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Nest-Substrate Variation and Breeding Performance of the Critically Endangered Indian Vulture (*Gyps indicus*) in the Bundelkhand Landscape, Central India

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Abstract

The survival of the Critically Endangered Indian Vulture (*Gyps indicus*) depends on appropriate nesting sites and adequate population growth in areas where breeding colonies share habitats with tourism, human settlements, and agriculture. This research examines differences in the number of active nests, nesting site characteristics, and reproductive performance across five selected sites in the Bundelkhand region of central India: the Chaturbhuj Temple, the Orchha Chhatris, Kankar village, the Lalitpur-Deogarh cliff system, and Sipri, Jhansi. The dataset examined consists of data collected over two breeding seasons between 2021 and 2024 at the sites listed above, which included examples of building colonies, cliff colonies, and tree colonies. The number of active nests increased from 120 in period 1 to 127 in period 2, although Kankar's nest count went from six to five active nests. There were a total of 131 eggs laid, resulting in 115 hatchlings and 84 fledglings, yielding a hatching success of 87.8% and a fledging success of 73%. The breeding success at the Lalitpur-Deogarh cliff system was the highest at 72.7%, followed by the Orchha Chhatris at 66.7%, the Chaturbhuj Temple at 61.3%, Sipri, at 50% and Kankar at 37.5%. Cliff breeding sites were approximately 32 to 55 meters tall, the monument breeding sites were 28 to 48 meters, and the tree breeding sites were 8 to 15 meters tall. Natural cliffs offered the best breeding sites due to their relative stability and low disturbance as well as the fact that they are set back more than 500 meters away from human development. Colonies built on buildings experienced moderate nesting densities but were often disturbed due to tourism and construction work while tree colonies were less numerous and vulnerable to bad weather, predators, and domestic dogs. Despite the lack of statistically significant differences in breeding success rates, it is recommended that different management practices be maintained to provide optimal nesting conditions at the two sites that were found to be successful for breeding.

Keywords: breeding success; Bundelkhand; cliff nesting; *Gyps indicus*; heritage monuments; nest-site selection; reproductive ecology

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Introduction

Vultures are one of the most functionally significant vertebrate scavengers, as they make use of dead animals and feed on them quickly. By performing these functions, vultures play important roles in nutrient recycling, reducing the time for dead animals to be available to facultative scavengers as well as stabilizing food webs for scavengers in pastoral and agricultural systems. The significance of vultures becomes even more important in the context of South Asia because of the large number of livestock present in the area and how carcasses are disposed of in a non-official manner. Despite the ecological importance of vultures, their numbers have drastically decreased throughout the years due to poisoning, pharmaceutical drugs, habitat destruction, collision and electrocution, food-system changes, and deliberate harm.

Three species of resident vultures, Gyps species of the Indian subcontinent experienced huge declines beginning the 1990s due to exposure to animal residue which occurred before death. The principal cause for the decline of the Gyps vultures is thought to be their sensitivity to diclofenac which leads to renal failure and visceral gout. As reported by national and regional surveys, there was a slowed decline of vultures due to limitations on veterinary diclofenac use; although, their numbers remain extremely low. Therefore, this remains a continued threat for vultures despite secure breeding habitats.

The Indian Vulture (*Gyps indicus*) is a large cliff-nesting species that is usually colonial or loosely colonial.Single egg-laying species usually lay a single egg, resulting in a longer incubation, chick care, and fledgling care period. This reproductive strategy thus may be limiting to adult mortality compensation as well as repeated nesting failures. Therefore, species requiring conservation assessment cannot solely rely on audit of visible birds. Information about active nests, hatching rates, fledgling production, age demography, and breeding territory persistence should be documented as they give more useful information.

Nest site selection of a large bird of prey is widely dependent on several factors such as topography or vegetation type. The availability of nesting sites will allow the population size of species residing in the habitat. Availability of ledges and cavities among natural rock formations, old trees, or artificial nesting sites contributes to the reproduction success of each species. Birds may nest in such sites, but high disturbance may cause them to act as ecological traps, whereby adult birds come to breed and lose their offsprings on an ongoing basis.

Bundelkhand, located in the states of Uttar Pradesh and Madhya Pradesh, is characterized by a combination of hard-rock cliffs, dry deciduous forests, rivers, lakes, scrubland, farmland, and architectural landmarks. Monuments built in the town of Orchha contain sufficient nesting traits such as ledges, arches, crevices, and other nesting areas in close proximity to food and water sources. In the Lalitpur-Deogarh sector, a rich presence of hard rocks with overhangs and roofs creates additional nesting sites while habitats like Kankar and Sipri have smaller cliffs and derelict structures suitable for nesting. Indian, White-rumped, Egyptian and Red-headed Vultures are present in this habitat mosaic, with Indian Vulture dominating the breeding component in bigger cliff and monument colonies. Some human-made nesting structures may provide good conservation outputs; however, their management will be complicated by factors such as monument restoration, cleaning, scaffolding, celebration events, drone operation, filming and heavy tourist movements, which might coincide with courtship, incubation or chick-rearing. Adult vultures can tolerate predictable human activities at a distance, especially if their nests are unreachable. We need more breeding data to provide a proper balance between the need for biodiversity conservation and human interventions.

As for natural cliff colonies, they can be subjected to a different set of threats quarrying of rocks, road building, blasting, climbing, and tourism activity can destroy the nests or the ledges, while different water and heat availability patterns can negatively affect the parental presence, and since tree-nesting sites might experience a higher threat of storms, loss of canopy, predation and different forms of human activities in the agricultural areas, we can state that the performance of breeding can differ among the substrate types.

In this study, we will use a specific dataset gathered in the five representative habitats of Bundelkhand that cover the two breeding seasons. The study will aim to compare the abundance of active nests in different breeding seasons; analyse the hatching, fledging and overall breeding success of the vultures; describe the structural and environmental differences between cliff, monolith, and tree nests; study the disturbance pattern of the vultures throughout their territory; and establish the management needs of each habitat and its priority for the preservation of the Indian Vulture. We expect the cliffs to have the best reproductive success as they are the most stable substrate level and have limited human access, while the monoliths would have almost the same density of nests compared to the cliff level, while the tree-nesting sites would have a lower reproductive success.

2. Materials and Methods

2.1 Study area- The survey examined five locales within the primary vulture habitats of the Bundelkhand region, which consisted of Chaturbhuj Temple and its associated Chhatris in Orchha; Kankar village; Lalitpur-Deogarh's rocky and wooded area; and Sipri at the edge of Jhansi Town. The region has a tropical climate with cooler and drier winters, hot pre-monsoon

summers and a brief monsoon season. The average temperature during the breeding season ranges about 16-25 °C while it reaches 38-45 °C during the months of April and June with maximum temperature peaking to about 47 °C during this period. The wind speeds increased considerably during the post-breeding period when dust storms were common. Orchha is a riverine heritage site situated on the banks of Betwa river. Chaturbhuj temple has high walls with many depressions, niches, crevices, ledges and architectural niches while Chhatri complex has domes, crests and crevices. Kankar in agricultural and scrubland has ephemeral lakes, community disposal sites for carcasses and limited possibilities of tree or cliff nesting. The Lalitpur-Deogarh arboreal area comprises of tropical evergreen forest with perennial water flows, large cliffs and access limitations for humans. Sipri area represents scrubland-stage and a town boundary with small rocky cliffs, dilapidated structures, ephemeral streams and dead animals by roadside.

2.2 Study period and survey framework- The dataset analyzed here consists of field observations from 2021 to 2024 consisting of an 18-month extensive field study and two breeding seasons (December to March 2021 and December to March 2022) and classified into pre-breeding period (October-November), breeding period (December to March), and post-breeding period of April to June. Observations of vultures nesting, perched, roosting, and soaring were done through point count and short distance road transects. Therefore, the analysis here will be regarded as comparative ecological assessment at five sites rather than a full census of the entire Bundelkhand vulture populations and making statistically conservative conclusions devoid of claims about nesting processes.

2.3 Active nests and nest substrates- An active nest is defined as a nest having ongoing adult attendance, nest defense, incubation, visible eggs, and a chick in dependence of its parents as indicators of a nest being active. Active nests would be counted multiple times for each breeding season. Nesting substrates may be categorized according to cliffs that are either natural or historic, and trees or low structures. The nest density that was reported under the major categories for the nesting substrate type was, respectively, 18 nests per square kilometer for successful exploitation of cliffs at Lalitpur-Deogarh and 14 nests per square kilometer for historic monuments in Orchha; and 3.0 nests per square kilometer and 3.2 nests per square kilometer for terrestrial trees.

2.4 Nest characteristics- The nest characteristics by substrate such as nest height, orientation, percentage of canopy cover, distance from anthropogenic activity and nest structure stability were compiled. For cliff nests, the average height was around 32-55 m from the ground level. Cliff nests were primarily oriented towards southeast and south direction and located more than 500 m from anthropogenic activities. Monument nests, on the other hand, were found at an average height of approximately 28-48 m with east/southeast orientation with distances of 50-150 m from minor human activities. Tree nests were around 8-15 m high. They are located under tree canopy cover with about 40-65% coverage. Nest orientation was primarily south and southwest among tree nests with distances of 100-250 m from anthropogenic activities.

2.5 Breeding performance- At each location, numbers of eggs laid, hatchlings seen, as well as fledglings leaving or surviving to fledging at the late stage were compiled for the combined data collection period. Hatching success was calculated by counting hatchlings divided by number of eggs laid. Fledging success after hatching was determined from the number of fledglings divided by the number of hatchlings. Breeding success was based on fledglings divided by number of eggs laid and reported as a percentage. Since the Indian Vulture typically only produces one egg each season, this value was largely equal to the number of confirmed nests, although there may be some doubt about nests that were not able to be visited.

2.6 Disturbance and habitat suitability- Various disturbances were classified indicating tourism, renovation or construction, noise, feral dogs, agricultural activities, nearness to settlements and water deficiency or heat stress disturbance level being classified. Disturbance was high on both Orchha monuments, moderate on Kankar, low on Lalitpur-Deogarh and moderate-high in Sipri. Habitat suitability scores as received from the dataset is 9.2 for Chaturbhuj Temple, 9.5 for Chhatris, 7.1 for Kankar, 9.7 for Lalitpur-Deogarh and 7.4 for Sipri.

2.7 Statistical analysis-Using Python, totals and percentages from each site were calculated. The change in active nests was expressed in relation to season no. 1. Then, reproductive outcomes were compared descriptively between each region. A 2 x 5 contingency table making comparisons of fledged vs. non-fledged breeding attempts was examined using Pearson's chi-square analysis, however, it is noted, that this test should be interpreted carefully because there were only five combined site units and there are low expected cell frequencies. The relationships of habitat-score are shown in graphs to generate hypotheses rather than stand-alone causal tests because the suitability index included variables that might also affect the reproductive outcome. Statistical significance is determined using $P < 0.05$.

Table 1. Ecological characteristics of the five study sites.

Study site	Principal habitat	Nesting substrate	Water proximity	Feeding context	Suitability
Chaturbhuj Temple	Riparian-urban heritage area	Monument niches and ledges	<1 km, Betwa River	Urban/roadside carcasses	High (9.2/10)
Chhatris, Orchha	Riparian scrub and cenotaph complex	Domes, cornices and crevices	<1 km, Betwa River	Riverbank and carcass dumps	High (9.5/10)
Kankar village	Open scrub and agriculture	Small cliffs and trees	Seasonal ponds, 1-3 km	Village disposal site	Moderate (7.1/10)
Lalitpur-Deogarh	Dry deciduous forest and rocky valley	Large cliffs and rock faces	Perennial rivers within 2 km	Valley carcasses and forest edges	Very high (9.7/10)
Sipri, Jhansi	Semi-scrub and town periphery	Low cliffs and abandoned buildings	Seasonal streams	Roadside carcasses	Moderate (7.4/10)

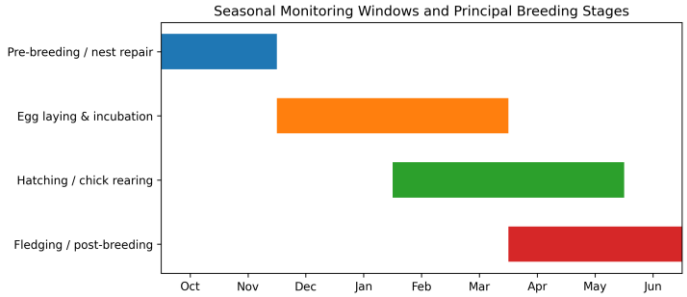

Figure 1. Seasonal monitoring windows and generalized breeding stages used in the study.

Results

3.1 Active-nest abundance and inter-seasonal change- In total, 120 active nests during the first breeding season and 127 during the second breeding season was found, which tells that there was an increase of about 5.8%. Lalitpur-Deogarh colony had also the largest number of nests during both seasons, which increased from 42 to 44. The Orchha Chhatris increased in numbers from 34 nests to 36 nests and Chaturbhuj Temple from 28 nests to 31 nests. Sipri increased its number from 10 nests to 11 nests. Kankar was the only site that decreased in number of nests going from 6 nests to 5 nests. The proportional increase was largest at Chaturbhuj Temple (10.7%), which was followed by Sipri (10%). Chhatris had the increase of 5.9% while Lalitpur-Deogarh had an increase of 4.8%. Kankar was with a decrease of 16.7%. In total there was a record of 247 active nests at five sites and Lalitpur-Deogarh contributed 34.8% of nests, Chhatris contributed 28.3% of nests, Chaturbhuj Temple contributed 23.9% of nests, Sipri contributed 8.5% of nests and Kankar contributed 4.5% of nests.

Table 2. Active Indian Vulture nests across two breeding seasons.

Site	Season 1	Season 2	Absolute change	Change (%)
Chaturbhuj Temple	28	31	3	10.7
Chhatris, Orchha	34	36	2	5.9
Kankar village	6	5	-1	-16.7
Lalitpur-Deogarh	42	44	2	4.8
Sipri, Jhansi	10	11	1	10.0
Total	120	127	7	5.8

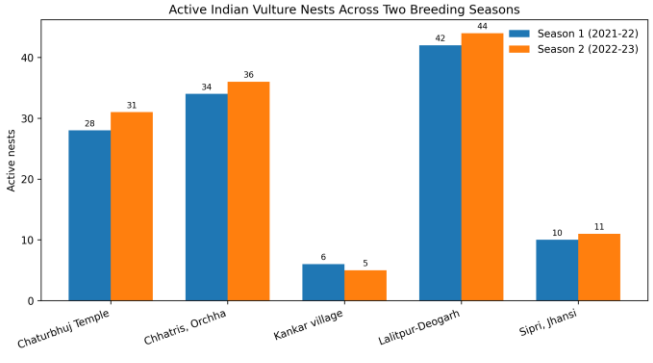

Figure 2. Active nests recorded at the five study sites during two breeding seasons.

3.2 Nest density and substrate characteristics- In terms of nest density, cliff habitat ranked first, climbing from 18 to 19 nests per square kilometer

across seasons. Monument habitat rose from 14 to 15 nests per square kilometer in that timeframe. The nest density in tree habitat, on the other hand, was significantly lower, changing minimally from 3.0 to 3.2 nests per square kilometer. For season 2, cliff habitat nest density was about 5.9 times more dense than tree habitat; monument habitat nest density was 4.7 more than tree habitat density.

However, the differences between the substrate categories included not only the density of nests but also their structural quality. Cliff nests had the tallest nests (32 to 55 m), were located far (500m+) from repeated human activity and were classified as very stable. Monument nests were somewhat tall as well (28 to 48 m), structurally stable, but were near (50 to 150m) repeated activity. Trees nests were much lower (8 to 15 m), were unstable to some degree and prone to exposure from wind, canopy shift, predation, and disturbance from agriculture and settlement.

Regarding the orientation, it seemed to indicate a tendency for nests to be heated by the sun in the morning. Cliffs nests had orientations that were mainly south-east or south facing, monument nests were oriented east or south-east, while tree nests could have faced south or south-west. It is likely that the orientation of the monument nests in the easterly and south-easterly direction provides warmth to nests after cold nights.

Table 3. Nest density and physical characteristics by substrate.

Characteristic	Natural cliffs	Monuments	Trees/low structures
Nest density, season 1	18 nests/km²	14 nests/km²	3.0 nests/km²
Nest density, season 2	19 nests/km²	15 nests/km²	3.2 nests/km²
Nest height	32-55 m	28-48 m	8-15 m
Preferred orientation	SE, S	E, SE	S, SW
Canopy cover	Not applicable	Not applicable	40-65%
Distance from human activity	>500 m	50-150 m	100-250 m
Structural stability	Very high	High	Low-moderate
Dominant breeding species	*Gyps indicus*	*Gyps indicus*; some Neophron	Mainly Neophron; few Gyps

3.3 Hatching, fledging and breeding success- In total, there were 131 eggs recorded amongst all the sites, where 115 hatchlings and 84 fledglings were observed. The overall hatching rate calculated from all the sites was 87.8%, the fledging rate after hatching was 73.0%, and the overall breeding success was 64.1%. Hence, there were 16 nests lost either at or before hatching and another 31 nests lost after hatching until fledging. Among the sites, Lalitpur-Deogarh had the highest number of eggs (44), hatchlings (40), and fledglings (32). The hatching success demonstrated by the site was 90.9%, the fledging success after hatching was 80.0%, and the breeding success was 72.7%. The second-highest success was recorded in Orchha Chhatris with a success figure of 66.7% while the other site was Chaturbhuj Temple with 61.3%. Sipri recorded 50.0% fledging success with six fledglings coming from twelve eggs while Kankar had only three fledglings from eight eggs, denoting 37.5% fledging success.

The site-based difference recorded in between the fledging and non-fledging site-wise outcomes was not statistically significant as per the total aggregation contingency (chi-square=5.13, df=4, P=0.274). However, the presence of statistical significance cannot be considered as equivalence in the analysis because of the very simple statistical calculations being taken into consideration in spite of Kankar's very little breeding attempts. Nonetheless, the distinct pattern was again recorded, as cliff colonies occupied the topmost portion followed by monument colonies, peri-urban sites and tree-associated rural sites when taking into hold ecological aspects and disturbance observations.

Table 4. Reproductive performance of Indian Vultures at the five study sites.

Site	Eggs	Hatchlings	Fledglings	Hatching (%)	Fledging of hatchlings (%)	Breeding success (%)
Chaturbhuj Temple	31	27	19	87.1	70.4	61.3
Chhatris, Orchha	36	32	24	88.9	75.0	66.7
Kankar village	8	6	3	75.0	50.0	37.5
Lalitpur-Deogarh	44	40	32	90.9	80.0	72.7
Sipri, Jhansi	12	10	6	83.3	60.0	50.0
Overall	131	115	84	87.8	73.0	64.1

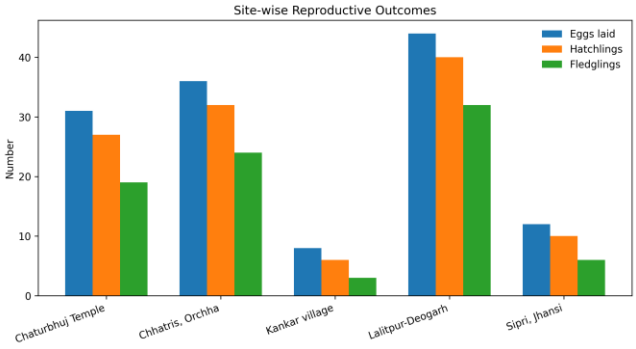

Figure 3. Numbers of eggs, hatchlings and fledglings recorded at each study site.

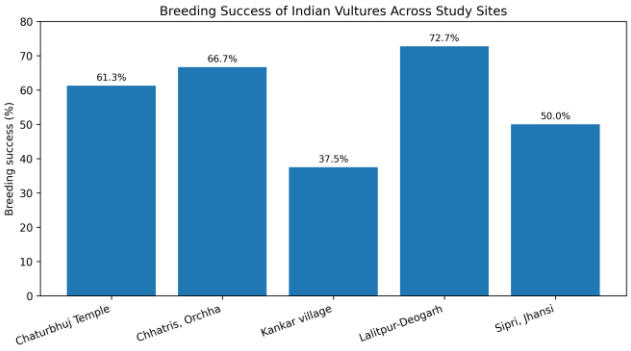

Figure 4. Site-wise breeding success expressed as fledglings per egg laid.

3.4 Disturbance gradient- The two Orchha monument sites were considered high-disturbance habitats due to the high tourism pressures, festival or vehicular noise at both sites; while there was low renovation and construction site activity in Chaturbhuj Temple, Chhatris recorded low-moderate site activity. Human disturbance because of urban settlements was, however, high, and feral dog presence was either moderate or high at both sites. These disturbances did not, however, compromise the presence of large breeding colonies at both sites that had a breeding success rate of at least 60%, proving the survival and maintenance of the elevated architecture of the monument sites in spite of the disturbances. Therefore, Orchha monument sites seemed to have lower breeding success rates as compared to Lalitpur-Deogarh due to their continuous exposure to humans and the increased construction programs in the region. Most of the activities of Lalitpur-Deogarh were limited to tourism, renovation of monuments, disturbances from urban settlements and feral dogs, while remaining in an undisturbed atmosphere.

Table 5. Qualitative disturbance intensity across the study sites.

Disturbance	Chaturbhuj	Chhatris	Kankar	Lalitpur - Deogarh	Sipri
Tourism pressure	High	High	Low	Very low	Low
Renovation/construction	High	Moderate	Low	Very low	Low
Noise	High	High	Moderate	Low	Moderate
Feral dogs	Moderate	High	High	Low	High
Agricultural disturbance	Low	Low	High	Moderate	Moderate
Settlement proximity	High	High	Moderate	Very low	Moderate
Water scarcity/heat stress	Moderate	Moderate	High	Moderate	High
Overall level	High	High	Moderate	Low	Moderate-high

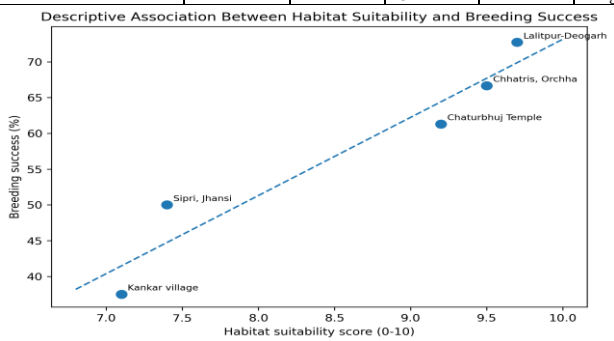

Figure 5. Descriptive relationship between the reported habitat-suitability score and breeding success.

3.5 Seasonal and behavioural context- The most active breeding period occurred during the relatively dry months of December through March (mean temperature range of 16-25°C) when rainfall was low and wind speed was usually 4-8 km/hr. Observations made in the months prior to the breeding period, in the months of October and November, included aggregation of vultures at nesting locations, attendance to nesting areas, and courtship behavior. The only observations that took place from April through June included high temperatures (38-45°C), dry air, and higher wind speeds (12-22 km/hr) during the post-breeding period. During morning basking and wing-spreading, adult vultures subsequently began soaring and searching for food as rising thermal conditions helped them gain altitude. Nest activity or parental behavior occurred every three-four hours. When experiencing extreme heat, adults shaded their chick and stayed with it while remaining inactive. High wind and dust levels highly affected vulture nests in the Kankar and Sipri areas.

Feral dogs also interfered with prolapse and delayed vulture feeding times for approximately 15-45 minutes depending on the disturbance observed. Certain disturbances tend to have a much larger impact on juveniles and smaller scavengers relative to adults. At Lalitpur-Deogarh, the relative absence of feral dogs and the stable roosting conditions allowed uninterrupted roosting and preening.

Discussion

The research has demonstrated the presence of a clear ecological gradient in the breeding performance of Indian Vultures throughout the Bundelkhand area. Natural cliffs in Lalitpur-Deogarh housed the biggest colony, with the highest nesting density and the most successful breeding. The historical sites of Orchha also act as extremely valuable surrogate cliffs, providing a large number of active nests while also maintaining moderate and high reproductive success results despite human disturbances. On the other hand, sites with tree- and low-structure had a low nesting density and success rates, especially Kankar. Although the increase of active nests from 120 to 127 between seasons indicates some positive trends, it should not be regarded as a reliable sign of population dynamics. Counts of active nests can fluctuate based on factors such as detection ability, occupancy of territory, the timing of observation, and the counting of replacements or repeated observations. Therefore, the period of two years is too short for separating the recovery from short-term fluctuation. Nonetheless, the fact that there are more than 100 active nests at the observed sites proves that Bundelkhand is an important breeding area. The most recent data regarding the population of Indian Gyps indicates a persistently low number of individuals and a certain degree of stability, which makes efficient breeding areas even more essential (Prakash *et al*. 2024).

The reproductive database has produced a totalsuccess rate of 64.1%. This total, which consists of 84 fledglings from 131 verified egg-laying attempts, confirms that there is some degree of recruitment occurring. Nevertheless, the extent to which these fledglings can actually contribute to demographic growth must take into account post-fledging mortality, the influence of toxic veterinary medications, and the fitness of adult birds. Survival of adults is particularly important regarding lengthy-lived vultures, as it has a marked effect on population augmentation.Even with adequate nest success, a colony may decline if adult population gets to be reduced because the adults have been killed off due to consumption of poisoned carcasses or deaths associated with human-created infrastructure.

The 72.7% chick survival rate at Laurepahari-Deogarh site was correlated to high and stable cliffs, very little human activity and disturbances along with high accessibility to flight altitudes of over 110 meters, reliable water sources and little tension from tourism.

Breeding at heights ranges from 32 to 55 meters reduces the risk of human access to the nesting colony. They are given free access to flying in and out of the colony without any impediments. Overhangs provide protection against heavy rainfall and direct sunshine for both eggs and chicks. Because of the natural characteristics of the site, there is a high occupancy level for the colony along with high productivity.

Orchha monuments act as a substitute for cliffs for the breeding process.

There were also some deep niches, domes, arches as well as joints that are naturally strengthened design components contributing towards high nesting.

Despite the additional disturbance in terms of noise due to high tourism on the recorded sites, Chaturbhuj Temple had a high number of renovation activities or constructions at the site, which did not render the disturbance level meaningless.

Normally, there will be no effect on the adult due to noise or disturbances registered at ground level while they would not tolerate movements associated with roofs or any disturbances occurring around nests.The repeated flushing presents possibilities of exposing the egg or young chick, lessening feeding rates, and raising energetic usage. The intermediate performance of the monument nests compared with those on cliffs shows that a precautionary approach to disturbance management is desirable.

The first goal of wildlife-sensitive heritage management should be to do an inventory of nests. Prior to any restoration activities, the active, recent and historical nest hollows should be mapped. All work in the region that involves drills, scaffolds, chemicals, rooftop access, or hollow closures must take place outside of the verified breeding season. If it is safe to do so, intact ledges or caves must be retained. Kankar had a success rate of 37.5%, matching its moderate nest stability and level of disturbance. The previous dataset shows low overall success in tree nests (e.g., 37.5%); because trees at 8 to 15 m (e.g., where bird nests are situated) are subject to wind and accessible from animals or humans.

Kankar's example of low success with respect to reproductive output should be kept within the context of local conditions and disturbances, given that the case of Sipri demonstrates that nestsNests are oriented based on how much sunlight they receive and how sheltered they are. Since nests on cliffs facing east or southeast get sunlight in the morning, the angle of the nest is very important for determining how efficient the nest will be. Cliff-nesting sites also receive strong winds in addition to sunlight, thus the orientation will be dependent on the location of the nests because of the presence of shade at each location. A more effective study would retrieve more information about how many cliffs are functional while comparing the selection of the cliff based on radiation, cliff width, cliff depth, cliff overhang, and the amount of heat from the sun.

There are climatic factors occurring at different times of the year during breeding. The months of December to March are relatively warm with low winds when the chicks are sitting on their eggs, while the months of April to June provide temperatures above 40 °C with dust storms. The cycle of breeding and hatching needs to be supervised because the adult vultures have the choice of keeping their young chicks in the shade or limiting their movement, which is stressful for nests with no cover.

Dogs create two main problems for vultures at feeding sites because dogs prevent vultures from gaining access to carrion piles and also leave the vultures with less food available. Dogs can change various factors such as population dynamics and change the situation with diseases. The response to dogs is based on strategies without eradication plans.Both the accessibility of carrion and pharmaceutical safety need to be considered. The use of the anti-inflammatory drug diclofenac has contributed greatly to the drastic decline of the Gyps vultures and the continued use of banned or legal veterinary drugs continues to have an adverse affect on the recovery of vultures. The breeding colonies mentioned should constitute the Bundelkhand Vulture Safe Zone where veterinary pharmacies, farmers and carcass disposal practices will be regulated. The mere availability of carcasses cannot guarantee safe food. Therefore, appropriate residue monitoring and promotion of vulture-safe alternatives must be implemented.

The strong correlation that appeared between habitat quality and success during this study was observed only in a limited data set of five locations. The habitat quality score was created using factors such as substrate, presence of water and disturbance so that data quality is questionable. In future research it would be advantageous to measure the various habitat components and use generalized linear mixed modelling of reproductive success and habitat variables at the nest level.

There were insufficient differences between sites shown by the aggregated chi-square test because of the limited numbers of nests located and monitored at the two studies of Kankar and Sipri. Improvements in the statistical power of the analysis can only be obtained through using data from each individual nest over a number of years. Survival analysis of the data from monitoring nests may help deal with unequal periods of observation and nesting attempts at different stages. Being able to give the exact dates for egg laying, hatching and fledging can lead to daily survival rate estimates for the nests.

Certain figures in the source chapter were stated as either approximate or synthesized and such a limitation is critical for publication. It is important to note in the submission that it is a high quality journal so that the author has distinguished between direct counts of nests and those created based on fieldwork. It is also essential to give the original nest monitoring record to act as supplementary information so that it can be utilized in the way intended. Although the exact coordinates of each nest cannot be identified, it is possible to give the separate ID of each nest along with the date that it was surveyed.

In relation to all of the limitations presented, the ecological trend is still valid. There is not one breeding habitat in Bundelkhand, but a variety of habitats that are complementary to each other. Natural cliffs are the safest areas with the highest productivity, while monuments can serve as surrogate cliffs. Management at both the colony and habitat levels is essential.

5. Conservation Implications

Quarrying, blasting, climbing, road construction, and tourism should be restricted on the Lalitpur-Deogarh cliffs. A seasonal buffer that takes into account the local topography, observed behavioral reactions, and line of sight should be created around all currently occupied cliff sectors from the pre-breeding settlement phase until fledging.

Biodiversity provisions should be included in heritage-management activity at Orchha. Before renovation works begin, a survey of nesting sites must be done. The use of loudspeaker systems, scaffolding, and drone services should be restricted during the breeding season.

In Kankar and Sipri, management should improve safety and cleanliness at carcass-site areas, limit access to and from feral dogs, preserve occupied trees and structures, and educate livestock owners to protect them from attacks.

Communication of carcass disposal protocols and veterinary drug monitoring in the Vulture Safe Zone region should be done on site. There should be reporting of active nests, eggs, hatchlings, and fledglings on an annual basis.

Conclusion

The proposed five-site survey provides evidence that the Critically Endangered Indian Vulture continues to breed in Bundelkhand although reproductive performance is dependent on the type of nest substrate and specific habitat conditions. The majority of nesting sites located on the natural cliffs of Lalitpur-Deogarh were the most productive with little disturbance, whereas vulture nesting sites on the monuments at Orchha had significant colonies, despite being under more disturbance pressure. Nesting sites that incorporated trees or low substrates had lower density and breeding success than sites located on cliffs. Overall, 131 eggs were laid by the Indian Vulture resulting in 84 fledglings which equates to a breeding success percentage of 64.1%. Conservation recommendations should include the development of high cliffs for rearing purposes, incorporation of vulture nesting needs into monument restoration, and avoiding disruption during the breeding period while ensuring that carcasses do not contain any harmful veterinary drugs. Future surveys should ensure data regarding individual nesting sites is kept similar to other nesting sites observed over time.

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Reference

Chaudhry, M. J. I., Ogada, D. L., Malik, R. N., Virani, M. Z., & Giovanni, M. D. (2012). First evidence that populations of the Critically Endangered Long-billed Vulture *Gyps indicus* in Pakistan have increased following the ban of the toxic veterinary drug diclofenac in South Asia. Bird Conservation International, 22, 389-397.

Cuthbert, R., Taggart, M. A., Prakash, V., Saini, M., Swarup, D., Upreti, S., Mateo, R., Chakraborty, S. S., Deori, P., & Green, R. E. (2011). Effectiveness of action in India to reduce exposure of Gyps vultures to the toxic veterinary drug diclofenac. PLoS ONE, 6(5), e19069.

Gilbert, M., Virani, M. Z., Watson, R. T., Oaks, J. L., Benson, P. C., Khan, A. A., Ahmed, S., Chaudhry, J., Arshad, M., Mahmood, S., & Shah, Q. A. (2002). Breeding and mortality of Oriental White-backed Vulture Gyps bengalensis in Punjab Province, Pakistan. Bird Conservation International, 12, 311-326.

Green, R. E., Newton, I., Shultz, S., Cunningham, A. A., Gilbert, M., Pain, D. J., & Prakash, V. (2004). Diclofenac poisoning as a cause of vulture population declines across the Indian subcontinent. Journal of Applied Ecology, 41, 793-800.

Green, R. E., Taggart, M. A., Senacha, K. R., Raghavan, B., Pain, D. J., Jhala, Y., & Cuthbert, R. (2007). Rate of decline of the Oriental White-backed Vulture population in India estimated from a survey of diclofenac residues in carcasses of ungulates. PLoS ONE, 2(8), e686.

Margalida, A., Donazar, J. A., Carrete, M., & Sanchez-Zapata, J. A. (2010). Sanitary versus environmental policies: Fitting together two pieces of the puzzle of European vulture conservation. Journal of Applied Ecology, 47, 931-935.

Mundy, P., Butchart, D., Ledger, J., & Piper, S. (1992). The vultures of Africa. Academic Press.

Oaks, J. L., Gilbert, M., Virani, M. Z., Watson, R. T., Meteyer, C. U., Rideout, B. A., Shivaprasad, H. L., Ahmed, S., Chaudhry, M. J. I., Arshad, M., Mahmood, S., Ali, A., & Khan, A. A. (2004). Diclofenac residues as the cause of vulture population decline in Pakistan. Nature, 427, 630-633.

Pain, D. J., Bowden, C. G. R., Cunningham, A. A., Cuthbert, R., Das, D., Gilbert, M., Jakati, R. D., Jhala, Y., Khan, A. A., Naidoo, V., Oaks, J. L., Parry-Jones, J., Prakash, V., Rahmani, A., Ranade, S. P., Baral, H. S., Senacha, K. R., Saravanan, S., Shah, N., & Green, R. E. (2008). The race to prevent the extinction of South Asian vultures. Bird Conservation International, 18(S1), S30-S48.

Prakash, V., Bishwakarma, M. C., Chaudhary, A., Cuthbert, R., Dave, R., Kulkarni, M., Kumar, S., Paudel, K., Ranade, S., Shringarpure, R., & Green, R. E. (2012). The population decline of Gyps vultures in India and Nepal has slowed since veterinary use of diclofenac was banned. PLoS ONE, 7(11), e49118.

Prakash, V., Galligan, T. H., Chakraborty, S. S., Dave, R., Kulkarni, M. D., Prakash, N., Shringarpure, R. N., Ranade, S. P., & Green, R. E. (2019). Recent changes in populations of Critically Endangered Gyps vultures in India. Bird Conservation International, 29, 55-70.

Prakash, V., Bajpai, H., Chakraborty, S. S., Mahadev, M. S., Mallord, J. W., Prakash, N., Ranade, S. P., Shringarpure, R. N., Bowden, C. G. R., & Green, R. E. (2024). