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DIETARY COMPOSITION AND PREY PREFERENCE OF ROYAL BENGAL TIGER (*PANTHERA TIGRIS TIGRIS*, LINNAEUS 1758) OF PARSA NATIONAL PARK, NEPAL

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Abstract.

Tiger diet composition study reflects forest health and aids in our understanding of large cat ecology for long-term effective management. The diet and prey preference of tigers of Parsa National Park (PNP) was studied from Nov-2019 to Feb-2020. The ratio of scat sample analyzed per tiger was 3.5 scats per tiger. The scat analysis identified 10 prey species and 81 prey items in the tiger's diet. Spotted deer was the frequently killed prey species followed by wild boar and barking deer. In terms of biomass consumption, large-sized sambar deer was on the top. The average weight of the prey killed was 138 kg. The Jacob Index for prey preference by tigers suggested that the tiger strongly selected sambar deer and weakly selected small-sized barking deer. Medium-sized prey species (spotted deer and wild boar) were neglected, i.e., consumed less than their actual proportion available in PNP. The large-sized prey and their density were the keys to increasing the tiger population in PNP. The absence of livestock in PNP's tiger diet suggests it to be a potential area for tiger conservation.

Key words: *Tiger, tiger scat, scat analysis, scat sample per tiger ratio, biomass consumption, prey preference, Parsa National Park*

Introduction

The diet and prey preference of the world's largest felid tiger (*Panthera tigris tigris*) is determined by their geographical distribution, social structure, habitat selection, prey size, movement, and breeding success (Sunquist 1981; Karanth & Sunquist 1995; Seidensticker et al. 1999). The tigers are 'energy maximizer' in habitats with a choice of variety of prey sizes selecting the largest available prey, under-representing the medium and small-sized prey species in their diet (Sunquist 1981; Seidensticker & McDougal 1993; Karanth & Sunquist 1995). If prey are limited in the habitat, they become 'number maximiser' and avoid prey selection (Griffiths 1975). Besides the large prey species, the tiger may shift to high-density medium-sized prey species that limits their tradeoff time in searching for the prey (optimal foraging theory) (Stephens & Krebs 1987; Lamichhane & Jha 2015).

Prey behavior is a crucial factor that determines their chances of predation. For instance, the large-sized gaur (*Bos gaurus*, 450kg) is favored by the ambush hunter tiger due to preferring the open clearing that makes them easy to locate and stalk (Karanth & Sunquist 1995). The predator also avoids prey species with aggressive behavior like wild boar (*Sus scrofa*) (Karanth & Sunquist 1995; Ramakrishnan et al. 1999). Prey species living in groups (e.g. spotted deer, *Axis axis*) reduces predation via "many eyes" hypothesis (Lima 1995; Ghosal & Venkataraman 2013). Similarly, prey species habituates itself closer to the humans to win the prey-predator space race reducing their chances of predation (Muhly et al. 2011). Likewise, ecological factors (topography, elevation, and forest cover) also influence the predation of prey (Sunquist 1999). For example, prey avoids predator by preferring a more rugged terrain compared to the predator (Muhly et al. 2011). Further, prey behavior also changes according to the season, e.g. in the dry season the nocturnal wild boar remains mostly solitary or in small groups with highly localized distribution and distinct foraging type which increases their chances of predation (Støen & Wegge 1996).

The tiger, leopard (*Panthera pardus fusca*), and dholes (*Cuon alpinus*) are the sympatric large carnivores of Parsa National Park (PNP) (Department of National Parks and Wildlife Conservation & Department of Forest and Soil Conservation 2018). Inter and intra-guild competition and co-existence of tigers with the sympatric carnivores suggest the importance of the appropriate range of prey size, prey density, and high tree cover. These factors provide the sympatric carnivores with distinct resources that they are fit to utilize better than other species (classical competition theory) (MacArthur & Levins 1967; Tilman 1982). For example, the abundant prey size in a habitat reduces the dietary overlap between them by selecting the prey according to the predator size (Johnsingh 1992; Karanth & Sunquist 1995; Farrell et al. 2000; Sunquist & Sunquist 2002; Reddy et al. 2019). It favors the inferior sympatric carnivores by limiting the exploitative competition (Terborgh 1992; Caro & Stoner 2003).

