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Diet of the snow leopard (*Panthera uncia*) in the Annapurna Conservation Area, Nepal

M. K. Oli[1,2], I. R. Taylor[1] and M. E. Rogers[1]

[1]*Institute of Cell, Animal and Population Biology, University of Edinburgh, West Mains Road, Edinburgh EH9 3JT, UK and* [2]*Annapurna Conservation Area Project, P.O. Box 4555, Kathmandu, Nepal*

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The diet of the snow leopard (*Panthera uncia*) was studied from 213 scats collected between April 1990 and February 1991 in the Annapurna Conservation Area, Nepal. Seven species of wild and five species of domestic mammals were taken, as well as an unidentified mammal and birds. Blue sheep (*Pseudois nayaur*) were the most frequently eaten prey. Himalayan marmots (*Marmota himalayana*) were also important, except in winter when they were hibernating. During winter, snow leopards ate more Royle's pika (*Ochotona roylei*) and domestic livestock. Yaks were eaten more frequently than other livestock types.

Contents

Introduction

The snow leopard (*Panthera uncia*) is sparsely distributed in the mountains of central Asia, and, in Nepal, it occurs in the Himalayas bordering Tibet (Schaller, 1977). Its elusive behaviour, low density and inaccessible habitat make study difficult. An understanding of the snow leopard's diet is important in order to elucidate other aspects of its ecology and to design and implement conservation programmes.

Snow leopards are reported to kill domestic livestock over most of their range (Schaller, 1977; Mallon, 1984; Schaller *et al.*, 1987; Fox *et al.*, 1988; Sherpa & Oli, 1988) which brings them into conflict with humans, but the extent of this predation has not been thoroughly assessed. Analysis of leopard faeces might show whether, and to what extent, livestock are represented in snow leopard diet.

Most snow leopard diet studies have been based on small sample sizes or on scats collected over short periods (Schaller, 1977; Schaller *et al.*, 1987, 1988*a*, *b*; Zhirjakov, 1990). This study was undertaken to gain a more detailed picture of the snow leopard's diet, to examine any seasonal variations, and to determine the importance of livestock predation.

Study area

This study was carried out in the upper Marsyangdi valley of Manang district (28° 30′ N to 28° 50′ N, 83° 50′ E to 84° 05′ E), in the north-western part of the Annapurna Conservation Area, Nepal. The study area lies in the rain shadow of the Annapurna mountain range and the climate is dry and cold. Minimum winter temperature falls below −20 °C and diurnal and annual variation in mean maximum and minimum temperatures are great. The climate is characterized by dry spring and autumn seasons interrupted by a few wet months, but the amount of precipitation is low as the south-easterly monsoon is blocked by the Annapurna mountain massif. Altitude ranges from 3600 m to over 6000 m.

Vegetation corresponds to the steppe vegetation type of Dobremez & Jest (1976). Up to an elevation of about 4800 m, this consists mainly of grasslands, interspersed with scrub. *Juniperus squamata* dominates the scrub community on gentle slopes whilst rocky areas and steeper slopes are dominated by *Caragana gerardiana*, *C. brevispina*, *Rosa sericea*, *Ephedra* spp. and *Lonicera* spp. Both grass and scrub become sparse and less important above 4800 m where *Rhododendron anthapogan*, *Potentilla biflora* and *Saxifraga* spp. dominate. The vegetation has not been investigated in detail.

The only large wild mammals found in this area are the snow leopard *Panthera uncia*, the blue sheep *Pseudois nayaur*, and the red fox *Vulpes vulpes*. Small mammals include the Himalayan marmot *Marmota himalayana*, Royle's pika *Ochotona roylei*, least weasel *Mustela nivalis*, stone marten *Martes foina*, and the Sikkim vole *Alticola sikkimensis*. The avifauna is relatively diverse and includes, among the larger ground living species, the Tibetan snowcock *Tetraogallus tibetanus*, Himalayan snowcock *Tetraogallus himalayensis*, and Chukar partridge *Alectoris chukar*.

Methods

Diet was assessed from the indigestible remains of hair and feathers extracted from snow leopard faeces. Scats, identified on the basis of size and associated signs such as scrapes and pugmarks, were collected whenever they were encountered throughout the study area between April 1990 and February 1991. There were no other predators of similar size to cause confusion. The age of scats was determined on the basis of smell and firmness, and old, degenerating scats were not collected. Collected scats were sun-dried, labelled and stored in polythene bags for laboratory analysis. Samples were washed with tap water in a fine mesh sieve and oven-dried at a temperature of approximately 60 °C. Each sample was further cleaned in an ether–alcohol mixture (1 : 1) and dried between absorbent paper before detailed examination. The clean and dry hairs were examined under binocular microscope, and different types of hair present in each scat sample were separated. Cross-sections, whole mount, and scale casts of each type of hair present in each scat sample were prepared according to the methods of Brunner & Coman (1974). Prey species were identified by a detailed comparison of all hair structures with a photographic reference key (Oli, 1993).

