Feeding habits and habitat use of barking deer (*Muntiacus vaginalis*) in Himalayan foothills, Pakistan

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Abstract

Northern red muntjac (*Muntiacus vaginalis*; “barking deer”) is a shy and small-sized cervid mammal, limited to the outer Himalayan foothill forests in Pakistan. Habitat characteristics were measured by locating direct and indirect signs. To quantify habitat utilization of barking deer, 80 field surveys were conducted in the study area along transects. 1200 Quadrats at 50 m intervals were deployed along these transect lines to determine microhabitat factors associated with seasonal distribution. The food composition of the barking deer was determined through fecal droppings analysis by micro-histological technique. Forty-five fecal samples of barking deer were collected from the study area (Murree-Kotli Sattian-Kahuta National Pak); summer (28) and winter (17). The micro-histological analysis revealed that more plant species are available in its habitat during the summer season (27) as compared to winter (19). Due to browsing nature barking deer mostly feed on trees in both seasons. While shrubs are slightly higher in winters. In summer barking deer consumed 10 Trees, 6 Shrubs, 5 Herbs, and 6 kinds of grass species. Dominant tree species were *Phyllanthus emblica* and *Acacia modesta*. Dominant shrub species were *Ziziphus nummularia* and *Justicia adhatoda*. In winter barking deer consumed 8 Trees, 7 Shrubs, 3 Herbs, and 1 Grass. Dominant tree species were *Bauhinia variegata* and *Acacia modesta* while shrubs included *Ziziphus nummularia* and *Carissa opaca*.

Introduction

Understanding the spatial distributions of wildlife species is a fundamental step in distinguishing the linkages between animals and their potential impacts on natural resources [1, 2]. The choice of ungulate habitat is strongly influenced by nutrients and energy demands for the growth of bones and body mass in males [3] as well as gestation and lactation of calves in
females [4]. These body needs are mitigated by the risk of predation, which varies in each habitat type [5]. Energy demands in different genders, particularly the risk of predation [6], have led to multiple examples of seasonal and sexual changes in habitat [7].

Habitat heterogeneity is believed to be important for several reasons. If less of the two resources are required when taken together (e.g. food and cover, or different nutrients), then these resources are said to be complementary [8]. Field observation has shown that this deer consumes fresh, tender fruit and buds and leaves from a variety of low-growing plants [9]. In Thailand, it is particularly fond of the fallen fruit and browses more than he grazes [10]. An opportunistic eater and its stomach contents consisted of a relatively large amount of plants grown on the ground, indicating that it was a selective food that survived as much on grasses [11].

Barking deer is classified as an omnivore and is considered both browser and grazer with grass, ivy, thorny bushes, low leaves, barks, twigs, grasses, fruits, eggs, and small blood animals. Barking deer is usually found at the edge of the forest or in open areas. Barking deer in southern India is also found in large tea plantations because they feed mainly on tea seeds. Their large canines help with the process of food recovery and ingestion [12].

Usually, they feed alone or in two or three, more are usually individuals sharing a food resource. The height of browsing varies between 50 cm and 90 cm but can be up to 20 cm when they stand on their hind legs [13]. Barking deer are nocturnal in their food activity, but can feed at dusk in undisturbed areas. They are very shy and stay close to their area. They defecate elongated pellets with sharp ends, especially places in their potential habitats [14].

General observations on the behavior of Barking Deer were made by Barrette [15] and Lekagul & McNeely [10]. Feeding Barking Deer usually move very slowly, zigzagging over a small area for a long time, usually keeping their nose very close to the ground, stirring the thin litter that covers the surface. Dinerstein [16] described that sometimes, Barking Deer stops for one or two seconds, stretch out his tongue to pick up something on the ground, chew it quickly while keeping the nose close to the ground, and move forward for further exploration.

The drinking behavior of Barking Deer has been described by Barrette [15]. Typically takes water in the middle of the morning and usually chooses a water point as close as possible to the point where he emerges from the forest. Roberts [14] described that he is constantly vigilant during drinking, raising the head every 8–12 seconds.

Barking Deer are considered delicate selective eaters, but seem able to survive as much as grasses. They are particularly similar to ripe fruit falling from various wild figs (Ficus spp.), fleshy flowers of silk cotton (Bombax malabaricum), and the laurel fruit (Z. mauritiana), all of which grow in the Margalla ravines frequented by this deer [14].

