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Original research article

Dietary composition of three sympatric carnivores in the high-altitude regions of Nepal

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A R T I C L E I N F O

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A B S T R A C T

Understanding the diet and resource overlap among sympatric carnivores is essential for conservation in high-altitude ecosystems where human-wildlife interactions are increasing. We analyzed diet composition, prey preferences, and dietary overlap among three sympatric large carnivores, red fox (*Vulpes vulpes*), Himalayan wolf (*Canis lupus*), and snow leopard (*Panthera uncia*) in the Upper Mustang Nepal, using 111 scat samples. Prey selection was evaluated using Ivlev's electivity index and dietary overlap was assessed with Pianka's index based on Relative Biomass Killed (RBK) and Relative Individuals Killed (RIK). Red foxes showed strong specialization on small mammals, particularly rodents and pika. Himalayan wolves preferred large wild ungulates, with blue sheep being the most selected prey. Snow leopards consumed both large ungulates and smaller mammals, with a notable preference for pika. Dietary overlap was low between red foxes and the larger predators, but wolves and snow leopards exhibited high overlap based in RBK (0.79) but low overlap based on RIK (0.24). Although wild prey dominated numerically, livestock contributed substantially to biomass loss. These findings highlight the importance of wild prey populations and implementing targeted conflict-mitigation strategies.

1. Introduction

The study of carnivorous species in ecosystems is crucial to understanding the dynamics of food webs and the ecological roles that large carnivores play in maintaining biodiversity and ecosystem health (Bhandari et al., 2020; del Rio et al., 2001; Ripple et al., 2014; Stier et al., 2016).). Large carnivores such as red foxes, wolves, and snow leopards occupy key ecological niches and regulate prey

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populations and vegetation structure through top-down processes (Fox et al., 2024; Hacker et al., 2022; Wolf and Ripple, 2017). Their feeding ecology provides insights into adaptive strategies, species interactions, and ecosystem processes (Baral et al., 2024a; Kachel et al., 2022; Ripple et al., 2014; Wolf and Ripple, 2017).

In high-altitude regions, predator-prey dynamics play a crucial role in maintaining the balance of mountain ecosystems, where unique interactions arise due to challenging terrain, harsh climate, and limited prey availability. Such extreme conditions shape carnivore behaviour and foraging strategies, requiring species to adopt specialized feeding mechanisms to cope with resource scarcity (Baral et al., 2022; Krauel et al., 2018; Sarkar et al., 2018). The fauna in these ecosystems is adapted to these conditions, with many species, including both carnivores and prey, exhibiting specialized behaviors to survive in such extreme environments (Owen-Smith and Mills, 2008; Pereira et al., 2014; Wegge et al., 2009). Studying diet in these landscapes therefore helps clarify how carnivores respond to ecological constraints and resource limitations.

Nepal contains diverse ecosystems that support a wide range of wildlife across varying elevations (Basnet et al., 2016; Heinen and Kattel, 1992). High-altitude regions such as Upper Mustang harbor important carnivore species, yet their dietary patterns remain less studied compared to populations in temperate or lowland systems species (Chetri et al., 2017; Wegge et al., 2012). A clearer understanding of their diets is essential for developing conservation strategies in areas where wildlife, livestock, and human communities coexist.

Snow leopards (*Panthera uncia*) function as solitary apex predators in Himalayan ecosystems and primarily depend on wild ungulates such as blue sheep (*Pseudois nayaur*) and Himalayan tahr (*Hemitragus jemlahicus*) for their energetic needs (Filla et al., 2022). In contrast, Himalayan wolves (*Canis lupus chanco*) exhibit social hunting behavior and a highly flexible diet, enabling them to exploit a wide range of prey species and to shift between active predation and scavenging as resources fluctuate across seasons and landscapes (Ansorge et al., 2006; Jkedrzejewski et al., 2012; Newsome et al., 2016). Red foxes (*Vulpes vulpes*), as meso-carnivores, mostly feed on small mammals, birds, invertebrates, and other readily available resources, reflecting strong dietary plasticity that facilitates persistence in the harsh, resource-limited environments of the high Himalayas (Klare et al., 2011; Soe et al., 2017). Together, these species represent a gradient of dietary specialization, from highly specialized to broadly opportunistic feeders, offering an ideal system for examining resource partitioning and mechanisms of coexistence.

The objective of this study is to examine the dietary composition of three sympatric carnivores snow leopards, Himalayan wolves, and red foxes in the high-altitude regions of Nepal using scat analysis as a non-invasive method for identifying prey remains.

