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ORIGINAL PAPER

Food habits of the snow leopard *Panthera uncia* (Schreber, 1775) in Baltistan, Northern Pakistan

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Abstract The snow leopard (*Panthera uncia*) inhabits the high, remote mountains of Pakistan from where very little information is available on prey use of this species. Our study describes the food habits of the snow leopard in the Himalayas and Karakoram mountain ranges in Baltistan, Pakistan. Ninety-five putrid snow leopard scats were collected from four sites in Baltistan. Of these, 49 scats were genetically confirmed to have originated from snow leopards. The consumed prey was identified on the basis of morphological characteristics of hairs recovered from the scats. It was found that most of the biomass consumed (70%) was due to domestic livestock viz. sheep (23%), goat (16%), cattle (10%), yak (7%), and cattle–yak hybrids (14%). Only 30% of the biomass was due to wild species, namely Siberian ibex (21%), markhor (7%), and birds (2%). Heavy predation on domestic livestock appeared to be the likely cause of conflict with the local inhabitants. Conservation initiatives should focus on mitigating this conflict by minimizing livestock losses.

Keywords Himalayas · Karakoram · Scat · Diet · Hair · Livestock · Biomass

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Introduction

Diet information is important for understanding a predator's ecology, predicting its influence on the dynamics of prey populations, and developing effective conservation initiatives. However, it is often difficult to study the diet of mammalian predators such as snow leopards, which are particularly elusive and inhabit rugged terrain. Attempts at examining kills made by radio-tagged snow leopards have proven exceptionally difficult due to precipitous terrain that often precludes access to suspected kill sites (Jackson 1996). Furthermore, this method is biased towards larger prey because small prey is entirely consumed. Data collected by local compensation schemes have also been used to assess the livestock damage caused by different predators including snow leopards (Sangay and Vernes 2008). However, such observations may not be completely reliable unless supported by scientific examination. Analyses of stomach contents of an endangered species are seldom possible. Therefore, observing prey remains in scats (feces) is often the only way available for investigators to study the diet of such animals as the snow leopard (Floyd et al. 1978; Oli 1993). The present study describes the diet of the snow leopard in the Himalayas and Karakoram regions of Baltistan (Pakistan) where livestock animals are the chief staples of its diet.

Snow leopards are widely, but sparsely, distributed over the Himalayas, Karakoram, Pamirs, Tien Shan, Altai Mountains, and other ranges (Schaller 1976; Nowell and Jackson 1996; Hussain 2003). Approximately 4,500–7,500 individuals are believed to persist in the wild, although these numbers are only rough estimates and likely outdated (Conservation News 2001). The snow leopard population is believed to be declining throughout its range, and hence, it has been listed by the IUCN as endangered species since 1972 (Hussain 2003) and critically endangered in the Red List of Pakistan Mammals (Sheikh and Malour 2005). Live trapping and hunting for fur, bones, and other body parts are identified as major threats in central Asia. In Pakistan, the major cause of population decline is hunting for fur and retaliatory killing in response to livestock depredation (Schaller 1971).

Due to over harvesting, populations of wild ungulates have declined in the range of the snow leopard, and resultantly, the predation pressure of the snow leopard has shifted to livestock (Ahlborn and Jackson 1988). Food habits of the snow leopard have been studied in China (Schaller et al. 1988), Nepal (Oli et al. 1993; Jackson 1996; Lovari et al. 2009), India (Chundawat and Rawat 1994; Bagchi and Mishra 2006), and Bhutan (Sangay and Vernes 2008), but diet information from Pakistan are not available.

Study area

The study was conducted in the eastern-most region of the Gilgit Baltistan province of Pakistan, which comprises central Karakoram and the western Himalayan mountain ranges. The study sites included Basha Valley (75° 26′ E, 35° 59′ N), including Beisil, Seisko, and Zill Villages (see map, Fig. 1), Hushey Valley (76° 20′ E, 35° 27′ N), Basho (75° 15′ E, 35° 25′ N) and Krabathang Valley (75° 19′ E, 35° 33′ N), and Sadpara Lake Valley (75° 38′ E, 35° 13′ N).