**Significance of the study**

Understanding the effects of barking deer on the forest, feeding habits in the study area is necessary. No quantitative study on the feeding habits of barking deer in Murree, Kotli Sattian, and Kahuta National Park has been conducted. However, the only information on feeding and feeding habits of the barking deer is based on general observations in the field. Not any literature is available on the composition of the diet and its variation with time and space in the Murree, Kotli Sattian, and Kahuta National Park. The present study was therefore conducted to study the seasonal variation in barking deer diet composition.

**Materials and methods**

As we didn’t handle or capture the barking deer from the field or study area only the habitat and other parameters of habitat were studies therefore there is no need to get any permission letter.
from any of the organization along with the field data collection. The consult department staff were also accompanying therefore no illegal act was performed during the field only handling and capturing need permission letter. No disturbance in the core habitat of the species was done.

Description of the study area

This study was conducted in newly established Murree, Kotli Sattian, and Kahuta National Park located in district Rawalpindi comprising an area of 5,7581 ha. This district is located on the southern slopes of the north-western reaches of the Himalayas, including large expanses of mountains with rich valleys crossed by mountains and rivers. Rawalpindi’s climate has generally been known to change rapidly because of its closeness to the Himalayas and the Pir Panjal Range.

Data collection

A reconnaissance survey of the study area, i.e. Murree, Kotli Sattian, and Kahuta National Park was conducted and potential habitat areas of barking deer were identified. Barking deer was found distributed in twenty-four (24) study sites which were further considered as a broad sampling unit for purpose of the present study (Fig 1). The presence was confirmed by direct observation of the barking deer or indirect evidence (footprints, calls, and fecal pellets). Each study site having reasonably uniform physio-biotic conditions was extensively searched by walking through the forest area (Table 1). Elevation and coordinates of barking deer occurrence sites were noted to use for developing a distribution map. The map was developed by using ArcGIS software 10.3 versions (Fig 2).

Phyto-habitat analysis

To quantify the habitat utilization of barking deer, each selected study site was sampled for floral diversity and community structure by quantifying different trees, shrubs, herbs, and grass species during 2015–2017. The quadrat method along a transect line was adopted to determine

Fig 1. Map of the study area showing study sites of barking deer.
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Table 1. Characteristics of study sites in Murree, Kotli Sattian, and Kahuta NP Pakistan.

| Site No. | Site name | Location | Elevation (m) | Slope (%) |
|----------|-----------|----------|---------------|-----------|
|          |           | North    | East          |           |
| 1        | Kathar    | 33.789677| 73.2900123    | 735–785   | 20–30     |
| 2        | Baroha    | 33.7988627| 73.2207127    | 498–928   | 50–55     |
| 3        | Benghal   | 33.69403773| 73.42551447   | 728–923   | 70–80     |
| 4        | Salgran   | 33.82647088| 73.29059175   | 814–1229  | 40        |
| 5        | Angoori   | 33.79181875| 73.352729     | 798–1143  | 40–50     |
| 6        | Numble    | 33.84065123| 73.32231038   | 1160–1263 | 60        |
| 7        | Simli     | 33.85787864| 73.32601007   | 1073–1263 | 50        |
| 8        | Phaphril  | 33.86014256| 73.407826     | 798–1263  | 70        |
| 9        | Gura      | 33.59281476| 73.55842247   | 557–593   | 60–70     |
| 10       | Thoa      | 33.657547  | 73.5657615    | 452–960   | 40–50     |
| 11       | Slember   | 33.65923889| 73.48762222   | 630–852   | 30        |
| 12       | Keral     | 33.79197273| 73.22409836   | 580–899   | 50        |
| 13       | Dalatar   | 33.657514  | 73.35557225   | 740–975   | 80        |
| 14       | Beor      | 33.59296021| 73.5634746    | 538–654   | 40        |
| 15       | Seri      | 33.54116414| 73.56057514   | 545–575   | 60        |
| 16       | Sang      | 33.69057021| 73.4264786    | 538–618   | 60        |
| 17       | khalol    | 33.57534213| 73.55849106   | 547–745   | 20–30     |
| 18       | Nahr      | 33.54092813| 73.5288563    | 547–745   | 30–40     |
| 19       | Badnian   | 33.79432177| 73.52552046   | 835–1250  | 60        |
| 20       | Makrosh   | 33.77104682| 73.55702127   | 598–1061  | 40        |
| 21       | Thun      | 33.75810145| 73.54085918   | 977–1120  | 70        |
| 22       | Santh Sarula | 33.842698  | 73.55469822   | 994–1277  | 60        |
| 23       | Santh Anwali | 33.85818907| 73.5751766    | 663–951   | 70        |
| 24       | Chakka    | 33.75858256| 73.44178306   | 735–786   | 30        |

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Fig 2. Distribution map of barking deer in Murree, Kotli Sattian and Kahuta National Park.

