The next important major difference was found in selection of langur where it was consumed proportionally more than its availability ($X^2 = 4.70$, $p < 0.05$) during summer season while proportionally equal ($X^2 = 0.001$, $p < 0.05$) to its availability during winter season ($X^2 = 0.34$, $p < 0.05$) respectively (Figure 3bandc). In case of lion, overall prey selectivity pattern was found significant ($X^2 = 34.33$, df = 3, $p < 0.05$) (Figure 4a). Further information exhibited that sambar and wild boar were consumed more than their proportional availability ($X^2 = 19.17$, $p < 0.05$) and ($X^2 = 9.18$, $p < 0.05$). Nilgai was consumed in proportion ($X^2 = 0.51$, $p < 0.05$) to its availability. Chital was avoided ($X^2 = 24.64$, $p < 0.05$) than proportion to its availability. On seasonal basis, a significant prey selectivity pattern of prey species emerged; for summer ($X^2_3 = 90.95$, $p < 0.05$) and for winter ($X^2_3 = 58.69$, $p < 0.05$) respectively. Sambar and nilgai were consumed more during both seasons viz. summer ($X^2 = 43.78$, $p < 0.05$) and ($X^2 = 29.8$, $p < 0.05$) and winter ($X^2 = 18.04$, $p < 0.05$) ($X^2 = 24.74$, $p < 0.05$). However chital and wild boar were avoided than their proportional availabilities during summer ($X^2 = 63.70$, $p < 0.05$) and ($X^2 = 8.01$, $p = 0.05$) and winter ($X^2 = 34.63$, $p = 0.0002$) ($X^2 = 4.08$, $p = 0.05$) season respectively (Figure 4b and c).

DISCUSSIONS

The Reliability of Scat Analysis: There are several methods to investigate food habits of large carnivores consists scat analysis [26], kill observation [35], DNA analysis [36], radio-telemetry technique [37] etc., have few merits and demerits [38]. Scat analysis allows a complete determination of diets avoiding underestimation of particularly smaller prey taxa. The seasonal period was chosen to collect scats for avoiding occurring biases due varying seasons.