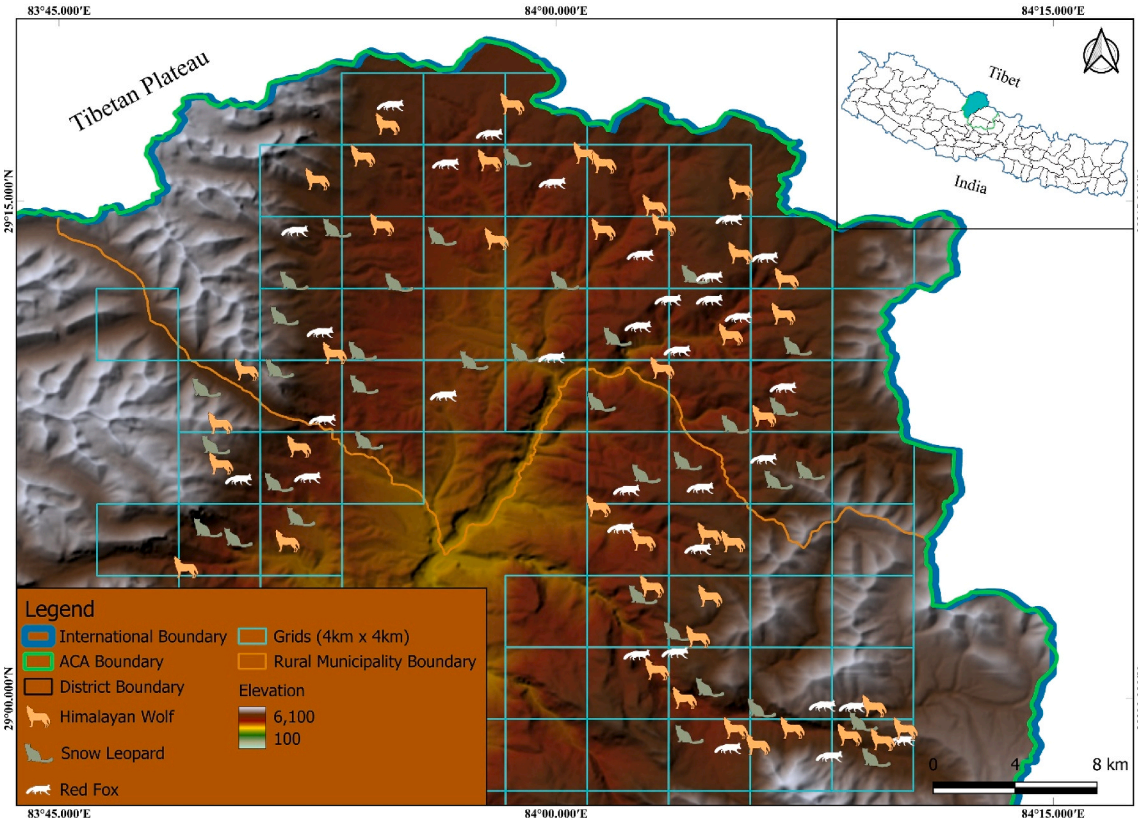

Fig. 1. Study area map showing the Mustang District in north-central Nepal and the scat collection locations of three species (Himalayan wolf, snow leopard and red fox). The spatial distribution of scats across high-altitude valleys and rugged terrain illustrates the broad habitat use of the three carnivores and supports the assessment of potential dietary overlap across shared landscapes.

Specifically, we aim to (i) identify the prey species consumed by each carnivore, (ii) quantify dietary overlaps among species, and (iii) evaluate patterns of resource partitioning that facilitate coexistence in a resource-limited environment. Based on differences in body size, hunting strategy, and ecological specialization, we hypothesize that snow leopards will exhibit a more specialized diet dominated by large ungulates, whereas wolves and red foxes will show broader and more flexible feeding habits. These hypotheses provide a framework for understanding species-specific feeding strategies and the ecological mechanisms that structure carnivore communities in high-altitude ecosystems.

2. Materials and methods

2.1. Study site

The Annapurna Conservation Area (ACA); IUCN Category VI is Nepal's largest protected area, covering 7629 km^2 within the Himalaya Biodiversity Hotspot (Bhuju et al., 2007; Myers et al., 2000). The ACA is situated in the central Himalayas and encompasses parts of the country's high mountain (3000–5000 m) and Himalayan (>5000 m) physiographic regions (Baral et al., 2024b). It spans a wide elevational gradient from subtropical lowlands to trans-Himalayan arid zones and supports at least 128 mammal, 523 bird species, 392 butterflies, 61 reptiles, 30 amphibians, 28 fishes (Baral, 2018; Baral et al., 2019; Baral and Kadariya, 2025). ACA is managed by the National Trust for Nature Conservation through a participatory approach, allowing local communities to reside and maintain traditional livelihoods within the protected area (Baral and Kadariya, 2025).

