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Spatial Distribution and Dietary Niche Breadth of Leopard Cats (*Prionailurus bengalensis*) Inhabiting Margalla Hills National Park, Pakistan

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The leopard cat (*Prionailurus bengalensis*) is distributed throughout the Himalayan foothills in Pakistan and occurs in moist temperate and dry coniferous forests. However, the cat species is categorized as “Data Deficient” in Pakistan. In the current study we aimed to investigate the leopard cat distribution and dietary niche in the Margalla Hills National Park, the lowest part of the Himalayan foothills in Pakistan. We recorded direct (field observations, camera trapping) and indirect signs (scats) of the species on 23 trails / tracks in the study area. The leopard cat was recorded at 13 different sampling sites in the park, with an altitudinal range between 664–1441 m asl. The diet composition of the species was investigated through scat analysis, with the species identity of the scats confirmed through the mitochondrial cytB region. The species’ diet comprised both animal and plant matter. The animal-based diet (in terms of frequency of occurrence) contained wild (51.75%) as well as domestic prey (7.69%), and plant species (31.47%). Wild prey included small mammals (rodents, two mongoose species, Asian palm squirrel, and Cape hare), birds, insects and snails. The domestic prey were poultry birds, sheep, goats and dogs. Consumption of wild prey was higher in summer (n = 31 scat), whereas intake of domestic prey was higher in winter (n = 37 scats). The dietary niche breadth was wider 14.84 in summer than winter 10.67. A chi-square test showed a significant difference in seasonal dietary intake of the leopard cat. The study concludes that the leopard cat feeds mainly on wild animal prey and plant species; however, in winter consumption of domestic prey increases.

Key words: Spatial distribution, Seasonal diet, Dietary composition, Prey species, Niche breadth.

BACKGROUND

There are two leopard cat species recognized by the IUCN Cat Specialist Group: the mainland leopard cat (*Prionailurus bengalensis*) and the Sunda leopard cat (*Prionailurus javanensis*). The mainland leopard cat is a relatively common and widespread small wild cat (Sunquist and Sunquist 2002; Ross et al. 2015) that is distributed throughout the South and East Asian mainland (Nowell and Jackson 1996). The leopard cat (*Prionailurus bengalensis*) is a relatively common and widespread small felid (Sunquist and Sunquist 2002) distributed throughout Southeast Asia (Nowell and Jackson 1996). However, its population status varies

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across the countries in its range, being endangered and critically endangered in Korea and Japan, respectively, comparatively stable in China and some parts of India, and data deficient in the Himalayan foothills Afghanistan and Pakistan (Shehzad et al. 2012; Ross et al. 2015).

In Pakistan, the leopard cat is mostly associated with Himalayan moist temperate forest, but also dwells further north in the Himalayan dry coniferous forest (Roberts 1997). Because no recent data are available on its population in Pakistan, the status of this species is categorized as "Data Deficient" (Sheikh and Molur 2005). The main threats to this species in Pakistan include hunting by commercial traders for its richly spotted fur mainly for decorations and coats, captive breeding as pets, interbreeding with domestic cats to make the domesticated Bengal cat and traditional medicinal use of bones (Nowell and Jackson 1996). More recently, this species continues to be hunted throughout most of its range for fur, for food and domestication (Ross et al. 2015). The species also faces retaliatory killing for hunting poulty. Island populations are small and seriously threatened in the Philippines and Japan.

The leopard cat consumes a broad spectrum of prey, hence its diet generally constitutes a variety of prey species including small mammals such as shrews and squirrels, birds, reptiles and fish, reflecting the cat's prey flexibility and habitat diversity in its diet (Grassman et al. 2005; Shehzad et al. 2012). Although the overall diet of the leopard cat is diverse and flexible, there are regional differences across the leopard cat range. In Sabah and Borneo part of Malaysia, the main prey of the leopard cat are mammals (murids), with Whitehead's rat (*Maxomys whiteheadi*) being the principal prey species. The preference for Whitehead's rat was also suggested to relate to its 'catchability' rather than its high prey density in oil palm plantations (Rajaratnam et al. 2007). Similarly, in the forests of Singapore, the leopard cat diet mainly consists of mammalian prey, with Oriental house rat (*Rattus tanezumi*) found in all scats (Chua et al. 2016). Insects were the second most frequently consumed food group (52.3% FOS), among which orthoptera appeared in 29.2% of scats, reptiles (18.5%), birds (15.38%) and amphibians (1.54%) were ranked third through fifth in terms of FOS. Although the leopard cat is generally flexible in its habitat choice and prey selectivity it still faces many threats including habitat loss due to anthropogenic activities, commercial exploitation for fur trade and competition with sympatric species (Izawa 1991).

Khan (2009) reported a leopard cat occurrence in Margalla Hills National Park Islamabad, Pakistan along with other 13 mammalian species. However, the park lacks a comprehensive study on leopard cat distribution and diet and there is paucity of information on how food selection is made by this felid species. Therefore, the current study aimed to confirm the occurrence of leopard cat in Margalla Hills National Park, Islamabad, and analyze its diet composition, and niche breadth, through scat analysis.