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the seasonal distribution of barking deer during summer (May-October) and winter (November-April). Vegetation data were collected twice a year, once in summer and winter.

Fifty (50) quadrats 50 m apart were taken at each study site, so a total of 1200 quadrats in total were placed perpendicular along a straight line at each sampling point. Density, frequency, and percent cover were noted at each quadrate for each plant species. The size of the sample plot for trees (10m x 10m), shrubs (4m x 4m), grasses, and grass (1m x 1m) were selected [17]. Collected plant samples were pressed, dried, and mounted on herbarium leaves. These plants were identified with already identified plants in the herbarium of Quaid-i-Azam University, Islamabad. Local people were asked to obtain vernacular names of species. To calculate density, frequency, coverage, relative density, relative frequency, and relative coverage equations of [18] were followed.

Microhistological analysis

The fecal analysis method has been widely adopted to reveal the feeding habits of ungulates [19]. Microhistological analysis of feces is widely used to study the diet composition of a variety of wild and domestic animals from herbivores, such as mammals chewing and degrading plants. The basic principle of this method is that the epidermis cuticle of the plant is a non-digestive part and can be identified by comparable plant reference materials [20]. By this method, the frequency of occurrence of different plant species in the fecal samples was determined [21, 22].

Sample size

A total of 45 groups of fecal pellets were collected in the study area between August 2015 and November 2017. A group of pellets was considered a sample. Samples were identified by size, structure, and shape (Fig 3).
Sampling procedure
Fecal samples were collected in summer (28) and winter (17) from twenty-four selected sites along the transect line. The freshness of fecal pellets was determined by color, moisture, and consistency.

Handling, processing, and storage of fecal pellets
All the collected pellet groups were packed individually in plastic bags, tied with a label containing all information like coordinates, time of collection, and place. The information on the label was recorded using a waterproof pen to minimize the risk of vanishing. The fecal pellets were transported to the Wildlife Management Research Laboratory at the PMAS Arid Agriculture University in Rawalpindi. The samples were air-dried and stored in a dry place.

Collection of reference plants
The collection of potential species of deer forage was conducted at the same time as the collection of fecal samples at each location for the reference slides. This collection of reference plants was based on information gathered from wildlife personnel, residents in the vicinity of Murree, Kotli Sattian, and Kahuta National Park, and direct observation of grazed vegetation. Two specimens of each plant were collected; one for the reference record and the other for the preparation of the reference key.

Slide preparation
In the Natural Science Research Laboratory of Wildlife Biology, University of Montana, each sample was ground separately in a mortar and pestle. The material was screened through double folds of fabric to remove dust and unidentifiable particles. This mash was washed in water and soaked in a solution (1 part distilled water, 1 part ethyl alcohol, 1 part glycerin) overnight and then homogenized again in the soil. Each sample is transferred to a test tube containing a freshly prepared solution of 5% sodium hydroxide. The test tube was warm in 5–7 minutes and allowed to precipitate. After decantation, the supernatant was removed. This step was repeated 3–5 times to get a clear liquid.

The material was heated and dehydrated by 25%, 50% to 75%, and 100% alcohol treatments for ten minutes. The alcohol was removed by a series of mixtures of xylene and alcohol. Then, a suitable part of this material was spread on a glass slide and mounted with DPX, and covered with a coverslip. The same procedure was followed by the preparation of the reference plant slides except using a 10% sodium hydroxide solution.

Slide interpretation
Two slides were prepared from each fecal sample for the microstructure of plant tissues such as cells, stomata fibers, and microscopic spaces. Photomicrographs of the reference plants were taken connected by digital cameras (DCE-2) with a compound microscope (XSZ-701AN / XSZ-107AN). Reference slide micrographs were used to compare and identify materials by Barking Deer with slides prepared from fecal samples.

The presence of plant species in each of the 45 groups of fecal pellets was estimated using an ocular grid micrometer in the microscope eyepiece. Ten micro-fields were selected on each slide and examined. First, the total number of plant species present in the entire slide has been identified. Next, the number of squares of the eye grid is filled with plant material in each row and squares of numbers in each row containing each plant listened to, counted. All data has been tabulated.
The frequency of the different food products of each fecal sample was calculated using the following formula:

\[
\text{Frequency occurrence} = \frac{A}{B} \times 100
\]

Where A is the No. of rows (ocular grid) filled with specific plant species and B is the No. of rows (ocular grid) filled with total plant species identified on the sample slide. This formula is used in two different research articles to determine frequency occurrence or percent composition [20, 22].