This study was conducted in the Upper Mustang region of the ACA (Fig. 1), a cold, arid trans-Himalayan landscape lying in the rain shadow of the Annapurna and Dhaulagiri ranges, bordering Tibet to the north (Aryal, 2013; NTNC, 2012). Our study covered local areas including Lo Manthang, Dhalung, Chumjung, Marang, the Lo Manthang Golf Course, Yara Top, and Damodar Kunda. The altitude ranged between 3500–5400 m, with alpine meadows, steppe, and sparse shrublands dominated by Caragana and Juniperus spp. (NTNC, 2012). The area supports key prey species for large carnivores, including blue sheep (*Pseudois nsayaur*), Tibetan argali (*Ovis ammon hodgsoni*), kiang (*Equus kiang*), and Himalayan marmot (*Marmota himalayana*) (Aryal et al., 2012; Baral et al., 2019; Schaller, 2000). Large carnivores present include brown bear (*Ursus arctos*), snow leopard (*Panthera uncia*), Himalayan wolf (*Canis lupus chanco*), and meso carnivores include red fox (*Vulpes vulpes*), golden jackal (*Canis aureus*) and Eurasian lynx (*Lynx lynx*) (Baral et al., 2019; Chetri, 2022). Pastoralism is the dominant livelihood, with livestock densities exceeding those of wild ungulates, potentially influencing predator diet composition (Bagchi and Mishra, 2006; Chetri et al., 2017).

2.2. Scat collection

The scat of three carnivorous species, red fox, wolves and snow leopards, was collected in September to October 2022, May to June 2023, and May to June 2024 in Upper Mustang, Nepal. To accurately identify the scats of these species, a local expert with extensive field knowledge was involved in the survey. Given the vast and rugged high-altitude terrain, accessing all areas on foot or by vehicle was not feasible. Therefore, before collecting scat samples, 62 camera traps station, a key tool for wildlife surveys, were installed in 4*4 km^2 grids. The primary purpose of these traps was to understand the habitat selection of large carnivores and scats identification. Scat collection was guided by multiple sources of evidence, including camera trap data, sign surveys (such as tracks and scratch marks), and direct interactions with local communities to gather information about species presence. Based on this data, we proceeded with scat collection. The survey was conducted twice within the grids, supplemented by an opportunistic survey. Any unidentified scat samples were excluded from the final analysis to ensure accuracy. All soil, leaves, and grass from the collected scat samples were removed, and the cleaned samples were then placed in zip-locked plastic bags for further analysis. Additionally, GPS locations were labeled on the zip-locked bags to ensure accurate spatial tracking of the samples. Camera-trap detections confirmed the presence of red foxes, Himalayan wolves, and snow leopards within the sampled grids, and these detections were used solely to support and validate field-based identification of scat samples. No additional camera-trap analyses are presented here, as detailed camera-trap results form part of a separate study.

2.3. Identification of snow leopards, wolves, and red foxes

Scat samples were identified using an integrative field approach combining key morphological characteristics, habitat context, and associated signs to minimize misclassification error, a known source of bias in fecal analysis (Davison et al., 2002; Weiskopf et al., 2016). Snow leopard scats were identified by their typically segmented form and loose composition, with diameters consistent with published ranges (mean ~2.1 cm; (Laguardia et al., 2015). They were predominantly collected in steep, rugged terrain such as cliff bases, rocky outcrops, and mountain ridges (Jackson and Hunter, 1996). The presence of associated scrapes, a hallmark marking behavior, provided secondary confirmation (Ahlbom and Jackson, 1986). Wolf scats were distinguished by their larger size (2.5–3.0 cm diameter), often unsegmented and bony composition, and a high density of coarse ungulate hair (Weaver and Fritts, 1979). They were primarily located in open habitats including valley floors, alpine meadows, and gentle slopes (Pal et al., 2022). Red fox scats were identified by their small diameter (1.5–2.5 cm) and a distinctive twisted, rope-like morphology, often tapering to a point (Reynolds and Aebischer, 1991). Their composition typically contained fine hair and bone fragments from small mammals. A key diagnostic was their frequent deposition on prominent, conspicuous objects such as rocks or trail junctions, consistent with scent-marking behavior.