The tiger plays a major role in shaping the prey communities (Karanth & Sunquist 1995) and reducing the cascading effect (Ripple et al. 2014). Studies of the tiger diet composition reflect the health of the forest and help us understand the large cat ecology for their long-term effective management (Biswas & Sankar 2002; Bagchi et al. 2003). For example, the presence of livestock in the diet of the tiger indicates the insufficient abundance of wild prey species (Sunquist 1981; Bagchi et al. 2003; Tamang & Baral 2008) because the predator avoids livestock in the presence of sufficient wild prey base (Biswas & Sankar 2002; Reddy et al. 2004).

Previous studies on diet analysis of tiger relied only on the number of scat samples. In this study, we refer to the systematic camera trap grids of the national tiger survey to search the scats in the forest roads/trails in each grid of the study area (DNPWC & DFSC 2018). Further, we also focused on the number of scats analyzed per the number of individual tigers in our study area. We believe that these will bring more representative results. This is the first diet analysis of tigers of Parsa National Park with scats collected by systematically surveying the total national park with high scat analyzed per tiger ratio. We tested the hypothesis that tigers select the large-sized available prey.

Materials & Methods

Study area

Parsa National Park (PNP) (N 27º 15' to 27º 33', E 84º 41' to 84º 58') was established as a wildlife reserve in 1984 with primary aim to conserve the Asian Wild Elephant (*Elephas maximus*) in their remaining habitat of historical forest famously known as Char-Koshe-Jhadi (4-mile-bush). Such huge forest once extended across the lowland (Terai) of Nepal. The park has a tropical and subtropical climate and spreads across Terai, Churia hills, and Bhawar region (PNP 2018). The core area of the PNP is 627.39 km^2 which is surrounded by a buffer zone of 285.3 km^2. The buffer zone functions to maintain ecological integrity and engages communities for biodiversity conservation (Lamichhane et al. 2019). On the western, the PNP borders with Chitwan National Park (CNP). Transboundary connectivity exists with the Valmiki Tiger Reserve, India through forest corridor in south-west of PNP (Fig 1).

PNP is a home for 37 species of mammals, 490 species of birds, 31 species of butterflies, 8 species of pisces (PNP 2018), and 51 species of herpetofauna (Bhattarai et al. 2018). Along with the tigers, this park is a home for species like elephants (*Elephas maximus*), leopard (*Panthera pardus fusca*), dholes (*Cuon alpinus*), striped hyaena (*Hyaena hyaena*), wolf (*Canis lupus*), rhinos (*Rhinoceros unicornis*), gaur (*Bos gaurus*), sambar deer (*Rusa unicolor*), nilgai (*Boselaphus tragocamelus*), spotted deer (*Axis axis*), hog deer (*Axis porcinus*), barking deer (*Muntiacus vaginalis*), four horned antelope (*Tetracerus quadricornis*),pangolin (*Manis pentadactyla*), sloth bear *(Melursus ursinus*), jungle cat (*Felis chaus*) and asian palm civet (*Paradoxurus hermaphroditus*).

Scat Collection

Different studies on tiger's diet in the lowlands of Nepal were focused only on the number of scat samples in their analyses (Lamichhane & Jha 2015; Bhandari et al. 2017; Upadhyaya et al. 2018). Tigers are territorial and their home range is large. There are many individual tigers in each lowland protected areas of Nepal. Further, the densities of prey species within the protected areas also differ spatially (DNPWC & DFSC 2018). Similarly, the vegetation index (NDVI), terrain ruggedness, water bodies, etc. that affect the tiger occupancy are not uniform in the Parsa National Park (Barbar-Meyer 2013). Hence, repeatedly searching for scats from the same areas