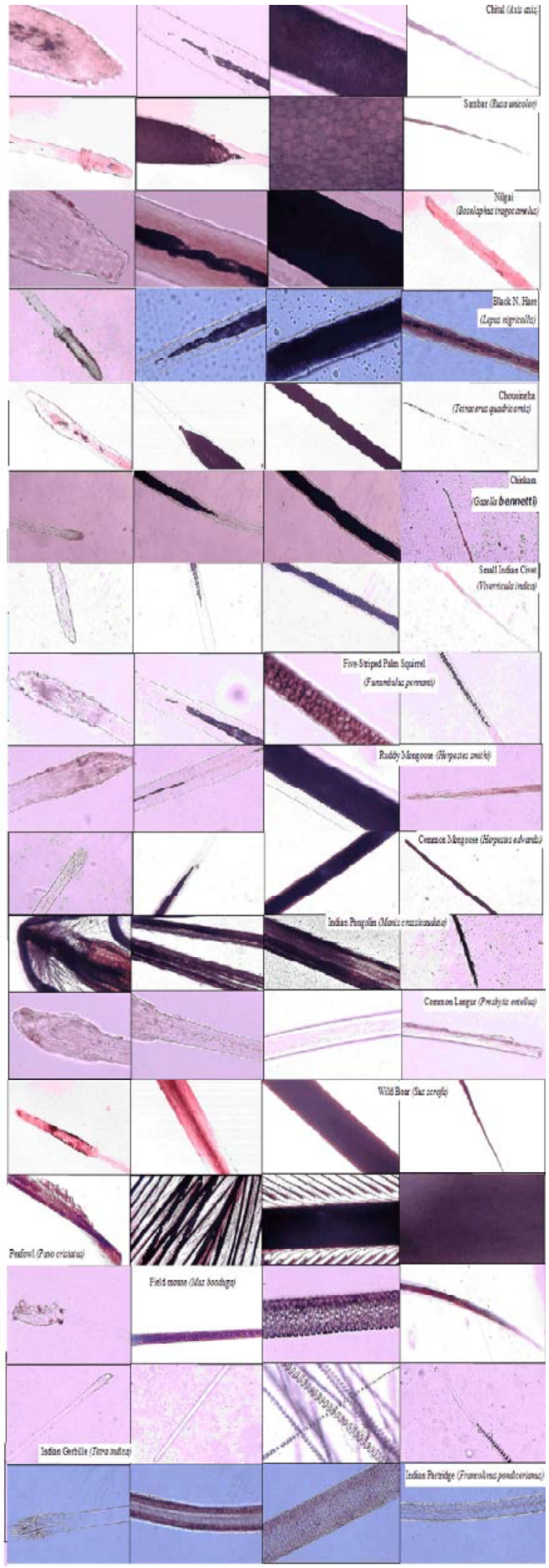

Fig. 5: Snapshot of hair structures (unique features) of identified prey species in GNPS, Gujarat.

Diet Construction: Chital is most abundant prey of GNPS with outnumbered females along with other age categories viz. adult, sub-adult, yearling and faun [20, 32], makes its high consumption convincing [17-19,43,52]. With the advantage over killing and handling a broad array of prey sizes from small rodents (100gm) to large nilgai (185kg), Gir leopards were seen to consume substantial proportions of smaller prey taxa (i.e. peafowl, black napped hare, rodents, small birds, squirrel and mongoose) to small-sized prey (i.e. langur, chousingha, porcupine, civet and chinkara) reported widely [8,18-20,44,47,50,68].Exceptionally lions preyed upon an array of prey taxa including peafowl, black napped hare, rodents, langur, chousingha, chinkara and civet [6,38,40,46,51]. Presence of pangolin in the diets of both carnivores is first to report in GNPS, elsewhere reported in case of leopard in Mudumalai [47]. The rich composition of the leopard's diet and presence of small to smaller prey taxa in lion's diets clearly indicated that coexistence of these two sympatric carnivores relatively succeeded cause of partitioning of different prey resources in different times [4,6,42,43]. High adaptability of leopards, various tests to diets in variety of habitats help them survive in a dominantly shared ecosystem [47,51]. It reduces sympatric feeding competition, revealed in expectedly low proportions of non-wild prey (buffalo, cow) occurred in the diets (Table 2). Moreover, variability in prey size, different activity schedule in different habitat types make coexistence sustainable [48] and reduce inter-specific competition which probably leaves a profound effect on structure, function and composition of an ecosystem [36,49]. Our study resulted in accordance with other similar studies on sympatric coexistence where they highly relied on locally abundant key prey rather than other prey taxa [5,18,50,51]. A non-significant difference in contributor prey to construct seasonal diets of leopard and lion exhibited the importance of all existing small to smaller prey taxa which facilitated consumption of large-sized prey owing seasonal needs, ecological paradigm and behavioural correlates [1]. The mean prey weight of leopard was found highest than African leopards reported to be =20kg [4]. High interspecific dietary niche overlap appeared in accordance with non-significant difference in seasonal diets (Table 5).

The rich prey diversity found in the diets of Gir leopards is uncommon in the Indian sub-continent albeit counted studies reported broadest prey spectrum of leopards in India [19,29]. African leopards have been reported to feed upon broadest spectrum from mice to adult eland [4, 49, 68]. The high mean of prey items per scat is almost double of Bandhipur

Fig. 6: Prey remains (hoovs, nails, bones, teeth, skin and feathers) separated from leopard and Asiatic lion scats in GNPS, Gujarat.

TR (1.18 prey items/scat) and Dudhwa TR (1.43 prey items/scat) respectively [18, 29]. For lions mean prey items per scat calculated higher than African lions to be 1.44 prey items per scat [38].