Physical characteristics of the habitat at each sampling point, like terrain, slope, water points, and disturbance level were also noted. Elevation and aspect were also noted using Global Positioning System (GPS) and Marching compass. Vegetation data were collected twice a year, once in summer and winter.

Results

Phytosociology

Data on the distribution of vegetation cover contributed by different species in different potential habitat areas suggested that a total of 67 plant species (trees = 23, shrubs = 17, herbs = 14, and grasses = 13) were recorded in the habitat of barking deer (Table 2). The tree canopy was open and provided an average of 30 percent vegetative cover.

Seasonal diet composition

The summer habitat of barking deer consisted of 47 plant species which comprised 16 tree species, 11 shrub species, 10 herb species, and 10 grass species (Fig 4). Dominant tree species were *Olea ferruginea* (IV = 49.70) and *Pinus wallichiana* (IV = 40.04), dominant shrub species were *Carissa opaca* (IV = 145.32) and *Rubus ellipticus* (IV = 51.53), dominant herb species were *Adiantum incisum* (IV = 26.87) and *Oxalis corniculata* (IV = 23.1) and dominant grass species were *Apluda mutica* (IV = 22.46) and *Bothriochloa ischaemum* (IV = 12.8).

Out of 28 fecal samples collected in the study area in summer, 27 plant species (tree = 10, shrubs = 6, grass = 5, and grass = 6) were recorded in the diet of barking deer. The analysis of fecal pellets revealed that the diet of deer consisted mainly of trees (37.03%), which constituted a major component of their diet, followed by shrubs and grasses consumed (22.22%). Presence of various foods in fecal samples recorded in the following order: *Phyllanthus emblica* > *Ziziphus nummularia* > *Justicia adhatoda* > *Acacia modesta* > *Grewia optiva* > *Apluda mutica* > *Bauhinia variegata* > *Carissa opaca* > *Micromeria biflora* > *Adiantum incisum* > *Woodfordia fruticosa* > *Bauhinia variegata* > *Maytenus royleanus* > *Bothriochloa ischaemum*. The rest of the plant species were consumed in trace amounts (Table 3).

A total of 41 plant species were observed in the winter habitat of barking deer, which included 14 tree species, 12 shrub species, nine grass species, and six grass species. (Fig 5) Dominant tree species during winter were *Pinus roxburghii* (IV = 61.42) and *Flacourtia indica* (IV = 29.72), dominant shrub species were *Dodonaea viscosa* (IV = 117.77) and *Myrsine africana* (IV = 88.19), dominant herb species were *Sida cordifolia* (IV = 56.5) and *Micromeria biflora* (IV = 27.05) and dominant grass species were *Cynodon dactylon* (IV = 14.25) and *Dichanthium annulatum* (IV = 12.79).

In winter, a total of 19 plant species (tree = 8, shrubs = 7, grass = 3 and grass = 1) were recorded in the diet of barking deer. Analysis of fecal pellets revealed that diet is predominantly composed of trees (42.10%), followed by shrubs (36.84%) and grasses (15.78%). Only
Table 2. Analysis of plant species found in barking deer habitat.