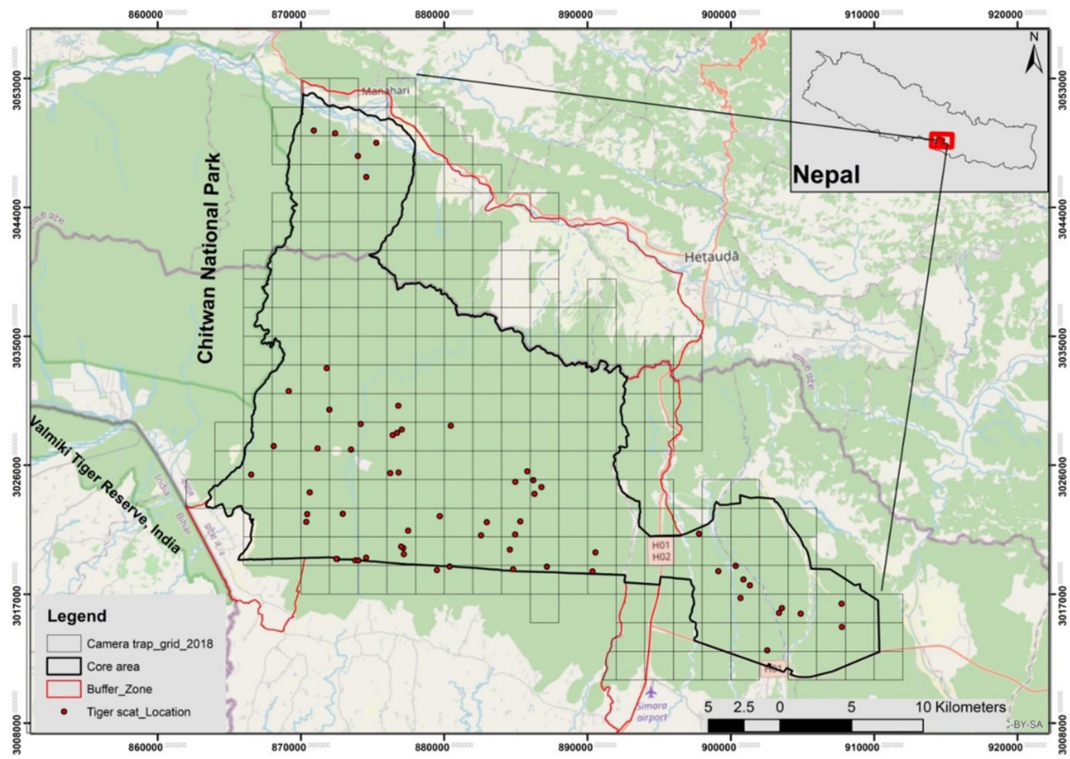

Figure 1: Study area (Parsa National Park) with camera trap grids used in the national tiger survey (DNPWC & DFSC 2018), along with the tiger scat samples collected points.

by spending more time or not covering the total study area to search for possible scats may bring bias. So, besides relying only on the number of scat samples, we considered i) scat per tiger ratio, i.e., the number of scats analyzed to the number of tigers present in the study area, and ii) systematic surveying for scats in the total study area.

We systematically searched tiger scats referring to the camera trap grids (2km *2km, n=177) used in the national tiger survey in PNP (DNPWC & DFSC 2018). We targeted the forest roads, trails, grasslands, and river/stream banks in each grid to collect the scat samples (Karanth & Sunquist 1995; Andheria et al. 2007; Lamichhane & Jha 2015; Reynaert 2018). We did not repeat the scat search in the same grid but rather moved to the next grid. We assumed that the number of scats encountered depends on the tiger number. Since the number of individual tigers in PNP is low ((n=18, density 0.92 (sd=0.95), DNPWC & DFSC 2018), we expected that there will be a high chance of collecting a low number of scats sample, but we estimated that the scat per tiger ratio will be high. We selected a team of 6 persons from the experienced rangers and game scouts of PNP. The team was divided into two groups and stationed at different places to systematically collect the scats.

The tiger scat was differentiated from other sympatric carnivores, particularly those of leopards based on their associated size and appearance, e.g., the tiger's stool diameter is ≥2.5 cm (Reddy et al. 2004). Similarly, the tiger scats have a lower degree of coiling, a relatively larger gap between two successive constrictions, and are deposited on the grassy strips at the edge or center of the forest roads and trails (Biswas & Sankar 2002; Andheria et al. 2007). The scats were collected in zip-lock bags; each was individually labeled with the collection date and location, including latitude and longitude from the global positioning system (GPS). Due to rugged terrain, 144 out of 177 national tiger survey camera trap grids were surveyed. Our team could only survey a grid per day per team, i.e., it took 72 days (November 2019 to February 2020, 432 man-days) to survey the 144 grids (576 km^2). We collected a total of 71 scat samples, out of which 63 scat samples were confirmed to be tigers by the experts of the National Trust for Nature Conservation-Biodiversity Conservation Center (NTNC-BCC). These confirmed scat samples of tigers were used for scat analysis. Aside from the 63 scat samples, one scat sample had python scales, which we excluded from our study.