The sampling sites were within a mountainous desert lacking monsoon rains (Schweinfurst 1975). The average monthly precipitation recorded from 2007 to 2008 was 13 mm. In the winter, the area experienced severe cold, with the temperature dropping below −20°C in the higher parts of the region. The rangeland was composed of temperate pastures (Umrani et al. 1998). The lower parts of the mountain sides were covered with glacial layers that formed steep slopes and gullies as a result of erosion by snow melt in the spring. Most of the remote areas were barren lands with rough, broken terrain. The vegetation of the area included plant species typically found in the high-altitude desert of Central Asia, such as artemisia (*Artemisia maritima*), ephedra (*Ephedra gerardiana*), wildrose (*Rosa webbiana*), scurbu (*Berberis lyceum*), seabuckthorn (*Hippophae rhamnoides*), and *Myricaria germanica*. The lower slopes were covered with blue pine (*Pinus wallichiana*) forests.

The only wild caprid on all the sampling sites was the Siberian ibex (*Capra sibirica*). The markhor (*Capra falconeri*) was restricted to Krabathang valley. Marmot (*Marmota caudata*) was common in the inner valleys, while at higher altitude, Royle's pika (*Ochotona roylei*) occurred.

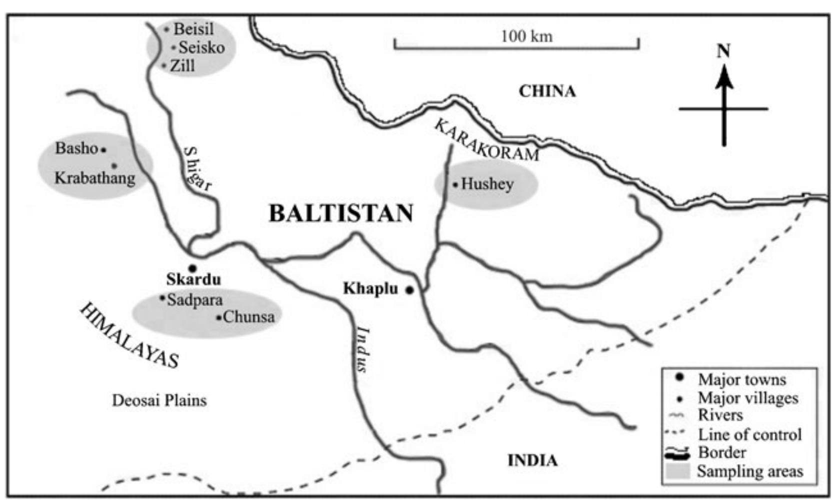

Fig. 1 Baltistan map (adapted from Hussain 2003) showing the villages whose environs were sampled for the scats of the snow leopard

Galliform birds such as chukar partridge (*Alectoris chukar*) and Himalayan snowcock or ram chukar (*Tetraogallus himalayensis*) were common. Sympatric mammalian predators included red fox (*Vulpes vulpes*), gray wolf (*Canis lupus*), Eurasian lynx (*Lynx lynx*), and snow leopard (*Panthera uncia*).

Livestock production was the major source of livelihood for local people living in the surrounding area. The approximate composition of the livestock was 25% due to large ruminants that included yak (*Bos grunniens*), cow (*Bos taurus*), and various yak–cow crossbreeds, and 75% due to small ruminants consisting of sheep (*Ovis aries*) and goat (*Capra hircus*).

Methods

Following Floyd et al. (1978), remnants of prey animals that included bones, hairs, feathers, beaks, and claws were used to identify the animals consumed by the snow leopard. The larger pieces of bones, beaks, and teeth were generally fragmented and rendered of little value. The only identifiable structure, which retained its morphological traits during the digestion process, was the hair (Oli 1993). The structural variations of the hairs of different mammalian prey species were used to identify by comparing a photographic reference key prepared following Oli (1993) and Teerink (1991).

