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Article *in* Mammalia · January 2016

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Seasonal variation in the diet of the grey goral (*Naemorhedus goral*) in Machiara National Park (MNP), Azad Jammu and Kashmir, Pakistan

DOI 10.1515/mammalia-2015-0075
Received May 2, 2015; accepted February 25, 2016

Abstract: Understanding food habits of wild ungulates is of paramount importance to ecology and wildlife management. We studied the food habits of grey gorals (*Naemorhedus goral*) using microhistological techniques at two sites (Machiara and Serli Sacha) that differed in livestock grazing pressure in the Machiara National Park (MNP), Azad Jammu and Kashmir, Pakistan during 2012–2013. Serli Sacha had 53 livestock units/km^2 while Machiara had 27 livestock units/km^2 in the habitat of grey gorals. Dietary diversity was higher in Machiara (21 plant species) than at Serli Sacha (15 plant species) but the frequency of plant species consumed by grey goral varied seasonally ($p<0.05$). Grey gorals consumed mostly forbs (75.57%) during summer (dominated by *Poa annua, Geranium wallichianum* and *Rheum australe*) and mostly browse (38.19%) during winter (dominated by *Berberis vulgaris, Skimmia laureola* and *Viburnum nervosum*). Grey gorals strongly preferred *G. wallichianum* in both sites during summer season. Wildlife managers at MNP should focus on increasing diversity of plant species and on reducing livestock grazing as it generally reduces plant diversity and also directly compete with *N. goral* for limited forage.

Keywords: diet composition; food habits; *Naemorhedus goral*; seasonal variation; threatened species.

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Introduction

The grey goral (*Naemorhedus goral* Hardwicke, 1825) is characterised by a goat-like appearance and they share the characteristics of the true goat, sheep, and antelope and is thus considered as a "goat-antelope". Evidence suggests continuous decline in the populations of grey gorals throughout its global range. This includes Pakistan where, absence of the species from some of its previously reported ranges (Himalaya and Hindukush at 800–2500 m, Murree Hills, Dir, Swat) (Singh and Singh 1986, Roberts 1997) suggesting an eminent decline in its population during the last century (Abbas 2006). The goral is classified as vulnerable in Pakistan but the species faces substantial extinction risk if the present trends continue (Shiekh and Molur 2005).

During grazing, gorals look around and move slowly with their muzzles close to the ground /vegetation (Abbas et al. 2011). After selecting food plant, they attempt a short nibble and after each nibble, the animal looks around with a turn of its head. The indices of food preference (consumed/availability) suggest that gorals prefer grasses (16.86 times of availability), followed by shrubs (3.3 times of availability), whereas trees and herbs are not preferred (Abbas et al. 2008).

The composition of diets selected by wild ungulates has been of interest to range and wildlife ecologists because knowledge of the food habits is a basic requirement for the management of wildlife and rangeland resources. In addition knowledge of feeding ecology is a major pre-requisite for assessing the possibility of multi-species rangeland management for co-existence (Bagchi et al. 2004).

The proportion of plant species in the diet of herbivores represent the composition and diversity of animal's food (Omphile et al. 2004, Prins et al. 2006). However, the feeding patterns of ungulate species differ according to seasons. Additionally nutrition of plant species changes with respect to age and season which influences the diet selection pattern of animals. The quality of food decreases as the growing season of plants progresses and plants get older (Gutbrodt 2006).

Sympatric species of herbivores which have same-size and grazing strategies may compete for food, as a result a high level of overlap arises in their use of space and food resources, and these resources can be scant for wild ungulates (Hulbert and Andersen 2001). So, the introduction of domestic ungulates in natural resources for grazing can lead to interspecific competition with resident species of ungulates, especially if the involved individuals are of same size and share related grazing strategies in limited trophic resources (Acebes et al. 2012).

The epidermis of plant material ingested by herbivores species, generally resistant to the process of digestion, remain intact while passing through the digestive tract and, therefore can be detected from the faecal samples through microhistological analysis (Alipayo et al. 1992). The cell structure of the epidermis is specific to each species of plant. Therefore, the analysis of faecal samples can provide precise information on the qualitative and quantitative composition of the ingested plant by herbivores (Baumgartner and Martin 1939, Alipayo et al. 1992).

Despite the conservation importance of the grey goral, little is known about their ecology behaviour in most of its distributional range. The diet of the grey goral consists of grasses, leaves and twigs (Duckworth and Mackinnon 2008). Grey gorals are grazers but they have also been recorded as browsing on the twigs and leaves of bushes (Roberts 1997). Our goal was to study food habits of the threatened grey goral in two locations in the MNP, Pakistan, that location differed in grazing pressure.