| S.No. | Plant Species       | Density | Frequency | Cover | Relative Density | Relative Frequency | Relative cover | Importance Value |
|-------|---------------------|---------|-----------|-------|------------------|-------------------|---------------|------------------|
| **Tree** |                     |         |           |       |                  |                   |               |                  |
| 1     | Acacia catechu      | 0.3     | 2.4       | 0.7   | 0.19             | 2.7               | 0.71          | 3.6              |
| 2     | Acacia modesta      | 2.4     | 34.7      | 2.8   | 1.55             | 39.08             | 2.84          | 43.47            |
| 3     | Acacia nilotica     | 1.5     | 10.4      | 0.8   | 0.97             | 11.71             | 0.81          | 13.49            |
| 4     | Albizia lebbeck     | 0.7     | 14.6      | 1.2   | 0.45             | 16.44             | 1.22          | 18.11            |
| 5     | Albizia odoratissima| 0.1     | 1.3       | 0.4   | 0.06             | 1.46              | 0.41          | 1.93             |
| 6     | Bauhinia varigata   | 0.6     | 5.6       | 0.4   | 0.39             | 6.31              | 0.41          | 7.11             |
| 7     | Celtis australis    | 1.3     | 19.8      | 1.1   | 0.84             | 22.3              | 1.12          | 24.26            |
| 8     | Dalbergia sissoo    | 1.8     | 16.8      | 1.2   | 1.16             | 18.92             | 1.22          | 21.3             |
| 9     | Ficus bipinnata     | 0.1     | 3.2       | 0.4   | 0.06             | 3.6               | 0.41          | 4.07             |
| 10    | Flacourtia indica   | 1.1     | 24.5      | 1.4   | 0.71             | 27.59             | 1.42          | 29.72            |
| 11    | Grewia optiva       | 0.3     | 5.1       | 0.6   | 0.19             | 5.74              | 0.61          | 6.54             |
| 12    | Mallotus philippinensis | 2.1   | 34.4      | 2.8   | 0.01             | 38.74             | 2.84          | 41.59            |
| 13    | Olea ferruginea     | 1.5     | 41.2      | 2.3   | 0.97             | 46.4              | 2.33          | 49.7             |
| 14    | Phyllanthus emblica | 0.9     | 5.3       | 1.8   | 0.58             | 5.97              | 1.83          | 8.38             |
| 15    | Pinus roxburghii    | 1.2     | 42.4      | 12.7  | 0.78             | 47.75             | 12.89         | 61.42            |
| 16    | Pinus wallichiana   | 2.7     | 31.2      | 3.1   | 1.75             | 35.14             | 3.15          | 40.04            |
| 17    | Phoenix loureir      | 0.5    | 4.3       | 1.2   | 0.32             | 4.84              | 1.22          | 6.38             |
| 18    | Pistacia chinensis  | 0.1     | 2.3       | 1.4   | 0.06             | 2.59              | 1.42          | 4.07             |
| 19    | Pyrus pashia        | 0.6     | 7.1       | 0.3   | 0.39             | 7.1               | 0.3           | 7.79             |
| 20    | Quercus incana      | 1.6     | 18.7      | 3.0   | 1.03             | 21.06             | 3.05          | 25.14            |
| 21    | Syzygium cumini     | 0.1     | 2.3       | 1.4   | 0.06             | 2.59              | 1.42          | 4.07             |
| 22    | Ziziphus mauritiana | 0.5     | 6.2       | 0.7   | 0.19             | 2.7               | 0.71          | 3.6              |
| **Shrubs** |                     |         |           |       |                  |                   |               |                  |
| 1     | Berberis lyceum     | 0.3     | 2.7       | 1.5   | 0.19             | 3.04              | 1.52          | 4.75             |
| 2     | Carissa opaca       | 21.8    | 87.4      | 32.3  | 14.1             | 98.42             | 32.8          | 145.32           |
| 3     | Deutzia staminea    | 0.7     | 4.2       | 0.9   | 0.45             | 4.73              | 0.91          | 6.09             |
| 4     | Dodonaea viscosa    | 15.6    | 76.7      | 20.0  | 10.1             | 87.37             | 20.3          | 117.77           |
| 5     | Galium asperfolium  | 0.2     | 2.4       | 1.3   | 0.13             | 2.7               | 1.32          | 4.15             |
| 6     | Justicia adhatoda   | 5.7     | 29.8      | 2.1   | 3.69             | 33.56             | 2.13          | 39.38            |
| 7     | Lantana camara      | 1.3     | 12.7      | 2.0   | 0.84             | 14.3              | 2.03          | 17.17            |
| 8     | Lespedeza cuneata   | 4.3     | 43.6      | 1.2   | 2.78             | 49.1              | 1.22          | 53.1             |
| 9     | Maytenus royleanus  | 3.1     | 73.2      | 2.4   | 2.01             | 82.43             | 2.44          | 86.88            |
| 10    | Myrsine africana    | 6.7     | 61.4      | 14.5  | 4.33             | 69.14             | 14.72         | 88.19            |
| 11    | Nerium oleander     | 1.7     | 14.2      | 0.9   | 1.1              | 15.1              | 0.91          | 17.11            |
| 12    | Puncia granatum     | 1.7     | 36.8      | 0.8   | 1.1              | 41.44             | 0.81          | 43.35            |
| 13    | Rosa webbiana       | 0.6     | 2.8       | 1.7   | 0.39             | 3.15              | 1.73          | 5.27             |
| 14    | Rubus ellipticus    | 5.2     | 32.4      | 11.5  | 3.36             | 36.49             | 11.68         | 51.53            |
| 15    | Sarcococca saligna  | 0.4     | 2.2       | 1.3   | 0.26             | 2.48              | 1.32          | 4.06             |
| 16    | Woodfordia fruticosa| 4.4     | 53.8      | 2.7   | 2.85             | 60.59             | 2.74          | 66.18            |
| 17    | Ziziphus nummularia | 0.2     | 1.8       | 0.7   | 0.13             | 2.03              | 0.71          | 2.87             |
| **Herbs** |                     |         |           |       |                  |                   |               |                  |
| 1     | Adiantum incisum    | 5.2     | 18.9      | 2.2   | 3.36             | 21.28             | 2.23          | 26.87            |
| 2     | Barleria crisata    | 0.4     | 9.6       | 0.2   | 0.29             | 10.81             | 0.2           | 11.3             |
| 3     | Diclyptera bupleuridoides | 2.3 | 4.5   | 0.8   | 1.49             | 5.068             | 0.81          | 7.37             |
| 4     | Duchesnea indica    | 2.7     | 5.5       | 0.4   | 1.75             | 6.19              | 0.41          | 8.35             |