A total of 95 visually identified snow leopard scats were collected in the four study sites during April 2007 to March 2009. Forty-eight scats were collected from Hushey Valley, 38 from Krabathang Valley, 4 from Kanday Valley, 2 from Seisko Valley, 2 from Sadpara Valley, and 1 from Basho.

The scats were collected using the criteria of Jackson and Hunter (1995) that maximized the likelihood of collecting snow leopard scats; some scats were also collected without employing these criteria on the recommendation of local guides who thought that they belonged to snow leopards. The criteria included association of the scats with scrapes or fresh pugmarks and their placement on ridges and saddles in steep terrain, bases of cliffs, or next to known kills. The signs associated with each scat were noted, and their approximate age was estimated. The GPS locations were recorded with a GARMIN GPS 12 unit. For the study of food habits, each scat was placed in a paper bag (so that it could dry); date and sample ID were written on the outside of the bag, as well as on the data form, and a label was also placed inside the paper bag which was taped in such a way that the contents could not fall out, yet leaving a gap for air-drying. “Moth-balls” (containing paradichlorobenzene, the active ingredient) were put in the bags to prevent insect damage.

Once air-dried, each scat was carefully prised apart to separate out any bone fragments, claws, feathers, twigs, or plant items or other non-soluble remains. This process thoroughly mixed the hair and other indigestible remains in the scat. The remaining scat material was washed with tap water in a fine-mesh sieve with a mesh size of 100 μm before being oven-dried at approximately 60°C. The contents of each sample was further cleaned in a 1:1 ether–alcohol mixture and dried between absorbent papers. Twenty guard hairs were randomly selected from each of the scats, and these were examined for the characteristics of the medulla, width of hair, and the cuticular scale patterns. The remaining parts of the samples were saved for later studies.

A hair reference collection consisting of all the potential prey species indicated by Jackson (1996) and Roberts (1997) was made. It was based on representative hairs collected from museum specimens, identifiable carcass remains found in the field, and skins owned by villagers. The hairs of small mammals were obtained from field-caught specimens. The hairs of sheep, goat, yak, cow, and zo (yak × cow hybrid) along with those of the Siberian ibex, markhor, musk deer (*Moschus chrysogaster*), marmot, and pika were represented in the reference collection.

The content of the snow leopard scats was presented as frequency of occurrence (percentage of scats in which an item was found) and percent occurrence (number of times the hair of a given prey was found as percentage of all prey items found) of each food item, including unidentified remains, plant matter, etc. Prey biomass consumed by the snow leopard was estimated using the above frequencies, following Ackerman et al. (1984).

For genetic identification of the snow leopard scats, a sample of each of the scat was taken in the field. These samples were stored in 15-mL centrifuge tubes with c. 12 mL of silica desiccant covered by a clean Kimwipes® tissue (Kimberly-Clark, Irving, TX, USA) to separate the desiccant from the scat. Qiagen Stool DNA extraction kit (Qiagen, Valencia, CA, USA) was used to extract DNA from scats at the Department of Veterinary Integrative Biosciences, Texas A&M University, Texas, USA. The Zoological Society of San Diego contributed two snow leopard DNA samples (one male and one female) as controls (Janečka et al. 2008). Scats were genetically identified by sequencing a small portion of cytochrome b and comparing the sequence to references ones' following Janečka et al. (2008).

Results

During field work, 95 unconfirmed snow leopard scats were collected in the proximity of six villages in Baltistan.

Genetic analysis revealed that 49 of the 95 scats were of snow leopard origin; these scats came from the elevation range of 3,114–3,744 m. Seventy-two percent of the snow leopard scats were from barren areas, 16% from alpine grassland, and 12% from mixed scrub areas. As far as terrain is concerned, 78% of the scats were collected from broken, 8% from smooth, 4% from very broken, 8% from cliff, and 2% from linear landforms.