Data were recorded as the presence or absence of each prey species in a scat sample, and were analysed as frequency of occurrence (percentage of total scats in which an item was found). The presence of plant material was noted but not included in the statistical analysis of diet. Scats were grouped into those collected in spring (April and May), summer (June, July and August), autumn (September, October and November), and winter (December, January and February).

Results

Overall diet

A total of 213 scats was analysed, from which seven species of wild and five species of domestic mammals were identified (Table I). Blue sheep was the most frequently identified prey item with its hair being detected in 51·6% of scats. Himalayan marmot was recorded in 20·7% and Royle's pika in 16% of scats. The domestic species identified included ox, sheep, goat, horse and yak with the latter occurring in 13·6% of the faeces analysed. Most of the scat samples (69%) contained remains of only one prey species, whilst two and three species were present in 25·8% and 5·2%, respectively, with an average of 1·3 prey types per scat. Plant materials, such as grass, and the leaves and twigs of various scrub species were found in 19·3% of scats. Although most of the occurrences of such materials were in small amounts and may have been consumed accidentally while feeding on the prey, six scats consisted mainly of plant materials, suggesting that snow leopards might eat plants deliberately. Similarly, small stones and soil were found in 5·6% of scats and two consisted of more than 50% of these materials.

Seasonal trends in diet

Blue sheep was the most frequently occurring item in all seasons and marmot was ranked second except in winter. The occurrence of marmot decreased from around 25–30% from spring through

TABLE I

Frequency of occurrence of prey remains in 213 snow leopard scat samples collected in the Annapurna Conservation Area, Nepal, between April 1990 to February 1991

	All seasons ($n=213$)		Spring ($n=61$)		Summer ($n=63$)		Autumn ($n=48$)		Winter ($n=41$)	
Prey species	n	%	n	%	n	%	n	%	n	%
Blue sheep (*Pseudois nayaur*)	110	51·6	35	57·4	30	47·6	24	50·0	21	51·2
Marmot (*Marmota himalayana*)	44	20·7	17	27·9	15	23·8	11	22·9	1	2·4
Royle's pika (*Ochotona roylei*)	34	15·9	2	3·3	11	17·5	8	16·7	13	31·7
Yak (*Bos grunniens*)	29	13·6	6	9·8	7	11·1	4	8·3	12	29·3
Royle's vole (*Alticola roylei*)	16	7·5	2	3·3	5	7·9	6	12·5	3	7·3
Unidentified hair	12	5·6	6	9·8	1	1·6	3	6·2	2	4·9
Weasel (*Mustela nivalis*)	10	4·7	4	6·6	2	3·2	2	4·2	2	4·9
Stone marten (*Martes foina*)	8	3·8	2	3·3	1	1·6	5	10·4	0	0
Horse (*Equus caballus*)	6	2·8	1	1·6	2	3·2	1	2·1	2	4·9
Bird	3	1·4	1	1·6	1	1·6	0	0	1	2·4
Red fox (*Vulpes vulpes*)	2	0·9	1	1·6	0	0	1	2·1	0	0
Ox (*Bos taurus*)	1	0·5	0	0	1	1·6	0	0	0	0
Goat (*Capra hircus*)	1	0·47	0	0	0	0	0	0	1	2·4
Sheep (*Ovis aries*)	1	0·47	0	0	0	0	0	0	1	2·4

Statistical comparisons:

For the occurrence of marmot, comparing spring with winter: $\chi^2=10{\cdot}91$, $P<0{\cdot}05$; summer with winter: $\chi^2=8{\cdot}71$, $P<0{\cdot}005$; autumn with winter: $\chi^2=7{\cdot}95$, $P<0{\cdot}005$.

For all livestock types combined, comparing spring with winter: $\chi^2=12{\cdot}34$, $P<0{\cdot}005$; summer with winter: $\chi^2=7{\cdot}10$, $P<0{\cdot}01$; autumn with winter: $\chi^2=10{\cdot}04$, $P<0{\cdot}01$.

to autumn, to only 2·4% in winter. Pika were eaten more frequently in winter than at other times. Livestock occurred in 17·8% of samples averaged over the whole year but were taken significantly more frequently in winter than at other times of year (Table I).