Scat Analysis

The prey hair consumed by predators while eating their prey passes undigested through their gut. These prey hairs in the scat samples were used for prey identification (Mukherjee et al. 1994a; Karanth & Sunquist 1995; Avinandan et al. 2008). To separate prey hair from other indigestible remains, the scat samples were washed through a fine-meshed sieve under running water. Each sample was washed separately to avoid intermixing. Our scat analysis season was winter, and the days were foggy. So, the hair samples were wrapped separately in newspapers and oven-dried at 52°C for a whole night (~12 hour). The other indigestible remains of prey like scales, quills, feathers were also analyzed to identify the prey species.

Slide preparation for species identification

A minimum of 20 hairs was randomly selected from each dried hair samples for analysis (Odden et al. 2010). A thin layer of clear water-colored nail polish was applied on glass slides and 5-7 hairs per slide were mounted. After the nail polish dried (~10 minutes), the mounted hairs were pulled off for their imprint to view the medullary pattern. The slides were then placed under a digital microscope (Model: Olympus CX21i) and pictures of the imprint were taken using Coslab Digital Camera (model: MDCE-5C). The medullar hair patterns were compared with reference slides available at NTNC-BCC and the prey hair reference guide book (Bahuguna 2010). Along with this, each hair was analyzed by their cuticular pattern and the gross morphological features (Mukherjee et al. 1994a, b; Katz 2005). The species identification was further supported by measuring the width of the hair, which differs with species, by using a microscopic stage micrometer calibration slide (scale-1mm; division-0.01mm) (Bonnin 2008). Then the number of prey items in each scat was recorded (Mukherjee et al. 1994b). The prey species were categorized according to their average weight into small (<20kg), medium (20-55kg), and large (>55kg) to understand the prey preference by tigers (Karanth & Sunquist 1995; Biswas & Sankar 2002; Andheria et al. 2007; Grey 2009; Wang & Macdonald 2009; Lamichhane & Jha 2015).

The effect of sample size on the results of scat analysis was also evaluated (Mukherjee et al. 1994a, b). For this, we chose 10 scats randomly and their prey scat frequency were analyzed. The process was continued until all 63 scats in the sample was analyzed once. Then, the cumulative frequency of occurrence of different prey in the scats over successive 10 randomly drawn scats was assessed to conclude the sample size effect on the results.

Estimating the relative biomass and relative number of individuals killed

Previous studies (Karanth & Sunquist 1995; Biswas & Sankar 2002; Andheria et al. 2007; Grey 2009; Wang & Macdonald 2009; Kapfer et al. 2011; Bhattarai & Kindlmann 2012; Lamichhane & Jha 2015, Bhandari et al. 2017) on predator's diet used a linear biomass model which created biased in the relative biomass consumed and relative number of prey killed (Chakrabarti et al. 2016). So, this study applied a non-linear (asymptotic) biomass model to compute prey biomass consumed (Y) per collected scat/predator weight using $Y=0.033–0.025exp^{-4.284(X/Z)}$, where X= average prey weight and Z=average predator weight (Chakrabarti et al. 2016). The Z and X values were referred from Lamichhane & Jha (2015) and Karanth & Sunquist (1995) respectively. The biomass consumed per prey species (Bp) was calculated by multiplying Y with the number of prey items in the scats collected. The relative biomass consumed (D) and the relative number of individual killed (E) of each species was calculated by using $(Bp/ \Sigma Bp)*100$ and $E = (D / X) / \Sigma (D / X)$, respectively (Karanth & Sunquist 1995; Biswas & Sankar 2002; Andheria et al. 2007; Grey 2009; Wang & Macdonald 2009; Bhattarai & Kindlmann 2012; Lamichhane & Jha 2015; Upadhyaya et al. 2018) (Table 2).