MATERIALS AND METHODS

Study area

The current study was conducted in the Margalla Hills National Park (MHNP) Islamabad, Pakistan, situated along the northern border of Federal Capital city, Islamabad at 33°43'N longitude and 73°55'E latitude (Fig. 1). Area of the park is approximately 17,386 ha (UNDP/IUCN/MINFA/CDA, 1991), having rugged topography comprising mainly of steep slopes and gullies with elevation ranging from 450 to 1,580 m asl (Jabeen et al. 2009). Its climate is an atypical version of a humid subtropical, with hot summers followed by monsoon season, and accompanied by mild and wet winters. It experiences two rainy seasons each year; summer monsoon (July–September) with heavy rainfall and evening thunderstorms and winter rain (January–March). Average minimum and maximum temperatures are 19.5°C and 33.3°C, respectively (Hussain 1986) and mean annual rainfall is about 94 cm. Average relative humidity during the monsoon period varies between 59% and 67% (Masroor 2011).

Study design

The occurrence of the leopard cat in the park was recorded by using the "sign survey" method, for which both direct (direct field observations, camera trapping) and indirect signs (mainly scats) of the species were recorded during field surveys following Wemmer et al. (1996). A total of 23 trails / tracks in the park were walked on foot to record the species signs from September 2015–December 2018 (Fig. 1 A, B). We also performed a camera trap survey for 3 months, for which we installed a total of seven (07) camera trap stations (Bushnell Trophy Cam HD Essential 2) in the study area along the selected trails with the most leopard cat activity to collect photographic evidence of its occurrence in the study area. During field visits, information on direct sightings, road kills, camera traps as well as fecal samples (data on site, geographic location, elevation, date and species identification for each scat) of the leopard cat were collected to map the spatial distribution of the species using Quantum

Geographical Information System (QGIS: Version 2.18) software. During field surveys, we collected scats of the leopard cat wherever we encountered it; these were later analyzed to identify leopard cat species through genetic analysis and to investigate the dietary habits of the species.

Scat collection

To obtain a detailed account of the leopard cat diet, its scat samples were collected year-round through regular surveys on specified trails (23 of selected trails and transects) from September 2015–December 2018. Each field survey was conducted by a team of three to four members including the author and field staff of Islamabad Wildlife Management Board (IWMB) to correctly identify scat morphology and other activity signs of carnivores. Initially, encountered scat morphology was identified in the field, relying on its smell, shape, length, diameter and other physical appearance (such as color and contents of scat *e.g.*, hairs, bones) following Jackson and Hunter (1996). Additionally, deposition site of the scat sample (either on rock or leaves) and other activity signs (scrapes, rubbings and footprints) were also taken into account. All scat samples were collected in self-sealing plastic bags and selected samples were separated and preserved in 95% ethanol for molecular analysis (which were fresh and intact). After the cats were dried, their morphological characteristics such as length, breadth and weight were recorded in the laboratory of the Department of Wildlife Management, PMAS-AAUR for initial investigation and storage.