Consumption of Prey Biomass and Individuals: Ungulates like chital, sambar and nilgai comprised the bulk of prey biomass of leopard and lion considering their large body mass as found elsewhere (e.g 1,19). It reflects the relationship between predator-prey size, where large carnivores consume high mean prey biomass per feeding effort [19,31,42]. A similar conclusion has been drawn in case of large African carnivores fed upon prey range avg. 250kg including giant prey like zebra, giraffe, blue beast to medium sized impala [6, 68] and in case of snow leopard fed upon avg.160kg ibex [21, 36]. GNPS is one of those parks where leopard and lion co-occur in highest density by selecting different prey items of different sizes and sex at different activity period [52]. During this study, there were 6 cases when lions killed non-wild prey and leopard scavenged on them (unless if they were calves, pada) however many cases of kill snatching by the lion from leopard were recorded [66]. We also noticed that leopards avoid locations even with of fresh kills; if sensed lions in the proximity. In India many cases of leopards killing by tigers have been reported due to coexistence [19, 47], we have not seen any incident of such kind during this study period probably due to avoidance behavior of leopards which develops in response to the cues of fatal risks, if involved species has a long evolutionary history [53-55,58]. It was the only rodent, consumed in highest numbers by both, leopard and lion during construction of their diets. We believe that diurnal rodents were coincided with Gir carnivores more being bush dweller compared to nocturnal. Rodents have widely reported constituting substantial portions of meso-carnivores diet [56], found to constitute 34% of the leopard's diet, 2.75% tigers diet and 3.06% of dhole diet in Pakke [1]. Similar to this, African leopards have been reported to consume more rodents and primates [4].

Prey Selection and Niche Overlap: Leopards appeared to consume chital in proportional availability on the overall account, however, it was avoided by lions. It perhaps resulted because lions chiefly have long been observed for snatching chital kills from leopards [57, 68]. Prey like chital has been reported a potential prey of non-selective leopard as it takes advantage of its affordable size for

Table 6: A comparative study of food habits (percent occurrence) of leopards in GNPS. Comparisons have been made from past studies.

Prey species	[1] scat/480	[2]scat/693	[3]scat/366
Chital	38.57	28.8	27.74
Sambar	21.42	26.3	5.87
Nilgai	8.28	1.6	3.7
Peafowl	0.51	1.1	6.37
Langur	2.9	7.3	14.28
Livestock	4.86	2.9	12.5
Chousingh	0.34	1.8	-
Chinkara	0.26	0.2	4.6
Porcupine	0.26	0.5	7.4
Rodents	9.98	3.7	4.6
Squirrel	0.94	0.1	4.59
Wild boar	0.85	3.6	4.6
Pangolin	0.51	-	-
Civet	4.44	11.1	4.6
Black N. hare	4.69	9.5	4.59

Source: [1] Present study 2009-2012, [2](20) [3](62), data not available (-).

Table 7: Percent occurrence of common prey species remains found in the leopard's scats in Indian subcontinent.

Prey species	[1]GNPS	[2]MM	[3]MUTR	[4]DTR	[5]NGR	[6]STR	[7]BTR	STTR
Chital	38.57	37.72	24.32	18.97	43.7	20.8	45.8	-
Sambar	21.42	28.95	9	2.78	13.5	33.7	6.1	20.2
Nilgai	8.28	-	3.7	4.46	-	5	-	-
Wild boar	0.85	-	0.92	2.07	-	2	8.4	2.1
Langur	2.9	17.54	8.33	1.86	2.1	10.9	9.1	-
Peafowl	0.51	13.89	-	-	8.9	-	-	-
Chousingha	0.34	-	-	0.4	-	3.1	-	3.1
Porcupine	0.26	-	1.39	1.1	2	-	-	-
Black N. hare	4.69	5.55	-	1.1	1	3.5	-	5.7
Small birds	0.26	-	6.72	-	-	-	-	-

Source: Present study [1]GNPS 2009-2012, [2](42, Mudunthurai-MM), [3](47, Mundanthurai-MTR), [4](29, Dudhwa-DTR), [5](31, Nagarhole-NGR), [6](51, Sariska-STR), [7](18, Bandhipur -BTR), [8](64, Satpura -STTR). Data not available (-).