Prey selection

The prey selection by the tiger was calculated using Jacob index (Ji) = (r-p)/(r+p), where r is the prey proportion in tiger's diet and p is the actual proportion of the prey available (Jacobs 1974) in Parsa National Park. The r and p values were calculated from the frequency of occurrence of prey items in tiger's diet (Chakrabarti et al. 2016) and the available prey species density (DNPWC & DFSC 2018; Dhakal et al. 2014) (Table 3) respectively. The outcome value of Ji ranges between +1 (strong preference) and -1 (strong avoidance).

Results

We identified and collected the tiger scats (*n*=63) from 34% grid of the total grid surveyed. The ratio of scat analyzed per tiger was 3.5. A total of 10 prey species and 81 prey items were identified in the tiger's diet of Parsa National Park (PNP). The hair of a single species was almost in 3/4th of the scat samples. The remaining 22% and 3% of scat samples constituted the hairs of two and three prey species respectively. Altogether, 87% of the scat samples bear the remains of bones and hooves, and plant materials were present in 3% of the scats.

The cumulative frequency of successive draws of 10 scats randomly from the sample size of 63 scats showed that the proportions of different prey species in scats were similar when sample size reached 50. So, we suggest using a minimum of 60 scats, collected after systematically surveying the total study area, to understand the diet and prey preference of tigers of PNP (Table 1).

According to relative number of prey species killed by tigers, spotted deer was the most frequent prey and killed in relatively large numbers followed by wild boar and barking deer (Table 2). In terms of biomass consumption, the top species were sambar and spotted deer. The tiger consumed the prey species between 8 kg (langur) to 450kg (gaur) and the weight of the average kill was 138 kg. Livestock hairs were absent in the scat samples. The Jacob Index for prey preference by tigers suggested that the tiger strongly selected the large-sized prey species sambar deer (Ji= +0.4599), weakly selected the small-sized prey species barking deer (Ji=+0.0190), and neglected the medium-sized prey species spotted deer (Ji= -0.1185) and wild boar (Ji=-0.2501), i.e., consumed less than their actual proportion available in PNP (Table 3, Fig 2).

Table 1: Effect of sample size on the cumulative frequency of occurrence of different prey species in the scats over successive 10 randomly drawn scats in Parsa National Park, Nepal.

Scat No.	Sambar Deer	Wild Boar	Spotted Deer	Barking Deer	Gaur	Nilgai	Hog Deer	Langur	Four Horned Antelope
10	25	15	20	10	25	0	0	0	5
20	32.5	7.5	15	5	22.5	15	0	0	2.5
30	26.09	6.69	21.74	7.69	21.74	10.03	1.00	3.34	1.67
40	25.81	13.78	20.05	5.76	16.29	10.03	3.26	3.76	1.25
50	26.65	14.03	19.04	6.61	16.03	11.02	2.61	3.01	1.00
63	23.76	11.72	27.77	8.51	12.84	9.31	2.09	2.41	1.61

Table 2: Estimating the relative biomass and the relative number of prey species killed by tiger in Parsa National Park

Prey species	Prey mass (X, kg)	Predator mass (Z,kg)	Biomass consumed per scat (Y)	no. of scats	Biomass consumed per species (kg) (Bp)	Relative Biomass consumed (D)	Relative number of prey killed (E)
Spotted Deer	55	187.5	4.85	21	101.92	25.12	29.71
Sambar Deer	212		6.15	19	116.86	28.81	8.84
Wild Boar	38		4.22	11	46.42	11.44	19.59
Gaur	450		6.19	9	55.69	13.73	1.98
Barking Deer	20		3.22	7	22.54	5.56	18.07
Nilgai	169		6.09	7	42.62	10.51	4.04
Langur	8		2.28	2	4.57	1.13	9.15
Hog Deer	40		4.31	2	8.62	2.12	3.45
Four Horned Antelope	20		3.22	2	6.44	1.59	5.16
					405.67		

$Y= 0.033–0.025exp^{-4.284(X/Z)}$; Bp= no.of scat*Y; D=(Bp/ ΣBp)*100; E=(D / X) / Σ (D / X)
#Python was removed from the diet analysis