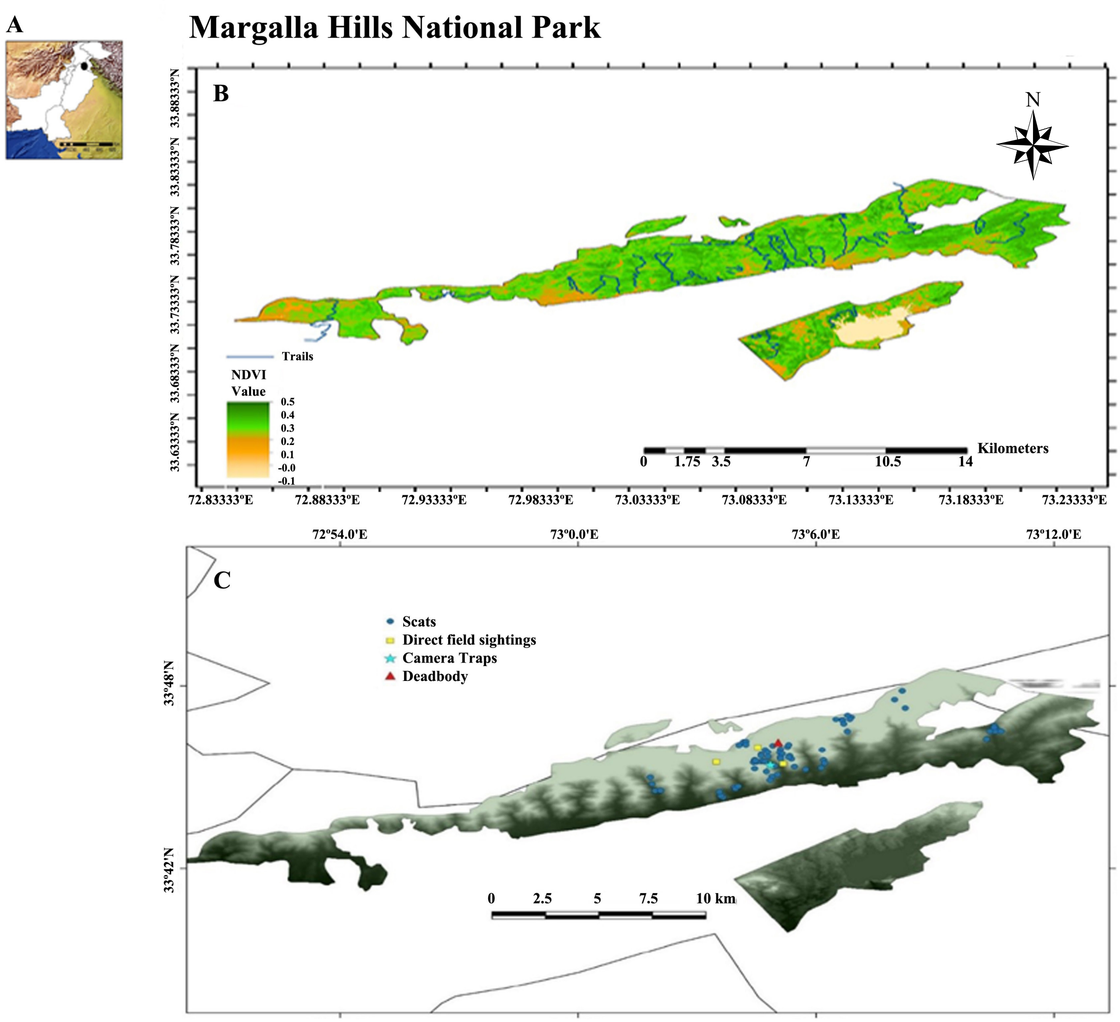

Fig. 1. (A) Map of Pakistan, illustrating the study area, the Margalla Hills National Park (MHNP), Islamabad. (B) Enlarged map of study area, illustrating the 23 transects and trails surveyed during the study period. (C) Map showing spatial distribution of the leopard cat in Margalla Hills National Park Islamabad, Pakistan Islamabad during the present study.

Molecular identification of scats

Molecular identification of leopard cat scats was carried out in the "Mammalian Ecology and Conservation Unit (MECU)" of the Veterinary Genetics Laboratory at University of California, Davis, USA, for species identification by sequencing ~425 bp of the mitochondrial cytochrome *b* region. For DNA extraction, we used QIAamp DNA Stool Mini Kits (Qiagen, INC., Valencia, CA). To keep track of possible contamination for each extraction set (12–18 samples) we included a negative control. We used the primer combination of RF14724 and RF15149 (Perrine et al. 2007) to produce 425-bp-long sequences of cytochrome B (5′ portion), which became 354 bp after trimming. The PCR thermal cycler program conditions were denaturation at 94°C for 10 min., then 40 cycles of PCR starting at 94°C for 30 sec., then annealing at 50°C for 30 sec. and elongation at 72°C for 45 sec. These cycles were followed by a 10-min extension step at 72°C. PCR product was cleaned up by performing ExoSAP reaction adding exonuclease I (Exo) and recombinant shrimp alkaline phosphatase (rSAP). We mixed ExoSAP in a micro centrifuge tube and in an appropriately labeled PCR plate. 1 µl od ExoSAP was added to each well while it was placed on ice beads. After a brief spin, we added PCR product to corresponding wells in the ExoSAP plate. Carefully, we sealed the plate and ran exo/sap Program: 37°C for 30 minutes, 80°C for 15 minutes, 15°C forever (ExoSAP recipe for 96 samples). We sequenced the PCR product in the forward direction using Big Dye Terminator v3.1 (Applied Biosystems, Foster City, CA). We placed an ABI plate containing the sequencing product in an ABI 3730 capillary sequencer (Applied Biosystems, Foster City, CA). We used Sequencher 5.4 to import all files from the AB1 folder as well as necessary cytb files (of the leopard cat) to read the sequences file for each sample. Once we got the sequences from all samples, we used Basic Local Alignment Search Tool (BLAST) in GenBank to identify the leopard cat species.

The field accuracy rate of the species was calculated by using the formula: sum of true positives and true negatives / the sum of all possible outcomes.

Scat analysis

Faecal samples of the leopard cat were analyzed in the lab using protocol following Kelly (1991). Each scat was emptied from its plastic bag into a 2.5 mm sieve positioned over a metal tray. Faecal residue was separated by hand for bone, hair, teeth, toenails, feather and diagnostic plant parts (Moore et al. 1974). The mass of each dietary item including hairs, bones, feathers, insects and plant parts were recorded using an electronic weighing balance to compute percent volume. The weights of different remains (*e.g.*, bones, hairs, seeds) in fecal samples reflect the intake that was not digested, and actually not the amount digested. However, it is useful to quantify the left-over undigested remains of food to use these measures to estimate the frequency and volume of different food components ingested. Therefore, although it is not appropriate to use weight as a proxy for intake proportions, weight does reflect the food item consumed by the animal, and the weights of remains measured can be useful in calculating the food items preferred and most or least consumed. Thus, it is assumed that the food remain that are represented maximum in scats, is most heavily consumed and preferred one. However, this method has important limitations because any food item that is totally consumed may not be reflected in the scat remain. Prey species of the leopard cat were identified using medullary pattern of the hairs recovered from scat samples as described by Moore et al. (1974), and a scale replication following Lavoie (1971). Hairs of mammalian prey were identified using light microscope. These prepared slides of samples hairs were then compared with reference hair slides for identification. These reference slides are a collection of light microscopic slides hairs of known mammalian species maintained in the "Mammalian Ecology and Conservation Lab" of the Department of Wildlife Management, PMAS-AAUR, Pakistan. Similarly, other segregated parts (such as bones, feathers, insects) were also compared to reference material for correct identification.

Plant remnants recovered from scats were comprised mainly of fruit and seeds eaten by leopard cat, and all recovered seeds and fruit residues along with reference material (known plant material collected from the study area) for identification were sent to Department of Plant Sciences, Quaid-e-Azam University, Islamabad in Plant Systematic and Biodiversity Lab for correct identification of plant remains.