Materials and methods

Study area and species

MNP lies in the Muzaffarabad District in the State of Azad Jammu and Kashmir, Pakistan in the Western Himalayan mountains (34°23′-35′ N, 73°30′-46′ E), covering an area of 13,532 ha (WWF 2008). We assessed diet composition of grey gorals in two sites within MNP, Machiara (34°31.55′ N, 73°38.03′ E) and Serli Sacha (34°30.04′ N, 73°38.47′ E), 275 ha and 680 ha size, respectively (Figure 1). Machiara had low grazing pressure from livestock, whereas Serli

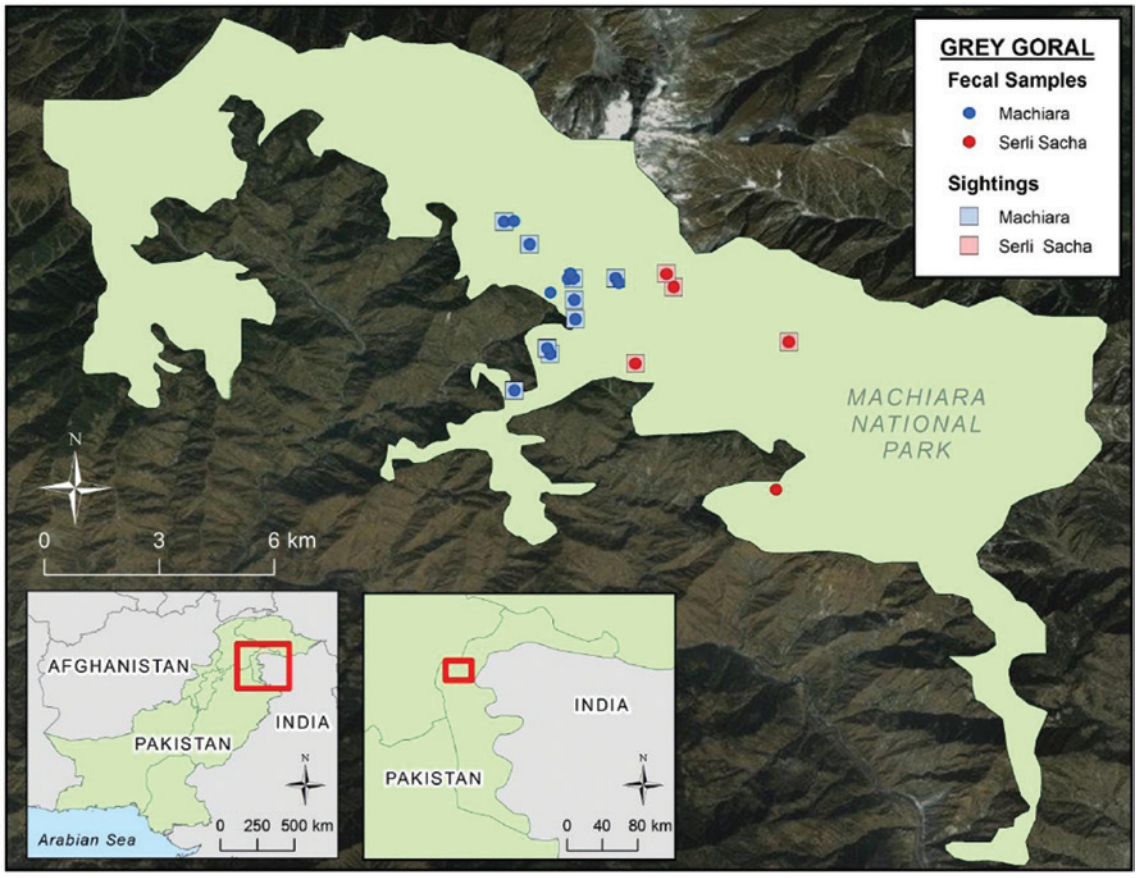

Figure 1: Location of direct sightings and faecal pellets of Himalayan grey goral (*Naemorhedus goral bedfordi*) within two compartments of Machiara National Park (MNP): Machiara and Serli Sacha.

Sacha had intensive livestock grazing. The total number of livestock units in Serli Sacha (179.9) was almost twice that in Machiara (97.9) (Ashraf et al. 2015). The natural vegetation of MNP is characterised by temperate Himalayan mixed-forest/alpine-scrub rangeland ecosystem (Qamar et al. 2008). The climate of the MNP varies with altitude and aspect, but forests generally fall in the moist temperate zone (Cochard and Dar 2014). Meteorological data from nearby Muzaffarabad (35 km southwest of MNP) showed that summers were hot (average maximum air temperature 30°–35°C) and winters were cold (average maximum and minimum air temperatures approx. 15°C and 0°C, respectively) (GOAJK 2005). Snowfall can be heavy, and high mountain peaks remained snow-covered until June (Cochard and Dar 2014).