2.4. Scat analysis

Collected scat samples were analyzed in the laboratory of the Central Department of Zoology, Tribhuvan University, Kritipur and Department of Zoology, Prithivi Narayan Campus, Pokhara. Including the author's team, some of the master's degree students were also involved in the scat analysis project, which was conducted in 2024. We followed published guidelines for scat analysis (Bahuguna et al., 2010; Bhandari et al., 2020; Ramakrishnan et al., 1999). The collected scat samples were washed through a 1.5 mm sieve under running water, and prey remains (such as hair, teeth, claws, and bones) were macroscopically sorted following the methods described by Bhandari et al. (2020), del Rio et al. (1993), Karanth and Sunquist (1995), Lamichhane et al. (2025), Ramakrishnan et al. (1999), Støen and Wegge (1996) and Timilsina et al. (2024).

To identify the prey species in each scat, a total of 20 hairs were randomly selected and placed in a 1:1 solution of ethyl alcohol and diethyl ether in a petri dish for 30 min. From these, five hairs were randomly chosen and laid out in parallel lines on a slide coated with transparent nail polish to observe the cuticle pattern (Bhandari et al., 2022; Lamichhane et al., 2025). The slides were then left to dry at room temperature for 45 min to 1 h. Once dried, the hairs were removed, and the imprints were observed under a compound stereoscopic microscope at 400X magnification.

Another set of five hairs from the original 20 hair sample was placed in acetone for 45 min to examine the medullary pattern using the same procedure. The cuticular and medullary images were then compared against reference keys by Bahuguna et al. (2010), De Marinis and Asprea (2006) and Thapa (2013). Additionally, reference images from the National Trust for Nature Conservation (NTNC) were used to confirm prey species identification. After analyzing all the collected scat samples, we systematically recorded the identified prey species and their proportions in an Excel sheet for basic descriptive analysis. This dataset included details on the

Table 1
Dietary composition of red foxes, wolves, and snow leopards based on scat analysis.

A. Domestic prey consumed by carnivores

Predators	Prey species	Composition	A	B	C	D	E
Wolves	Domestic Goat	5	7.8	20	0.75	3.5	27.5
	Domestic Sheep	1	1.6	35	1.05	1	5.5
	Horse	1	1.6	380	7.95	7.4	5.5
	Yak	3	4.7	300	6.35	17.6	16.5
Snow leopards	Domestic Goat	9	14.3	20	2.68	9.2	0.7
	Domestic Sheep	7	11.1	35	3.2	8.6	0.4
	Dog	1	1.6	10	2.33	0.9	0.1
	Horse	2	3.2	380	15.28	11.7	0
	Yak	3	4.8	300	12.48	14.3	0.1

B. Wild prey consumed by carnivores

Predators	Prey species	Composition	A	B	C	D	E
Red fox	Blue Sheep	7	16.7	35	1.05	31.8	1
	Himalayan Marmot	4	9.5	4	0.43	7.4	2
	Pika	6	14.3	0.5	0.36	9.3	20.5
	Woolly Hare	11	26.2	2	0.39	18.6	10.2
	Rodent (Rat)	8	19	0.2	0.354	12.3	67.3
	Stone Marten	6	14.3	1.2	0.374	9.7	8.9
Himalayan wolf	Blue Sheep	19	29.7	35	1.05	18.4	104.6
	Tibetan Argali	2	3.1	70	1.75	3.2	11
	Tibetan Gazelle	3	4.7	13	0.61	1.7	16.5
	Himalayan Marmot	6	9.4	4	0.43	2.4	33
	Pika	4	6.3	0.5	0.36	1.3	22
	Woolly Hare	4	6.3	2	0.39	1.4	22
	Rodent (Rat)	6	9.4	0.2	0.354	2	33
	Stone Marten	2	3.1	1.2	0.374	0.7	11
	Kiang	3	4.7	250	5.35	14.8	16.5
	Mountain Weasel	2	3.1	0.3	0.356	0.7	11
	Unidentified	3	4.7	0	0	0	0
Snow leopard	Blue Sheep	17	27	35	3.205	20.8	0.9
	Tibetan Gazelle	2	3.2	13	2.435	1.9	0.2
	Tibetan Argali	1	1.6	13	2.435	0.9	0.1
	Himalayan Marmot	10	15.9	4	2.12	8.1	3.1
	Pika	5	7.9	0.1	1.9835	3.8	57.6
	Woolly Hare	5	7.9	2	2.05	3.9	3
	Rodent (Rat)	1	1.6	0.2	1.987	0.8	5.8

