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Research Article

Ecological and Seasonal Patterns of Vulture Assemblages Influenced by Human-Linked Food Availability in the Terai region of Uttar Pradesh, India

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ABSTRACT

Vultures are crucial for the ecosystem as they are good scavengers and their population declined because of habitat destruction and food unavailability. This study focuses on the vultures associated with the Gau Shala located in Madhwaliya forest range of Sohagi Barwa Wildlife Sanctuary in Maharajganj district of Terai region of Uttar Pradesh. Association of vulture with Gau Shala helps them to find food. Gau Shala is situated near large grassland area, and the grassland is also used as dumping site of carcass. This grassland provides suitable habitat for foraging because of water availability nearby Gau Shala and presence of trees like Sheesham (*Dalbergia sissoo*), and Semal (*Bombax Ceiba*) which provide suitable roosting sites for vultures. Maharajganj district is located on the international Indo-Nepal border in the North of Uttar Pradesh. This study shows the population of vultures in three different seasons i.e., Summer (n=6), Winter (n=33) and Monson (n=12) in the area of interest. The inter-species correlation analysis revealed distinct ecological associations. White Rumped Vulture showed negative or independent correlations with both Eurasian Griffon Vulture and Himalayan Griffon Vulture (Pearson r = –0.188), suggesting differing ecological niches or avoidance patterns among species. On the other hand, Eurasian Griffon Vulture and Himalayan Griffon Vulture exhibited perfect positive correlation (r = 1.0).

Key words: Ecology, Grassland, Habitat, Seasonal Patterns, Terai, Vultures

INTRODUCTION

One of nature's most efficient scavengers, vultures play a crucial role in maintaining ecological balance, while having commercial benefits, and being associated with cultural traditions (Iqbal *et al*., 2011). To prevent infections from spreading to other species, including humans, vultures remove meat from carcasses before they decompose, which is an essential part of nature's sanitation processes (MoEF, 2006). Several conservation programs have been launched to combat the drastic reduction in vulture populations in South Asia, particularly India. One of the most significant breakthroughs was the identification of the veterinary medicine NSAIDs diclofenac as a key cause of vulture death related to kidney failure (Oaks *et al*., 2004). The finding led to the Government of India banning the veterinary use of diclofenac in 2006, followed by awareness campaigns and the promotion of safer alternatives such as meloxicam (Cuthbert *et al*., 2011). India has established captive breeding programs for critically endangered vulture species such as the white-rumped vulture (*Gyps bengalensis*) (WRV), Indian vulture (*Gyps indicus*), and slender-billed vulture (*Gyps tenuirostris*) with the help of the Vulture Conservation Breeding Centers (VCBCs) (MoEFCC, 2020). Vulture safe zones (VSZs) have been established in regions with significant drug monitoring and awareness initiatives, and some success has been found stabilizing populations within protected areas (Galligan *et al*., 2016). Limited data on ecology, feeding, anthropogenic pressures in the study area of the Terai region of Uttar Pradesh, India, and region-specific ecological factors regulating vulture distribution are poorly understood. The present study aimed to investigate the status, habitat, and association with Gau Shala, with a focus on contributing new insights to inform conservation strategies .

Nine vulture species have been found in India: the Red-headed or King Vulture (*Sarcogyps calvus*), the Eurasian Griffon Vulture (*Gyps fulvus*) (EGV), the Himalayan Griffon (*Gyps himalayensis*) (HGV), the Oriental White-backed or White-rumped Vulture (*Gyps bengalensis*), the Slender-billed Vulture (*Gyps tenuirostris*), the Egyptian Vulture (*Neophron percnopterus*), and the Bearded Vulture or Lammergeier (*Gypaetus barbatus*). Uttar Pradesh is home to eight species of vultures: the Himalayan Griffon (*Gyps himalayensis*), Eurasian Griffon Vulture (*Gyps fulvus*), Cinereous Vulture (*Aegypius monachus*), the White-rumped Vulture (*Gyps bengalensis*), the Red-headed Vulture (*Sarcogyps calvus*), the Indian Vulture (*Gyps indicus*), Slender-billed Vulture (*Gyps tenuirostris*), and Egyptian Vulture (*Neophron percnopterus*). Five vulture Species are residential i.e. the White-rumped Vulture (*Gyps bengalensis*), the Red-headed Vulture (*Sarcogyps calvus*),

