

Between skies and shrinking spaces: Understanding distribution and threats to raptors in Ladakh

Ajaz Hussain, Mriganka Shekhar Sarkar, Anchal Bhasin, Tribhuwan Singh, Asif Hussain & Pankaj Raina

Hussain, A., Sarakar, M. S., Bhasin, A., Singh, T., Hussain, A., & Raina, P., 2025. Between skies and shrinking spaces: Understanding distribution and threats to raptors in Ladakh *Indian BIRDS* 21 (4): 109–114.

Ajaz Hussain, Department of Wildlife Protection Leh, UT Ladakh, 194101, India. Email: spengku1913@gmail.com [AJH] [Corresponding author]

Mriganka Shekhar Sarkar, North East Regional Centre, G.B. Pant National Institute of Himalayan Environment, Chandranagar (Near Neni Hyundai Service), Itanagar - 791113 Arunachal Pradesh, India. Email: mriganka.bio@gmail.com [MSS]

Anchal Bhasin, Department of Wildlife Protection Leh, UT Ladakh, 194101, India. Email: anchalbhasin1310@gmail.com [AB]

Tribhuwan Singh, Wildlife Institute of India, Dehradun, Uttarakhand, 248001, India. Email: treebhoovana@gmail.com [TS]

Asif Hussain, O/o Lt. Governor Ladakh, Leh, UT Ladakh 194101, India. Email: hussain.asif6@gmail.com [ASH]

Pankaj Raina, Department of Wildlife Protection Leh, UT Ladakh, 194101, India. Email: pankaj.acf@live.com [PR]

Manuscript received on 04 September 2024.

Abstract: Bird species that scavenge and hunt prey play a vital role in the ecosystem. However, there is limited information on raptors and their distribution in the Trans-Himalayan regions of India. The current study was conducted in Ladakh between March 2018 and November 2023 to document the diversity, distribution, nesting sites, and threats of various raptors belonging Accipitridae, Falconidae, and Strigidae families in Ladakh. In total, 196 villages were surveyed in Kargil and Leh district during field surveys. A total of 50 trails and road routes were surveyed, covering a combined distance of 2,116 km across various habitats. A total of 886 individuals of 27 raptor species were recorded during the study including three species recognized as Endangered, and four as Near Threatened. Encounter rates of 15 regularly occurring raptors were derived. Bearded Vulture *Gypaetus barbatus* and Himalayan Vulture *Gyps himalayensis* were the most abundant and widely distributed scavenging raptors. Black Kite *Milvus migrans* and Golden Eagle *Aquila chrysaetos* were the most abundant predatory raptors in the landscape. A total of 52 nesting sites were recorded in the study site of which 13 were of Bearded Vulture. Three major threats that were identified by the community were free-ranging dogs, habitat degradation, and unregulated mass tourism. Long-term monitoring of raptors in the Ladakh landscape must continue with focus on population status, threats, and conservation challenges.

Introduction

Raptors are recognized as ecological indicator species as they occupy a high trophic level in the food web (McClure et al. 2019). These also include scavenging species that are instrumental in maintaining environmental health, help limit the spread of pathogens, and provide other key ecosystem services (O'Bryan et al. 2018). Raptors often serve as iconic flagship species for biodiversity conservation programmes and cultural symbols around the world (Sergio et al. 2008; Donazar et al. 2016). Although raptors are generally easy to detect, their relatively low population densities, except in migration bottlenecks, may contribute to the limited monitoring focus on them (Farmer et al. 2007). The use of diclofenac, an anti-inflammatory drug administered to livestock, has led to a catastrophic decline in vulture populations, particularly in South Asia (Prakash et al. 2003). The vulture population in the Indian subcontinent declined by around 90% due to the concentration of diclofenac administered to cattle and consumed by these birds (Green et al. 2004). However, detection of such a precipitous decline took a decade of monitoring and research to establish; indicating several other moderate raptor declines may have gone unnoticed. Globally, raptors are threatened by pollution, both indiscriminate and targeted, as well as habitat destruction and degradation (McClure 2025); all of them are broadly applicable to India as well (SolB 2023).