(Continued)
herbs (5.26%) were consumed. Winter is a time when most grasses become dry due to night freezing. The only green matter available to the deer was leaves of shrubs and trees which were

Table 2. (Continued)

| S.No. | Plant Species         | Density | Frequency | Cover | Relative Density | Relative Frequency | Relative Cover | Importance Value |
|-------|-----------------------|---------|-----------|-------|------------------|-------------------|---------------|------------------|
| 1     | Apluda mutica         | 2.1     | 17.3      | 1.6   | 1.36             | 19.48             | 1.62          | 22.46            |
| 2     | Aristida mutabilis    | 1.7     | 0.5       | 0.3   | 1.1              | 0.56              | 0.3           | 1.96             |
| 3     | Bothriochloa ischaemum| 1.6     | 9.1       | 1.5   | 1.03             | 10.25             | 1.52          | 12.8             |
| 4     | Brachiaria ramose     | 0.3     | 0.2       | 0.1   | 0.2              | 0.22              | 0.1           | 0.52             |
| 5     | Cymbopogon jwarancusa | 3.4     | 12.3      | 2.6   | 2.2              | 13.85             | 2.64          | 18.69            |
| 6     | Cynodon dactylon      | 1.9     | 10.3      | 1.4   | 1.23             | 11.6              | 1.42          | 14.25            |
| 7     | Desmostachya bipinnata| 0.3     | 0.2       | 0     | 0.2              | 0.21              | 0             | 0.41             |
| 8     | Dichanthium annulatum | 1.7     | 9.3       | 1.2   | 1.1              | 10.47             | 1.22          | 12.79            |
| 9     | Eleusine indica       | 0.3     | 0.1       | 0     | 0.2              | 0.11              | 0             | 0.31             |
| 10    | Heteropogon contortus | 0.4     | 0.1       | 0.1   | 0.26             | 0.11              | 0.1           | 0.47             |
| 11    | Imperata cylindrical  | 0.8     | 0.5       | 0.3   | 0.52             | 0.56              | 0.3           | 1.38             |
| 12    | koeleria macrantha    | 0.5     | 0.7       | 0.2   | 0.32             | 0.79              | 0.2           | 1.31             |
| 13    | Themeda anthera       | 1.1     | 0.4       | 0.2   | 0.71             | 0.45              | 0.2           | 1.36             |

Grasses

- Apluda mutica
- Aristida mutabilis
- Bothriochloa ischaemum
- Brachiaria ramose
- Cymbopogon jwarancusa
- Cynodon dactylon
- Desmostachya bipinnata
- Dichanthium annulatum
- Eleusine indica
- Heteropogon contortus
- Imperata cylindrical
- koeleria macrantha
- Themeda anthera

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Fig 4. Plant species recorded in summer from the habitat of barking deer.

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Table 3. Frequency occurrence (%) of different food items in fecal samples (summer season) of barking deer.