The grey gorals occupy the Himalayan mountains where their distributions are believed to be separated by the Sutlej River in the region of Punjab (Valdez 2011). They are endemic to mountainous central-east Asia, occurring from northern Pakistan to eastern China. In Pakistan, the grey goral occurs in small, often isolated populations and they are classified as Near-Threatened on The IUCN Red List (Valdez 2011).

Sample collection and analysis

Examining faecal samples by microhistological techniques is the most commonly used method for determining the botanical composition of herbivore diets (Alipayo et al. 1992). This method is based on the fact that fragments of epidermis and cuticula of plants ingested by animals remain intact when they pass through the digestive system of an animal and can be identified from the faecal samples on the basis of cellular characteristics (Gutbrodt 2006). We used microhistological techniques to identify plant species consumed by the grey goral (Alipayo et al. 1992).

Reference plant samples were collected during 2012 and 2013 of all potential forage plants species. Reference slides were prepared from all plant species (10 trees, 15 shrubs, 11 herbs and six grasses) occurring in the habitat of the grey goral (Appendix 1); selection of these species as potential food plants was on the basis of field observations of feeding and confirmed by the experienced herders and park rangers. Plant samples were dried, ground and stored in plastic vials and processed for microhistological examination following the method of Sparks and Malechek (1968) and Kittur et al. (2007).

A total of 145 pellet groups, 105 from Machiara (summer=52, winter=53) and 40 from Serli Sacha (summer=19, winter=21), were collected from MNP. Pellets of one natural group of faeces were considered as one sample. Samples were collected from 60 sampling plots on 50 m intervals along five tracks in Machiara and 48 sampling plots along four tracks in Serli Sacha. Sampling plots were designed in a systematic random manner, from randomly placed starting points all sampling points were laid parallel to the track and almost equidistant (100 m) from one another. Four randomly selected pellets from each pellet group collected from Machiara and Serli Sacha were mixed to form a single composite sample for each site and season (Harris and Miller, 1995). Freshness of each sample was determined by an experienced observer of the MNP and also by texture (moisture, gloss) and state of decay of the faecal sample, as coprophagous insects were highly active on samples especially during the wet season (Edwards 1991, Leuenberger 2004). Further, we collected a reference set of pellets from grey gorals to separate pellets of goral from goats/sheep, and used the set of criteria developed by Abbas (2006) to test field personnel and differentiate between the faecal bolus and individual pellets of each species. We followed the method of Latham et al. (2013) to age pellets as fresh (moist or oily texture), old (dry, slightly crusted), or aged (decaying). Shape and size of pellets was species-specific and error of identification was very unlikely.

The samples were ground, sieved and slides were prepared using the method described by Sparks and Malechek (1968) and Fjellstad and Steinheim (1996).

Plant species found in faecal samples were identified after a detailed comparison of all cell characteristics with the reference collection. The numbers of fragments differed for each pellet group. We made three slides of each pellet group and took three grid observations of each slide to identify the fragments. These data were pooled for further analysis. The relative frequency of a plant species in the faecal samples was calculated and expressed as the relative importance value (RIV), which is the total number of fragments identified for a given food species divided by the total number of all counts made in the sample and expressed as a percentage (Jnawali 1995).

Diet selection value (DSV) was calculated as follows (Jnawali 1995):

$$DSV_x = \frac{RIV_x}{PV_x}$$

where RIV_x is the RIV for species x, and reflects the relative frequency of a plant species in the faeces. PV_x is the prominence value (PV) for species x, and reflects the relative availability of plant species in the grey goral habitat. Data on availability of plant species were taken from

Ashraf et al. (2015), where PV was calculated as (Koirala et al. 2000):

$$PV_x = M_x \times \sqrt{f_x}$$

where M_x is the % cover of species x and f_x is the frequency of occurrence of species x in sample quadrats.

Diet breadth, representing diet diversity per faecal sample, was calculated following Levin's measure of niche breadth (B), based on the following formula (Krebs 1999, Prins et al. 2006):

$$B = \frac{1}{\Sigma Pi^2}$$

Pi=% of total sample belonging to species *i* (*i*=1,2,.., *n*),

We used χ^2 test to determine the significance of any differences in consumption of each plant species during both season. Two way ANOVA was used to test for the effects of season and sites on diet breadth.

