Encounter rates and active nests of raptors in the Indian Trans-Himalaya: Towards a long-term monitoring program

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Abstract:
Raptor populations are declining worldwide, including in India, where populations of several open-landscape raptors are of concern. To understand these declines, monitoring trends in raptor populations is crucial, especially in the long-term. We set up two long-term raptor monitoring projects in Spiti and Ladakh in the Trans-Himalaya, an understudied region for raptors in India, with the goal of monitoring raptor populations over time. To understand patterns of abundance and distribution, we counted raptors along 10 transects laid along roads in valleys, gorges and rolling hills in both regions, twice a year. We calculated overall and species-specific encounter rates per kilometre. To understand breeding raptor populations at the landscape scale in Ladakh, we also enumerated the number of active nests of raptors during peak nesting times, along the same roads. Initial results from two and a half years of raptor monitoring in Spiti and half a year in Ladakh suggest that Spiti harbours relatively lower numbers of raptors that hunt prey when compared to scavenging raptors than Ladakh. We recorded eight species of raptors across both regions and the overall encounter rates of raptors in these regions ranged from 18 (95% CI: 12–23) to 61 (50–72) individuals/100 km, which were higher than or similar to those in other steppe habitats worldwide. We found 58 nests across the landscape in Ladakh, with the nests of the Golden Eagle being the most abundant (n = 17), followed by vultures (n = 16). The overall number of active nests was low (n = 11), and several nests were old and potentially used in previous years. Because raptors use multiple nests in their territory, monitoring unused nests could help understand patterns of nest occupancy in the long-term. We hope that over time, these long-term raptor monitoring projects will help us understand the population trends of raptors across Spiti and Ladakh.

Introduction

Raptors (birds of prey) are apex predators, exhibiting top-down pressures on the ecosystem, thereby helping stabilize food webs and maintain biodiversity (Sergio et al. 2005; Sekercioglu 2006; Ritchie & Johnson 2009; Buechley & Şekercioğlu 2016). Because they provide key ecosystem services, such as nutrient recycling, they are used as potential ecological indicators of the habitat and are often characterized as flagship or umbrella species (Sergio et al. 2008; Donázar et al. 2016; McClure et al. 2018). They also play an important role in the culture of human communities and are known to aid in human well-being (Helander et al. 2008; Lu et al. 2009; Negro 2018; O'Bryan et al. 2018) and some species are closely tied to human activities (Kumar et al. 2018).

Their high position in the trophic level, combined with low population densities and low fecundities, makes raptors disproportionately more vulnerable to extinction than taxonomic groups worldwide (McClure et al. 2018; O'Bryan et al. 2022) and their decline in recent decades has been documented globally (Ogada et al. 2016; Ganesh & Prashanth 2018; McClure & Rolek 2020; Shaw et al. 2024). These declines have been associated with habitat loss, changes in land use, depletion of their prey base, collision with human infrastructure, hunting, and poisoning, both intentional and unintentional (Carrete et al. 2009; Ogada et al. 2016; Donázar et al. 2016; Shaw et al. 2024). Unintentional poisoning through the ingestion of diclofenac has caused severe declines in vultures, with steep population crashes in multiple species from different parts of the world (Prakash et al. 2003; Oaks et al. 2004; Virani et al. 2011; Ogada et al. 2016). In India, vultures have declined by more than 95% between 1992 and 2007, the effects of which are cascading, such as increased human rabies cases (Markandya et al. 2008). While the vulture population decline may have slowed in India after the diclofenac ban (Galligan et al. 2014; Prakash et al. 2019), it has likely not ceased, as indicated by the recent State of India's Birds report (SoIB 2023). Other raptor species, especially several open country specialists including the widely distributed Eurasian Kestrel *Falco tinnunculus*, were also reported to be declining in India (Ganesh & Prashanth 2018; SoIB 2023).

Monitoring raptor populations is key to understanding the current declines observed in India and elsewhere (Mahananda et al. 2022). Monitoring over time can help provide crucial insights into population dynamics and their drivers, thereby helping frame conservation priorities for species as well as landscapes (Lindenmayer et al. 2012). Raptor research priorities are among the highest in South Asia (Buechley et al. 2019); this region is not only greatly understudied but also harbours a high diversity of raptors, including threatened species (Buechley et al. 2019, Mahananda et al. 2022). Particularly, long-term raptor nest monitoring can help understand breeding raptor populations, especially for these threatened species (McClure et al. 2021).