(A = Frequency of occurrence of prey, B = Estimated live weight of prey, C = Correction factor, D represents the Relative Biomass Killed (RBK), and E represents the Relative Individuals Killed (RIK).
Note: Scientific names of prey species:
Domestic prey: Domestic goat (*Capra hircus*); Domestic sheep (*Ovis aries*); Dog (*Canis lupus familiaris*); Horse (*Equus caballus*); Yak (*Bos grunniens*).
Wild prey: Blue sheep (*Pseudois nayaur*), Himalayan marmot (*Marmota himalayana*), Pika (*Ochotona* spp.), Woolly hare (*Lepus oiostolus*), Rodent/Rat (*Rattus* spp.); Stone marten (*Martes foina*), Tibetan argali (*Ovis ammon hodgsoni*), Tibetan gazelle (*Procapra picticaudata*), Kiang (*Equus kiang*), Mountain weasel (*Mustela altaica*).

frequency of occurrence of each prey species in the carnivore diet. Organizing this information allowed us to assess the dietary composition of the studied carnivores.

To estimate prey biomass, Relative Biomass Killed (RBK), Relative Individuals Killed (RIK), electivity index, and dietary overlap, we used standard regression equations and correction factors described in previous carnivore diet studies. All full equations, correction factors, and parameter definitions used in these calculations are provided in Supplementary Material (Appendix S1). The analytical steps remain identical to established methods.

Dietary overlap among red foxes, wolves, and snow leopards was quantified using Pianka's niche overlap index based on standardized RBK and RIK values, with the complete mathematical expression also presented in Appendix S1.

3. Results

3.1. Diet composition and prey selectivity

Camera traps confirmed the presence of all three carnivores within the surveyed grids, and these detections were used to support field identification of scat samples. A total of 111 scat samples were collected between September- October 2022, May to June 2023, and May to June 2024 comprising 33 from red foxes, 42 from wolves, 36 from snow leopards. The samples were analyzed to determine the dietary habits of the three sympatric carnivores. For clarity and readability, the dietary data are presented in two separate tables: Table 1A (domestic prey) and Table 1B (wild prey). The analysis revealed distinct foraging strategies and prey preferences among the three predators (Table 1**A** and Table 1**B**).

The red fox demonstrated a highly specialized diet, primarily focused on small mammals. Woolly hare (*Lepus oiostolus*) constituted the largest proportion of its diet by frequency of occurrence (26.2 %), followed by rodents (19.0 %) and pika (*Ochotona* spp.; 14.3 %). Selectivity indices (Fig. 2), however, revealed its strongest positive preferences for the smallest prey items: rodents (Ei = 67.3) and pika (Ei = 20.5), indicating a deliberate selection for these abundant, low-biomass prey.

Likewise, wolves exhibited a diet heavily reliant on ungulates, both wild and domestic. Blue sheep (*Pseudois nayaur*) were the most frequently consumed prey item (29.7 %), and it was also the most strongly preferred wild species (Ei = 104.6; Fig. 2). Wolves also