Results

Machiara

At Machiara, during the summer, diet of the grey goral comprised mainly palatable herbs (44.96%) followed by grasses (28.94%) and shrubs (23.56%) (Figure 2). The most abundant plant species during summer were; *Poa annua* and *Geranium wallichianum* and preferred plant species were *Rheum australe* followed by *G. wallichianum, P. annua, Themeda anathera* and *Cymbopogan martini,* (i.e. eaten in proportions higher than their availability). While during winter *Berberis vulgaris* and *Justicia adhatoda* were more frequently used food species and preferred species were *B. vulgaris* followed by *Plectranthes rugosis, Dryopteris stewartii* and *Persicaria nepalensis* (Tables 1 and 2). Diet composition differed between summer and winter (χ^2=28.35, p<0.05).

Table 1: Mean relative importance values (RIVs±SE) of food plants in the faecal samples of the grey goral during summer and winter seasons in Machiara and Serli Sacha, Machiara National Park, (MNP) Pakistan.

Plants	Machiara		Serli Sacha	
	Summer (% occurrence)	Winter (% occurrence)	Summer (% occurrence)	Winter (% occurrence)
Abies pindrow (T)	0	0	1.03±0.30	2.65±0.55
Cedrus deodara (T)	0	6.5±0.11	0	2.08±0.34
Picea smithiana (T)	0	2.78±0.12	0	0
Justicia adhatoda (S)	0	13.65±0.15	0	0
Berberis vulgaris (S)	0	28.35±0.29	5.56±0.24	15.37±0.71
Desmodium elegans (S)	4.15±0.18	0	0	0
Skimmia laureola (S)	0.73±0.10	0	0	16.31±0.38
Indigofera heterantha (S)	3.99±0.20	0	4.53±0.28	0
Jasminum humile Linn (S)	6.42±0.31	0	0	0
Viburnum nervosum (S)	0	3.37±0.16	0	21.15±0.73
Viburnum cotinifolium (S)	0	0	4.01±0.25	0
Sorbaria tomen tosa (S)	4.21±0.20	0	0	0
Plectranthes rugosis (S)	4.06±0.21	9.87±0.14	2.78±0.34	0
Prunus padus (S)	0	0	2.65±0.11	0
Rumex nepalensis (H)	4.31±0.25	0	0	0
Artemisia mauiensis (H)	4.41±0.24	0	0	0
Rheum australe (H)	12.18±0.20	0	19.67±0.51	0
Aconitum chasmanthum (H)	1.59±0.17	0	0	0
Bergenia ciliate (H)	0	0	0	10.34±0.64
Persicaria nepalensis (H)	6.71±0.19	13.3±0.25	13.65±0.21	9.86±0.39
Geranium wallichianum (H)	15.76±0.28	3.25±0.16	19.93±0.36	16.03±0.80
Dryopteris stewartii (G)	0	13.36±0.19	3.81±0.25	0
Cymbopogan martini (G)	4.85±0.16	0	0	0
Themeda anathera (G)	6.45±0.34	0	0	0
Poa annua (G)	17.64±2.69	0	20.19±0.53	3.13±0.37
Unidentified	2.46±0.27	5.52±0.12	2.13±0.27	3.03±0.38

T, Trees; S, shrubs; H, herbs; G, grasses.

Table 2: Diet selection values (DSV) of the grey goral during the summer and winter season in Machiara and Serli Sacha, Machiara National Park, Pakistan.

