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CATS, CANINES, AND COEXISTENCE: DIETARY DIFFERENTIATION BETWEEN THE SYMPATRIC SNOW LEOPARD AND GREY WOLF IN THE WESTERN LANDSCAPE OF NEPAL HIMALAYA

Anil Shrestha, Kanchan Thapa, Samundra Ambuhang Subba, Maheshwar Dhakal, Bishnu Prasad Devkota, Gokarna Jung Thapa, Sheren Shrestha, Sabita Malla & Kamal Thapa

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Abstract: Understanding the dietary habits of sympatric apex carnivores advances our knowledge of ecological processes and aids their conservation. We compared the diets of the sympatric Snow Leopard *Panthera uncia* and Grey Wolf *Canis lupus* using standard micro-histological analyses of scats collected from the western complex of Nepal Himalaya. Our study revealed one of the highest recorded contributions of livestock to the diet of top predators (55% for Grey Wolf and 39% for Snow Leopard) and high dietary overlap (0.82) indicating potential exploitative or interference competition. Their diet composition, however, varied significantly based on their consumption of wild and domestic prey. Limitation in data precludes predicting direction and outcome of inter-specific interactions between these predators. Our findings suggest a high rate of negative interaction with humans in the region and plausibly retaliatory killings of these imperilled predators. To ensure the sustained survival of these two apex carnivores, conservation measures should enhance populations of their wild prey species while reducing livestock losses of the local community through preventive and mitigative interventions.

Keywords: *Canis lupus*, dietary pattern, dietary overlap, livestock, Naur, negative interaction, *Panthera uncia*, scat analysis, sympatry.

Nepali abstract: सार: एकै भौगोलिक क्षेत्रमा बस्ने खाद्य श्रृङ्खलामा शीर्ष स्थानमा रहेका मांसाहारीको आहारका बारेमा हाम्रो बुझाई राम्रो भएमा उनीहरूको पारिस्थितिकिय प्रक्रियाका बारेमा थप जानकारी हासिल गर्न सकिनेका साथै संरक्षणमा पनि टेवा पुग्दछ। हामीले नेपालको हिमाली भेगको पश्चिमी क्षेत्रबाट संकलित हिम चितुवा तथा ब्याँसो को दिशाको माइक्रो-हिस्टोलोजिकल प्रविधिबाट विश्लेषण गरी यिनीहरूले खाने आहार प्रजातिको तुलना गरेका थियौं। हाम्रो अध्ययनबाट यी वन्यजन्तुले खाने आहारमा घरपालुवा जनावरहरूको हिस्सा धेरै मात्रामा रहेको (ब्याँसो र हिम चितुवाका लागि क्रमशः ५५% र ३९%) तथा खाने आहार प्रजाति एकैखाले सूचकाङ्क दुल्लो (०.८२) देखिएको छ, जसबाट शोषणकारी वा हस्तक्षेपकारी प्रतिस्पर्धा हुने संकेत देखिन्छ। तथापी, यिनीहरूबीच आहार संरचनाको आधारमा घरेलु वा जंगली जनावरको सिकार गरी खाने तथ्याङ्कमा निकै नै फरक रहेको पाइयो। तथ्याङ्कको सीमितताले गर्दा यी वन्यजन्तुबीचको पारस्परिक अन्तरक्रियाको दिशा तथा परिणामको पूर्वानुमान गर्न मुश्किल पर्ने देखिन्छ। हाम्रो अध्ययनले उक्त क्षेत्रमा मानवसँग यी जनावरहरूको नकारात्मक अन्तरक्रियाको दर उच्च रहन सक्ने तथा यी दुर्लभ जनावरहरू सिकारीको प्रतिसोधमा मारिने पक्का-पक्की देखिन्छ। यी दुई शीर्ष मांसाहारी वन्यजन्तुको दिगो अस्तित्व सुनिश्चित गर्नका लागि संरक्षणका विभिन्न उपायहरू मार्फत यिनीहरूको संख्या बढाउनुका साथ-साथै स्थानीय समुदायको पशुधन हानी कम गर्ने रोकथाम तथा न्यूनीकरणका कार्यक्रमहरू अघि सार्नेपनि आवश्यकता देखिन्छ।

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INTRODUCTION

Dietary habits of sympatric apex carnivores advance our understanding on ecological processes and regulation of the ecosystem functions, aiding their conservation (Macdonald 1983). In Nepal Himalaya, inter-specific interactions between apex predators have consequences for predator-prey relationships, habitat, and the entire ecosystem; this can also have a spillover effect on their relation to humans, through livestock depredation and retaliatory killing (Chetri et al. 2017). Information on dietary overlap and interactions of sympatric carnivores, however, is limited in these mountainous landscapes and nonexistent from the western complex of Nepal Himalaya.