| S.No. | Vernacular names   | Plant species            | Part used | % Occurrence |
|-------|--------------------|--------------------------|-----------|--------------|
| 1     | Amla               | *Phyllanthus emblica* (T) | leaves    | 57.24        |
| 2     | Phulai             | *Acacia modesta* (T)     | leaves    | 31.56        |
| 3     | Dhaman             | *Grewia optiva* (T)      | leaves    | 27.3         |
| 4     | Kachnar            | *Bauhinia variegata* (T) | leaves    | 26.35        |
| 5     | Beri               | *Zizyphus mauritiana* (T) | leaves    | 7.9          |
| 6     | Kamila             | *Mallotus philippinensis* (T) | leaves | 6.9          |
| 7     | Dandal             | *Xylosma longifolia* (T) | leaves    | 4.5          |
| 8     | Phagwara           | *Ficus bippinnata* (T)   | leaves    | 3.8          |
| 9     | Ban                | *Quercus incana* (T)     | leaves    | 1.3          |
| 10    | Chir pine          | *Pinus roxburghii* (T)   | leaves    | 1.2          |
| 11    | Khair              | *Ziziphus nummularia* (S) | leaves    | 46.2         |
| 12    | Baiker             | *Justicia adhatoda* (S)  | leaves    | 33.6         |
| 13    | Grinda             | *Carissa opaca* (S)      | leaves    | 22.7         |
| 14    | Dhawi              | *Woodfordia fruticosa* (S) | leaves | 17.56        |
| 15    | Pataki             | *Marryten royleanus* (S) | leaves    | 16.8         |
| 16    | Gukoon             | *Myrnye Africana* (S)    | leaves    | 13.7         |
| 17    | -                  | *Asiantum incisum* (H)   | leaves    | 18.5         |
| 18    | Beine              | *Micromeria biflora* (H) | leaves    | 5.1          |
| 19    | Khatti buti        | *Oxalis corniculata* (H) | leaves    | 4.16         |
| 20    | Kali jiri          | *Saussurea heteromella* (H) | leaves | 3.6          |
| 21    | Beni               | *Thalictrum footidum* (H) | leaves    | 2.4          |
| 22    | Ghagari            | *Aphuda mutica* (G)      | leaves    | 26.8         |
| 23    | Palwan            | *Bothriochloa ischaemum* (G) | leaves | 16.5         |
| 24    | Khuskus grass      | *Cymbopogon jwarancusa* (G) | leaves | 9.7          |
| 25    | Sarriya gaas       | *Heteropogon contortus* (G) | leaves | 7.4          |
| 26    | Mandhano           | *Eleusine indica* (G)    | leaves    | 6.8          |
| 27    | White grass        | *Themeda anamhera* (G)   | leaves    | 3.8          |

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Fig 5. Plant species recorded in winter from the habitat of barking deer.
a major component of his diet. Presence of various foods in fecal samples recorded in the following order: Ziziphus nummularia > Oxalis corniculata > Carissa opaca > Bauhinia variegata > Justicia adhatoda > Acacia modesta > Phyllanthus emblica > Puncia granatum > Pinus roxburghii > Grewia optiva. The rest of the plant species were consumed in trace amounts (Table 4).

**Distribution of barking deer in the study area**

Barking deer was not evenly distributed with vegetation types of the study area. The most preferred vegetation types were trees and shrubs with 30 and 69 percent cover, respectively. Barking deer was mostly distributed in shrubby vegetation as compared to avoided thick tree cover which ultimately hinders free movement and escapes of barking deer from a predator. More fecal pellets were collected near shrub species. No significant difference ($\chi^2 = 6.37$, $df = 3$, $p = 0.19 < 0.05$) in seasonal vegetation cover was recorded in habitat of barking deer.

Comparison of plant species recorded in barking deer diet in two different seasons revealed that a significantly higher plant species ($t = 5.78$, $p = 0.04 < 0.005$) were available in summer as compared to winter.

**Diet preference**

Analysis of fecal samples of barking deer showed a high preference for trees in both seasons as mostly tree leaves were consumed. Dominant tree species were Phyllanthus emblica, Acacia modesta, Grewia optiva, Bauhinia variegata, and shrubs including Ziziphus nummularia, Justicia adhatoda, Carissa opaca, Woodfordia fruticosa, Maytenus royleanus, and Myrsine africana. Preferred herbal species were Oxalis corniculata Adiantum incisum, Micromeria biflora, and Saussurea heteromella. Only two grass species Apluda mutica and Bothriochloa ischaemum were recorded in large quantities from fecal samples. The barking deer was recorded as a

| S.No. | Vernacular names | Plant species | Part used | % Occurrence |
|-------|------------------|---------------|-----------|--------------|
| 1     | Kachnar          | Bauhinia variegata (T) | leaves   | 25.8         |
| 2     | Phulai           | Acacia modesta (T) | leaves   | 19.52        |
| 3     | Amla             | Phyllanthus emblica (T) | leaves & fruit | 19.04        |
| 4     | Chir pine        | Pinus roxburghii (T) | leaves   | 11.78        |
| 5     | Dhaman           | Grewia optiva (T) | leaves   | 11.7         |
| 6     | Kahu             | Olea ferruginea (T) | leaves & fruit | 8.4          |
| 7     | Ban              | Quercus incana (T) | leaves   | 3.1          |
| 8     | Beri             | Zizyphus mauritiana (T) | leaves | 2.7          |
| 9     | Khair            | Ziziphus nummularia (S) | leaves & fruit | 53.5         |
| 10    | Grinda           | Carissa opaca (S) | leaves   | 32.3         |
| 11    | Sumbul           | Berberis lyceum (S) | leaves   | 29.8         |
| 12    | Baiker           | Justicia adhatoda (S) | leaves | 24.6         |
| 13    | Daruna           | Puncia granatum (S) | leaves   | 13.44        |
| 14    | Gukoorn          | Myrsine Africana (S) | leaves | 6.1          |
| 15    | Pataki           | Maytenus royleanus (S) | leaves | 5.3          |
| 16    | Khati buti       | Oxalis corniculata (H) | leaves | 42.7         |
| 17    | Kali jiri        | Saussurea heteromella (H) | leaves | 9.4          |
| 18    | Dil-patri        | Sida cordifolia (H) | leaves   | 2.3          |
| 19    | Khabal           | Cynodon dactylon (G) | leaves   | 6.3          |