Dietary niche breadth

We computed the dietary niche breadth of the leopard cat species using standardized Levins index (*Lst*) (Colwell and Futuyma 1971; Levins 1968) based on the following formulae:

$$L = \left(\sum_{i=1}^{n} p_i^{2}\right)^{-1} \quad \text{and} \quad L-1/n-1$$

Prey species indices

Similarly, the prey indices including prey species richness (S), diversity index (H') and prey evenness (E) indices were computed using the following formulae:

Diversity Index (H')
$H' = -\Sigma\ [pi \times \ln pi]$

where pi represents the prey index and ln pi is the natural log of pi.

Prey species richness was calculated by considering the total number of prey species consumed by each carnivore in a specific season.

Prey Evenness Index was calculated by using the formula:

$E = H' / \ln \text{ of } S$

where, S represents the prey species richness and H' represents the diversity index.

Statistical analysis

We used the Chi-square test for independence, also called Pearson's chi-square test, to assess if there is any statistical relationship between two categorical variables. Chi square analysis was performed to assess if there were significant differences ($p < 0.05$) in the consumption of wild prey species, domestic animals, plant matter and anthropogenic matter in the diet of leopard cat species between summer and winter. We categorized the leopard cat diet into four categories: wild prey, domestic prey, plant materials, and anthropogenic matter; using the total frequencies of each dietary category, we compared dietary intake season wise, that is, in summer and winter, to check if dietary intake differed seasonally. All analysis was performed in SPSS software (Version 20).

RESULTS

Spatial distribution

Among all surveyed sampling sites (N = 23), leopard cat (*Prionailurus bengalensis*) occurrence was recorded at 13 different sites; evidence consisted of scats, direct sightings, camera traps, and carcasses (Table 1; Fig. 1C; Fig. 2). The altitudinal range of leopard cat distribution in the MHNP was between 664–1441 m. Scats of the species (N = 68) were found at all 13 positive sampling sites. The leopard cat was also sighted in the field at three sampling sites while one carcass was recovered from Trail-5A in the study area. The highest number of field signs of leopard cat was also recorded at Trail-5A. The leopard cat species was camera trapped at only one site, and that camera trap site is shown as blue "asterisk" (*) in figure 1C; one leopard cat carcass was found at one site (Trail-5), shown as a red triangle, while all rest of the sites contained leopard cat scats (Fig. 1B and C).

Diet composition

Physical characteristics of scats

The collected leopard cat scat scats (N = 68) were measured in the laboratory; length = 9.76 ± 0.05 cm, breadth = 1.21 ± 0.01 cm and weight = 7.36 ± 0.04 g.

Molecular identification of scats

Out of the 68 total scats collected from the field, 56 were confirmed to belong to the leopard cat based on the mitochondrial cytochrome B region. Remaining $n = 12$ scats were not subjected to molecular analysis just to reduce the cost of analysis, since those scats were collected from the same latrine of the leopard cat and confirmed in the field morphologically based on their shape, size and contour. Similarly, those scats that were found together (12) were also not processed for genetic analysis. However, these 12 scats were included in the final diet analysis of the species.

Table 1. Signs of the leopard cat recorded at Margalla Hills National Park Islamabad, Pakistan

Type of evidence	Numbers recorded (N)
Presence recorded (Trails)	13
Scats (N)	68
Direct field sightings	3
Camera trap success	1
Road kills / carcass	1

Diet group

Analysis of leopard cat scats (N = 68) in the laboratory revealed that they comprised (in terms of percent volume occurrence in scats) of bones, hairs, plant remains, feathers, insects body parts, snails, and anthropogenic matter (Table 2). Bones and hairs were the most voluminous items recovered from the scats analyzed, followed by plant remains.

The scats primarily contained remnants of rodents, and a variety of plant species (Table 3). The leopard cat consumed several species of rodents, including house rat (*Rattus rattus*), house mouse (*Mus musculus*), Indian gerbil (*Tatera indica*), Indian Musk Shrew (*Suncus murinus*), and Indian Mole Rat (*Bandicota bengalensis*) along with Asian palm squirrel (*Funambulus*