With this background, we studied the dietary habits of the Snow Leopard *Panthera uncia* and Grey Wolf *Canis lupus* (hereafter referred to as 'Wolf') which live sympatrically in the western complex of Nepal Himalaya. Snow Leopards are twice the body size of Wolves (Jnawali et al. 2011) and are solitary hunters with a stalking ambush hunting behaviour (Jackson & Hunter 1996). In contrast, Wolves are coordinating cursorial pack-hunters (Viripae & Vorobiev 1983).

We specifically investigated (a) the dietary pattern and relative importance of prey types for the sympatric Snow Leopard and Wolf, and (b) their dietary overlap in the western complex of Nepal Himalaya.

MATERIALS AND METHODS

Study area

Our study was carried out in the western landscape of Nepal Himalaya (83.281–28.493 in the east to 80.586–29.542 in the west) across the potential habitat of the Snow Leopard and the Wolf (Fig. 1). This covers an area of over 38,312 km² with an altitude range of 3,000–5,500 m. Of the total study area, barren area (22%) is the most dominant land cover, followed by rugged and broken snow-capped mountains and glaciers (17%), alpine rolling grasslands (17%), and agriculture and settlement (12%) (ICIMOD 2010). The total potential habitat within the western landscape covers an area of 11,261 km². The western landscape is one of three priority landscapes identified by The Global Snow Leopard and Ecosystem Protection Program (GLSLEP) (DNPWC 2017).

Wild prey species recorded in the study area included Bharal/ Blue Sheep/ Naur *Pseudois nayaur*, Himalayan Tahr *Hemitragus jemlahicus*, Kiang *Equus kiang*, Tibetan Argali *Ovis ammon*, Alpine Musk Deer *Moschus*

chrysogaster, Tibetan Gazelle *Procapra picticaudata*, pika *Ochotona* spp., marmot *Marmota* spp., and Woolly Hare *Lepus oiostolus*.

With pastoralism as the main occupation of the local community, this region harbours a high density of livestock (73 head per km²), including domestic yak *Bos grunniens*, cow *Bos* spp. and hybrid, horse *Equus ferus caballus*, goat *Capra hircus*, sheep *Ovis aries*, and pig *Sus scrofa domesticus* (CBS 2011).

Scat survey

We systematically collected putative Snow Leopard and Wolf scat samples from each of the 56 grids measuring 16 km² (4 km x 4 km; effective sample area ~896 km²; Fig. 1) spread across 11,261 km² following standard protocol (Thapa 2007) during the late spring season (April–May) in 2014. Within each grid, at least two transects (0.4–2.8 km) were laid 1.0–1.5 km apart (Jackson & Hunter 1996) and surveyed. Upon encounter of fresh scat samples, a few grams were collected and stored in 15 ml tubes containing silica desiccant for micro-histological studies; the remaining scat was left in the field to avoid disturbing the regular movements and territorial marking of the predators (Lovari et al. 2009). All putative scat samples (n=265) were screened for species identification through molecular scatology (Kelly et al. 2012).

DNA extraction

DNA was extracted from scat samples using commercially available DNA stool kit (QIAGEN Inc.) following manufacturer instructions. We kept one negative control (water) in each batch of samples to monitor contamination during DNA extraction.

Species identification

All the samples were screened for PCR-based species identification using mitochondrial DNA (mtDNA) cytochrome-b segment Snow Leopard-specific primers (Janecka et al. 2008, 2011). All Snow Leopard-negative samples were further screened using D-Loop section of mtDNA (MIT forward/ reverse) with Wolf specific primers (Parra et al. 2008; Pilot et al. 2010). All PCR reactions for both Snow Leopard and Wolf were performed in duplicate for confirmation. Similar results in duplicate PCR runs were considered (Snow Leopard/ Wolf) positive samples. Non-conformity and/or discrepancy in two PCR runs were verified with a third run for confirmation.