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browser during the winter and it was a browser and a grazer in the summer. There was no sign of his predation on animal matter.

Discussion

Data on the distribution of vegetation in potential habitat areas suggested that most of the vegetation cover was occupied by shrubs (69%). It avoided thick tree cover which ultimately hinders movement and escapes from a predator. The tree canopy was opened and provides an average of 30 percent of total vegetative cover.

The results of the present study generally support the findings of Hameed et al. [23], who suggested a major part of the absolute cover of barking deer habitat was contributed by shrubs (30.3–68.7%)., tree cover above 20% might be lethal for survival from a predator. In an article, it is reported that barking deer is a browser, so greater shrub cover ensures the availability of food [10]. The preference of the thick canopy of barking deer can reduce visualization which is an anti-predatory strategy [24]. The selection of a high percentage of plant cover is also a predator defense strategy for ungulate calves [25, 26].

Information on food habits of this study suggested that barking deer is a browser as it tends to be feed on leaves of plant species present in the study area. Similar trends were reported in Thailand, that barking deer browses more than it grazes [10].

No seasonal changes in diet were observed and the results of this study revealed that seasonal differences are associated with the percentage of plant species available in each season. Significant seasonal differences in the diet of barking deer were recorded in the frequency of consumption of different foods, but not in terms of volume [27]. The presence of trees, shrubs, and forbs in the diet of barking deer was proportional to their availability in the habitat during both seasons. None of the plant species were used more than its availability [28].

In both seasons trees and shrubs dominated the flora and it contributed a major part of the diet of Barking Deer. In winter low availability of grasses due to frost was avoided in food items. Similar trends were observed in Chitwan National Park [29]. They switched to other food items when grass availability became less in winter. He also observed that the animals used to feed on fresh twigs of Imperata cylindrica. The newly growing plant leaves and shoots in the rainy season could cause deer to switch from grazing to browsing.

This study suggests that the barking deer feed mainly on the leaves and fruits of Phyllanthus emblica, Olea ferruginea, and Ziziphus nummularia. While only the leaves of the rest of the plant species were consumed. In Pakistan, barking deer preferred ripened fallen fruits of wild figs (Ficus sp.), fleshy flowers of Salmalia malabarica (Cymbal), and fruits of Zizyphus nummularia (jangliberi or mallah) [14]. The diet of barking deer in Nepal; he prefers grasses, such as Imperata cylindrica and Cynodon dactylon, and fallen trees fruits, such as Ficus glomerata, Schleidora trijuga, and Eugenia jambolina [16]. Field observation has shown that this deer consumes fresh, tender fruit and buds and leaves from a variety of growing plants [30]. Imperata cylindrica, Smilax aspera, Moghania strobilifera, and Arundinaria afalata were major food items in both seasons. Fruits of Prunus cerasoides, Berberis asiatica, and Rubus ellipticus and bark of Pinus roxburghii and Castanopsis indica were also taken in significant amounts [27].

In this study, no evidence of animal forage was recorded in the diet of barking deer. No animal remains registered in the diet [27]. The results of the study suggest that barking deer were mixed feeders.

Management recommendation

Deer species are the best indicator of the forest because they are specialized in habitat and particularly sensitive to habitat changes. Given the food requirements and availability of Barking
Deer in different habitats, managers should maintain the strategy in a way that minimizes grazing pressure and anthropogenic pressure and maximizes the efficiency of deer feeding. Also, park management regimes must ensure that the availability of preferred plant species in barking deer habitat exclusively. Similar data on the feeding habits of wild ungulates will be important for the rational management of many protected areas in Pakistan.

Supporting information
S1 Annex. Record of observations in each study site at different field visits. (DOCX)

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