In India and the Himalaya, raptor research is not uncommon (Paudel et al. 2016; Kumar et al. 2019, 2022; Arya et al. 2021), but long-term field raptor studies are scarce. Studies are restricted in time, space, and often to a single species (Lu et al. 2009; Kumar et al. 2019; McClure et al. 2021). This is true in the high-elevation steppe and rangelands as well (Singh et al. 2013; Murali et al. 2017). These rangelands are important to pastoralist communities for livestock grazing as well as several charismatic and threatened fauna, including the Golden Eagle *Aquila chrysaetos* and the Bearded Vulture *Gypaetus barbatus*. We set up long-term raptor monitoring and raptor nest monitoring projects in the Trans-Himalayan regions of Spiti and Ladakh to monitor raptor population trends over large scales, at a landscape level. We describe our projects and present initial results in this article. We hope that over time, this long-term raptor monitoring project will help us understand the population trends of raptors across Spiti and Ladakh. This understanding can then form the basis of contextual and adaptive conservation priorities for raptors in the region.

Methods

Study Area

We carried out our study in two regions of the Indian Trans-Himalaya – in the Spiti River Valley, Lahaul and Spiti District, Himachal Pradesh, and the south and south-eastern parts of the Union Territory of Ladakh. The elevation in both these regions ranges between 3,500m–6,000m and the terrain is highly undulating and rugged, with deep valleys, rocky outcrops, and rolling hills. The regions are characterized by a cold, desert climate and the vegetation is classified as 'dry alpine steppe' dominated by short shrubs (Champion & Seth 1968). The common breeding raptors of these regions include the Golden Eagle, Himalayan Griffon *Gyps himalayensis*, Bearded Vulture, Upland Buzzard *Buteo hemilasius*, Eurasian Eagle-Owl *Bubo bubo*, and the Eurasian Kestrel (eBird 2021).

Raptor Monitoring

We set up road transects in Ladakh and Spiti for monitoring diurnal raptors (Fig. 1–2). Road transects are widely used across the world for surveying raptors (Prakash et al. 2003; Carrete et al. 2009; Virani et al. 2011; Pomeroy et al. 2015; Garbett et al. 2018; Kumar et al. 2022). Road transects have inherent biases, but multiple studies have noted the advantages of using this method, especially in large areas with scant information (Ellis et al. 1990; Carrete et al. 2009; Garbett et al. 2018). We began the raptor monitoring project in Spiti in autumn 2021 and in Ladakh in autumn 2023. We counted raptors along 10 transects laid along existing roads in both regions, in valleys, gorges, and rolling hills, with each transect covering *c.*.5 km in length (Spiti: Mean 14.97 ± 2.48 km; Ladakh: Mean 15.03 ± 1.75 km) while ensuring that the transects had minimal bends and turns to avoid double-counting of individuals (Fig. 1–2). We conducted the survey twice a year, during the beginning and the end of the breeding season – in early summer (late May) and late autumn (late Oct). We ensured that the total effort in each season and region remained similar. The counts were conducted by trained observers mounted on a vehicle, which was driven at a steady speed of 20 km/h. From pilot surveys conducted in 2021 in Spiti, we found that the ideal time for maximum detections was between 1100 h and 1300 h and this was largely followed subsequently. We surveyed only on relatively clear and sunny days and we recorded the raptor species, the number of individuals, and any notable behavior (e.g., hunting, courtship, carrying nesting material, etc.). Transects close to each other were either surveyed simultaneously or one after the other to limit pseudo-replication across transects. We calculated overall and species-specific encounter rates per kilometre (detections/effort) by pooling data from all transects, in each season and region. We estimated species-specific encounter rates only for the most common raptor species such as the Golden Eagle and Himalayan Griffon, among others, and calculated confidence intervals for each estimate through bootstrap resampling with 1,000 iterations.

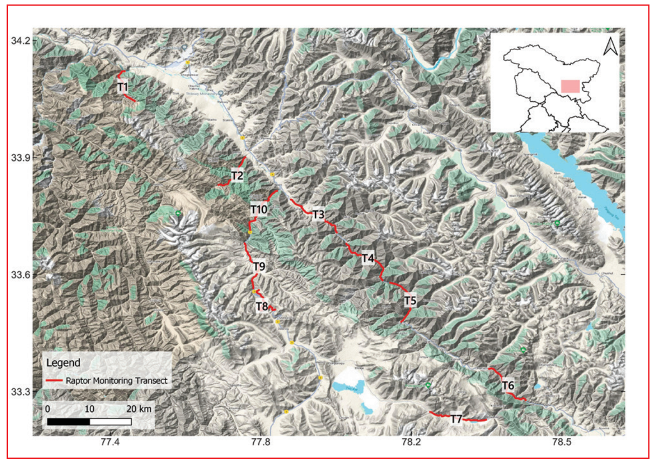

Fig. 1. Map of Ladakh depicting the location of the raptor monitoring transects. Base map derived from Google Maps (Map data, 2023 Google).