Diet analysis

Species-positive scat samples for Snow Leopard and

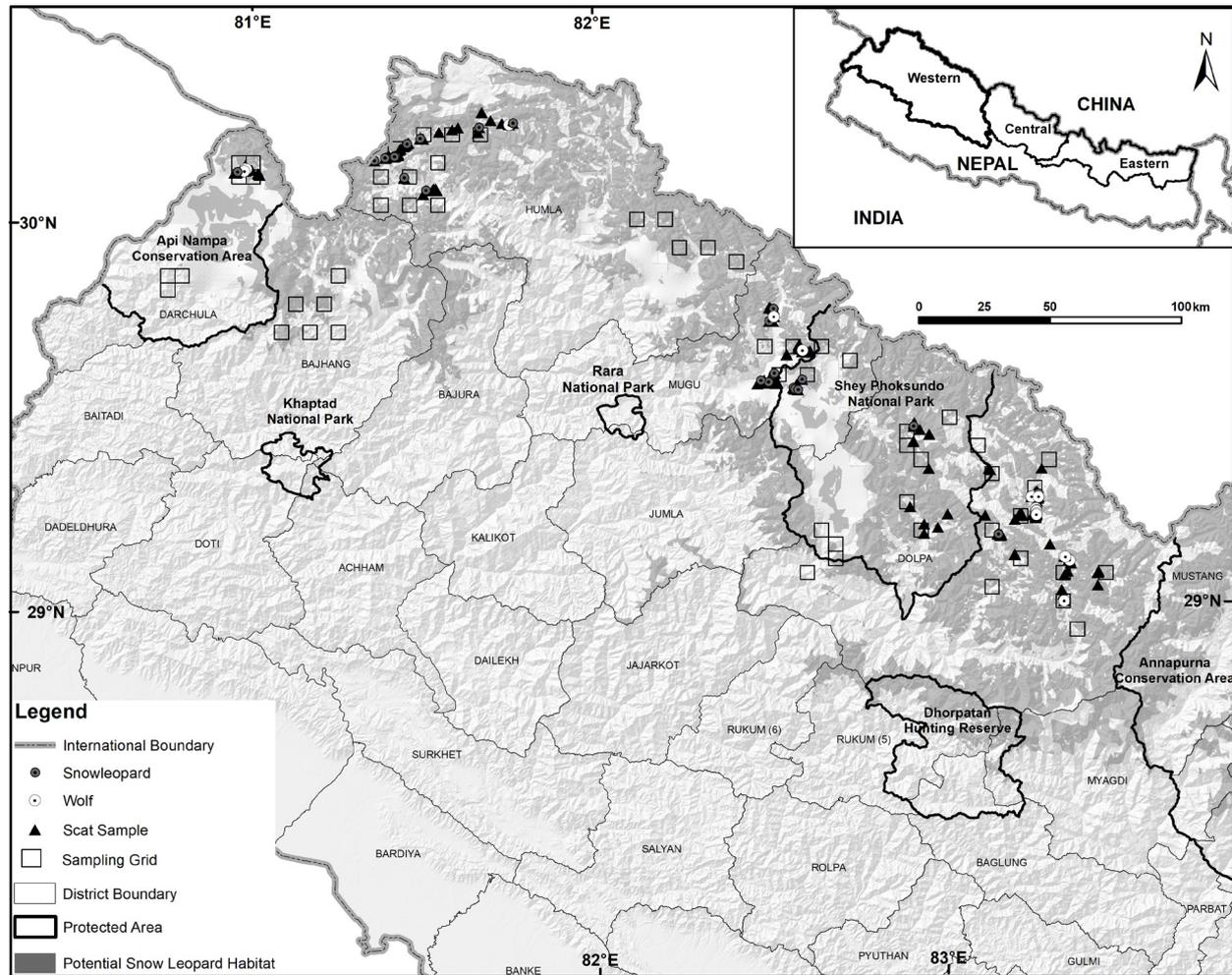


Figure 1. Study area and spatial location of sampling grids (n=56; 4km x 4km) covering an area of 896km² for opportunistic survey of scat samples and locations of Snow Leopard and Grey Wolf positive samples across the potential habitat in the western landscape of Nepal Himalaya.

Wolf were analyzed using a standard micro-histological study method (Oli et al. 1993; Devkota et al. 2013). Prey species were identified by comparing hair samples collected from these species-positive scat samples with reference to hair samples of all potential prey species (Oli et al. 1994; Wegge et al. 2012).

We calculated and compared relative frequencies of occurrence of each prey species:

$$\left[\left(\frac{\text{No. of occurrences of each food item when present}}{\text{Total no. of occurrences of all food items}} \right) \times 100 \right]$$

(Lucherini & Crema 1995) for all mammalian prey items, which were identified to species level. To investigate the relative importance of prey type, we used χ^2 analysis to compare differences in frequencies of occurrence of prey items between the diet of the Snow Leopard and Wolf in terms of wild versus domestic prey

(Azevedo et al. 2006).