Plants	Machiara				Serli Sacha			
	Summer		Winter		Summer		Winter	
	PV[a]	DSV	PV[a]	DSV	PV[a]	DSV	PV[a]	DSV
Cedrus deodara (T)	2.20	0	5.30	1.22	0	0	6.50	0.32
Abies pindrow (T)	0	0	0	0	6.32	0.16	6.41	0.41
Picea smithiana (T)	2.93	0	13.70	0.20	0	0	0	0
Desmodium elegans (S)	2.1	2	4.87	0	0	0	0	0
Justicia adhatoda (S)	0	0	3.69	3.69	0	0	0	0
Berberis vulgaris (S)	0	0	2.06	13.76	3.09	1.79	4.0	3.8
Skimmia laureola (S)	3.09	0.23	1.80	0	0	0	4.01	4.06
Indigofera heterantha (S)	4.60	0.86	5.10	0	3.72	1.21	8.5	0
Jasminum humile Linn (S)	5.40	1.18	0	0	0	0	0	0
Viburnum cotinifolium (S)	0	0	0	0	3.97	1.01	4.11	0
Viburnum nervosum (S)	4.1	0	18.3	0.18	0	0	4.12	5.13
Sorbaria tomentosa (S)	4.7	0.89	3.79	0	0	0	0	0
Plectranthes rugosis (S)	4.1	0.99	2.1	4.7	1.35	2.05	0	0
Prunus padus (S)	0	0	0	0	2.96	0.89	16.71	0
Rumex nepalensis (H)	4.5	0.95	5.3	0	0	0	0	0
Artemisia mauiensis (H)	5.2	0.84	8.17	0	0	0	0	0
Rheum australe (H)	1.47	8.28	0	0	4.4	4.4	0	0
Aconitum chasmanthum (H)	3.90	0.40	0	0	0	0	0	0
Bergenia ciliate (H)	0	0	0	0	5.42	0	4.7	2.2
Persicaria nepalensis (H)	2.7	2.4	3.3	4.0	3.17	4.30	4.43	2.22
Geranium wallichianum (H)	3.4	4.6	4.42	0.7	3.46	5.76	4.91	3.26
Dryopteris stewartii (G)	0	**0**	3.2	4.1	6.22	0.61	3.3	0
Cymbopogan martini (G)	2.1	2.30	2.1	0	0	0	0	0
Themeda anathera (G)	2.0	3.22	2.3	0	0	0	0	0
Poa annua (G)	4.1	4.30	1.3	0	8.78	2.29	3.5	0.89

[a]Prominence value (a measure of availability).

Serli Sacha

Herbs and grasses (77.25%) were the most frequently consumed food items during the summer, whereas during the winter shrubs (52.83%) formed the largest component of grey gorals diet (Figure 2). During the summer the most frequently found species were *Poa annua* and *Geranium wallichianum* and preferred species were *G. wallichianum* followed by *Persicaria nepalensis* and *Plectranthes rugosis*. During the winter season *Viburnum cotinifolium* and *Skimmia laureola* were the dominant plants and the preferred species were *Viburnum nervosum* and *S. laureola* (Tables 1 and 2). Chi square tests showed that consumption of plant species was significantly different (χ^2=21.15, p<0.05) among the two season in Serli Sacha.

A wider range of dietary items was utilized by the grey goral in Machiara as compared to Serli Sacha. In Machiara the consumption of *Rheum australe, Geranium wallichianum* and *Berberis vulgaris* was high. While in Serli Sacha, the diet variety of *R. australe*, *G. wallichianum* and *Viburnum nervosum* was relatively high in comparison to other species (Table 3). However, diet variety did not differ significantly between seasons (df=1; F=5.012; p=0.267) or between study sites (df=1; F=1.675; p=0.419).

Discussion

Information about food habits is an important component of an animal's life history and knowledge on diet composition and selection is a fundamental element to understanding many aspects of ungulate ecology (Bhattacharya et al. 2012). Additionally, knowledge on the food habits of wild ungulates is a basic requirement for the conservation and management of rangeland resources. The grey goral is believed to be predominantly a grazer, depending upon the type of grasses, yet the proportion of the grazing and the browsing vary with the season and the area (Mead 1989, Roberts 1997). At Machiara, there were 40 plant species, whereas at Serli Sacha 17 species of plants were found. At both locations, shrubs dominated the flora, followed by trees and herbs, and grasses being the least dominant (Ashraf et al. 2015). In