Table 8: A comparative study of food habits (percent occurrence) of lion in GNPS. Comparisons

Prey species	[1]2009-2012	2008	1993	1973
Chital	44.58	32.3	38.8	9
Sambar	25.59	26.1	15.4	4.3
Nilgai	18.21	9.3	8.3	1.7
Livestock	5.48	19.9	25.1	81
Wild boar	2.01	-	-	4

Source: [1] (Present study), [2](46), [3](65), [4](63).have been made from past studies.

concealing and protecting from coexisting sympatric carnivores [6,58]. Gir leopards were also seen to protect their kills from lions by dragging up on high trees (particularly fresh kill), concealing below litters and hiding in big bolder dens in rivulets [66]. Selection of sambar possibly occurred under influence of its distribution occupied patch of *Tectona-Acacia-Zizyphus* and its availability, although sambar prefers slightly dense habitat and hilly topography [24]. Elsewhere the selection of sambar was reported in the influence of good abundance, high availability and probably homogenous distribution [5, 19, 59]. It contrasted findings of the study reported avoidance of sambar instead of constituting the largest proportion of the diet of leopard [1]. Although scat analysis does not provide information on age and sex of prey consumed but can be suspected of yearling and faun age in case of large-sized prey consumed by leopards (Pers. Obs.). The same phenomenon was found for nilgai, were significantly avoided by leopards; however, it was selected by lions in its proportional availability. It supports that large carnivore's population merely linked with distribution and availability of large ungulates owing seasonal influence [8, 47]. The anti-predatory strategies of wild boar may have played a role in its avoidance by both leopard and lion contrasted by findings reported its selectivity [4, 60], selected by African carnivores [6,8]. High consumption of langur occurred cause of arboreality and crypticity of leopards where they can consume its food without fear of coexisting competitor [5]. Although, it was reported as an alternative preferable prey of leopards in case of prey scarcity [51] which contrasted to our findings in presence of abundant potential prey species. Selection of peafowl or other supplementary small to smaller prey taxa seems reasonable for energy gain per hunting efforts, maximize the resource leopard has for survival when lost immediate hunting to lion [6]. Peafowl consumption by leopards was also reported in Sariska TR [59]. The selection of large-sized prey by lions is in accordance with food habits of African lions where they mostly depend on large-sized prey [6]. It eventually indicates that along with differing body size and activity pattern, nature and availability of prey individuals also play an important behavioral role contribute to prey selection by large carnivores simultaneously.

Despite substantially high dietary overlap between these two sympatric large carnivores and broad niche breath, highlights high dietary competition in GNPS [19, 41] similar to that observed in the African Savannah [6,38,68]. High dietary competitions mostly draw inferior competitor out of the prey-rich zone or administrative park boundaries where they raid villages for domestic animals [5,17, 47, 61], consequently invite conflict [15]. It apparently noticed in Gir where avg.138 large carnivores (leopard and lion) land on transitional zone every year, involved in the high level of carnivore-human conflict [66]. In GNPS resource partitioning at different time period has been assumed to sustain coexistence of leopard and lion.

Comparison from past and Other Studies: In light of earlier studies of leopard and lion food habits in GNPS, our findings exhibited a tremendous change in the construction of their diets over a past decade. Earlier livestock's constituted *c.*12.50% of the leopard's diet which has today reduced to *c.*4.86%, sambar contribution increased from 6 to 21% with increment in a number of prey items respectively (Table 6) [62]. Lion's diet had revealed *c.*81% livestock contribution which has reduced to *c.*5.48% and minimum chital contribution increased up to five-fold (Table 8) [65]. Compared to other studies from different protected areas of the Indian-subcontinent, findings of our study resemble in high consumption of large to medium-sized prey. Presence of small to smaller prey taxa has also been reported for constructing a substantial portion of leopards diets irrespective of the density of large to medium size prey species (Table 7).

Our study exhibits that investigating food habits of sympatric large carnivores like leopard and lion revealed the potential for their coexistence. Simultaneously, it also revealed the complexity of the relationship and certainly crucial role of smaller to small prey taxa. We agree that remarkable changes in the diets of large carnivores and dependency on wild prey taxa undoubtedly occurred due to improved prey availability resulted cause of various wise decisions and action have been taken by forest management particularly in context to the conservation of a sole population of Asiatic lion. But knowledge of the ecological interactions amid leopard and lion can aid park managers in making more informed decisions when trying to achieve long-term conservation and management of these apex carnivores of widely renowned GNPS and also to avoid carnivore-human conflict in the Gujarat.