Table 3: The prey proportion in tiger's diet (r) and the actual proportion of the prey available (p) in Parsa National Park

Prey Species	Scat frequency	Proportion in diet (r)	Density	Proportion in field (p)
Spotted Deer	17.3	0.38702	8.82*	0.49109
Sambar Deer	14.8	0.3311	2.2*	0.12249
Wild Boar	7.3	0.16331	4.89*	0.27227
Barking Deer	5.3	0.11857	2.05**	0.11414

#Only the prey species with available density were used for prey selection analysis
* DNPWC & DFSC 2018
** Dhakal et al. 2014

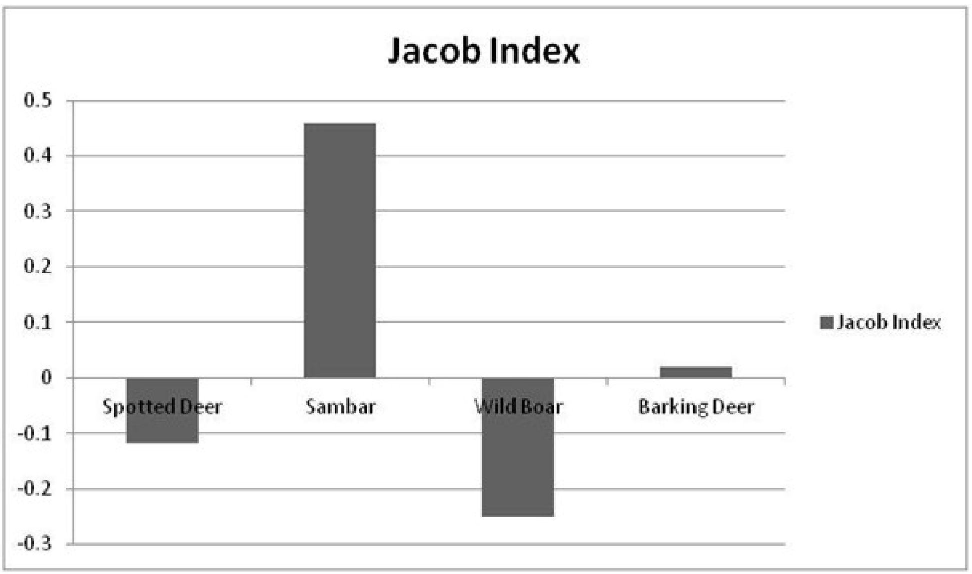

Figure 2: Prey selection by Bengal Tiger of Parsa National Park calculated using Jacob index (Ji) = (r-p)/(r+p). The Ji ranges between +1 (strong preference of prey species by tiger) and -1 (strong avoidance of prey species by tiger).

Discussion

Several studies have been undertaken to examine the diet composition and prey preferences of tigers (Kapfer et al. 2011; Lamichhane & Jha 2015; Bhandari et al. 2017; Upadhyay et al. 2018). Rather than focusing solely on the number of scats, tiger diet studies should concentrate on the size of the study area, as changes in the study area alter the relative contribution of prey species in the tiger's diet (Kapfer et al. 2011). We surveyed the entire study area, which increased the percentage and frequency of occurrence of sambar deer by 4 and 5 times, respectively, and of spotted deer by 1.5 times, when compared to the diet analysis of PNP tigers by Maharjan (2012). This is because tigers are territorial, and the prey density and habitat covariates (ruggedness and NDVI) differ spatially within the protected areas (DNPWC & DFSC 2018). In their study, the scat sample size was also low (n=15). In addition, rhesus monkey and hare were consumed by PNP's tigers (Maharjan 2012) which were absent in our study. Here, sambar deer, spotted deer, barking deer, wild boar, gaur, and nilgai were identified as the principal prey species of PNP, accounting for 95% of the biomass consumed and 82 % of the relative number of prey species killed. Different studies on the diet of tigers of lowland protected areas of Nepal identified these species, where present, as a principal prey species for tigers (Lamichhane & Jha 2015; Reynaert et. al 2018; Kelchtermans2020).