We also calculated Pianka's index to measure the dietary overlap between Snow Leopard and Wolf (Pianka & Pianka 1970):

$$DO = \frac{\sum P_{ij}P_{ik}}{\sqrt{\sum P_{ij}^2 \sum P_{ik}^2}}$$

where, DO is dietary overlap and P_{ij} and P_{ik} are the respective proportions of prey category i in the diet of the two predators ' j ' and ' k '. The value ranges from zero to one, indicating no dietary overlap (DO=0) to complete overlap (DO=1), respectively.

RESULTS

Diet composition of carnivores

Of the 265 putative scat samples collected and genetically screened, 35 (13%) belonged to Snow Leopards and 24 (9%) to Wolves; the rest (78%) belonged to other species. Five wild prey species—Bharal, hare, pika, marmot, and Musk Deer—were identified in both Snow Leopard and Wolf scat samples. Of the domestic prey species identified, Snow Leopard scat was found to have goat, sheep, domestic yak, cow, dog, and horse, while Wolf scat had five of these, excluding horse. Spatial distribution of genetically screened scat samples as Snow Leopard, Wolf, and negative is shown in Fig. 1.

Snow Leopard diet

The Snow Leopard diet was dominated by wild prey comprising about 61%, followed by domestic livestock making up for 39% of the total identified species (Fig. 2). Bharal was the most significant prey of Snow Leopard, contributing 29%, followed by goat (21%), hare (15%),

pika (5%), domestic yak (5%), domestic cow (4%), and others (Fig. 3). About 54% of the confirmed Snow Leopard scats comprised a single prey species, followed by 32% with two species and 14% with three species.

Wolf diet

Domestic livestock contributed more than half (55%) of the Wolf's diet while wild prey comprised only 45% (Fig. 2). Wolf diet was dominated by Bharal (28%), followed by domestic cow (15%), sheep (15%), goat (10%), dog (8%), domestic yak (8%), marmot (7%), and others (Fig. 3). About 46% of the confirmed Wolf scat comprised of a single prey species, followed by 29% comprising two species and 25% with three species.

Diet overlap between Snow Leopard and Wolf

High diet overlap (DO=0.82) was found between the sympatric Snow Leopard and Wolf. The diet composition (wild prey vs. domestic prey) of Snow Leopard and Wolf, however, varied significantly ($\chi^2=5.13$, d.f.=1, $P<0.023$).

DISCUSSION

This appears to be the first study on Snow Leopard (Image 1) and Grey Wolf (Image 2) dietary pattern in western Nepal Himalaya applying standard micro-histological analysis of genetically confirmed scats. We compared our results specifically with similar studies that employed genetic screening to avoid biases (Weiskopf et al. 2016).

Our results showed that the diet of the Snow Leopard in the western landscape of Nepal Himalaya was dominated by wild herbivores (61%), with majority contributed by one principle prey species, i.e., Bharal, followed by livestock. This is consistent with the dietary

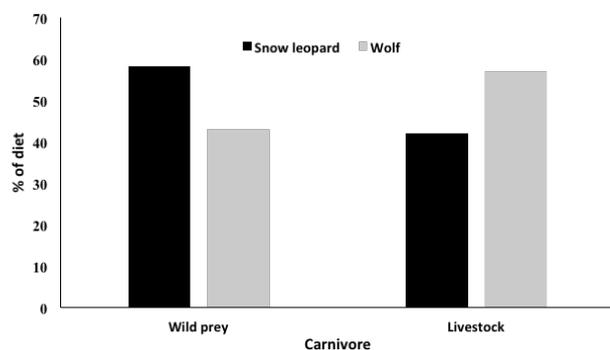


Figure 2. Diet comparison between Snow Leopard and Grey Wolf based on wild prey and livestock expressed as relative frequency of occurrence (%).

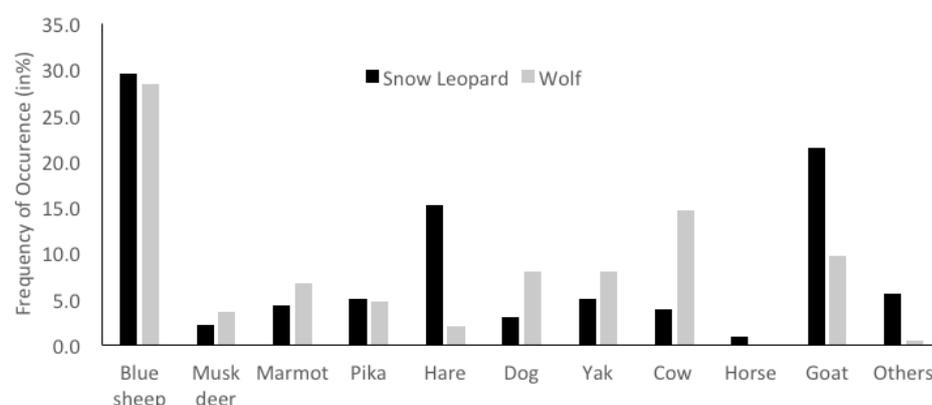


Figure 3. Prey species proportion in the diet of Snow Leopard and Grey Wolf expressed as relative frequency of occurrence (%).