It was revealed through genetic identification that, from the collected scats, 52% belonged to the snow leopard, 21% to the hill fox (*V. vulpes*), 11% to the gray wolf (*C. lupus*), and 3% to the corsac fox (*Vulpes corsac*). The measurements of the snow leopard scats were compared with those of the foxes and wolf (Fig. 2). The leopard's scats were not statistically significantly different from those of the foxes and the wolf with respect to their length and number of segments (Fig. 2). Likewise, the scats having blunt and tapered ends were not associated with any particular species at a significant level. However, one-way ANOVA tests revealed that the diameter ($P=0.012$) and weight ($P=0.028$) of the scats of the snow leopard, hill fox, and gray wolf were different. The diameter of the scats of the snow leopard was significantly different from that of the hill fox (LSD test, $P=0.013$) and gray wolf (LSD test, $P=0.008$). The error was higher; perhaps some of the scats were collected ignoring the pugmarks and scratches. The genetic identification could not be made on 13% of the scat samples because of contamination.

The identity of the prey species, whose hairs were present in the scats, was ascertained after carefully comparing all hair characteristics contained in the photographic reference key which included data for ten potential mammal prey species. A total of 93 prey items were identified in the 49 verified snow leopard scats; thus, there were 1.90 prey items per scat. In the pool of 93 prey items, domestic sheep (16.1%) and domestic goat (11.8%) evidenced higher frequencies than the Siberian ibex (9.7%), markhor (3.2%), and birds (2.2%). The two wild ungulates together accounted for about 13% of the prey items, while about 28% of the items belonged to livestock species; 17.2% of the items could not be identified.

Of the total biomass consumed by the snow leopards of our study area, 97.9% was from large mammals. Of this, 70.7% was from domestic bovids, and 27.8% from the wild bovids. The domestic prey species represented in the scats were sheep, goat, cattle, yak, and hybrids of cattle and yak, which respectively accounted for 23.3%, 16.1%, 10.1%,