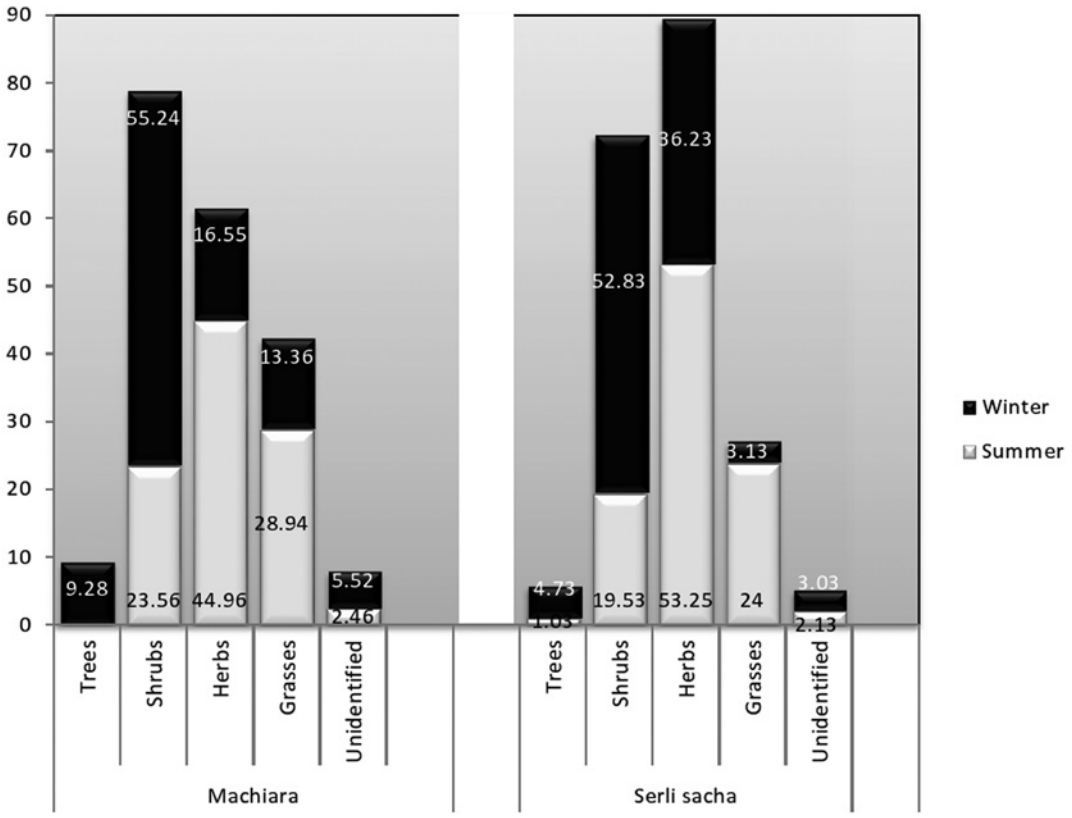

Figure 2: Percent diet composition of trees, shrubs, herbs and grasses in the diet of the grey goral, as determined from faecal samples collected from 2012 to 2013 in Machiara National Park (MNP).

MNP during both the summer and winter, herbs and shrubs were found to be important components of the grey goral diet. We found that seasonal differences in the diet of the grey goral were associated with the changing proportions of herbs, grasses and shrubs. As during the winter season in both study sites shrubs were dominant while during the summer season herbs formed the largest component of the grey goral diet. Valva (1979) in Primorsky Krai (Russia) reported a similar trend in that gorals have been frequently regarded as both grazers and browsers, and the extent of grazing and browsing changes with the season.

We found that grey gorals strongly preferred *Rheum australe*, *Poa annua*, *Geranium wallichianum*, *Dryopteris stewartii*, *Persicaria nepalensis*, *Plectranthes rugosis*, *Berberis vulgaris* and *Viburnum nervosum*. Yet other studies have reported subtle differences in goral preference for diet compared to our study. For example, Anwar and Chapman (2000) found that in Margalla Hills National Park, Pakistan, grey gorals prefered *Themeda anathera* (35.36%), *Chrysopogon aucheri* (18.49%), *Digitaria decumbens* (10.19%) and *Heteropogon contortus* (8.88%). In India, Junaid et al. (2012) reported that *Themada anathera* (21.25%) *Apluda aristata* (16.27%), *Digitaria decumbens* (8.75%), *Alchemilla vulgaris* (19.55%) and *Daphne oleoides* (5.04%) contributes the major part of the diet of grey gorals. This subtle difference between studies probably reflected the differences in the availability of plant species within the localities where the grey goral occurred.

Anwar and Chapman (2000) in Margalla Hills National Park, Pakistan suggested that the grey goral is basically a grazer and it prefered foraging on leaves of dry grasses rather than the green leaves available on some species of shrubs. The preference of dry leaves of grasses over the green leaves of shrubs has also been reported in other species of goral, i.e. the Amur goral (Dang 1968). Green (1987) while working in the Kedarnath Wildlife Sanctuary (India) also suggested that grasses comprise an important part of the food consumed by the goral. Abbas (2006) showed that the grey goral is basically a grazer (63% of its food), though it can use its browsing mode as per the demands of the area and the environmental conditions. The results of our assessment of the grey goral diet in MNP were similar to these studies; we found that during the summer season the grey goral's diet comprised mainly forbs in both study sites; Machiara (73.9%) and Serli Sacha (77.25%).

The pre winter diet composition of the grey goral in MNP was characterised by a high share of herbs. Based on the data obtained by the faecal analysis it was presumed

Table 3: Diet breadth of plants species in the diet of the grey goral based on faecal analysis, during summer and winter season in Machiara and Serli Sacha, Machiara National Park, Pakistan.

Plants	Diet breadth (B)			
	Machiara		Serli Sacha	
	Summer	Winter	Summer	Winter
Abies pindrow (T)	0	0	2.85	3.89
Cedrus deodara (T)	0	7.14	0	2.99
Picea smithiana (T)	0	6.02	0	0
Justicia adhatoda (S)	0	11.06	0	0
Berberis vulgaris (S)	0	17.18	6.09	6.09
Desmodium elegans (S)	15.92	0	0	0
Skimmia laureola (S)	5.84	0	0	7.19
Indigofera heterantha (S)	16.61	0	5.05	0
Jasminum humile Linn (S)	13.85	0	0	0
Viburnum cotinifolium (S)	0	0	4.01	0
Viburnum nervosum (S)	0	6.02	0	9.28
Sorbaria tomen tosa (S)	9.3	0	0	0
Plectranthes rugosis (S)	17.51	9.34	3.95	0
Prunus padus (S)	0	0	4.01	0
Rumex nepalensis (H)	9.2	0	0	0
Artemisia mauiensis (H)	9.1	0	0	0
Rheum australe (H)	26.88	0	11.94	0
Bergenia ciliate (H)	0	0	0	6.02
Aconitum chasmanthum (H)	8.78	0	0	0
Persicaria nepalensis (H)	22.12	9.52	8.13	5.07
Geranium wallichianum (H)	25.64	6.06	11.06	7.09
Dryopteris stewartii (G)	0	10.34	4.016	0
Cymbopogan martini (G)	19.84	0	0	0
Themeda anathera (G)	13.8	0	0	0
Poa annua (G)	19.26	0	11.01	3.98

that despite the availability of browsing, grey gorals tend to prefer herbs as the main component in its diet. Compared to the earlier study, Prokesova (2004), the ungulates in Estonia were seen to consume more forbs and fewer woody plants during the summer season. According to Abbas (2006) the calculated values of preference indices for trees (0.10), shrubs (3.31) and forbs (10.27) suggested that forbs are highly preferred items of goral food.

During the winter season shrubs formed the largest component of the grey goral's diet in both study sites, i.e. Machiara (55.24%) and Serli Sacha (52.83%). The most common dietary shrubs were *Berberis vulgaris* and *Viburnum nervosum*. In contrast to our results, Abbas (2006) reported that shrubs contribute the lowest (<1%) part in the total food of the grey goral, but his study was based on only 15 faecal samples and also lacked information about seasonal variation of the grey goral diet. But the findings of Wagner and Peek (2006) are in line with our result that shrubs were most heavily consumed by ungulates during the winter season. Wikeem and Pitt (1992) reported that bighorns (sheep) in British Columbia mostly browsed during the winter and shrubs contributed the greatest proportion of the diet.

Beside shrubs three species of trees, i.e. *Picea smithiana, Cedrus deodara, Abies pindrow* were also found in the grey goral diet (14.01%), during the winter season only. Presumably this can be explained by the decline in the availability of grasses during the winter and trees shed their leaves in this season, as a result the usage of browsing increased (N. Ashraf, personal observation). This explanation is supported by Ligi and Randveer (2012), they reported that leaves are nutritious in nature and preferred by ungulates in Estonia as a food resource during the winter in order to enhance the quality of food when grasses are in decline. The same behaviour has been observed in Primorsky Krai (Russia) by Valva (1979), where extent of grazing and browsing of goral varies with the availability of graze or browse species in its habitat.

We found that the overall diet variety of the grey goral was higher in Machiara (ΣB=316.33) as compared to Serli Sacha (ΣB=123.72) (N. Ashraf, unpubl. data). A possible explanation of this regional difference in the diet composition of the grey goral is that the grey goral had a restricted narrow distribution range in Serli Sacha as compared to Machiara. Additionally, Serli Sacha had more livestock around grey goral habitats as compared to Machiara (N. Ashraf, unpubl. data), so high numbers of livestock from three species (cattle, sheep and goats) at Serli Sacha may have resulted in the lower diversity of vegetation due to over grazing. The mean number of livestock at Serli Sacha was significantly higher ($\bar{x}$=51.65) than at Machiara ($\bar{x}$=29.50). Serli Sacha had 53 livestock units per km^2 of grey goral habitat compared with 27 in Machiara – almost a 50% difference (Ashraf et al. 2015). Further, during the winter season domestic livestock in the study area are kept at low altitude close to the settlements, because high elevation rangelands remain inaccessible to them due to the cold and snow. On the other hand, in summer, domestic livestock are taken to high elevation pastures for foraging, where they stay until the beginning of the winter season. Grey gorals also utilize these high altitude areas (2400–2900 m a.s.l.) during the summer season, which results in an overlap in habitat use. Fankhauser (2004) reported that domestic livestock usually have an advantage over their wild competitors as their herd densities are often far above those of wild species and they are released to the best grazing grounds; as a result, wild herbivore species are likely to be competitively displaced.