Globally, there are 561 recognized raptor species (McClure 2025) of which 112 have been reported from India (Praveen 2025); c.20% of the world's raptor species. Despite its rich species diversity, studies of raptors in India have been quite patchy with very few long-term studies barring the vultures

(Mahananda et al. 2022; Subedi et al. 2025). Despite the Himalayan landscape being a crucial habitat for both migratory and resident raptor species (Subedi et al. 2025), there are very few studies on raptors from the Indian Himalaya (Arya et al. 2021; Kumar et al. 2022). This includes Ladakh, which lies within the trans-Himalayan biogeographic zone, and comprises approximately 80% of India's trans-Himalayan zone (Rodgers & Panwar 1988). Ladakh serves as an essential staging ground for migratory birds along the Central Asian Flyway. However, due to its geographical position and habitats, the region hosts only about 25% of India's diverse avifauna, a sizeable number of them being passage migrants (eBird 2025; Praveen 2025). It also provides a breeding habitat for some raptors and various prey species for raptors, including the Bar-headed Goose *Anser indicus*, Ruddy Shelduck *Tadorna ferruginea*, and Great Crested Grebe *Podiceps cristatus*.

Avifaunal studies in Ladakh began in the 19th century (Adams 1859; Hume 1873; Richmond 1896) and continued extensively through the early and mid-20th century with significant contributions from ornithologists (Osmaston 1925, 1926; Koelz 1940). These studies laid a foundational understanding of Ladakh's birdlife, followed by later surveys, and distributional updates (Holmes 1986; Pfister 1997, 2004; Sangha & Naoroji 2006; Tak et al. 2008; Delany et al. 2014; Ahmed et al. 2019; Bhardwaj & Sen 2021). A few specific raptors in Ladakh have also undergone more detailed studies beyond a mere report, such as the Golden Eagle *Aquila chrysaetos* (Naoroji & Sangha 2004; Naoroji 2006), Saker Falcon *Falco cherrug* (Sangha et al. 2014), Upland Buzzard *Buteo hemilasius* (Naoroji & Forsman 2001), and the Long-eared Owl *Asio otus* (Stanba 2022). A recent study

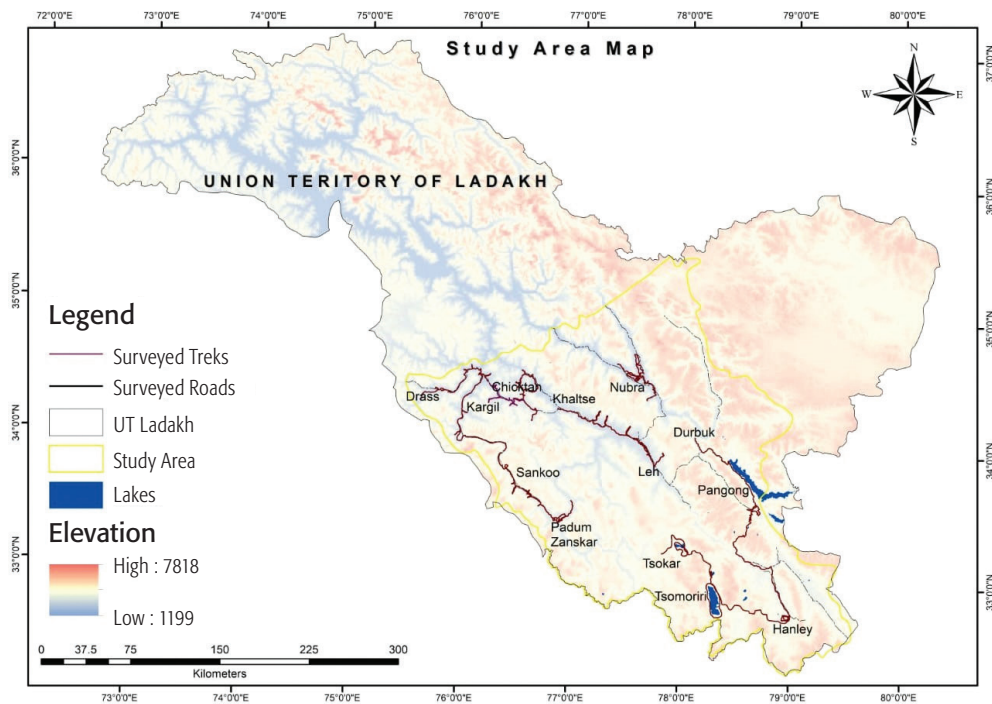


Fig. 1. The map of study area with distribution of bird survey treks and routes.