Discussion

There are a number of difficulties inherent in the interpretation of carnivore diet based on the analysis of scats. Only indigestible materials can be recorded so that the consumption of soft tissue from large carcasses without the ingestion of hair would be difficult to detect. It is also impossible to differentiate with certainty between prey that have been killed by the predator and those that have been scavenged. Conversion of items from frequency of occurrence to contribution to the diet of biomass is also liable to severe bias. Large prey cannot be consumed totally at one meal and the remainder could either be eaten at subsequent meals or alternatively by other predators and scavengers. Small items may be consumed totally but the presence of their remains in scats cannot be used to determine how many individuals were represented. Furthermore, small prey contain a relatively higher proportion of indigestible matter (hair, bones and teeth), and their remains are over-represented in scats (Floyd, Mech & Jordan, 1978). This makes analysis of diet data involving percentage volume or percentage weight of prey remains in scats biased towards smaller prey. Scats also cannnot be identified to individual predators, so that specialist and generalist foragers cannot be distinguished. Interpretation of data based on scat analysis must, therefore, be done cautiously within the constraints of the methodology.

Blue sheep remains occurred more frequently in the scats than the remains of any other prey species in all seasons, and as blue sheep were also considerably larger than any of the other wild prey species, it is probably safe to conclude that they were also the most important in terms of biomass. Marmots weighed over 5 kg (Feng, Cai & Zeng, 1986), so were probably also important in terms of biomass. Their very low occurrence in winter was almost certainly a result of their hibernation behaviour which would render them unavailable to snow leopards (Arnold & Psenner, 1990). Pika remains occurred in a higher percentage of scats in winter than at other times, and this may have been in response to the reduced availability of marmots.

Blue sheep have been recorded as the main prey or as significant prey in Shey and Lapche, Nepal (Schaller, 1977) and in Qinghai and Gansu Provinces (Schaller *et al.*, 1988*b*), and Taxkorgan Reserve, China (Schaller *et al.*, 1987, 1988*a*). Elsewhere, other large wild herbivore species were more important; Ibex (*Capra ibex*) in Tomur Feng, China (Schaller *et al.*, 1988*a*) and in Zailisky-Alatan, USSR (Zhirjakov, 1990) and Markhor (*Capra falconeri*) in Chitral, Pakistan (Schaller, 1977). Marmots constituted a significant proportion of snow leopard's diet in Xinjiang, Qinghai and Gansu Provinces, China (Schaller *et al.*, 1987, 1988*a*, *b*).

Livestock remains, mostly of yak, were found in 39% of scats collected during the winter in Manang so these prey may have made up a significant proportion of the diet biomass at that time. The increase compared with summer and autumn may have been in response to the reduced availability of marmots, but it is also likely that the more adverse weather conditions in winter, especially deep snow, encouraged the snow leopards to forage closer to human habitation and livestock herds. Livestock were also much less widely dispersed in winter and yaks, especially, were available at higher densities. It may, therefore, have been more profitable for the snow leopards to concentrate on this food source rather than increase their predation on blue sheep. Yak were grazed on open pasture throughout the year but, with the exception of the males which were not considered to be vulnerable to snow leopard attacks, herds were not left unattended for long periods. The conditions of the animals were constantly monitored by herdsmen who initiated searches for missing animals within a day or so. Dead animals were recovered for their meat and hides. This reduces the possibility that significant numbers of yaks were available to the leopards as carrion and it is likely that most, and perhaps all, of those eaten were killed by leopards. Villagers reported that dead animals with signs of leopard predation were generally in good condition beforehand. The habit of searching for and removing carcasses also meant that it was unlikely that the leopards could utilize the carcass for more than one or two meals, and this could have resulted in them killing a larger number of animals. Alternatively, were the herdsmen to allow the leopards to consume the whole of their kill unmolested, the profitability of yak predation would increase, perhaps encouraging more leopards to specialize on this food source.

The snow leopard's predation on livestock, which occurs widely throughout its range (Mallon, 1984; Schaller *et al.*, 1987, 1988*a*, *b*; Sherpa & Oli, 1988; Fox *et al.*, 1988, 1991), brings it into direct conflict with herdsmen. Illegal killings of the leopards seems widespread but is impossible to quantify. The future conservation of the snow leopard will undoubtedly depend upon the successful resolution of this conflict. However, various options for solving the problem must be considered carefully in relation to the leopard's requirements in present day landscape.

Compensation schemes are costly and difficult to implement, and killing of the leopards is clearly counter-productive. Exclusion of the leopards by changes in husbandry or other means might be suggested, but if livestock are now an essential component of the leopard's diet, this could have detrimental effects. A much more detailed study of snow leopard foraging behaviour in winter, based on radio-tagged individuals, is needed to elucidate the exact significance of livestock as a food source, and to determine if livestock killing occurs widely in the leopard population or if it is restricted to specialist individuals.

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