Six plant species (*Berberis vulgaris*, *Viburnum cotinifolium*, *Rheum australe*, *Poa annua*, *Skimmia laureola*, *Geranium wallichianum*) dominated the annual diet of the grey goral in MNP. Given that the grey gorals in the MNP are important both recreationally and as a primary prey base

for endangered species, i.e. snow leopard (*Uncia uncia*). Park management regimes must ensure the continued availability of the preferred plant species in the habitat of the grey goral and eliminate the livestock grazing pressure particularly in the core habitat of the grey goral.

Acknowledgments: We thank the Higher Education Commission, Pakistan for funding this project. We are also thankful to the officials and field staff of the Department of Wildlife and Fisheries, Azad Jammu and Kashmir for their support and guidance during field work.

Appendix

Appendix 1: Plant species included in reference collection with prominence values (explanation of calculation presented in main text).

Scientific name	Local name	Availability (prominence value)			
		Machiara		Serli Sacha	
		Summer	Winter	Summer	Winter
Abies pindrow (T)	Fir	18.35	5.88	6.32	6.41
Aesculus indica (T)	Ban khor	7.79	7.07	0	0
Pinus wallichiana (T)	Kail	13.71	28.82	48.50	51.66
Populus ciliate (T)	Bagnoo	0.23	0.10	0	0
Juglans regia (T)	Akhrote	1.93	2.0	0	0
Acer caesium (T)	Tarkana	0.57	0.73	0	0
Quercus incana (T)	Reen	0.77	2.0	0	0
Taxus wallichiana zucc. (T)	Bermi	0.62	0	1.14	0
Picea smithiana (T)	Kachal	2.93	13.70	0	0
Cedrus deodara (T)	Deodar	2.20	5.30	0	6.50
Indigofera heterantha (S)	Kainthi	4.60	5.10	3.72	8.5
Viburnum nervosum (S)	Guch	4.1	18.3	0	4.12
Viburnum cotinifolium (S)	Rech guch	0	1.0	3.97	4.11
Skimmia laureola (S)	Naira	3.09	1.80	0	4.01
Desmodium elegans (S)	Chamkath	2.1	4.87	0	0
Plectranthes rugosis (S)	Peomar	4.1	2.1	1.35	0
Justicia adhatoda (S)	Baiker	0	3.69	0	0
Berberis vulgaris (S)	Kala sumbal	0	2.06	3.09	4.0
Sorbaria tomentosa (S)	Karli	4.7	3.79	0	0
Lonicera quinquelocularis (S)	Khutt	0	1.46	0	0
Berberis lyceum (S)	Sumbal	0	2.64	0	0
Rosa moschata (S)	Garacha	7.56	0	17.83	0
Jasminum humile Linn (S)	Chamba	5.40	0	0	0
Juniperus communis (S)	Metheri	4.0	0	4.86	0
Prunus padus (S)	Perth	0	0	2.96	16.71
Geranium wallichianum (H)	Raton jog	3.4	4.42	3.46	4.91
Ajuga bracteosa (H)	Ratti buti	0	4.86	0	0
Bergenia ciliate (H)	Batbhyva	7.18	1.49	5.42	4.7
Artemisia mauiensis (H)	Kala choh	5.2	8.17	0	0
Artemisia absinthium (H)	Safaid choh	0	3.40	0	0
Plantago major (H)	Chamchipatter	0	0.54	0	0
Fragaria nubicola (H)	Budi meva	0	0.83	0	0
Persicaria nepalensis (H)	Masloon	2.7	3.3	3.17	4.43
Rumex nepalensis (H)	Hola	4.5	5.3	0	0
Aconitum chasmanthum (H)	Mohri	3.90	0	0	0
Rheum austral (H)	Chityal	1.47	0	4.4	0
Dryopteris stewartii (G)	Kunji	0	3.2	6.22	3.3
Dryopteris dilatata (G)	Rech kunji	0	0.15	0	0
Themeda anathera (G)	Baroo	2.0	2.3	0	0
Poa annua (G)	Booji	4.1	1.3	8.78	3.5
Adiantum incisum Forsk (G)	Kahkwa	0	1.56	0	0
Cymbopogan martini (G)	Gogoo	2.1	2.1	0	0

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