According to previous research, the percentage occurrence of prey items tends to stabilize between 50 and 60 scats (Biswas & Sankar 2002, Bagchi et al. 2003). Hence, we evaluated the effect of sample size on the results, and our findings were similar to theirs, which determined that a minimum of 60 scats should be analyzed to understand the pattern of prey use by tigers after methodically surveying the entire study area. If this is correct, data from studies predicting tiger diet using less or equivalent numbers of scats without covering the total study area should be interpreted with caution (Kapfer et al. 2011). Similarly, tiger scats rarely have more than two prey items (Bagchi et. al 2003; Grey 2009; Reynaert 2018). According to our findings, 3% of the scats comprised hair from three prey species, whereas the remaining 97% of the scats contained hair from one or two prey species.

In this study, the hair of a single prey species was present in 75% of the scats. It is obvious because the tiger stays for 1-7 days to consume their kills (Karanth 2003). The result was consistent with Biswas & Sankar (2002), Grey (2009), and Lamichhane & Jha (2015). The presence of plant materials (3.17%) in the scat sample may be due to the accidental consumption of plants by tigers along with their kill. Further, they aid in digestion and fiber helps the animal to defecate easily. The plant materials in tiger scat samples were also reported in Chitwan National Park (Lamichhane & Jha 2015) and Bardia National Park (Grey 2009). Likewise, the presence of python scales in one of the scat samples explains that the tiger occasionally consumes python.

The size of the predator determines their prey size to hunt (Sunquist 1981; Seidensticker & McDougal 1993; Andheria et al. 2007), i.e. the tiger kills larger prey in compare to its sympatric carnivores. Our results were consistent with this finding because the relative biomass consumed, and species wise biomass contributions of large-sized prey species were highest. But in the case of large-sized gaur, despite being spatially overlapped with the tiger (Dhakal et al. 2014), their low population number (n=164, PNP (2022)) and distribution in the foothills of Chure range may be the reason for their low consumption. Generally, predators such as tiger avoid the rugged terrain like the foothills of Chure range (Muhly et al. 2011; DNPWC & DFSC 2018). Also, medium-sized prey species contributed 38% of the biomass consumption of the tiger. Hence, this study identifies the importance of large and medium sized prey species to maintain the viable population of tigers of PNP (Biswas & Sankar 2002; Karanth & Sunquist 1995; Andheria et al. 2007; Grey 2009; Lamichhane & Jha 2015; Upadhyaya et al. 2018). However, we cannot overlook the importance of small prey species in a tiger's diet, since they provide sufficient food when large prey like sambar deer is unavailable; even so, a tigress raising a cub only on small prey species is quite improbable (Kapfer et. al 2011; Kelchtermans et. al 2020).

In our study, spotted deer was the frequently killed medium-sized prey species by tigers, which is consistent with findings where spotted deer abundance was high, particularly in Nepal's low land protected areas (Kelchtermans et. al 2020). The high density of spotted deer (8.82/ km^2, DNPWC & DFSC 2018) in PNP may have increased their encounter rate and hence the chances of being killed by a tiger. Similarly, the relative number of wild boar (~38kg) and barking deer (~20kg) kills were high. This may displace inferior sympatric competitors like leopards, disturbing the PNP's carnivore communities (Sunquist 1981; Karanth & Sunquist 1995; Støen & Wegge 1996; Biswas & Sankar 2002;Odden et al. 2010). In the presence of sufficient large prey species, tigers avoid medium and small-sized prey and hence minimize their dietary overlap with sympatric carnivores like leopards and dholes (Karanth & Sunquist 1995; Farrell et al. 2000; Sunquist & Sunquist 2002; Johnsingh & Goyal 2005). However, we propose studying leopard and dhole diets in PNP to better understand the diet patterns of these sympatric species. Further, in our study, the large-sized prey species (sambar deer, gaur and nilgai) contributed more than 50% of the biomass consumed and the average weight of prey killed was 138 kg. These findings highlighted that the tigers of PNP prefer large-sized prey species. Therefore, PNP should focus on activities to increase the density of the large-sized prey species that supports the coexistence of the tiger with their sympatric carnivores.

According to Jacob's Index of prey selection, sambar deer (Ji= +0.4598) was strongly preferred by tigers. The large size of the sambar deer (~212 kg), predation profitability, nocturnal habitat, and solitary nature may have made them vulnerable to predation (Biswas & Sankar 2002; Bagchi et al. 2003). This selective predation of large size sambar deer by Parsa tiger rejected the hypothesis of non-selective predation (Abhinandan et. al 2008; Grey 2009). In contrast, the small-sized barking deer was also weakly selected (Ji= + 0.0190). Analyzing the camera trap photos of PNP from the national tiger survey (DNPWC & DFSC 2018), the barking deer has more widespread spatial distribution than spotted deer or sambar deer that may have increased their chances of killing by tigers. The preference of barking deer by tigers were also reported from other studies (Reynaert 2018; Kelchtermans et. al 2020). The wild boar (Ji= -0.2501) and spotted deer (Ji= - 0.1185) were avoided. Wild boars are aggressive and generally carnivore avoids aggressive prey (Eisenberg & Lockhart 1972; Karanth & Sunquist 1995; Ramakrishnan et al. 1999). The avoidance of spotted deer may be due to their gregarious nature (Johnsingh 1992; Karanth & Sunquist 1995) and according to the "many eyes" hypothesis, the chances of scanning the tiger increases with their group size that reduces their chances of predation (Lima 1995; Ghosal & Venkataraman 2013). Furthermore, the ambush hunter tiger's ability to hunt down their prey may have been hampered by the low percentage of grassland in PNP (~5 percent, PNP 2018). Prey selection in medium-sized prey species such as spotted deer and wild boar has varied results, with some reporting positive selection and others reporting negative selection (Karanth & Sunquist, 1995; Bagchi et al., 2003; Grey 2009; Lamichhane& Jha 2015; Bhandari et. al 2017; Krishnakumar et al. 2020; Kelchtermans et. al 2020). It could be due to seasonal fluctuations in prey abundance and vulnerability caused by birth pulses, mating season behavior, migration, number of scats analyzed, and limited spatial extent compared to the study area (Schaller 1967; Sunquist 1981; Stoen & Wegge 1996; Biswas & Sankar 2002). Our study is limited to annual scat analysis rather than seasonal scat analysis. So, we urge that seasonal changes in the tiger diet be included in future studies.

There are livestock grazing at the fringes of the PNP (Park Authority, personal communication) but they were absent in the diet of the tiger. The absence of livestock in tiger's diet was also observed in other studies (Stoen and Wegge 1996; Lamichhane &Jha 2015). There are only 18 tigers in PNP and the density of wild ungulates (22.02 km^{-2}, DNPWC & DFSC 2018) is abundant for tigers to avoid livestock (Biswas & Sankar 2002; Reddy et al. 2004). Additionally, cattle are corralled outside of the PNP at night, which helps to reduce predation (Gurung et. al 2009; Kolipaka et. al 2017). The absence of livestock in the tiger scat samples symbolizes the reduced human-tiger conflict in and around the PNP. This can be observed by the null reported case of human injured/killed and only 8 goats (~20-30 kg) depredated by tigers in the previous Nepali fiscal year 2076/077 (Jun 2019-Jul 2020). We should note that people largely mistake leopards and tigers in livestock depredation cases (PNP 2020).

This tiger dietary study will assist researchers better understand the significance of various-sized ungulates in supporting PNP's tigers. Our result highlighted the relevance of large-sized prey and their density as significant factors of PNP tiger diets. It should be noted that, despite the availability of abundant large prey species, studies have shown that the tiger population does not increase with the presence of abundant small-sized prey species (Sunquist 1981; Karanth & Sunquist 1995). As a result, managers should place a considerable emphasis on increasing large-prey species in order to increase PNP's tiger population. Our research will assist park officials in developing efficient conservation planning measures (Kapfer et al. 2011; Kerley et al. 2015). The research finding of this study remains a base for future reference and to identify any changes in the diet of the tiger.

Author Contribution

PP & SL: Equal contribution on study design, scat collection, data analysis, and writing the articles. DRT, PRR: Data analysis and writing the articles. AM, BRL: Study design and technical advice.

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Conflict of Interest:
No conflict of interest.

Ethical standard:

The non-invasive scat collection technique was used and hence, no wildlife was harm during any steps of this research. Prior to conduct the research, all the necessary permits were obtained from the Department of National Parks and Wildlife Conservation, Nepal.

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