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the Indian Vulture (*Gyps indicus*), Slender-billed Vulture (*Gyps tenuirostris*), and the Egyptian Vulture (*Neophron percnopterus*), and three are non-residential i.e. the Himalayan Griffon (*Gyps himalayensis*), and Eurasian Griffon Vulture (*Gyps fulvus*), Cinereous Vulture (*Aegypius monachus*). Tree species used for nesting or roosting included Silk Cotton (*Bombax ceiba*), Sheesham (*Dalbergia sissoo*), Sacred Fig (*Ficus religiosa*), Banyan (*Ficus benghalensis*), Haldu (*Haldina cordifolia*), Axlewood (*Anogeissus latifolia*), Cluster Fig (*Ficus racemosa*), and Tamarind (*Tamarindus indica*). White-rumped vultures were observed roosting on Sacred Fig and Silk Cotton trees, while Himalayan Griffons were found on Sheesham (*Dalbergia sissoo*) (Jha, 2015). Various vulture species utilize diverse habitats for roosting and nesting, including vast agricultural fields, rocky cliffs, monuments, forested areas, scattered trees, and riverbanks. According to (Jha, 2015), all six species of vultures, including the egyptian vulture, himalayan griffon vulture, long billed vulture, red-headed vulture, slender-billed vulture, and white-rumped vultures, were most prevalent in the Tarai eco-zone throughout the year. Typically, large vultures used lofty, sparsely branched trees in the forest area for roosting and nesting because they were easier to take off, provided a better view of the surroundings, and provided protection from predators (Yamac, 2007). Whenever tall trees are not available, vultures have been observed to use smaller trees in the open landscape, such as Khejri (*Prosopis cineraria*) (Khatri, 2013), Margosa (*Azadirachta indica*) (Kambale, 2011), Babool or Indian gum Arabic (*Aecacia nilotica*), and Mango (*Mangifera indica*). This study focuses on the vultures associated with the Gau Shala located in the Madhwaliya forest range of Sohagi Barwa Wildlife Sanctuary in Uttar Pradesh. The association of vultures with Gau Shala helps them find food. Gau Shala is situated near a large grassland area, which is also used as a dumping site for carcasses. The presence of Gau Shalas in Maharajganj district providing consistent food availability, leading to increased species richness and feeding activity at these sites compared to surrounding areas without Gau Shala.

MATERIAL AND METHODS

Study Area

In India's northern state of Uttar Pradesh, Sohagi Barwa Wildlife Sanctuary (SBWLS) is a lesser-known, currently ecologically valuable protected area. The sanctuary is located in the Maharajganj district, which is between (27.2074° N and 83.4340° E). The Terai region is rich in varied ecosystems, including forests, wetlands, and grasslands. The area is ecologically diversified, with a number of small rivers and water bodies meandering through the landscape and a mixture of open grasslands and dense Sal forests. This study focused on the vultures associated with the Gau Shala located (27.3557° N 83.6699° E) in the Madhwaliya forest range of the Sohagi Barwa Wildlife Sanctuary in the Maharajganj district of the Terai region, Uttar Pradesh **(Figure 1)**. Sohagi Barwa Wildlife Sanctuary's climate is typical of the northern Indian Terai region, which is marked by distinct seasons and a monsoon-driven weather pattern. This area experiences three distinct seasons, i.e., summer, monsoon, and winter. In summer (March to June), peak temperatures often occur in May and June, with the maximum temperature during this season's range being between 30°C and 40°C (86°F and 104°F) (Singh and Singh, 2015). During the monsoon season (July to September), the region receives an annual rainfall of 1,000 to 1,500 mm (Gupta and Prasad, 2019). In winter (October to February) December and January are the

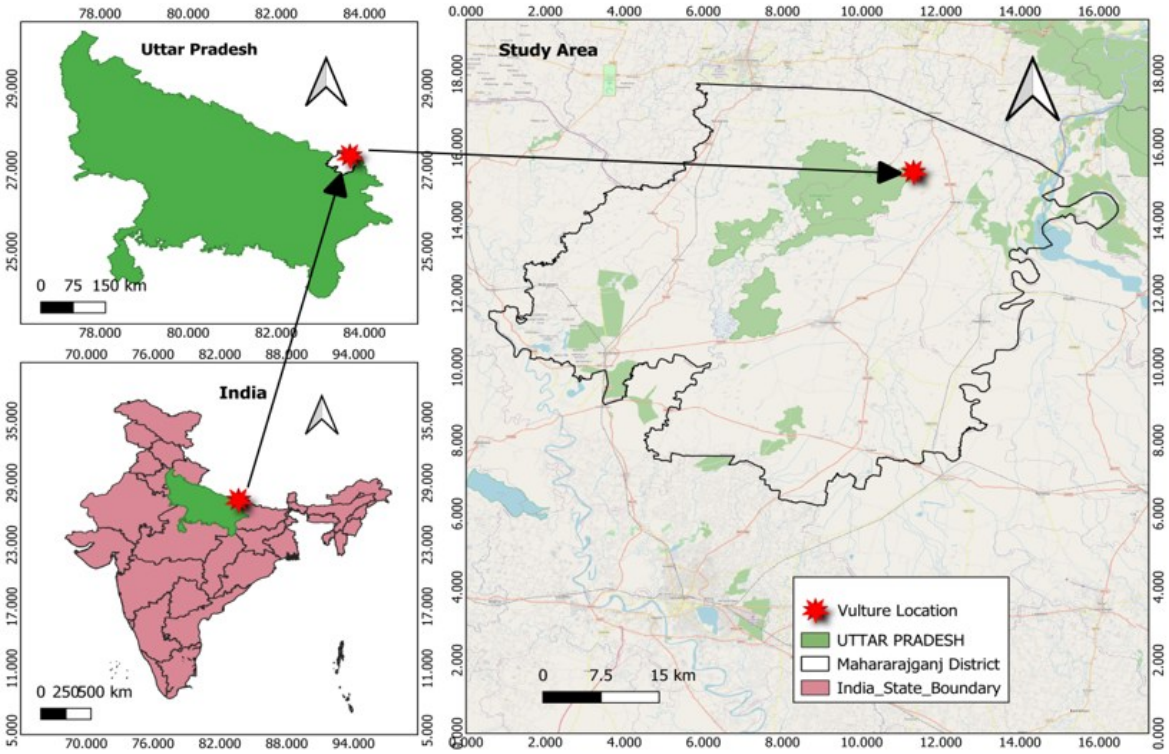


Figure 1. Map of the study area

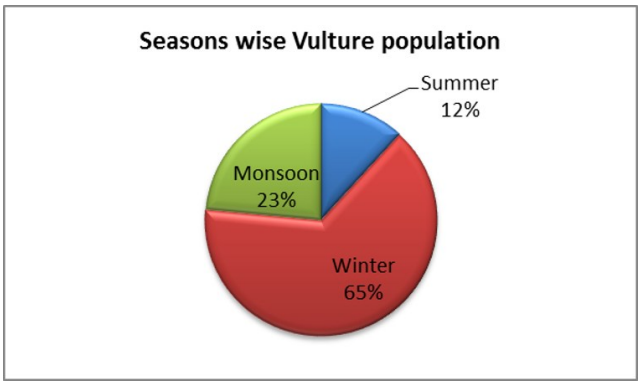


Figure 2. Vulture population in percentage in three seasons of 2023-2024

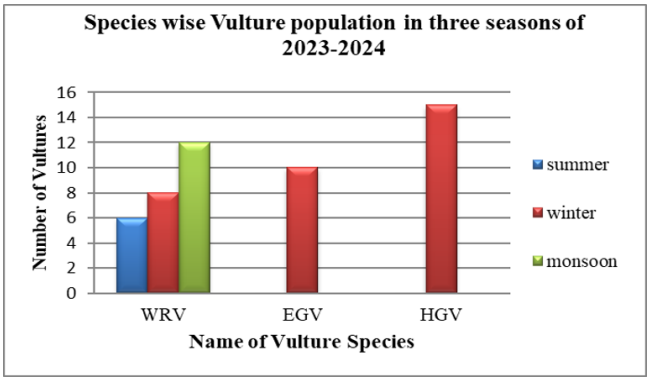


Figure 3. Species wise Vulture population in three seasons of 2023-2024

coldest months, with temperatures ranging from 06°C to 20°C (42.6°F to 68°F) during the winter months.

Study design

Studies on vultures associated with the Gau Shala in Maharajganj district were conducted in 2023-2024, focusing on their habitat-use patterns across different seasons. Observations were made with the help of 10×40 Bushnell field binoculars and a digital camera, the Nikon Coolpix B500. Identifications were confirmed using (Grimmett *et al*., 2016). Road surveys were carried out in order to count the number of vultures, either by driving along the roads or by counting the number of vultures around carcasses that were observed next to the roadways. There was a total of 108 km of travel and 9 survey days (3 days per season) during this study. Vultures were recorded for six hours daily, totaling approximately 54 hours during this study. Surveys for vultures were conducted from 06:30 to 09:30 and then again from 14:30 to 17:30 during the seasons. Every Transects were 2 km distance and 500 meter in width to count the vulture population. Visits were initially conducted to survey the area, identify possible vulture habitats, and interview locals. For vulture counting and other data collection, possible vulture sites were revisited. The appropriate time of day and season were taken into account in the survey. Conditions including specific types of habitats, survey time, and weather were noted. By integrating local knowledge with systematic observations, the aim was to gain a better understanding of vulture populations and their ecological roles in the region. Map was generated with the help of QGIS v3.4 and data were analyzed by using MS Excel and Minitab Software Surveys were conducted under similar weather and visibility conditions to reduce variability in detection probability.

RESULTS

The study was done in three different seasons of 2023-2024 in Sohagi Barwa Wildlife Sanctuary of Maharajganj District, Uttar Pradesh. Three vulture species were recorded: one resident species and two non-resident species, observed in different seasons. In summer WRV were found and in winter season HGV and EGV were found because they are winter migrants to the study area. Population of vulture in different seasons– Summer (n=6), Winter (n=33) and Monson (n=12) were found. Vultures used different tree species for roosting included Sheesham (*Dalbergia sissoo*), and Semal (*Bombax Ceiba*). At the study time total of 3 vulture species were recorded and the total number of individuals were 51 in different seasons Monsoon, Winter and Summer **(**Figure 2). Two species were migratory, while one was resident. Vultures were observed roosting on dry Sheesham trees and on the ground, with their numbers peaking in winter and reaching their lowest in summer. The Bar graph (Figure 3) shows the highest number of HGV in winter and WRV in the summer seasons.

The **boxplot analysis** further reinforces the patterns observed in seasonal fluctuations. WRV exhibits low variability in population numbers, reflecting its stable presence. However, EGV and HGV display high variability, with HGV having the highest fluctuations. This suggests that HGV might be a highly migratory species that visits the study area primarily during winter when food sources, such as carrion, are more abundant (Figure 4).

Seasonal variation in species composition indicated a broadly similar pattern between summer and monsoon, while winter differed in overall abundance and relative species representation (Fig. 5). The similarity between summer and monsoon is reflected in the comparable presence of species across these seasons. In contrast, winter recorded higher overall counts along with a shift in the proportional contribution of species. These observations suggest seasonal variation in vulture occurrence within the study area; however, given the limited sample size and uneven sampling effort, the results are presented as descriptive trends without implying definitive ecological groupings.

DISCUSSION

The observed variation in species composition and abundance across seasons provides preliminary insight into vulture occurrence within the study area. Winter records showed relatively higher abundance and changes in proportional species representation compared to other seasons. While such patterns may reflect differences in resource availability or seasonal movement, the present study emphasizes observed trends rather than inferring strong ecological relationships. Further investigation with more extensive and systematically collected data would be required to robustly evaluate these patterns.

In terms of species associations, EGV and HGV demonstrate a strong positive association, typically co-occurring across habitats and seasons. This suggests that while EGV and HGV share similar ecological preferences or responses to environmental conditions, WRV species display contrasting habitat usage or seasonal occurrence patterns. Consequently, during summer and monsoon, the species composition is dominated entirely by WRV individuals, whereas winter

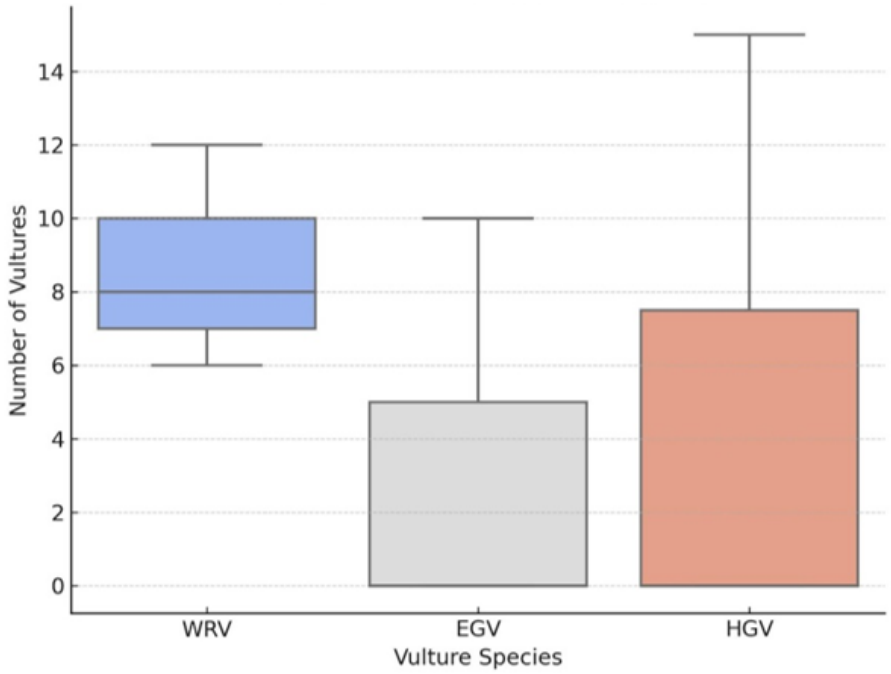


Figure 4. Boxplot: Shows that WRV has a stable presence, while EGV and HGV have highly variable distributions.

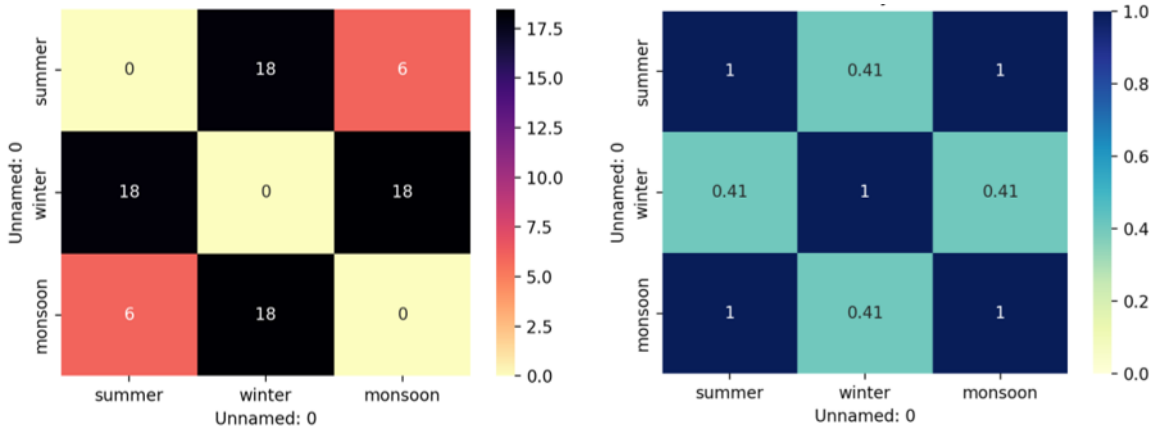


Figure 5. Euclidean distance and Cosine Similarity of Seasons

assemblages uniquely include both EGV and HGV components, leading to distinct ecological structuring. Overall, these findings underscore that the similarity metrics and interspecific associations consistently delineate a clear ecological divide, with summer and monsoon forming a cohesive compositional unit and winter representing a markedly distinct faunal assemblage.

Seasonal Variation in Vulture Assemblage

The present study revealed clear seasonal shifts in the vulture assemblage composition, reflecting the influence of climatic and ecological factors on species occurrence and abundance. Among the three recorded species - WRV, EGV and HGV marked differences were observed across seasons. During summer and monsoon, only WRV was present, whereas winter supported all three species, with notably higher counts of EGV and HGV. This pattern indicates that WRV is a resident and ecologically resilient species capable of withstanding the thermal and hydrological variations of the warmer months. The exclusive appearance of EGV and HGV during winter suggests migratory influx or seasonal range expansion in response to favorable environmental conditions and food availability, as also reported by (Ogada *et al*., 2016; Prakash *et al*., 2012). The habitat of the study area consisted of grassland and Sheesham plantations. A Gau Shala (cow shed) was located near the grassland, and vultures were associated with it due to the availability of carcasses. A nearby dumping site also served as a roosting spot, where vultures perched on Semal trees to sunbathe. Close to the dumping site, there was a pond, which was particularly favorable for vultures because they prefer to bathe after feeding. It was also observed that vultures were often disturbed by crows while they were roosting.

Community Similarity and Cluster Structure

The statistical analyses substantiate the observed seasonal segregation. Cosine similarity and Euclidean distance metrics confirmed that the summer and monsoon

Table 1. Cosine similarity, Euclidean distance

Cosine similarity between seasons:			
	Summer	Winter	Monsoon
Summer	1.0	0.405616	1.0
Winter	0.405616	0.99999	0.405616
Monsoon	1.0	0.405616	1.0
Euclidean distance between seasons:			
	Summer	Winter	Monsoon
Summer	0.0	18.138	6.0
Winter	18.138	0.0	18.466
Monsoon	6.0	18.466	0.0

Table 2. Shows the Season by Species head, Pearson and Spearman Correlation among species

Season by Species head :			
	WRV	EGV	HGV
Summer	6	0	0
Winter	8	10	15
Monsoon	12	0	0
Pearson Correlation among species:			
	WRV	EGV	HGV
WRV	1.0	-0.188982236	-0.188982236
EGV	-0.1889822365	1.0	1.0
HGV	-0.1889822365	1.0	1.0
Spearman Correlation among species:			
	WRV	EGV	HGV
WRV	1.0	0.0	0.0
EGV	0.0	1.0	1.0
HGV	0.0	1.0	1.0

assemblages were compositionally identical, exhibiting a perfect cosine similarity of 1.0 and minimal Euclidean distance (6.0). In contrast, the winter assemblage was highly distinct (cosine ≈ 0.4; Euclidean distance ≈ 18), indicating substantial turnover in community composition **Table 1**.

Similar seasonal clustering patterns in raptor assemblages have been observed in other regions, reflecting shifts in resource distribution and climatic tolerance (Cuthbert *et al*., 2016; Mundy *et al*., 1992).

Species Associations and Ecological Relationships

The inter-species correlation analysis revealed distinct ecological associations. WRV showed negative or independent correlations with both EGV and HGV (Pearson r = –0.188), suggesting differing ecological niches or avoidance patterns among species. A high correlation between EGV and HGV was observed in the dataset; however, this result is likely influenced by the limited sample size and their co-occurrence within a restricted number of observations. winseason rather than true ecological synchrony, as only one season has both species present and sample size might have inflated correlation. This pattern likely arises from their overlapping ecological roles as facultative scavengers that exploit similar carcass resources in the cooler months (Margalida and Donázar, 2020).

The Spearman rank correlation confirmed this trend, showing strong positive rank-order association between EGV and HGV, while WRV remained ecologically independent. Such associations are ecologically plausible given the differing foraging strategies - WRV being a lowland resident species, whereas EGV and HGV are more migratory and opportunistic (Botha *et al*., 2017; Gilbert *et al*., 2007) **Table 2**.

Ecological and Conservation Implications

The observed seasonal variation in vulture abundance provides site-specific insight into the use of Gau Shala-associated resources within the study area. Relatively higher counts during winter and the continued presence of vultures in other seasons suggest that these sites may serve as consistent foraging locations, particularly where carcass availability is maintained. While differences in species representation were noted across seasons, the present dataset does not support strong conclusions regarding ecological roles or trophic structuring. Instead, the findings indicate that Gau Shala environments may contribute to sustaining vulture presence by providing predictable food resources in a human-dominated landscape. From a conservation perspective, these observations highlight the importance of maintaining safe and reliable carcass disposal practices at Gau Shalas. Ensuring that livestock carcasses are free from harmful

veterinary drugs (e.g., diclofenac) and that disturbance at feeding and roosting sites is minimized could support both resident and seasonally occurring vulture species. However, given the limited scope of the study, these recommendations should be viewed as preliminary and would benefit from further investigation across larger spatial and temporal scales.

Given the historical declines of these species due to diclofenac poisoning, food scarcity, and habitat fragmentation (Das *et al*., 2011; Oaks *et al*., 2004; Prakash *et al*., 2003), ensuring continuous food supply and safe roosting sites can help stabilize local populations.

CONCLUSIONS

The findings highlight the significance of the Gau Shala and its surrounding habitat in supporting vulture populations. From an ecological perspective, these findings suggest that vulture community composition in the study area is seasonally dynamic, driven by resource availability and possibly temperature-related constraints. The observed assemblage restructuring aligns with the concept of anthropogenic carrion subsidies shaping scavenger guild dynamics. Predictable carcass deposition at Gau Shala sites functions as a localized resource pulse, attracting migratory Gyps vultures during winter when thermally suitable soaring conditions and food predictability coincide. Similar resource-driven seasonal assemblage shifts have been documented in avian communities inhabiting heterogeneous wetlands and anthropogenically modified landscapes in India, where habitat structure and food pulses regulate temporal species turnover. This highlights that human-managed carcass provisioning, when free from toxic veterinary drugs, may play a complementary role in sustaining both resident and migratory vulture populations. This study underscores the necessity of season-specific conservation strategies. Protecting critical foraging areas during winter and ensuring year-round food availability for resident species could help maintain healthy vulture populations. Future studies should explore the specific ecological drivers behind these seasonal trends and assess potential threats such as poisoning, food competition, and habitat degradation to develop targeted conservation efforts.

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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:

Photographs of vulture species taken during the survey: Figure 1. Gau Shala, Figure 2. Vultures roosting on Shemal tree, Figure 3. White - rumped vultures, Figure 4. Eurasian griffon vulture and Himalayan griffon vulture