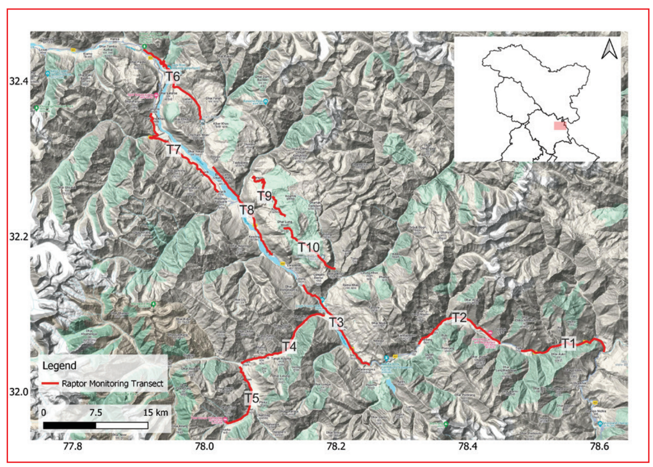

Fig. 2. Raptor monitoring transect locations in Spiti. Base map derived from Google Maps (Map data, 2023 Google).

Raptor Nest Monitoring

To understand breeding raptor populations at large scales, we piloted the nest monitoring study in Ladakh to determine feasibility, with the hope of extending it to Spiti in the future. We initially located nests of these species with the help of local people and conducted a recce survey in March 2023. The recce survey, along with information from published sources (Ferguson-Lees & Christie 2001; Katzner et al. 2004; Billerman et al. 2022), suggested that most raptors in the region breed between January and August, with laying dates between April and May. We observed birds sitting on nests and assumed that they were potentially incubating eggs or brooding young. This helped us confirm the peak nesting times for the raptors in the region, based on which we surveyed in May 2023. The areas covered for this survey included the major valleys of south and south-eastern

Ladakh, along the same roads as the raptor monitoring transects (Fig. 3). We divided these areas into blocks and attempted to cover each block within a day. We scanned the cliff faces for signs of bird droppings to locate nests. Upon encountering a nest, we noted the location, its status (occupied/unoccupied), and the identity of the species. Vulture nests usually appear bare and without many twigs or other material, as opposed to nests of Golden Eagles and Upland Buzzards, whose nests have a large amount of nesting material (Photo 1, 2). Because nests can be left unoccupied for some periods of time (even in the case of an active nest), we asked the local people if the nest had been active and we also waited for at least 20 minutes near the nest to check for raptors returning to the nest. We used a spotting scope to observe nests from a safe distance, ensuring minimal disturbance to the nest. If the nest was unoccupied, we noted its status as unoccupied and enquired the local people about the identity of the raptor(s) that used the nest previously. Unoccupied vulture nests were sometimes difficult to attribute to a particular species and were noted as 'vulture sp.', and other unclear raptor nests were recorded as 'unknown'. We sampled nests once per year, since large-bodied raptors are unlikely to have multiple broods in a year (Tapia & Zuberogoitia 2018).

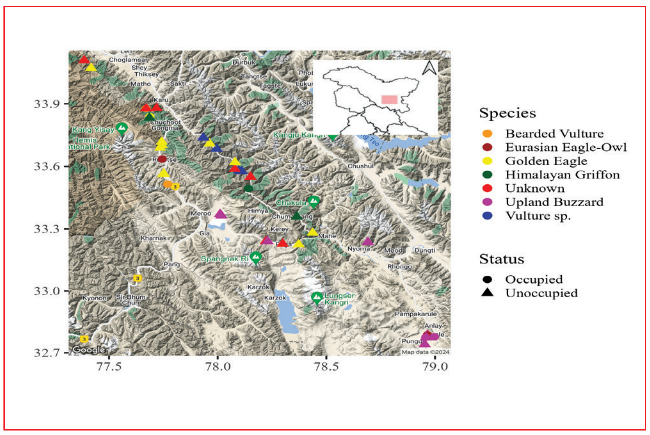

Fig. 3. Map of Ladakh showing the nests of raptor species. Base map derived from Google Maps (Map data, 2023 Google).