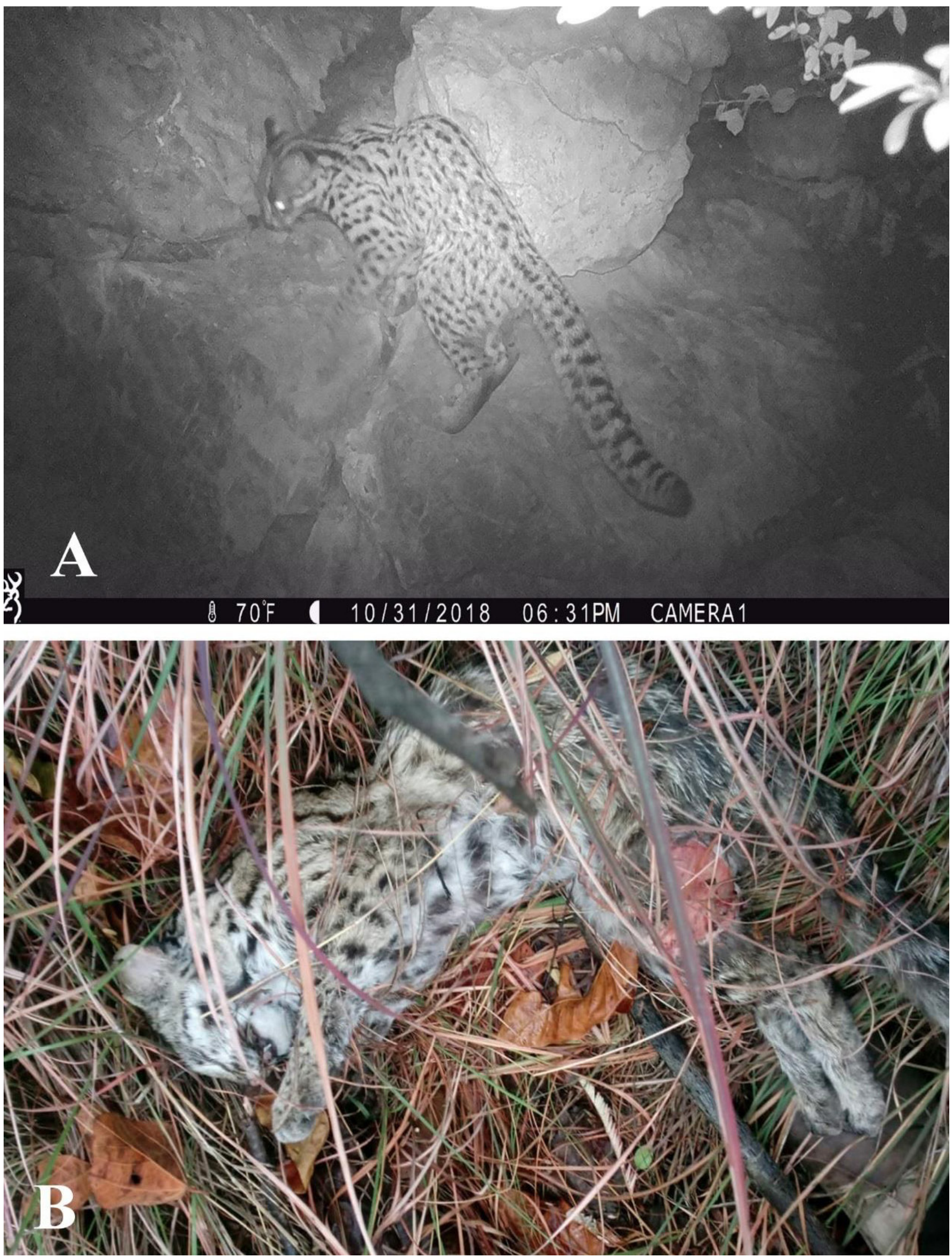

Fig. 2. (A) Camera trapped photograph of leopard cat in MHNP. (B) a carcass of leopard cat recovered from the study area.

palmarum). Rodents comprised 67.70% (FO) of the diet, more in summer (87.09%) than in winter (51.35%). Wild carnivora in the leopard cat diet were represented up to 10.29%, lagomorphs 4.41%, wild ungulate (wild boar) 2.94%). Invertebrates contributed 13.23% to the leopard cat diet including snails and insects. The diet is comprised of wild prey (including 10 mammal species, birds, insects, and snails), domestic prey (4 species), plants (13 species), and anthropogenic matter (plastic bag material mostly).

Wild prey was most frequently consumed (51.75%), followed by plant material (32.41%) that could have been secondarily ingested by eating prey, and domestic prey species (7.69%) (Fig. 3). Among wild prey species, house rat (20.59%) was most frequently eaten, followed by house mouse (11.76) and Indian musk shrew (10.26%). The other wild prey species eaten were small Indian mongoose, grey mongoose, Asian palm squirrel and Cape hare. The wild boar was most probably scavenged by the leopard cat. Birds, insects and snails also contributed in the diet of leopard cat.

Among domestic prey items, poultry consumption was highest (5.88%), followed by sheep, goat and dog. Among 13 plant species consumed, most frequently utilized was the daisy (*Bellis perennis*; 30.88%). The share of anthropogenic matter in the leopard cat diet was approximately 12% (Table 2).

Seasonal variation in diet

Among the 68 scat samples of leopard cat, 31 were collected in summer while 37 were collected in winter. In general, consumption of wild prey was higher in summer than winter. Similarly, intake of domestic prey was higher in winter than summer. Plant matter intake was higher in winter (97.30%) than summer (35.48%).

Prey species richness for the leopard cat was comparatively higher in winter but lower in summer. Similarly, the diversity index was also slightly higher in winter than summer. The prey species evenness index was higher in summer than winter (Fig. 4).

Chi-square test for independence showed a significant difference ($\chi^2 = 20.304$, *d.f.* = 3, $p = 0.0001$; $\alpha = 0.05$) in dietary intake between summer and winter seasons.

Niche Breadth

Leopard cat's dietary niche breadth (L) and standardized niche breadth (*Lst* Values 0-1) were found wider (L = 14.84, and *Lst* = 0.43) during summer season but narrower during the winter (L = 10.67, and *Lst* = 0.30) while the total niche breadth of the leopard cat was L = 17.52 and *Lst* = 0.52.