on raptors encounter rate and active nesting sites was carried out in the eastern parts of Ladakh (Srinivasan et al. 2024). Although research on the avifauna of Ladakh has documented various bird sightings and behaviours over the years, there remains a substantial gap in understanding the distribution, threats, and conservation needs of raptors in the Indian Himalaya, especially in Ladakh (Srinivasan et al. 2024).

This study aims to address these critical gaps by mapping raptor distribution, identifying crucial habitats, and nesting sites in Ladakh. Additionally, it seeks to evaluate the primary threats these species are facing, providing essential information for conservation efforts. The findings of this research are expected to be valuable inputs for conservation planning, ensuring the preservation of raptor populations in this ecologically sensitive region.

Methods

Study area

Ladakh (32° – 36° N and 75° – 80° E) is an arid, high-altitude landscape with diverse mountain ranges dotted with lakes, wetlands, and vegetation patches along rivers and mountain steppe. Our study area lies in the Indian-administered part of the Ladakh union territory (Fig. 1). Here, human settlements are concentrated along the Indus River System and its tributaries that drain this landscape; including the Suru, Zangskar, Nubra, and Shayok, which are fed by streams such as Kanji, Wakha, Drass, etc. (Fig. 1). These valleys include small agricultural fields, plantations, fruit orchards, wetlands, and, pasturelands. The eastern part of Ladakh includes many lakes, arid grasslands, and wetlands, which serve as critical habitat for many wildlife species. The altitudinal range of the study area lies between 2,600 and 7,200m asl, and the temperature ranges from -30°C in the winter to $+35^{\circ}\text{C}$ in the summer. Currently, there are three protected areas, namely Hemis National Park, Changthang Cold Desert Wildlife Sanctuary, and Karakoram Wildlife Sanctuary and two Ramsar sites, Tsomoriri (Ramsar site no. 1213/120 km²) and Tso Kar

(Ramsar site no. 2443/96 km²). These protected area networks and important wetlands in Changthang, Suru, Drass, and Rangdum areas attract a diversity of breeding birds. These areas also serve as important staging grounds for species that migrate between Central Asia and the Indian subcontinent and beyond.

Distribution surveys

The study was carried out between March 2018 and November 2023 through road transect and trail walks (Bibby et al. 2000). A total of 196 villages from the landscape of Ladakh were surveyed by vehicle survey and trail walks covering all the seasons (Fig. 1). During the field survey, we walked 33 trails, totalling 462 km (each between 3 to 9 km), passing through riverine valleys, wetlands, lakes, human habitation, mountain

passes, pasture lands, small forest patches and agricultural fields of various localities between the elevation of 2,750 – 5,950 m asl. A total of 1,654 km was surveyed by road transect with four-wheelers (open hood gypsy) at a constant speed of 20 –30 km/hr, mainly in summer. (Fig. 1).

Observations were conducted to prevent double counting by documenting the species identified, flock size, flight direction, and the date and time of each sighting (Arya et al. 2021). The raptor survey was conducted once a week, on average, between 0700 and 1130 hours and between 1300 and 1800 hours. The full details of survey months in different trails and roads are provided in Supplementary Table 1.

Using a pair of Nikon 8×40 field binoculars, we observed and identified raptors, recording their presence and numbers. Further, during analysis, we categorized them based on habitat, migration status, conservation status, and threat category using field guides and reference books (Ali & Ripley 1983; Pfister 2004; Grimmett et al. 2011; Rasmussen & Anderton 2012; SolB 2023; Praveen 2025). Many birds observed during the survey were photographed using a Nikon 7000 camera for record and identification. However, unidentified birds (3.27% of total observation) were not included for further data analysis. Encounter rate was calculated by dividing the number of observations of each species by the total distance covered for that transect. As there was no specific standard for classifying raptors as predatory and scavenging, we used a number of references (Ali & Ripley 1983; Naoraji 2006) for each species to deduce the right classification for the same; most of them were in fact obvious (e.g., vultures are scavengers). We do not report encounter rates or flock size when the sample size is low.

To examine whether encounter rates differed among bird groups with different migratory statuses, a one-way Analysis of Variance (ANOVA) was conducted using Migratory Status (i.e., Summer Visitor, Winter Visitor, Passage Migrant, and Resident) as the categorical independent variable. Following the ANOVA,

Tukey's Honest Significant Difference (HSD) test was performed for post-hoc pairwise comparisons between groups. Statistical significance was assessed at the 0.05 level.

Nest Surveys and Monitoring

Nest monitoring was carried out opportunistically during field surveys, with local villagers providing information on nest locations near their villages. Field visits were conducted to verify and record nest locations for mapping. In some cases, identified nests were monitored during subsequent visits, but most appeared to be used only for resting, as no clutch was observed. Additionally, villagers provided insights into year-round nesting activity, helping to determine raptor presence across different seasons. The distribution and nesting sites of raptors were mapped using 1,512 GPS locations collected during field surveys and analysed in ArcGIS 10.8.1. All statistical analyses were conducted using R version 4.4.1 (R Core Team 2021).

Threat Information Gathering

Community interactions and focal group discussions were conducted to gather information on threats to raptors, their cultural

significance, and their sighting frequency in surveyed villages. Villagers provided insights into habitat changes, disturbances, and other potential threats affecting raptor populations. This information was crucial for understanding human-raptor interactions and assessing conservation challenges in the study area.

Results

Raptor diversity and conservation status

During the field survey between 2018 and 2023, 886 individuals of 27 raptor species (Table 1) belonging to Accipitridae, Strigidae, and Falconidae were reported from seven survey routes in Ladakh. This included 76 individuals from four species of scavenging raptors and 810 individuals from 23 species of predatory raptors. Amongst these, three species (Egyptian Vulture *Neophron percnopterus*, Steppe Eagle *Aquila nipalensis* and Saker Falcon) are listed as Endangered by the IUCN and four (Bearded Vulture *Gypaetus barbatus*, Cinereous Vulture *Aegypius monachus*, Himalayan Vulture *Gyps himalayensis*, and Mountain Hawk-Eagle *Nisaetus nipalensis*) as Near Threatened (Table 1). Among the 27 raptor species, 21 raptor species are under Schedule I and six raptors under Schedule II of the Wildlife

Table 1. Status and details of the raptors recorded during the survey in Ladakh.

Migration Status: SV: Summer Visitor, WV: Winter Visitor, PM: Passage Migrant, R: Resident, U: Uncertain

IUCN Red List: CR: Critically Endangered, EN: Endangered, NT: Near Threatened VU: Vulnerable, LC: Least Concern.

SoIB Status: H: High, M: Moderate, L: Low.

Encounter rate and flock size calculated only when sufficient encounters were recorded.

Species	Encounter rate	Flock size (Mean \pm SD)	Migratory Status	WLPA Schedule	IUCN Red List	SoIB
Family: Accipitridae						
Bearded Vulture <i>Gypaetus barbatus</i>	2.42	1.5 \pm 0.9	R	I	NT	H
Egyptian Vulture <i>Neophron percnopterus</i>	-	-	U	I	EN	H
Oriental Honey-buzzard <i>Pernis ptilorhynchus</i>	2.13	1.0 \pm 0.0	PM	II	LC	L
Cinereous Vulture <i>Aegypius monachus</i>	-	-	PM	I	NT	M
Himalayan Vulture <i>Gyps himalayensis</i>	1.29	1.8 \pm 2.1	R	I	NT	M
Mountain Hawk-Eagle <i>Nisaetus nipalensis</i>	-	-	PM	I	NT	L
Booted Eagle <i>Hieraaetus pennatus</i>	1.07	1.2 \pm 0.7	PM/SV	I	LC	L
Steppe Eagle <i>Aquila nipalensis</i>	-	-	PM	I	EN	L
Golden Eagle <i>Aquila chrysaetos</i>	2.64	1.4 \pm 0.7	R	I	LC	L
Eurasian Sparrowhawk <i>Accipiter nisus</i>	4.10	1.1 \pm 0.5	SV/PM	I	LC	L
Northern Goshawk <i>Astur gentilis</i>	-	-	PM	I	LC	L
Western Marsh Harrier <i>Circus aeruginosus</i>	-	-	PM	I	LC	H
Hen Harrier <i>Circus cyaneus</i>	-	-	PM/WV	I	LC	M
Black Kite <i>Milvus migrans</i>	19.21	7.5 \pm 18.6	SV/PM	II	LC	L
Common Buzzard <i>Buteo buteo</i>	1.63	1.1 \pm 0.3	WV/PM	I	LC	L
Long-legged Buzzard <i>Buteo rufinus</i>	1.4	1.2 \pm 0.8	SV	I	LC	L
Upland Buzzard <i>Buteo hemilasius</i>	1.74	1.6 \pm 1.0	R	I	LC	
Himalayan Buzzard <i>Buteo refectus</i>	2.36	1.1 \pm 0.4	WV/PM	I	LC	
Family: Strigidae						
Eurasian Eagle-Owl <i>Bubo bubo</i>	0.22	1.4 \pm 0.5	R	I	LC	
Little Owl <i>Athene noctua</i>	0.9	1.4 \pm 0.7	R	II	LC	
Long-eared Owl <i>Asio otus</i>	-	-	PM	I	LC	
Short-eared Owl <i>Asio flammeus</i>	-	-	PM	I	LC	L
Family: Falconidae						
Lesser Kestrel <i>Falco naumanni</i> (?)	-	-	U	II	LC	
Common Kestrel <i>Falco tinnunculus</i>	3.88	1.4 \pm 0.9	R	II	LC	H
Eurasian Hobby <i>Falco subbuteo</i>	-	-	SV	II	LC	L
Saker Falcon <i>Falco cherrug</i>	0.22	1.0 \pm 0.0	R/PM	I	EN	H
Peregrine Falcon <i>Falco peregrinus</i>	-	-	PM	I	LC	L

(Protection) Amendment Act, 2022 (Table 1). In India, five of them (Bearded Vulture, Egyptian Vulture, Western Marsh Harrier *Circus aeruginosus*, Common Kestrel *Falco tinnunculus*, and Saker Falcon) are classified as High Conservation Priority as per SolB (2023) and three as Moderate (Table 1).

The analysis of the data revealed that a major proportion of the raptors recorded during the surveys were summer visitors (49%), followed by passage migrant species (37%), and residents (14%) (Table 1). ANOVA followed by Tukey's multiple comparisons revealed no significant effect of Migratory Status on the encounter rate ($p = 0.431$) of different groups of Migratory Status. Pairwise comparisons between groups also indicated no significant differences.

The present study recorded nearly 95% of the regular occurring raptors in our study area (eBird 2025). We were able to calculate encounter rates and flock size for 15 regularly occurring raptors of Ladakh. Among the scavenging raptors, Bearded Vulture was the most recorded species and widely distributed, followed by the Himalayan Vulture. The overall encounter rate for scavenging raptors was 0.07 birds/km, with the Bearded Vulture exhibiting the highest encounter rate (2.42 birds/km), followed by the Himalayan Vulture (1.29 birds/km) (Table 1). In contrast, the encounter rate for predatory raptors was significantly higher at 1.87 birds/km, with the Black Kite *Milvus migrans* having the highest encounter rate (19.21 birds/km), followed by the Eurasian Sparrowhawk *Accipiter nisus* (4.1 birds/km), and the Common Kestrel (3.88 birds/km) (Table 1).

Raptor distribution

During the survey, Bearded Vultures and Himalayan Vultures were mostly recorded near summer cattle camps in summer. In contrast, we recorded only Bearded Vulture near villages in winter (seasonal encounter rates of raptor species provided in Table 2 of supplementary file). We found that most scavenging raptors tend to soar over summer livestock camps and prefer to roost on steep mountains and rocky cliffs. Based on the field survey, we found that the distribution of scavenging raptors in Ladakh is clustered around summer and winter cattle camps used by local herders (Fig. 2). During the field survey, we recorded Bearded Vulture in all the seven study sites, while Himalayan Vulture was recorded only near the summer and winter cattle camps in all the study sites. The Bearded Vulture seems to be Ladakh's main resident scavenging raptor.

Black Kite, Eurasian Sparrowhawk, Common Kestrel, and Himalayan Buzzard, were seen near human habitations, small

forest patches, or agricultural areas. On the other hand, Oriental Honey-Buzzard *Pernis ptilorhynchus*, Upland Buzzard *Buteo hemilasius*, Mountain Hawk-Eagle *Nisaetus nipalensis*, Hen Harrier *Circus cyaneus*, Long-Legged Buzzard *B. rufinus*, Northern Goshawk *Astur gentilis*, and Western Marsh Harrier were recorded in wetlands and marshlands in the region. Saker Falcon, Booted Eagle *Hieraaetus pennatus*, Little Owl *Athene noctua*, and Eurasian Eagle-Owl *Bubo bubo* were recorded in wetlands, marshlands, or pasturelands.

Among the raptors documented, the least frequently observed species, with fewer than three sightings, included the Egyptian Vulture, which was spotted near the Khumbuthang Army Cantonment Area and Sankoo Town during the summer field survey of June and July 2021. A putative Lesser Kestrel was observed near Upshi Bridge, close to agricultural fields on 27 October 2022. The Cinereous Vulture was recorded in the Chicktan Valley, at two distinct locations: Chulichan and Yokmakharboo. The Short-eared Owl *Asio flammeus* was documented in the Shey marshes inside densely planted areas. The Long-eared Owl *Asio otus* was observed at Loma bridge in the Changthang Wildlife Sanctuary, located at an elevation of approximately 4,100 m above sea level, on 09 October 2021. In addition, there was a single sighting of the Eurasian Hobby during the survey in Shayok Valley in Karakoram Wildlife Sanctuary on 10 September 2022. However, Eurasian Hobby is regular in the landscape of Ladakh, particularly in the Shey marshes, along the valleys of Indus and Suru Valley, during summer. Details of sighting location coordinates of these least frequent species are available in Table TS3 in supplementary files.

Raptors nesting and roosting sites

During the field survey, 52 nesting sites of both scavenging and

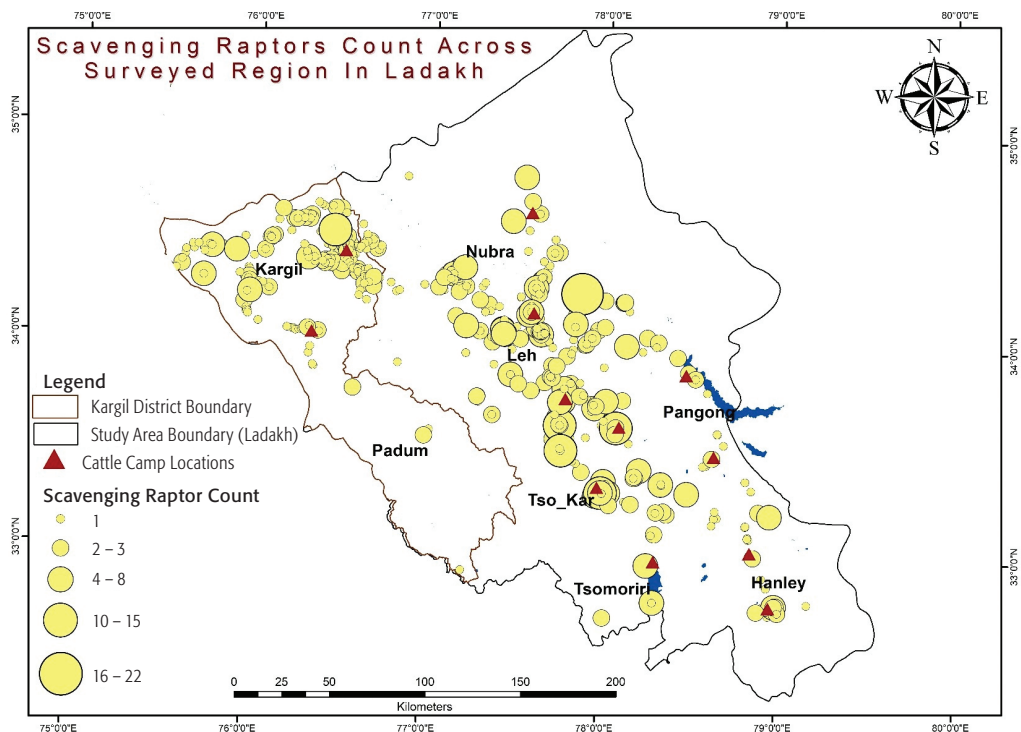


Fig. 2. The distribution map of scavenging raptors across the surveyed region in Ladakh, represented through a bubble plot, illustrates their spatial presence in relation to cattle camps. The yellow bubbles indicate the frequency of scavenging raptor sightings, with larger bubbles representing areas of higher sightings, while smaller bubbles indicate relatively lower occurrences. The overlay of cattle camps provides insight into potential influences on raptor distribution, suggesting a possible correlation between the availability of livestock carcasses and raptor congregation.

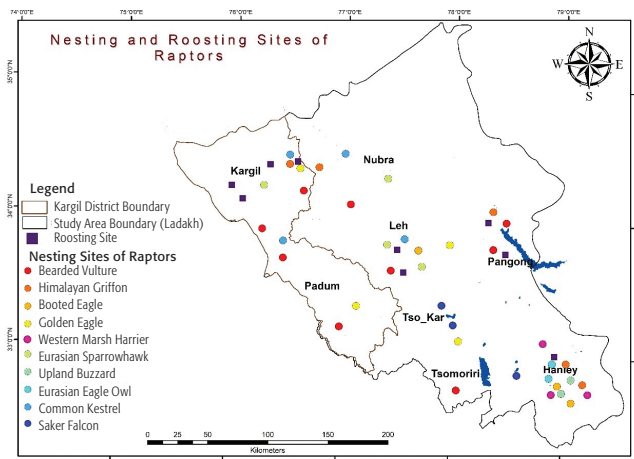


Fig. 3. Map showing locations of nesting and roosting sites of raptors across surveyed region in Ladakh.

predatory raptors were recorded, all situated on rocky cliffs (Fig. 3). We identified 13 occupied nest locations of Bearded Vultures in Lukung Pangong, Chiktan Valley, Warila Pass, Tanglangla Pass, Giya Meru, and Kukshow. Notably, only three Bearded Vulture nests remained active throughout the study period, and all the nests were on rocky cliffs. Additionally, two Himalayan Vulture nests were recorded, one in Chiktan Valley and the other in Digar. During the field survey, we identified nine roosting sites across the region. Specifically, we found three roosting sites in the Kargil district area, all of which were used by the Black Kite. In Leh, we identified two roosting sites used by the Black Kite, while in Pangong, we found two roosting sites used by the Himalayan Vulture. Additionally, we located one roosting site near Hanle and one in Wari-la, which the Himalayan Vulture also used. The nesting and roosting patterns highlight habitat preferences tied to specific land-use types, particularly the clustering of scavenging raptors near summer and winter cattle camps used by local herders (Fig. 2).

Threats

A total of 44 community interactions and focus group discussions were conducted across the Ladakh region to assess the threats faced by raptors (Fig 4). Among the participants, 74.1% identified free-ranging dogs as a major threat to raptors, while the remaining considered them a minor concern, particularly in Muslim-majority areas, where such dogs are less common. Poaching was largely seen as a low-level threat, with 88.9% of respondents downplaying its severity. In tourist-dense areas, 70.4% of respondents flagged over-tourism as a concern, especially due to off-roading by heavy vehicles and motorcycles and camping in ecologically sensitive zones that support raptor prey species. Habitat degradation emerged as a worry, with 66.7% rating it as a high threat and the rest viewing it as less serious, highlighting growing anxiety over habitat loss from human activities. Climate change and high-tension power lines were considered low threats by 70.4% of respondents. This perception may reflect a general lack of awareness, as only few raised these issues during discussions.

Discussion

During the study, we recorded three out of the four raptor families known to occur in Ladakh including 87% species known from this region. The only family not observed during fieldwork was Pandionidae. Additionally, Tytonidae, a family of nocturnal raptors found elsewhere in India, is not present in Ladakh. We found that

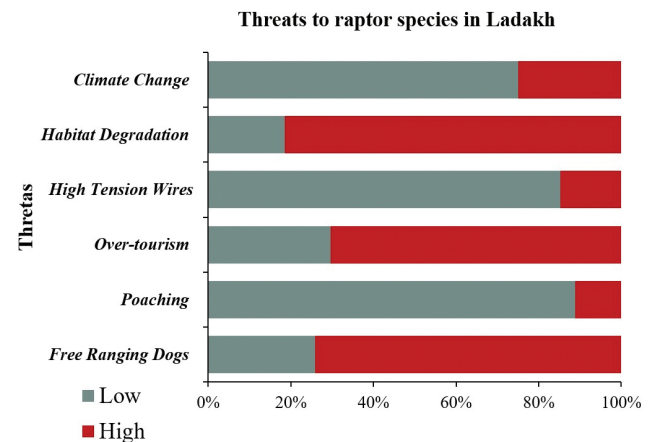


Fig. 4. Graph showing the percentage of community responses to various threats to raptors, based on issues identified during community interactions.

raptor species like Bearded Vulture, Himalayan Vulture, Golden Eagle, Black Kite, Common Kestrel, and Eurasian Sparrowhawk are the most abundant and widely distributed raptors in our study area, the first two occurring near cattle camps, particularly in the summer. This is probably because livestock density is higher in summer than winter cattle camps, which provides ready access to livestock carcasses. Our result is similar to that of Srinivasan et al. (2024) who found the maximum encounter rates for these two vultures. In contrast, the Eurasian Eagle-Owl and Little Owl were primarily observed in wetlands and pasturelands. This is probably due to rodents and small birds in such habitats, which constitute the primary prey species for owls. Our results also indicated that agricultural areas, human habitations, and riverine habitats have a higher concentration of small predatory raptors as these areas serve as habitats and nesting sites for small bird species.

The identification of active raptor nests is important from a long-term point of view for annual monitoring. For landscapes like Ladakh where the cost of maintaining long-term surveys is high, monitoring the active nests like ours and Srinivasan et al. (2024) provides a decent surrogate of population status and hence may provide early indications of declines. Most of these nests are exclusively found on slopes, inaccessible cliff faces, which naturally safeguard them from most direct human disturbances, and hence, any decline in nest-occupancy or nesting success is likely to relate to more landscape level changes than anything at the immediate proximity.

To date, no focused study has been conducted on threats to raptors in the Indian Trans-Himalaya. However, a few recent studies have addressed broader threats to wildlife in the region, particularly the impacts of free-ranging dogs on wildlife and anthropogenic pressures on birds (Naoraji & Sangha 2011; Mahar et al. 2024). In the present study, we realize that the community already realizes the threat posed by free-ranging dogs to the raptors in Ladakh along with habitat degradation. Though raptors spend considerable time in the air, away from the purview of free-ranging dogs, many raptors frequent wetlands and marshlands, where they hunt small mammals on the ground, such as voles *Microtus* spp., pikas *Ochotona* spp., and birds. During our field surveys, we observed multiple instances of free-ranging dogs actively chasing raptors in wetlands, marshlands, and pasturelands. In one notable incident, a pack of dogs was seen chasing a wake of Himalayan Vultures feeding on a Himalayan Marmot *Marmota himalayana*, eventually snatching the carcass

from them. This interaction highlights how free-ranging dogs not only pose direct threat to raptors but also disrupt their access to their prey.

Conclusion

The diverse landscape of Ladakh supports foraging, roosting, and breeding habitats for 15 raptor species that were regularly encountered during our study. This includes four species classified as of High Conservation Priority (SolB 2023). The identification of multiple nesting and roosting sites provides an opportunity for a long-term monitoring to study the population of raptors that are resident or summer visitors. Increasing population of free-ranging dogs and ongoing habitat degradation emerge as the most immediate concerns for raptor populations. Hence, this study provides critical baseline information on the status, distribution, and threats facing raptors in the trans-Himalayan region of Ladakh.

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