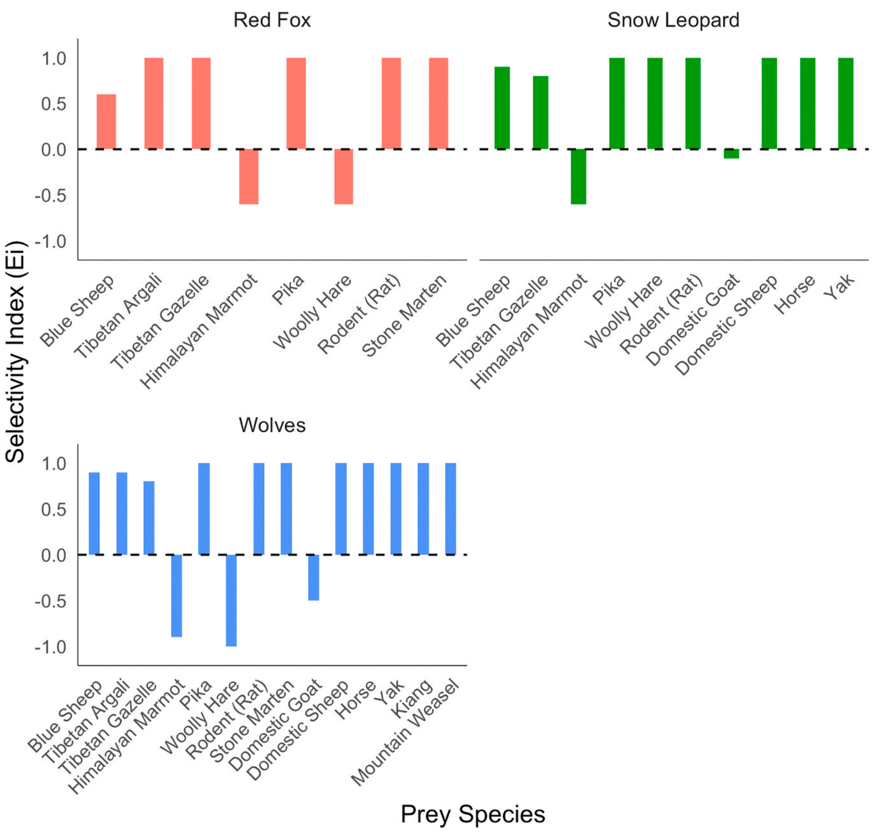

Fig. 2. Selectivity Index (Ei) of prey species for red foxes, wolves, and snow leopards. Positive values indicate preference, while negative values indicate avoidance. Red foxes and wolves showed strong selectivity for small mammals and wild ungulates, respectively, whereas snow leopards exhibited a broad prey spectrum with moderate selectivity. These patterns suggest resource partitioning among the three carnivores, reducing direct competition for prey in their shared habitat.

consumed large domestic animals, including horse (*Equus ferus caballus*) and yak (*Bos grunniens*). However, the moderate selectivity indices for these domestic species suggest their consumption was more opportunistic than preferential.

Snow leopards displayed the broadest dietary niche among the three carnivores, consuming prey ranging from small mammals to large ungulates. While blue sheep formed a significant portion of their diet (27.0 %), the analysis revealed a surprising and strong selective preference for much smaller prey. The highest selectivity index was observed for pika (Ei = 57.6; Fig. 2), indicating a pronounced preference for this small, accessible lagomorph.

3.2. Dietary overlaps

Pianka's niche overlap index was calculated to quantify the degree of dietary competition between the predator pairs. The results indicated a low dietary overlap between the red fox and both the wolf and snow leopard.

Notably, the dietary overlap between wolves and snow leopards was complex and depended on the metric used. When based on the Relative Biomass Killed (RBK), the overlap was high (Ojk = 0.79), indicating that the two species derive a similar proportion of their energy intake from prey species of similar biomass classes. However, when calculated based on the Relative Individuals Killed (RIK), the overlap was considerably lower (Ojk = 0.24; Fig. 3). This discrepancy reveals that while wolves and snow leopards target prey of similar size, they differ significantly in their numerical consumption, likely due to the snow leopard's additional reliance on a higher number of small prey individuals and its solitary foraging habitat.

3.3. Contribution of wild prey versus livestock

An assessment of the biomass contributions highlighted a critical aspect of human-carnivore conflict. Wild prey species contributed a higher proportion to the total relative biomass of individuals consumed by the predator community. However, when examining the relative biomass killed, the contribution from wild prey and livestock was nearly equal (Fig. 4).

This finding suggests that while the three predators consume a greater number of wild prey individuals overall, each livestock predation event results in a disproportionate loss of biomass. This indicates that depredation on livestock, though potentially less frequent than predation on wild ungulates in certain contexts, has a significant economic and ecological impact due to the substantial size of domestic animals like yak and horse.

4. Discussion

Our analysis of the dietary composition of three sympatric carnivores red fox, wolf, and snow leopard in the Upper Mustang region of Annapurna Conservation Area, reveals a complex picture of niche partitioning with significant dietary overlap, which suggests a potential for interspecific competition, particularly between these apex predators. To improve clarity, we streamlined repeated arguments and presented the main findings more concisely below.

The carnivores selected for this study represent a diverse group of predators with varying degrees of dietary specialization (Bocci et al., 2017; Chetri et al., 2017; Shrotriya et al., 2022). These species exhibit different foraging strategies, ranging from highly specialized predation techniques to more generalized feeding behaviors, which are influenced by their ecological roles and the availability of prey in high-altitude ecosystems (Chetri et al., 2017; Shrotriya et al., 2022).

The red fox specialized in small mammals, particularly rodents, pika, and woolly hare, as indicated by high selectivity indices. This