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REFERENCES

1. Selvan, K.M., G.G. Veeraswami, S. Lyngdoh, B. Habib and S.A. Hussain, 2013. Prey selection and food habits of three sympatric large carnivores in a tropical Lowland forest of the Eastern Himalayan Biodiversity Hotspot. Mammalian Biology, 78: 296-303.
2. Lanszki, J., S. Kormendi, C. Hancz and A. Zalewski, 1999. Feeding habits and trophic niche overlap in a carnivore community of Hungary. Acta Theirologica, 44: 429-442.
3. Athreya, V., M. Odden, J.D.C. Linnell, J. Krishnaswamy and U. Karanth, 2013. Big cats in our backyards: Persistence of large carnivores in a human dominated landscape in India. PLoSONE. 8: e57872.
4. Henschel, P., K.A. Abernethy and J.T. White, 2005. Leopard food habits in the Lopé National Park, Gabon, Central Africa. African Journal of Ecology, 43: 21-28.
5. Wang, S.W. and D.W. Macdonald, 2009. Feeding habits and niche partitioning in a predator guild composed of tigers, leopards and dholes in a temperate ecosystem in central Bhutan. Journal of Zoology, 277: 275-283.
6. Hayward, M.W. and G.I.H. Kerley, 2008. Prey preference and dietary overlap amongst Africa's large predators. South African Journal of Wildlife, 38(2): 93-108.
7. Balme, G., L. Hunter and R. Slotow, 2007. Feeding habitat selection by hunting leopard panther pardus in a woodland savanna: prey catchability versus abundance. Animal Behavior, 3: 589-598.
8. Hayward, M.W., P. Henschel, J. O'Brien, M. Hofmeyr, G. Balme and G.I.H. Kerleg, 2006b. Prey preferences of the leopard (*Panthera pardus*). Journal of Zoology, 270: 298-313.
9. Bailey, T.N., 1993. The African leopard. Ecology and behavior of a solitary felid. First ed. Columbia University Press, New York.
10. Karanth, K.U. and M.E. Sunquist, 2000. Behavioural correlates of predation by tiger (Panthera tigris), leopard (*Panthera pardus*) and dhole (*Cuon alpinus*) in Nagarahole, India. Journal of Zoology, 250: 255-265.

