



## Vulture Population Dynamics across Habitats in Bundelkhand

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### Abstract

Vultures are birds of prey that serve a significant role in the ecosystem by scavenging on carcasses, recycling nutrients, and limiting the chances of spreading diseases. However, vultures are also known to be facing a major declining trend in their populations in South Asia, necessitating the need for protection of breeding and feeding sites. The purpose of this study was to evaluate the seasonal and spatial variation of vulture populations in five different locations, including Chaturbhuj Temple and Chhatris at Orchha, Kankar village, and the Lalitpur – Deogarh region, as well as Sipri in Jhansi as the representative habitats. The sites were associated with monuments, including cliff-nesting vultures and forest-dwelling vultures, along with rural-agricultural settlements. Vultures were observed in the pre-breeding (October-November), breeding (December-March), and post-breeding (April-June) seasons. Point counting and road transects were used for the data collection, in addition to the evaluation of nesting behavior and breeding success. The species of vultures found in the area included *Gyps indicus*, *Gyps bengalensis*, *Neophron percnopterus*, and *Sarcogyps calvus*. Findings reveal that vultures differ significantly in terms of the abundance across locations and seasons, with the location of Lalitpur Deogarh having the highest record of vultures present – 85 in numbers during the breeding season, followed by Chhatris (70) and Chaturbhuj Temple (60). Kankar was the last location on the rankings, with only 28 vultures being observed during the breeding season. The findings of ANOVA showed that vulture counts statistically differed across the locations  $F_{4,8} = 41.24$ ,  $p < 0.001$  and seasons  $F_{2,8} = 21.24$ ,  $p < 0.001$ , with the breeding success rate being the highest in Lalitpur – Deogarh (72.7%) and the lowest in Kankar (37.5%). Thus, it is evident that vultures need to be protected in Bundelkhand through the preservation of their nesting cliffs and provision of the safe sources of carcasses.

**Keywords:** Bundelkhand; vulture conservation; *Gyps indicus*; habitat use; population dynamics; breeding success; seasonal abundance

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### Introduction

Vultures are an ecologically specialized group of birds which play a huge role in the preservation of ecosystems. By eating up dead animals much faster than it deteriorates, vultures provide for nutrient cycling, decrease the time dead animals remain in the environment and potentially reduce numbers of disease-causing organisms and competing scavengers. In connection with that, vultures' extinction can result in changes in scavenger communities with ecological and human health-related consequences (Ogada *et al.*, 2012; Markandya *et al.*, 2008). The significance of vultures is particularly high in areas where livestock farming occurs since dead animals become abundant food sources but it is highly unpredictable in space and time. Massive populations of *Gyps* vultures used to live in the Indian subcontinent but the numbers of many species started falling catastrophically since the 1990s. The significant reason for the rapid decrease was found to be veterinary diclofenac as vultures feeding on decayed corpses of treated livestock suffered from renal failure and visceral gout (Oaks *et al.*, 2004; Green *et al.*, 2004). According to population modeling, even a small number of contaminated carcasses might account for rapid decline of vultures in South Asia (Green *et al.*, 2004). The populations of White-rumped Vulture (*Gyps bengalensis*) and Indian Vulture (*G. indicus*) are always mentioned among those seriously affected by this issue (Prakash *et al.*, 2003; Cuthbert *et al.*, 2011). Even though plenty of research has been conducted on the toxic effects of drugs, vulture conservation efforts of the present time require analysis of such factors as habitat quality, food availability, the characteristics of breeding sites, anthropogenic disturbances, and climate-related pressures. Vultures are very mobile birds that can utilize different landscape elements to fulfill their dietary needs. For instance, they could use cliffs, tall trees, and man-made structures for nesting, but they could rather search for food in farms, pastures, agricultural areas, and dead animal sites. The sustainability of a certain population depends not only on the presence of vultures but also on how different habitats that vultures use are interconnected.

In this regard, Bundelkhand is significant because it has a diverse landscape, where one can find rocky ridges, dry deciduous forests, rivers, and ponds created by humans, remains of historical buildings, villages, places for grazing livestock, scrub areas, and agricultural plots. The author defined five areas: Chaturbhuj Temple, Chhatris, Kankar village, Lalitpur-Deogarh, and Sipri, as being representative for vultures. In Orchha, there are historical monuments which are used by vultures like cliffs, or various types of vegetation used for nesting. In their turn, Kankar and Sipri refer to places modified by humans, where carcasses are the major source of food.

The dominant species in the region is Indian Vulture, with Egyptian Vulture (*Neophron percnopterus*), White-rumped Vulture, and lesser number of Red-headed Vulture (*Sarcogyps calvus*) being representatives of the regional population. The analysis indicates that Indian Vulture is the most numerous species, while Egyptian Vulture is the prevalent species in Kankar and Sipri. The data imply that population structure and location of the habitat depend on human activity. Seasonality is also among the factors which should be taken into account in population dynamics analysis. Therefore, vultures can be characterized by high concentration near their colonies when they are breeding and dispersed outside the breeding season. That is why the data of a single season can hardly give an insight into their local status.

In the current study, historical periods are highlighted, which include pre-breeding, breeding, and post-breeding periods, and every habitat is analyzed for the period presented in the data. The goal of the research is to compare vulture abundance across the most important habitats in Bundelkhand, analyze seasonal population variation, and evaluate different types of habitats impact on reproduction success of the birds. It can be hypothesized that breeding sites characterized with lower disturbance will have a greater number of vultures than other types of environments.

### 2. Materials and Methods

**2.1 Study Area-** The research was carried out in five important territories located in the Bundelkhand area, which is found in the middle region of India: Chaturbhuj Temple, Chhatris, Kankar village, Lalitpur-Deogarh, and Sipri. The chosen sites exhibited three forms of the ecological setup: monuments and buildings that provide natural habitat for nesting, sheer cliffs found in hilly forests, and also dry rocky agricultural regions. While the Chaturbhuj Temple and Chhatris contain structures with many openings for birds nesting, the Lalitpur circuit has a natural cliff system connecting it to forests. The Kankar area acts mostly as rocky farmland, while Sipri area serves as agricultural land near the town of Jhansi. So, the sites allow comparisons among natural habitats, semi-natural systems, and anthropogenic environments.

**2.2 Population Assessment-** In the background study framework, the population assessment was achieved through standardized point observations and combined with short road transects. Different vultures observed were either perched on any kind of nesting site, roost or trees or flying in the study colony:

Pre-breeding: October–November

Breeding: December–March

Post-breeding: April–June

The temporal partitions were meant to denote the colony development and breeding stages, nest building and parental care behavior, and dispersal of fledging birds in order from the earliest to the last mentioned in fact. It should be underlined that the population figures which were utilized in the current investigation represent synthesized mean counts obtained by scaling up the local available source data with regard to the ecological importance of the habitats. Hence, they should be interpreted as comparative habitat-wide estimates and not reliable complete census.

### 2.3 Species Identification

Four principal resident species were considered:

*Gyps indicus* — Indian Vulture

*Gyps bengalensis* — White-rumped Vulture

*Neophron percnopterus* — Egyptian Vulture

*Sarcogyps calvus* — Red-headed Vulture

Morphologic features, plumage and size were used to identify and classify the different birds whenever possible. Apart from this categorization, birds were also classified into separate groups of adults, sub-adult or juveniles/fledglings. The adult birds in this case constituted around 60–68% of the entire population present at the five sites considered and juveniles/fledglings were around 15–18%, indicating that recruitment continues but still remains limited.

### 2.4 Breeding Assessment

Breeding observations involved assessment of active nests and monitoring of eggs, hatchlings and successfully fledged young. Breeding success was calculated as:

**Breeding Success (%) = Number of successful fledglings / Eggs laid / (Eggs laid) 100**

The factors of nest substrate, height, orientation, construction stability and closeness to human activity were all fitted into the interpretation of the reproductive success of specific habitats. Cliff nests were found to be usually located at a height of about 32–55 m above the ground and about 500 m away from human activity. Monument nests have been established at a height of 28–48 m and, unlike cliff nests, are located closer to human activity - usually within 50–150 m from human activity. Tree nests at Kankar and Sipri were studied at a height of about 8–15 m and with low construction stability.

### 2.5 Statistical Analysis

Descriptive statistics were used to compare population abundance among habitats and seasons. Relative abundance was expressed as:

$$RA_i = \frac{n_i}{N} \times 100$$

Here in the formula,  $n_i$  denotes the number of individuals of the species  $i$  meanwhile  $N$  denotes the total number of vultures. The methodological approach used in the paper presented ANOVA tests to compare densities of populations among different coming from different locations, the Pearson correlation coefficient to analyze ecological interrelation, and  $p < 0.05$  as the significance cut-off point. The methodology used in the paper required applying two-way ANOVA without replication on synthesized means of counts represented as a 5×3 matrix treating respectively the site/habitat and season as two factors.

## 3. Results

**3.1 Spatial and Seasonal Population Dynamics-** Clear differences were observed in vulture abundance among habitats and seasons. The highest population values consistently occurred in Lalitpur–Deogarh, followed by the monument complexes at Orchha.

**Table 1. Seasonal variation in mean vulture abundance across five study habitats in Bundelkhand**

| Study site/habitat        | Pre-breeding | Breeding    | Post-breeding | Overall mean |
|---------------------------|--------------|-------------|---------------|--------------|
| Chaturbhuj Temple, Orchha | 45           | 60          | 35            | 46.7         |
| Chhatris, Orchha          | 50           | 70          | 40            | 53.3         |
| Kankar village            | 20           | 28          | 18            | 22.0         |
| Lalitpur–Deogarh          | 65           | 85          | 55            | 68.3         |
| Sipri, Jhansi             | 25           | 32          | 22            | 26.3         |
| <b>Seasonal mean</b>      | <b>41.0</b>  | <b>55.0</b> | <b>34.0</b>   | —            |

Source: synthesized mean counts from the study dataset.

Total individuals recorded at Lalitpur–Deogarh was 65 during the pre-breeding phase, which then increased to 85 during the breeding phase and declined to 55 during the post-breeding phase. The Chhatris also exhibited a pattern, where 50 individuals were recorded during the pre-breeding phase, followed by 70 individuals during the breeding and 40 during the post-breeding phases. Chaturbhuj Temple witnessed the existence of 45, 60, and 35 individuals respectively during the mentioned phases. Conversely, Kankar recorded merely 20 individuals, 28 during the breeding phase and 18 during the post-breeding phase. Sipri recorded 25 individuals during the pre-breeding period, 32 during the breeding, and 22 during the post-breeding

period. Therefore, the mean abundance during the three phases of breeding collected from various regions were in the following order: Lalitpur–Deogarh (68.3), Chhatris (53.3), Chaturbhuj (46.7), Sipri (26.3), and Kankar (22.0). Overall, the mean abundance was recorded at 41.0 individuals during the pre-breeding phase and increased to 55.0 individuals during the breeding phase (an increase of around 34.1 %), and later decreased again to 34.0 during the post-breeding season (which was about 38.2 % lower than breeding mean).

### Statistical analysis

Two-factor ANOVA of the seasonal count matrix demonstrated a highly significant site/habitat effect:

$$F_{4,8} = 41.24, p < 0.001$$

Season also produced a highly significant effect:

$$F_{2,8} = 21.24, p < 0.001$$

These results demonstrate that variation in observed vulture abundance was associated with both spatial habitat differences and breeding-season phenology.

**Figure 1. Seasonal population dynamics of vultures across five habitats in Bundelkhand**

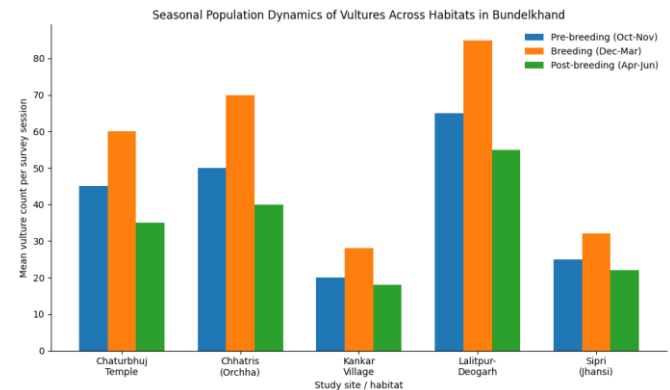


Figure 1. The average population of vultures throughout the pre-breeding, breeding and post-breeding phases in Chaturbhuj Temple, Chhatris, Kankar village, Lalitpur–Deogarh and Sipri. The amount of vultures recorded during breeding was higher than that of both pre-breeding and post-breeding periods, and Lalitpur–Deogarh had the largest concentration of vultures. The large concentration of vultures during their breeding is due to the accumulation of the adult and immature birds in nesting areas and consecutive visits of parents during incubation and fodder feeding. Post-breeding decrease in the number of vultures can be attributed to the fact that the nesting young have started to disperse further.

### 3.2 Habitat-specific Breeding Performance

Substantial differences in reproductive performance were observed among the five locations.

**Table 2. Breeding performance of vultures across major habitats of Bundelkhand**

| Site              | Eggs laid | Hatchlings | Fledglings | Breeding success (%) | General habitat condition                |
|-------------------|-----------|------------|------------|----------------------|------------------------------------------|
| Chaturbhuj Temple | 31        | 27         | 19         | 61.3                 | Monument; relatively high human activity |
| Chhatris, Orchha  | 36        | 32         | 24         | 66.7                 | Monument/cenotaph complex                |
| Kankar village    | 8         | 6          | 3          | 37.5                 | Rural scrub/agriculture; tree nesting    |
| Lalitpur–Deogarh  | 44        | 40         | 32         | 72.7                 | Natural cliffs/forest; low disturbance   |
| Sipri, Jhansi     | 12        | 10         | 6          | 50.0                 | Scrub/town periphery                     |

Breeding data represent the combined source-study breeding assessment. The highest breeding success in Lalitpur–Deogarh was recorded at 72.7%. In contrast, Chhatris was found next in line at 66.7%. Chaturbhuj Temple had the third-highest rate of reproductive performance at 61.3%. Sipri was an intermediate performer in terms of reproductive success at 50.0%. The minimum breeding success was reported in Kankar at 37.5%.

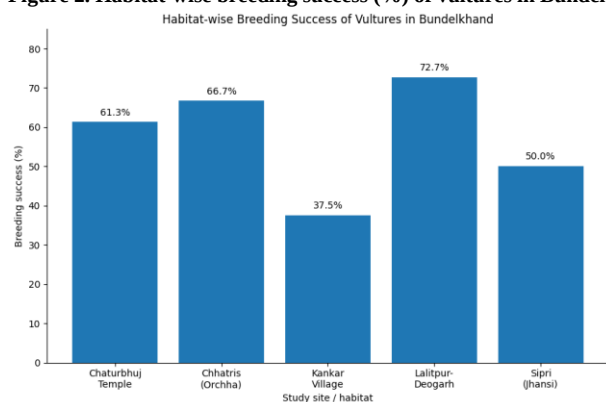
**Figure 2. Habitat-wise breeding success (%) of vultures in Bundelkhand**

Figure 2. Among the five study locations that were investigated, Lalitpur–Deogarh had the highest success in breeding (72.7%) while Kankar village was found to have lowest (37.5%). Natural cliffs were also the most favorable nesting sites, having the highest density of nesting sites at around 18 nests km<sup>-2</sup> in Season 1 and increasing to around 19 nests km<sup>-2</sup> in Season 2. Monument habitats had a nesting density of between 14 and 15 nests km<sup>-2</sup> and tree-dominated nesting sites had, at most, about 3.0–3.2 nests km<sup>-2</sup>.

#### 4. Discussion

According to the findings, there is a solid association among habitat configuration, seasonality, and vulture abundance in Bundelkhand. Lalitpur–Deogarh is considered the most significant region among the five chosen regions because it supported the most significant population sizes and the highest reproduction rate. The prevalence of cliff habitats can be explained partly by their nesting safety. High cliffs create a shield against ground predators, stability, and good access to thermal currents. The observations of cliff nesting show that these nests were at much higher altitudes compared to those made on trees and that they were located much farther from the human population. The Orchha monuments can be considered the second center of population. Chhatris had a mean breeding season population of 70 vultures and Chaturbhuj Temple had a mean population of 60 vultures. The monuments function as artificial cliffs because of the stone design. Thus, various stone protrusions, holes and ledges create suitable conditions for nesting of vulture species belonging to the genus *Gyps*, showing that man-made structures do not always negatively affect wildlife. Nonetheless, the reproductive outcomes at the monuments were lower than those observed in Lalitpur–Deogarh. The breeding success rate in Chaturbhuj is 61.3 % and in Chhatris is 66.7 % while it is equal to 72.7 % in Lalitpur–Deogarh region. According to the study, tourism, noise, reconstruction works and vicinity to the human population can be the potential reasons of disturbance of the colonies residing at the sites. It is therefore essential for conservation efforts directed towards vultures that nest on historical monuments to combine the objectives of tourism with effective protection during the breeding period. Implementation of temporary bans on activities that disturb nests as well as the prohibition of renovation works during the period from December to March may provide an efficient tool for management. Another important variable influencing the abundance of vultures at particular locations was seasonality. The number of vultures recorded while breeding was higher at any of the selected sites. The average number of vultures recorded in the previous years was 41, increasing to 55 during breeding, and dropping to 34 during post-breeding. Such differences are statistically significant ( $p < 0.001$ ). The explanation for this phenomenon stems from the fact that adult birds spend considerable time around established colonies due to frequent visits to the nests. In fact, the authors of the study state that the high visibility of vultures in the period of December to March is also related to nesting. A gradual decline after the breeding season does not mean that the observed decrease is due to deaths of vultures or total population decline. Juvenile birds may travel farther away from the site where they were raised and become capable of finding enough food in wider areas. Therefore, it is crucial to standardize the timing of monitoring programs. Otherwise, the results may prove to be inaccurate.