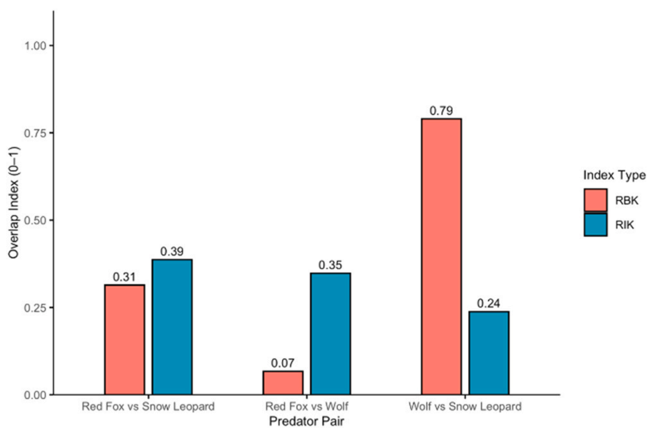

Fig. 3. Pianka's niche overlap index values among red foxes, wolves, and snow leopards based on Relative Biomass Killed (RBK) and Relative Individuals Killed (RIK). Higher values indicate greater dietary similarity between predator pairs. RBK reflects prey biomass contribution, while RIK represents the number of individuals consumed. Overlap is high in terms of biomass but low in individual prey numbers, suggesting that while predators exploit similar prey types in terms of energy, they partition resources by targeting different numbers of individuals, reducing direct competition.

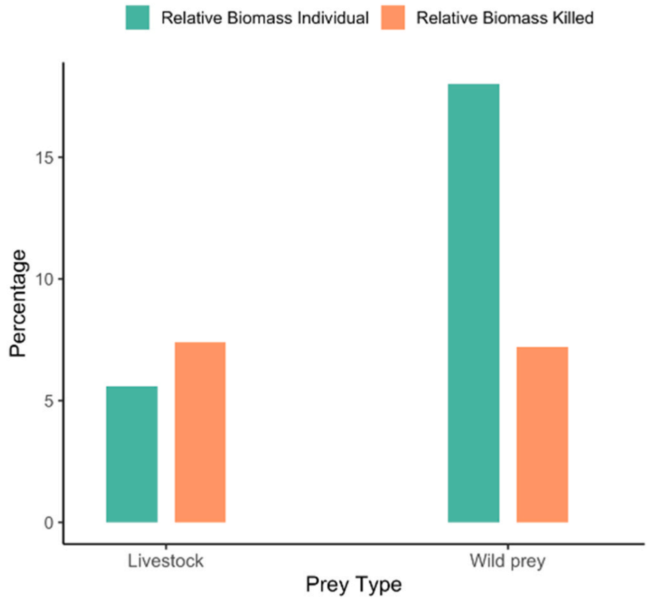

Fig. 4. Relative biomass of individuals and biomass killed to prey type by predators (red foxes, wolves, and snow leopards). Wild prey dominated overall consumption, but livestock contributed equally to biomass killed, indicating notable depredation impact. This pattern highlights that predators rely primarily on wild prey for nutrition while also exploiting livestock, suggesting potential for human-wildlife conflict in the study area.

narrow dietary niche effectively reduces direct competition with larger carnivores, a common strategy for coexistence (Gómez-Ortiz et al., 2015). Occasionally larger prey remains, such as blue sheep, likely reflect scavenging rather than active predations, a behavior frequently observed in Trans-Himalayan studies (Ferretti et al., 2021; Reshamwala et al., 2018). This opportunistic scavenging allows the red fox to exploit resources without directly competing for kills.

The high dietary overlap between wolves and snow leopards (Pianka's index: 0.79 based on biomass) indicates substantial potential for exploitative competition. This overlap was notably presented once to avoid unnecessary repetition. higher than that reported in central Nepal (0.44; Chetri et al., 2017) but aligns with findings from other regions like western Nepal (0.82; (Shrestha et al., 2019) and Pakistan (0.74; Bocci et al., 2017). This suggests that competitive dynamics are highly context-dependent, varying with local prey availability and habitat structure (Lyngdoh et al., 2020). Although both species rely on ungulates, the contrast between the high RBK overlap (0.79) and low RIK overlap (0.24) highlights differences in prey size and hunting strategies: Wolves, as pack hunters, more frequently utilize large domestic ungulates, while snow leopard focus more on wild ungulates like blue sheep (Lovari et al., 2013; Wang et al., 2014).

The heavy dependence of wolves and snow leopards on livestock in our study among the highest reported in their ranges (Chetri et al., 2017; Lyngdoh et al., 2020; Werhahn et al., 2019), likely results from both low wild prey density (Berger et al., 2013; Singh and Milner-Gulland, 2011) and the high livestock abundance in the region (Khanal et al., 2020). While livestock currently subsidizes the predator populations, this reliance intensifies human-carnivore conflict and increases the risk of retaliatory killings (Nowell, 2016; Sonam et al., 2022). If livestock availability declines, competition between wolves and snow leopards may further intensify due to pressure on the limited wild prey base (Steinmetz et al., 2021).