11. Jacobson, A.P., P. Gerngross, Jr., J.R. Lemeris, R.F. Schoonover, C. Anco, C. Breitenmoser-Wursten, M.S. Durant, P. Henschel, J.F. Kamler, A. Laguardia, S. Rostro-Grrcia, A.B. Stein and L. Dollar, 2016. Leopard (*Panthera pardus*) status, distribution and the research efforts across its range. DOI 10.7717/peerj.1974
12. Mann, M.A. and A.A. Chaudhry, 2000. Common Leopard (*Panthera pardus*) - our endangered heritage needs special conservation. Tiger Paper, 27: 14-17.
13. Wolf, C. and W.J. Ripple, 2016. Prey depletion as a threat to large carnivores. R. Soc. open sci. 3: 160252. http://dx.doi.org/10.1098/rsos.160252.
14. Stein, A.B., V. Athreya, P. Gerngross, G. Balme, P. Henschel, U. Karanth, D. Miquelle, S. Rostro-Garcia, J.F. Kamler, A. Laguardia, I. Khorozyan and A. Ghoddousi, 2016. Panthera pardus. The IUCN Red List of Threatened Species:e.T15954A102421779. http://dx.doi.org/10.2305/IUCN.UK.2016-1.RLTS.T15954A50659089.en.
15. Pettigrew, M., Y. Xie, A. Kang, M. Rao, J. Goodrich, T. Liu and J. Berger, 2012. Human–carnivore conflict in China: a review of current approaches with recommendations for improved management. Integrative Zoology. doi: 10.1111/j.1749-4877.2012.00303.x
16. Biswas, S. and K. Sankar, 2002. Prey abundance and food habit of tigers (*Panthera tigris tigris*) in Pench National Park, Madhya Pradesh, India. Journal of Zoology, 256: 411-420.
17. Bagchi, S., S.P. Goyal and K. Sankar, 2003. Prey abundance and prey selection by tigers (*Panthera tigris*) in a semi–arid, dry deciduous forest in western India. Journal of Zoology, 260(3): 285-290.
18. Andheria, A.P., K.U. Karanth and N.S. Kumar, 2007. Diet and prey profiles of three sympatric large carnivores in Bandipur Tiger Reserve, India. Journal of Zoology, 263: 169-175.
19. Ramesh, T., R. Kalle, K. Sankar and Q. Qureshi, 2012. Dietary partitioning in sympatric large carnivores in a tropical forest of western Ghats, India. Mammal study, 37(4): 313-321.
20. Khan, J.A., S.S. Usham and P.P. Raval, 2007. Ecology and management of leopard in Gir Lion Sanctuary and National Park. Project report submitted to DST and Gujarat state forest department Wildlife circle, Junagadh, Gujarat.
21. Lyngdoh, S., S. Shrotriya, S.P. Goyal, H. Clements, M.W. Hayward and B. Habib, 2014. Prey preference of snow leopard (*Panthera uncia*) regional diet specificity holds global significance for conservation. PLoS ONE, 9: e88349.
22. Kumar, S. and R.L. Meena 2012. Gir Management Plan, Gujarat State. pp: 280.
23. Champion, H.G. and S.K. Seth, 1968. A revised survey of the forest types of India. Delhi,
24. Khan, J.A. R. Chellam, W.A. Rodgers and A.J.T. Johnsingh, 1996. Ungulate densities and biomass in the tropical dry deciduous forest of Gir, Gujarat, India. Journal of Tropical Ecology, 12: 146-162.
25. Mukherjee, S., S.P. Goyal and R. Chellam, 1994b. Standardization of scat analysis techniques for leopard (*Panthera pardus*) in Gir National Park, Western India. Journal of Mammalogy, 58: 139-144.
26. Purchase, G.K. and J.T. Du. Toit, 2000. The use of space and prey by cheetah in Matusadona National Park, Zimbabwe. African Journal of Wildlife Research, 30: 139-168.
27. Koppikar, B.R. and J.H. Sabnis 1976. Identification of hairs of some Indian mammals. Journal of Bombay Natural History Society, 73: 5-20.
28. Ackerman, B.B., F.G. Lindzey and T.P. Hernker, 1984. Cougar food habits in Southern Utah. Journal of Wildlife Management, 48: 147-155.
29. Ahmed, K. and J.A. Khan, 2008. Food habits of leopard in tropical moist deciduous forest of Dudhwa National Park, Uttar Pradesh, India. International Journal of Ecology and Environmental Sciences, 34(2): 141-147.
30. Prater, H.S., 1993. The book of Indian animals. Fourth Edition. JBNHS and Oxford University Press. pp: 324.
31. Karanth, K.U. and M.E. Sunquist, 1995. Prey selection by tiger, leopard and dhole in tropical forests. Journal of Animal Ecology, 64: 439-450.
32. Zehra, N., R.L. Meena, A.P. Singh, S. Kumar and J.A. Khan, 2016. Assessment of prey biomass availability for leopard and lion in Gir National Park and Sanctuary, Gujarat, India. International Journal of Ecology and Environmental Sciences, 42(1): 239-248.
33. Link, W.A. and K.U. Karanth, 1994. Correcting for over dispersion in tests of prey selectivity. Journal of Ecology, 75(8): 2456-2459.
34. Pianka, E.R., 1973. The structure of lizard communities. Annual Review of Ecology and Systematics. 4: 53-74.

35. Odden, M. and P. Wegge, 2009. Kill rates and food consumption of leopards in Bardia National Park, Nepal. Acta Theriologica, 54(1): 23-30.
36. Shehzad, W., T.M. McCarthy, F. Pompanon, L. Purevjav, E. Coissac, T. Riaz and P. Taberlet, 2012. Prey preference of snow leopard (*Panthera uncia*) in South Gobi, Mongolia. PLoS ONE, 2, e32104.
37. Frohlich, M., A. Berger, S. Kramer-Schadt, I. Heckman and Q. Martins, 2012. Complementing GPS cluster analysis with activity data for studies of leopard (*Panthera pardus*) diets. Suth African Journal, 42(2): 104-110.
38. Breuer, T., 2005. Diet choice of large carnivores in northern Cameroon. African Journal of Ecology, 43: 97-106.
39. Ghoddousi, A., M. Soofi, A.Kh. Hamidi, L.E. Lumetsberger, I. Khoeozyan, B.H. Kiabi and M. Waltert, 2016. Assessing the role of livestock in big cat prey choice using spatiotemporal availability patterns. PLoS ONE: DOI:10.1371/journal.pone.0153439.
40. Devidson, Z., M. Valeix, F.V. Kesteren, A.J. Loveridge, J.E. Hunt, F. Murindagamo and D.W. Macdonald, 2013, Seasonal diet and prey preference of the African lion in a waterhole-driven semi-arid savanna. PLoS ONE: e55182.
41. Radloff, F.G.T. and J.T.Du. Toit, 2004. Large predators and their prey in south African savanna: a predators size determines its prey size range. Journal of Animal Ecology, 73: 410-423.
42. Ramesh, T., V. Snehlatha, K. Sankar and Q. Qureshi, 2009. Food habits and prey selection of tiger and leopard in Mudumali Tiger Reserve, Tamil Nadu, India. Journal of Scientific Transactions in Environment and Technovation, 2: 170-181.
43. Mills, M.G.L., 1984. Prey selection and feeding habits of the large carnivores in the southern Kalahari. Supplement of Koedoe: 281-294.
44. Reddy, H.S., C. Srinivasulu and K.T. Rao, 2004. Prey selection by the Indian tiger (*Panthera tigris tigris*) in Nagarjunasagar Srisailam Tiger Reserve, India. Mammalian Biology, 69: 384-391.
45. Sankar, K. and A.J.T. Johnsingh, 2002. Food habit of tiger (*Panthera tigris*) and leopard (*Panthera pardus*) in Sariska Tiger Reserve, Rajasthan, India, as shown by scat analysis. Mammalia, 66: 285-289.
46. Meena, V., Y.V. Jhala, R. Chellam and B. Pathak, 2011. Implications of diet composition of Asiatic lions for their conservation. Journal of Zoology, 284: 60-67.
47. Ramakrishnan, U., R.G. Coss and N.W. Pelkey, 1999. Tiger decline caused by the reduction of large ungulate prey: evidence from a study of leopard diets in southern India. Journal of Biological Conservation, 89: 113-120.
48. Husseseman, J.S., D.L. Murray, G. Power, C. Mack, C.R. Wenger and H. Quigley, 2003. Assessing differential prey selection patterns between two sympatric large carnivores. Oikos, 101: 591-601.
49. Ray, J.C. and M.E. Sunquist, 2001. Trophic relations in a community of African rainforest carnivores. Oecologia, 127: 395-408.
50. Arivazhagan, C., R. Arumugam and K. Thiyagesan, 2007. Food habits of leopard (*Panthera pardus fusca*), Dhole (*Cuon alpinus*) and Striped Hyena (*Hyaena hyaena*) in a tropical dry thorn forest of Southern India. Journal of Bombay Natural History Society, 105: 247-254.
51. Bodendorfer, T., B. Hoppe-Dominik, F. Fischer and K.E. Linsenmair, 2006. Prey of the leopard (Panthera pardus) and the lion (*Panthera leo*) in the Comoé and Marahoué National Parks, Côte d'Ivoire, West Africa. Mammalia, 70(3-4): 231-246.
52. Zehra, N., R.L. Meena, A.P. Singh, S. Kumar and J.A. Khan, 2016. Abundance and habitat use of leopard and lion in Gir National Park and Sanctuary, Gujarat, India. International Journal of Ecology and Environmental Sciences, 42(2): 143-161.
53. Garvey, P.M., A.S. Glen and R.P. Pech, 2016. Dominant predator odour triggers caution and eavesdropping behaviour in a mammalian. Journal of Behavioral Ecology and Sociobiology, 70: 1-12. DOI: 10.1007/s00265-016-2063-9.
54. Anderson, G.E., C.N. Johnson and M.E. Jones, 2016. Sympatric predator odour reveals a competitive relationship in size structured mammalian carnivores. Journal of Behavioral Ecology Sociobiology: DOI 10.1007/s00265-016-2189-9.
55. Leo, V., R.P. Reading and M. Letnic, 2015. Interference competition: odours of an apex predator and conspecifics influence resource acquisition by red foxes. Journal of Oecologica, 179(4): 1033-40.
56. Mukherjee, S., S.P. Goyal, A.J.T. Johnsingh and M.R.P.L. Pitman, 2004. The importance of rodents in the diet of Jungle Cat (*Felis chaus*), Caracal (*Caracal caracal*) and Golden Jackal (*Canis aureus*) in Sariska Tiger Reserve, Rajasthan, India. Journal of Zoology, 262: 405-411.

57. Mills, M.G.L. and H.C. Biggs, 1993. Prey appointment and related ecological relationships between large carnivores in Kruger National Park. Symposia of the Zoological Society of London. 65: 253-268.
58. Hart, J.A., M. Katembo and K. Punga, 1996. Diet prey selection and ecological relations of leopard and golden cat in Ituri Forest, Zaire. African Journal of Ecology, 34: 364-379.
59. Mondal, K., S. Gupta, Q. Qureshi and K. Sankar, 2011. Prey selection and food habits of leopard (*Panthera pardus fusca*) in Sariska tiger reserve, Rajasthan, India. Mammalia, 75: 201-205.
60. Sharbafi, E., M.S. Farhadinia, H.R. Rezaie and A.R. Braczkowski, 2016. Prey of the Persian Leopard (*Panthera pardus saxicolor*) in a mixed forest-steppe landscape in northeastern Iran (Mammalia: Felidae). Zoology in the Middle East. http://dx.doi.org/10.1080/09397140.2016.1144286.
61. Inskip, C. and A. Zimmerman, 2009. Human-felid conflict: a review of patterns and priorities worldwide. Oryx, 43: 18-34.
62. Dharaiya, N., V.C. Soni, M. Singh and P.P. Raval, 1998. Seasonal changes in food habits of the Asiatic lion and leopard in the Gir protected area. J. Wildl. Conserv. Resea. Manage. A Technical publication of WII, Dehradun, India. pp: 40-43.
63. Joslin, P., 1973. The Asiatic lion: a study of ecology and behaviour. Ph.D Thesis, University of Edinburgh, UK.
64. Edngaonkar, A., 2008. Ecology of the Leopard (*Panthera pardus fusca*) in Satpura National Park and Bori Wildlife Sanctuary. Ph.D/Dissertation, Saurashtra University, Rajikot.
65. Ravi Chellam, 1993. The ecology of Asiatic lion Panthera leo persica. PhD thesis, Saurashtra University.
66. Zehra, N., J.A. Khan, S. Kumar and R.L. Meena, 2013. A study of large mammalian prey predators of Gir Lion Sanctuary, Gujarat, India, Final Technical Report submitted to University Grant Commission (UGC), New Delhi by Department of Wildlife Sciences, AMU Aligarh.
67. Mondal, D., K. Basak, R.P. Mishra, R. Kaul and K. Mondal, 2017. Status of leopard *Panthera pardus* and striped hyena *Hyaena hyaena* and their prey in Achanakmar Tiger Reserve, Central India. The Journal of Zoology Studies, 4(4): 34-41.
68. Preez, B.du, J. Purdon, P. Trethowan, D.W. Macdonald and A.J. Loveridge, 2017. Dietary niche differentiation facilitates coexistence of two large carnivores. Journal of Zoology, doi:10.1111/jzo.12443.