Species composition is an additional indicator of the ecological peculiarities of the habitat studied. Indian Vultures turned out to be the most widespread species throughout the study area, especially on cliffs and monuments. On the other hand, Egyptian Vultures appeared to be more common in Kankar and Sipri where agriculture and habitation were prevalent. This difference implies that ecological partitioning occurs in the regional scavenger community. The low reproductive success and the low abundances recorded at Kankar should be noted. In contrast to the large colonies on the cliffs and monoliths, Kankar had a very small number of active nests and depended more on nesting and foraging in the trees. The number of active nests decreased from six in the first season to five in the second; meanwhile, the

number of active nests at Lalitpur and Deogarh increased from 42 to 44. Although the differences stated are small, the overall trend is a corroboration of the low reproductive performance at Kankar. Nests in trees were less stable and were at lower heights. The source study points out that storms, predation, and disturbances were the things that made these nests vulnerable. The success of breeding at Kankar, which is only 37.5%, must be due to the combination of the factors mentioned above and not only a single limiting factor.

Climate could intensify the differences stated in this section. Bundelkhand has high summer temperatures, and the observations of the source state that in extremely hot conditions, the temperature was more than 44 degrees centigrade and was accompanied by low humidity and strong winds, which all led to the alterations of the search activity in adults and led to the problem of dehydration of the chicks and the instability of the nests. Cavities in cliffs and holes in monuments have more climatic protection than open trees.

The habitat differences described above have their significance for conservation. South Asian vultures have already experienced severe declines connected with the veterinary pharmaceuticals, especially diclofenac (Oaks *et al.*, 2004; Green *et al.*, 2004; Cuthbert *et al.*, 2011). The prevention of pharmaceutical poisoning is still important, but it is impossible to expect any success if breeding habitats are prone to habitat degradation or disturbances. The conservation in Bundelkhand should be organized at the landscape level, and Lalitpur and Deogarh should be considered as the key areas for breeding, as this area shows high abundance of vultures, and high breeding success. Orchha should receive special measures aimed at habitat management in the colonies located on the rocks. Even though Kankar and Sipri do not have big breeding populations, they should not be considered as unimportant points. According to the research source, even though these rural and semi-urban landscapes have low breeding populations, they still serve as feeding points of vultures. The other important result is that breeding populations still show some recruitment. Juveniles make about 15–18% of the population depending on the region. It is important for long-living species, which have low reproductive rates. Thus, juvenile recruitment is vital for the survival of vultures.

#### 5. Conclusion

This research highlights that vulture populations exhibit remarkable spatial and temporal variability in different habitats of Bundelkhand. It was noted that Lalitpur–Deogarh was the most important geographical region for vultures. It had the maximum number of vultures during breeding season (85 birds), the mean abundance in different periods of the year (68.3), and the highest breeding success (72.7%). The Orchha monument complex had a considerable number of vultures, indicating the importance of conservation practices that make use of anthropogenic objects for breeding. Kankar and Sipri sites were less important, as they had fewer vultures and lower reproduction results, but they still played a significant ecological role as feeding and roosting grounds. Statistical analysis of collected data showed significant differences in the abundance of vultures at various study sites ( $F_{4,8} = 41.24$ ,  $p < 0.001$ ) and during different seasons ( $F_{2,8} = 21.24$ ,  $p < 0.001$ ). The fact that the number of vultures in Bundelkhand is always the highest during the breeding season indicates the importance of this aspect when making plans on population studies. In designing conservation plans for Bundelkhand, one has to focus on conservation of special cliff colonies, minimizing human disturbance in areas of monuments from December to March, conservation of feeding areas of vultures, control over the populations of stray dogs, securing nesting areas from the effects of veterinary medications.

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