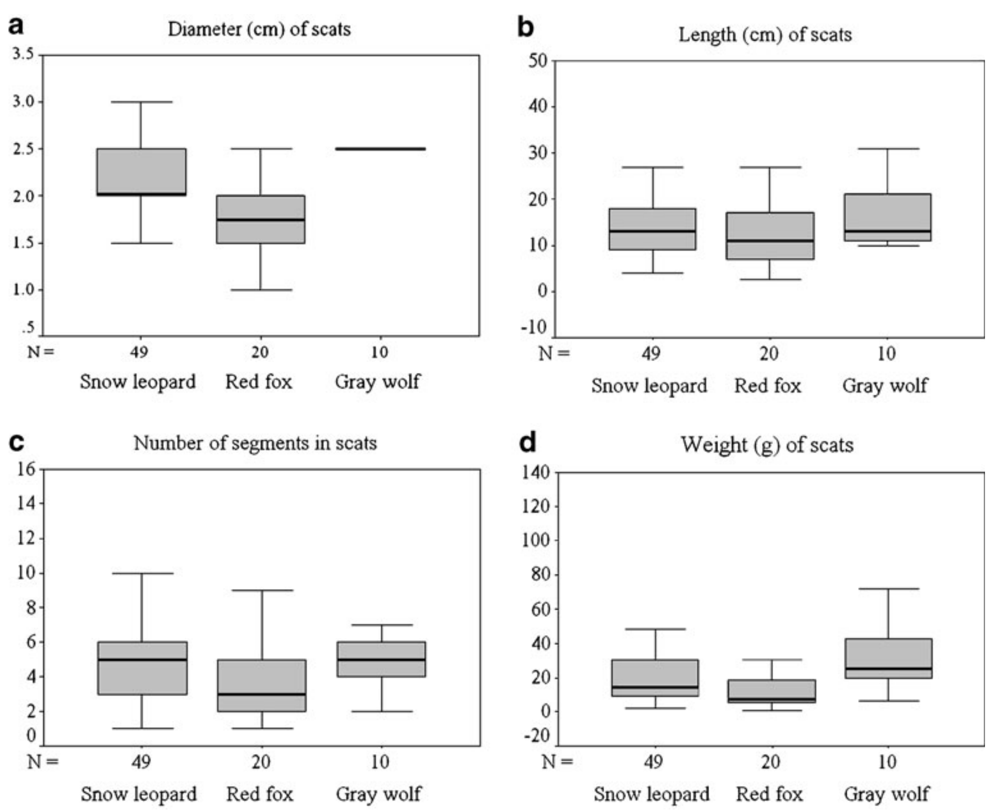

Fig. 2 A comparison of the diameter, length, number of segments, and weight of the scats of the snow leopard, red fox, and wolf. In each panel the *black horizontal lines* indicate the median values, the *boxes* depict upper and lower quartiles, and the *vertical lines* with *horizontal bars* at the end indicate the sample range

6.4%, and 14.1% of the total biomass consumed by the snow leopard. There was no evidence of the remnants of marmot and pika in scats of the snow leopard. Birds accounted for 2.1% of the total biomass of the diet (Table 1).

Discussion

Our results supported previous studies that reported that the snow leopards primarily consumed small ungulates (Schaller et al. 1988; Oli et al. 1993; Jackson 1996; Bagchi and Mishra 2006). On study sites, where ibex was scarce, the snow leopard hunted blue sheep (*Pseudois nayaur*) and Ladakh urial (*Ovis orientalis*) (Table 2). Blue sheep is the main prey species of the snow leopard in northwestern India (Chundawat and Rawat 1994), Nepal (Oli et al. 1993; Schaller 1977), and parts of Tibet (Jackson et al. 1994). Siberian ibex and markhor were the wild ungulates that jointly contributed 28% of the biomass consumed by the snow leopard population of our study area (Table 2).

Populations of wild ungulates of our study area have been depleted due to extensive hunting. On account of the limited availability of the natural prey species, the snow leopard has supplemented its diet with domestic livestock. The absence of small mammals from the diet of the Baltistan population of the snow leopard seems to suggest that livestock animals are easily and sufficiently available to the small population of the snow leopard of our study area.

Small mammals like hare, pika, marmot, cricetid and murid rodents, mustelids, and canids appeared in the diet of the snow leopard populations of central Asia, India, and Nepal (Heptner and Sludskii 1992; Oli et al. 1993; Chundawat and Rawat 1994; Jackson 1996; Bagchi and Mishra 2006). Although scat sampling for this study was carried out during March and April, no small mammal remnant was found in any of the scats. In Ladakh, most of the summer and spring diets was supplemented with marmots (Chundawat and Rawat 1994), while in Nepal, the marmots along with Royle's pikas and Royle's voles (*Alticola roylei*) were the staples of the snow leopard's diet (Oli et al. 1993).

Domestic sheep and goat, along with the Siberian ibex, accounted for 60% of the prey biomass eaten by the snow leopards of the Himalayas and Karakoram areas of Baltistan. Schaller (1976) reported that these animals were the major food items of the snow leopard in Chitral. In our study area, markhor was restricted to

Table 1 Frequency of occurrence and estimates of the biomass (kilogram) of various prey species consumed by the snow leopards in Baltistan (Himalayas and Karakoram), Pakistan

Prey species	Frequency	Percent frequency	Assumed weight (*A*)	Biomass per scat (*B*)	No. of scats (*C*)	Biomass consumed (*D*)	Percentage consumption (*E*)
Small ungulates							
Domestic sheep	15	16.1	30.0	3.0	15	45.5	23.34%
Domestic goat	11	11.8	25.0	2.9	11	31.4	16.13%
Ibex	9	9.7	70.0	4.4	9	39.9	20.48%
Markhor	3	3.2	80.0	4.8	3	14.3	7.36%
Small mammals							
Marmot	0	0.0	4.5	2.1	–	–	–
Pika	0	0.0	0.2	2.0	–	–	–
Birds	2	2.2	1.5	2.0	2	4.1	2.09%
Large ungulate							
Cattle	3	3.2	130	6.5	3	19.6	10.06%
Zo/zomo	4	4.3	140	6.9	4	27.5	14.13%
Yak	1	1.1	300	12.5	1	12.5	6.41%
Plant matter	29	31.2	–	–	–	–	–
Unidentified remains	16	17.2	–	–	–	–	–