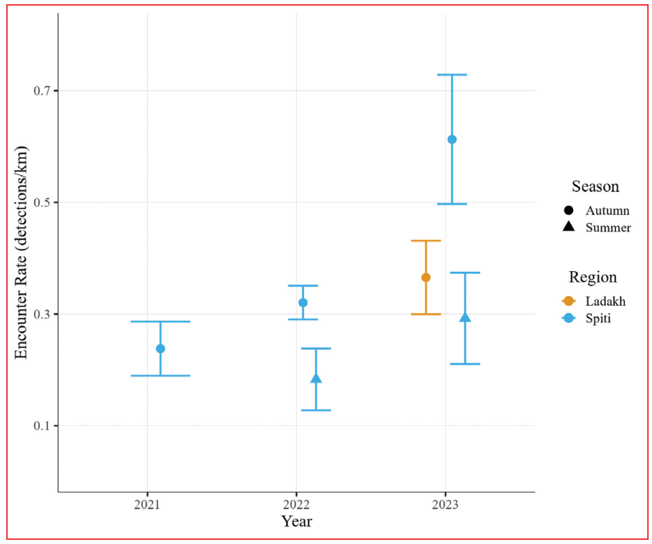

Fig. 4. Total encounter rates (detections per km) by season and across years in Spiti and Ladakh. The error bars indicate 95% confidence intervals.

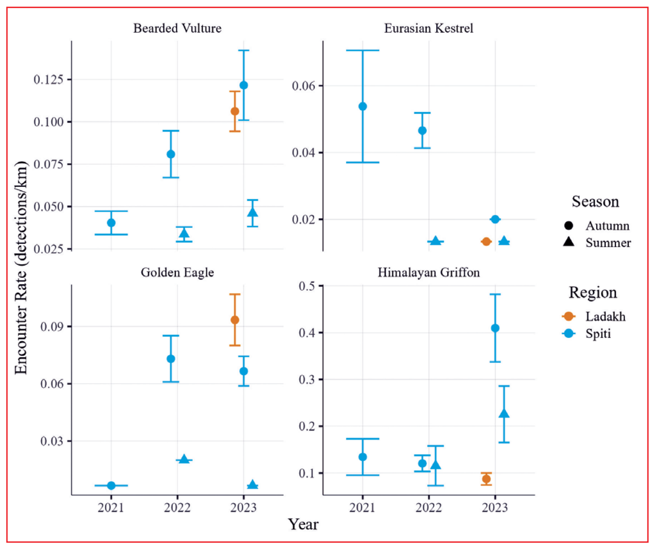

Fig. 5. Encounter rates (detections per km) of the most common raptor species, by season and across years in Spiti and Ladakh. The error bars indicate 95% confidence intervals.

Results

Raptor Monitoring

We present results from two and a half years of raptor monitoring in Spiti and half a year in Ladakh. We covered a total of ~150 km in each season and region. We recorded a total of eight species of raptors across both regions. Saker Falcon *Falco cherrug*, Black Kite *Milvus migrans*, and Eurasian Sparrowhawk *Accipiter nisus* were recorded only in Ladakh, although the latter is not uncommon in Spiti (eBird 2021). In Spiti, we encountered more raptors in autumn than in summer in all the sampled years (Fig. 4). The total encounter rate of raptors in Ladakh in autumn 2023 seemed to be lower than that of Spiti (Mean 0.37 (95% CI 0.3–0.43) vs. 0.61 (0.5–0.72)).

Vultures were the most encountered raptor species in both regions, with the Himalayan Griffon being more common in Spiti and the Bearded Vulture being more common in Ladakh (Fig. 4). The Golden Eagle was encountered more often in Ladakh than in Spiti (0.09 (0.07–0.1) vs. 0.06 (0.05–0.07)) at least in the autumn of 2023. Interestingly, in Spiti, the most common raptor species seemed to show an increasing trend (barring the Eurasian Kestrel), especially in autumn (Fig. 5).

Raptor Nest Monitoring

We covered roughly 175 km and found 58 nests in total across the landscape in Ladakh (Fig. 3). Nests of the Golden Eagle were the most abundant (n = 17), followed by the vultures (n = 16) and the Upland Buzzard (n = 10). The overall number of active nests was low – only 11 out of the 58 nests were active (Table 1). Vultures had the highest number of active nests with six occupied nests, while the Golden Eagle had the lowest – we found only one occupied nest for 16 unoccupied nests. Both the Upland Buzzard and Eurasian Eagle-Owl had two occupied nests each. We could not attribute the species of 20 unoccupied nests.