Our prey selectivity results provide important ecological insight. Snow leopard's exhibited strong selectivity for the relatively small Himalayan marmot and pika, smaller, more abundant, and easier to capture prey suggesting a risk-reward trade-off strategy that complements their dependence on wild ungulates (Kachel et al., 2022; Schaller et al., 1988). Wolves also shows notable selectivity for yak and domestic dogs, indicating human-modified landscapes directly influence prey choices, and create new ecological interactions.

Although dietary overlap was substantial, we condensed previously repeated arguments about spatial and temporal segregation. Spatial separation (Wolves in open valley, snow leopards in rugged terrain and differing activity patterns likely reduce direct encounter (Habib et al., 2013; Watts et al., 2019).

To ensure that these ecological findings translate into practical conservation actions, it is essential to align them with the responsibilities of key management stakeholders in Upper Mustang. The Annapurna Conservation Area Project (ACAP) and the Department of National Parks and Wildlife Conservation (DNPWC) are positioned to lead wild ungulate recovery programs, regulate grazing pressure, and strengthen livestock-protection and compensation schemes. At the community level, Conservation Area Management Committees (CAMCs) and herder groups are central to implementing predator-safe corrals, improving herding practices, and engaging in conflict-mitigation initiatives. Linking dietary outcomes to these stakeholder roles enhances the real-world applicability and effectiveness of prey-augmentation and conflict-reduction strategies in the region.

We acknowledge limitations in our study. The sample size, though informative, was limited and collected over a relevant season. Our scat samples were collected only during specific months within 2022–2024; therefore, seasonal dietary shifts common in

Himalayan ecosystems may not be fully captured. This is an important limitation and future work should include multi-season sampling to clarify temporal dietary changes. Additionally, prey identification relied on morphological scat analysis, which carries inherent risks of misidentification. Using DNA metabarcoding in future studies could improve accuracy and reduce bias (Ando et al., 2020).

5. Conclusion

This study elucidates the intricate diet compositon and resource partitioning among three sympatric carnivores in the high-altitude ecosystem of Upper Mustang region. Our analysis confirms distinct predator foraging strategies: the red fox operates as a specialized mesopredator strongly reliant on small mammals, the wolf functions as a generalist apex predator capable of switching between wild and domestic ungulates, and the snow leopard exhibits a flexible feeding strategy, utilizing both large wild prey and smaller, accessible species. A critical finding is the significant dietary overlap, particularly in biomass consumption, between snow leopards and wolves, indicating a tangible potential for exploitative competition. This competition is likely driven by a constrained wild prey base, which forces both apex predators to rely heavily on livestock, as evidenced by the disproportionate biomass contribution of domestic species to their diets. This high dependence on livestock underscores a severe risk of human-carnivore conflict and retaliatory killing. Effective long-term management will require coordinated actions from relevant agencies. ACAP and DNPWC should prioritize wild ungulate recovery, regulate grazing pressure, and strengthen compensation and insurance schemes, while community-level bodies such as Conservation Area Management Committees (CAMCs) and herder groups can implement predator-safe corrals and improved livestock-herding practices. Integrating these stakeholder-specific measures with landscape-level planning that considers spatial and temporal predator segregation will help reduce conflict and support predator coexistence. Ultimately, addressing prey scarcity and improving community based conflict mitigation are essentials steps toward maintaining ecological balance and ensuring the long-term persistence of carnivore populations in the trans-Himalayan region.

CRediT authorship contribution statement

Naresh Subedi: Visualization, Validation, Supervision, Resources, Investigation, Conceptualization. **Bishnu Prasad Bhattarai:** Writing – review & editing, Validation, Supervision, Methodology, Investigation, Data curation. **Bishal Subedi:** Project administration, Methodology, Data curation. **Ganesh Bahadur Thapa:** Writing – review & editing, Resources, Data curation. **Ashok Subedi:** Resources, Project administration, Methodology, Data curation. **Rajan Prasad Paudel:** Writing – review & editing, Validation, Resources, Methodology. **Rabin Kadariya:** Validation, Supervision, Resources. **Bed Kumar Dhakal:** Supervision, Resources. **Michito Shimozuru:** Writing – review & editing, Validation, Supervision, Resources, Methodology, Investigation, Conceptualization. **Toshio Tsubota:** Writing – review & editing, Visualization, Validation, Supervision, Resources, Methodology, Investigation, Funding acquisition, Conceptualization. **Rishi Baral:** Writing – review & editing, Writing – original draft, Validation, Software, Resources, Project administration, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the author used ChatGPT to improve the readability, grammar, and overall clarity of the manuscript. After using this tool, the author carefully reviewed, edited, and verified all content, and takes full responsibility for the integrity and accuracy of the manuscript.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.gecco.2025.e04037.

Data Availability

Data will be made available on request.

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