The data are based on 49 scats of the snow leopards

A assumed weight (kilogram) of the prey species, *B* estimated weight of prey consumed per collectible scat ($B = 1.98 + 0.035 \times A$), *C* number of scats in which prey species were identified, *D* biomass consumed (i.e., B × C), *E* percentage consumption $(B \times C)/\Sigma(B \times C) \times 100$

Table 2 A comparison of the frequency of occurrence (percent) of various prey species in the scats of snow leopards collected from different parts of its range

Prey items	Oli et al. (1993) Manang, Nepal (*n*=213)	Chundawat and Rawat (1994) Ladakh, India (*n*=173)	Jackson (1996) Nepal (*n*=78)	Bagchi and Mishra (2006) Pin Valley, India (*n*=51)	Bagchi and Mishra (2006) Kibber, India (*n*=44)	Present study, Baltistan, Pakistan (*n*=49)
Wild						
Blue sheep	51.6	23.4	34.0	–	20.5	–
Himalayan tahr	–	–	10.7	–	–	–
Ladakh urial	–	0.4	–	–	–	–
Siberian ibex	–	–	–	56.9	9.1	9.7
Markhor	–	–	–	–	–	3.2
Royle's pika	15.9	–	1.0	–	–	–
Royle's vole	7.5	–	–	–	–	–
Hare	–	3.1	–	3.9	6.8	–
Rodents	–	4.3	–	–	–	–
Marmot	20.6	9.8	–	–	–	–
Cricetid	–	–	8.7	–	–	–
Murid	–	–	8.7	–	–	–
Least weasel	4.7	–	–	–	–	–
Marten	3.7	–	–	–	–	–
Red fox	0.9	–	–	–	–	–
Birds	1.4	3.1	1.9	–	15.9	2.2
Domestic						
Yak and cattle	14.1	1.2	–	2.0	6.8	8.6
Sheep and goat	0.9	12.5	–	5.9	13.6	27.9
Horse	2.8	0.8	–	11.8	4.5	–
Donkey	–	0.4	–	3.9	13.6	–
Plant matter	–	41.0	16.5	25.5	27.3	31.2
Unidentified remains	–	–	18.4	5.9	19.5	17.2

Karabathang and hence the reason for its lesser consumption here. Seventy percent of the food biomass was contributed by livestock animals, while the remaining 30% was due to the wild animals, the major contributors being the Siberian ibex (20.5%) and markhor (7.4%). This dietary picture of the snow leopard population of our study area indicated that there was an acute paucity of their natural prey species. Consequently, the snow leopard suffered severe retaliatory persecution by the local people who were also responsible for depleting the natural prey species. A study in Sagarmatha National Park revealed that snow leopard predation shifted to livestock when the population of the Himalayan tahr (*Hemitragus jemlahicus*) had declined (Lovari et al. 2009).

The villagers of our study area strongly supported Mallon (1984) who described that the snow leopard would often enter the livestock enclosures and kill several animals (10–15 and, very rarely, 34) in a mad spree. In response to this behavior, the herdsmen often resort to retaliatory killing of the culprit cat. In the past, it has been tried to restore snow leopard populations by declaring a large area as a nature reserve, but such type of plans cannot work without the involvement of local people. Governmental financial schemes compensate a very small amount (3%) as compared to losses incurred by the snow leopard (Bagchi and Mishra 2006).

In order to compensate the herdsmen's losses and soften their attitude towards the snow leopard, the Project Snow Leopard (PSL) under the Baltistan Wildlife Conservation and Development Organization (BWCDO) has been initiated involving the local farmers and the Ecotourism Enterprises of Baltistan in the form of an insurance scheme (Hussain 2000). The PSL program is jointly managed by a committee of villagers and PSL officials. In case of snow leopard predation on livestock, the village committee and PSL officials determine the amount of compensation money to be given to the aggrieved policy holders. It may help in the conservation of snow leopards in the area.

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