Image 1. Snow Leopard *Panthera uncia*. © DNPWC/WWF Nepal.



Image 2. Grey Wolf *Canis lupus*. © DNPWC/WWF Nepal.

pattern of the Snow Leopard in the central landscape of Nepal Himalaya (Wegge et al. 2012; Aryal et al. 2014). Similar trends were also recorded in other Snow Leopard range states, except that the principal prey species was not Bharal (Jumabay-Uulu et al. 2014; Weiskopf et al. 2016). The proportion of livestock (39%) and small mammals (30%) in Snow Leopard diet, however, was found to be higher in the present study as compared to other similar studies (Shehzad et al. 2012; Lovari et al. 2013; Aryal et al. 2014; Jumabay-Uulu et al. 2014; Weiskopf et al. 2016; Chetri et al. 2017).

As a whole, more than half of the Wolf's diet (55%) was dominated by domestic livestock, but the single-most frequently encountered species was wild prey—Bharal (28%). Our findings confirm the preference of large prey by pack-living Wolves (Chetri et al. 2017) but differ in the proportion contributed to their diet by the cliff-dwelling primary wild prey, Bharal. Further detailed studies are needed to understand the underlying reason for this observation. As compared to other studies, the contributions of livestock to Wolf diet recorded here were among the highest (Jumabay-Uulu et al. 2014; Wang et al. 2014; Chetri et al. 2017). Interestingly, the contribution of wild prey and small mammals to Wolf diet was less in our study as compared to other studies (Jumabay-Uulu et al. 2014; Chetri et al. 2017). These findings may be an outcome of local circumstances; further research will be needed to verify the causes and effects of these findings.

Our study revealed a very high dietary overlap (0.82) between these sympatric predators. This differs significantly from a recent study carried out in the central landscape of Nepal Himalaya wherein a dietary

overlap of 0.44 was recorded (Chetri et al. 2017).

High dietary overlap along with their dependence on one primary wild prey species, Bharal (contributing one-third of their diet), may warrant higher potential exploitative or interference competition between Snow Leopards and Wolves in the western landscape.

Interestingly, the finer scale dietary pattern showed a higher contribution of wild prey to the diet of Snow Leopard as compared to that of the Wolf; domestic livestock was dominant in the diet of the latter. The direction and outcome of the interaction between these two predators, however, are difficult to predict from our current study due to our limited sample size, restricted collection season (limited to spring), and lack of information on the population density of the prey species.

Nevertheless, in our study area, the relative contribution of livestock to the diet of both top predators (55% for Wolves and 39% for Snow Leopards) was higher as compared to other studies (Chetri et al. 2017). Further exploration would be necessary to establish if seasonality and local herding practices had a role in bringing this about.

Additionally, prime habitats of these species in the study area see very high anthropogenic activity in the form of Caterpillar Fungus *Ophiocordyceps* spp. ('yarsagumba') collection during the latter part of the scat collection season (April–May). This may also have had direct or indirect impacts on wild and domestic prey availability or accessibility, leading to greater livestock in the predator diet.

Increased dependence of both apex carnivores on livestock may lead to further escalation of human-

carnivore negative interactions in the long run. This may trigger retaliatory killings of Snow Leopard and Wolf, as was reported from the region, thereby affecting the abundance of these predators in the region. Conservation measures focusing on preventive and mitigative measures that aid in securing people's livelihoods can potentially reduce retaliation against the predators. We recommend further detailed research on population trends of both predators and their principal prey species in the region to determine the degree of their interaction and ramification on livestock depredation in the area.

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Author contribution: KaT (Kamal Thapa), MD and GJT designed the study. KaT, AS and BPD contributed to the sample collection. BPD analyzed the hair samples. AS and KT analyzed the data and discussed the results. AS and KT wrote manuscript. SAS, MD, BPD, GJT, SS, SM and KaT participated in the manuscript editing.

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