Discussion

The initial results from our raptor surveys spanning two and a half years show that the Spiti Valley landscape harbors relatively lower numbers of raptors that hunt prey (Golden Eagle, Eurasian Kestrel) when compared to scavenging raptors (Himalayan Griffon, Bearded Vulture) (Fig. 5). While this was true in Ladakh

76. A Himalayan Griffon nesting in Shyang Valley, Ladakh.

Both: Sidharth Srinivasan

77. A nest of a Golden Eagle on a high cliff in Rumbak Valley, Ladakh.

Table 1. Total number of occupied and unoccupied nests per species in Ladakh

Species	Number of occupied/unoccupied nests
Bearded Vulture	2/0
Eurasian Eagle-Owl	2/0
Golden Eagle	1/16
Himalayan Griffon	4/3
Upland Buzzard	2/8
Vulture sp.	0/7
Unknown	0/13

as well, we encountered more species of prey-hunting raptors and encountered them more often than in Spiti (for example, the Golden Eagle). While we need more data to investigate patterns, initial trends indicate that the encounter rates of a few common raptor species in Spiti, barring the Eurasian Kestrel (Fig. 5), seemed to be increasing over the years. The Eurasian Kestrel showed a marginal decline (albeit with very low encounter rates) with very few detections in 2023. Although the Bearded Vulture and Himalayan Griffon showed an increase over the years, both species and the Kestrel have been reported to be declining over much of India (SoIB 2023) and it would not be surprising to see this pattern over a longer time period in this region as well. Very little data exists for other raptors, such as the Golden Eagle and the Upland Buzzard. Continued monitoring in this landscape is essential to obtain baseline information for these species and to confirm trends.

The overall encounter rates of raptors in this region range from 18 (12–23) to 61 (50–72) individuals/100 km, which is higher than or similar to other steppe habitats around the world (23–57/100 km in Kazakhstan and 10–32.6/100 km in Patagonia) (Ellis et al. 1990; Donazar et al. 1993; Sánchez-Zapata et al. 2003), indicating that these rangelands are important habitats for raptors. The total encounter rates seem to be higher in the autumn in Spiti (Fig. 4), presumably because of the addition of young individuals and because both adults are more likely to be detected in the autumn, with nesting duties being completed by then.

We found a total of 11 active nests in Ladakh. Himalayan Griffon had the highest number of active nests, whereas the Golden Eagle had the lowest, with only one occupied nest. Raptors are known to build, maintain and use multiple alternative nests throughout their breeding territory (Newton 1979; Ontiveros et al. 2008; Millsap et al. 2015). Golden Eagles have been recorded to use between 1–18 nests per territory, with 5–8 nests being the most common (Kochert & Steenhof 2012). The reasons for alternative nests are not well known, but prey availability is most likely an important factor (Millsap et al. 2015). Since the nests were along the road, prey availability in the vicinity might have reduced following development along the road. Several nests were also relatively old and active many years previously (>8 years according to local people); hence, the raptors might have moved further into relatively less disturbed valleys. This might explain the low number of active nests of the Golden Eagle nests and possibly other raptors in our study, although information on alternative nests for raptors such as the Upland Buzzard does not exist. Raptors are known to reuse older nests or construct newer nests in their vicinity once conditions around the nest become favourable again (Millsap et al. 2015). Therefore, it is important to continue monitoring unused nests in subsequent surveys since nest reuse among raptors is very likely (Newton 1979; Jiménez-Franco et al. 2014a, b).

Long-term monitoring studies provide important information about population trends (Lindenmayer et al. 2012) and we intend that these surveys be a part of a long-term monitoring effort of raptors in the high elevations of the Himalaya. These raptors can act as important indicators of the overall health of the rangeland, and their decline can signify habitat degradation and loss of biodiversity. In the following years, we aim to find and survey more nests and explore long-term trends related to the factors influencing raptor nest site selection, encounter rates of raptors, relative encounter rates of different age classes of raptors, and possibly discern the effects of climate change on these raptor communities. Given the ongoing decline of open-country and specialist raptors in India (SoIB 2023), long-term monitoring efforts should be prioritized and conducted in lesser-known landscapes, such as the Trans-Himalaya.

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