DISCUSSION

In the current study, we recorded different signs of occurrence of the leopard cat at 13 different sampling sites (trails) in the study area, including field sightings ($n = 3$), camera trap photographs ($n = 1$), road kills ($n = 1$), and scats ($n = 68$). Most leopard cat occurrence data were recovered around dense vegetation areas that were away from the villages' outskirts, reaffirming previous findings that the leopard cat prefers areas of thick vegetation cover (Roberts 1997). Based from our signs, the species does not occur uniformly in the MHNP, but its population was found confined to some areas associated with dense and thick forests across the elevational range of 664–1441 m. In Pakistan, the leopard cat is normally associated with Himalayan moist temperate forests, but it also penetrated the Himalayan dry coniferous forests and into dry sub-tropical scrub forests in the foothills (Roberts 1997). Margalla Hills National Park, in this context, comprises of the foothills of the front range of the Himalayas; therefore, MHNP may be the edge of leopard cat distribution in Pakistan.

Table 2. Food items (% volume) recovered from leopard cat scats in Margalla Hills National park, Islamabad, Pakistan

Recovered Prey items	S ($n = 31$)	W ($n = 37$)	Mean ± SE
Bones	45.61	34.72	39.69 ± 0.02
Hairs	28.23	21.36	24.49 ± 0.02
Feathers	3.42	6.49	5.09 ± 0.02
Insects Parts	1.30	3.77	2.64 ± 0.01
Plant Remains	11.90	25.86	19.50 ± 0.02
Soil/ Sand	4.69	0.00	2.14 ± 0.01
Snails	0.00	5.35	2.91 ± 0.01
Anthropogenic matter	5.40	2.07	3.59 ± 0.01

*S= Summer season; *W= Winter season.

Table 3. Frequency of occurrence (%) of prey items identified from the scats of the leopard cat

Prey Species	S (*n* = 31)	W (*n* = 37)	(%) F
Wild Prey			
Rodents			
House Rat (*Rattus rattus*)	29.03	13.51	20.6
House mouse (*Mus musculus)*	16.13	8.11	11.8
Indian Gerbil (*Tatera indica*)	12.90	8.11	10.3
Indian Musk Shrew (*Suncus murinus*)	12.90	8.11	10.3
Indian Mole Rat (*Bandicota bengalensis*)	9.68	2.70	5.88
Palm squirrel (*Funambulus pennantii*)	6.45	10.81	8.82
Sub-Total	87.09	51.35	67.70
Carnivora			
Small Indian mongoose (*Urva auropunctatus*)	9.68	5.41	7.35
Grey mongoose (*Herpestes edwardsii*)	3.23	2.70	2.94
Sub-Total	12.91	8.11	10.29
Lagomorpha			
Cape hare (*Lepus capensis*)	-	8.11	4.41
Sub-Total	-	8.11	4.41
Wild ungulates			
Wild boar (*Sus scrofa*)	6.45	-	2.94
Sub-Total	6.45	-	2.94
Invertebrates			
Snails	-	8.11	4.41
Insects	6.45	10.81	8.82
Sub-Total	6.45	18.92	13.23
Birds	12.90	8.11	10.3
Domestic Prey			
Poultry birds (*Gallus gallus domesticus*)	3.23	8.11	5.88
Sheep (*Ovis aries*)	6.45	2.70	4.41
Goat (*Capra hircus*)	-	5.41	2.94
Dog (*Canis familiaris*)	-	5.41	2.94
Sub-Total	9.68	21.63	16.17
Plants consumed			
Amaltas (*Cassia fistula*)	3.23	0.00	1.47
Peach (*Prunus persica*)	9.68	0.00	4.41
Shareen (*Albizzia lebbek*)	6.45	0.00	2.94
Yarrow (*Achillea millefolium*)	3.23	5.41	4.41
Daisy (*Bellis perennis*)	-	56.76	30.9
Bindweed (*Convolvulus arvensis*)	3.23	2.70	2.94
Chandan (*Chenopodium ambrosioides*)	-	2.70	1.47
Bair (*Zizyphus muritiana*)	-	8.11	4.41
Bitter apple (*Solanum incanum*)	-	2.70	1.47
Wild pomegranate (*Punica granatum*)	-	8.11	4.41
Alu Bokhara (*Prunus bokhariensis royle*)	9.68	-	4.41
Granda (*Carissa opaca*)	-	8.11	4.41
Maize (*Zea mays*)	-	2.70	1.47
Soil	16.13	-	7.35
Anthropogenic matter	19.35	5.41	11.8

*s = summer; *w = winter; *F = frequency of occurrence.

We confirmed scats collected from the field to belong to leopard cat species through molecular analysis, before analyzing them for determine the dietary habits of the species. The analysis of scats showed that the species consumes both wild prey (51.75%), domestic prey (7.69%) and plant matter (32.41%), along with some anthropogenic matter (3.50%) in the study area. Our results revealed presence of a variety of mammals in the dietary menu of the leopard cat, with a high intake of rodents, including five different species—house rat, house mouse, Indian gerbil, Indian musk shrew, and Indian mole rat. These findings are in line with Shehzad et al. (2012) who reported that the leopard cat has a diversified diet, dominated by house rat (in 68% processed scats).

In the current study, we report that rodents make up the majority of the leopard cat's diet year-round. Our results are in line with many previous studies (Austin et al. 2007; Fernandez and de Guia 2011; Shehzad et al. 2012). The leopard cat does not just feed on rodents, but also tree nesting birds (Nowell and Jackson 1996). In Ayubia National Park (ANP) and Chitral Gol National

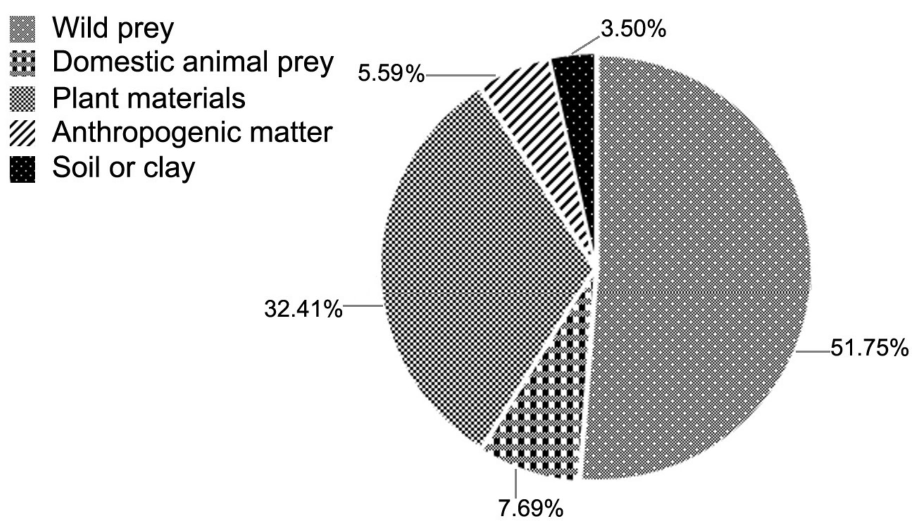

Fig. 3. Percentage frequency (%F) of food items (wild and domestic prey & plant matter) in the diet of the leopard cat occurring in MHNP.

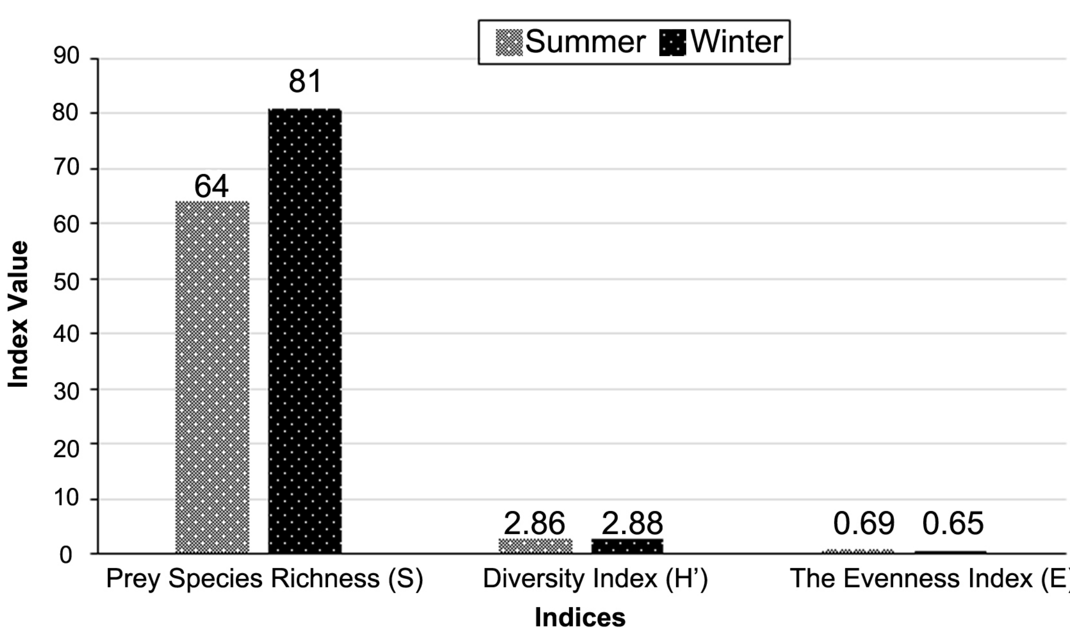

Fig. 4. Seasonal indices in prey species of the leopard cat in Margalla Hills National Park Islamabad, Pakistan.

Park (CGNP), molecular barcoding results revealed 18 different prey taxa in the diet of leopard cat with Rodentia dominating the diet (Shehzad et al. 2012). Specifically, the house rat predominated the diet (in 68% of the faeces), followed by Asiatic white-toothed shrew (32%) and Murree hill frog (27%). Another recent study in Pakistan showed that the diet of the leopard cat in Murree, Kotli sattian - Kahuta National Park comprised nine mammalian species, mostly rodents (89.5% FO), particularly in winter season (Khatoon et al. 2019). Therefore, our study adds another location in Pakistan that supports that the leopard cat diet in Pakistan is dominated by rodents.

In the current study, a considerable amount of birds remains and domestic prey was evident in the diet of leopard cat. Previously, Nowell and Jackson (1996) had reported that arboreal behavior broadens the dietary niche breadth of the leopard cat because it allows it to eat tree nesting birds. Among the domestic prey of sheep, goat, and dogs, the leopard cat predominately consumed poultry chicken. Poultry chicken and sheep were consumed in both seasons, while goat and dogs were predated in winter season only. These large domestic animals (goats and dogs) were not scavenged by the leopard cat in the study area because people keep these animals at home and after their death do not throw them away in the open. So, these were predated and not scavenged.

In terms of domestic prey in the winter, there could be fewer prey options available to the leopard cat, pressuring it to eat other available domestic prey species. Feeding on poultry chicken and domestic prey or livestock raises concerns for potential human-wildlife conflict, which would be of interest to park managers and for conservation.

Results of our analyses of leopard cat faeces also revealed plant material in the cat's faeces, which from a nutritional perspective does not likely benefit leopard cats because they do not have the digestive ability to extract meaningful amounts of energy from plants, especially the seeds found in this study. The plant material found in leopard cat scats may have been either secondarily ingested from eating their prey, or the ingestion of plant parts for roughage or intestinal issues. In Korea, although the leopard cat primarily consumes rodents, it was also reported that scats had 29.3% plant matter in the faeces, which is similar to the amount we recorded in our study (29.3% plant material) (Lee et al. 2014). The occurrence of plant material in leopard cat faeces could be interpreted as aligning with digestive issues such as chimpanzees, which use the Velcro effect of certain plants to eliminate parasites from their body, and Alaskan brown bears (*Ursus arctos*), which take in fiber-rich and sharp *Carex* spp. to eliminate tapeworms Huffman (1997). Two main methods for eliminating parasites through consumption of plants have been reported, that is, induced vomiting to remove parasites from the mouth and induced excretion of parasites from the anus (Engel 2002). Traminoid grass was found in about 10% of the leopard cats from Tsushima Islands, Japan, and it was interpreted that grass likely improves occasional intestinal disorders (Tatara and Doi 1994). Indeed, in our study the leopard cat consumed the following plants with known medicinal properties: Amaltas *Cassia fistula* (Bhalerao and Kelkar 2012), Shareen *Albizia lebbek* (Mishra et al. 2010), Bair *Ziziphus mauritiana* (Dahiru et al. 2006), Alu Bokhara *Prunus bokhariensis royle* and Granda (*Carissa opaca*). Additionally, we found that plants were consumed more in the winter when rodent availability may be lower. Nonetheless, recovery of plant matter from the faeces of leopard cat does not conform to the usual dietary habit of the species, and plant matter was probably ingested either secondarily through eating prey or it was consumed to treat some digestive disorders. This will require more studies on leopard cat to evaluate these possibilities.

Lastly, we observed differences in diet composition and diversity between summer and winter months. First, domestic preys' intake was merely 9.68% in summer and 21.62% in winter scats. This increase in domestic intake in winter may reflect scavenging activity due to possible seasonal scarcity of its natural prey. Besides rodents, we also recovered other opportunistic prey species as well including meso mammals such as wild boar and small Indian mongoose in summer, barking deer in winter season, from scats of leopard cat. Previous studies have reported that sometimes small carnivores scavenge on remains of large mammals (Lanszki and Heltai 2010), which may explain presence of barking deer and wild boar in leopard cat scats. Ingestion of insects and birds were observed year-round; this was also supported by previous studies (Mukherjee et al. 2004; Ogurlu et al. 2010). The carnivores can also potentially affect community and food-web structure of lower trophic levels (Palomares and Caro 1999). Second, we also report here that the leopard cat dietary niche breadth is wider during summer than winter, suggesting that the leopard cat's summer intake was more diverse than its winter one.

Finally, it is worth mentioning that the leopard cat is not the only mammalian predator in the Margalla Hills National Park. In addition to the leopard cat, MHNP also harbors other potentially competing sympatric carnivores including common leopard (*Panthera pardus*), Asiatic Jackal (*Canis aureus*), Red fox (*Vulpes vulpes*), Jungle cat (*Felis chaus*), Palm Civet (*Paradoxurus hermaphroditus*), small Indian civet (*Viverricula indica*), Indian grey mongoose (*Herpestes edwardsii*), and small Indian mongoose (*Urva auropunctatus*). Overall, the fauna of the national park comprises 250 species of exotic birds, song-birds and birds of prey belonging to 24 families; 38 mammal species representing 8 orders; at least 13 taxa of reptiles; and numerous insects (Roberts 1997). Since eight other carnivore species are sympatric to leopard cat in the MHNP, the leopard cat dietary habits are expected to overlap with other carnivores in the area, and there may be dietary niche overlap with other felids and carnivores of the park. But for that, a separate study has to be designed and caried out to assess any dietary competition.

CONCLUSIONS

The study concludes that the leopard cat occurs in Margalla Hills National Park at an elevation of 664–1441 m asl (above sea level). Its diet comprises 10 wild and four domestic animal prey species, along with some plant matter that might have been consumed secondarily. Small mammals (five different species) are the main prey species of the leopard cat; the species has also been shown to eat Asian palm Squirrels, birds and insects. It also preys on some wild meso mammal including small Indian mongoose, grey mongoose, and cape hare, and scavenges on wild boar. The current study highlights ecological role of leopard cat as "natural predator" of different rodent species in the park. The dietary niche breadth of the species being narrower in winter season is indicative of more feeding options in the summer.

List of abbreviations

asl, above sea level.
ln, log natural.
Lst, Standardized niche breadth.
MECU, Mammalian Ecology and Conservation Unit.
MHNP, Margalla Hills National Park.
QGIS, Quantum Geographical Information System.
IWMB, Islamabad Wildlife Management Board.
°C, degree centigrade.
PCR, Polymerase chain reaction.
H', Diversity Index.
S, Species richness.
E, Evenness Index.

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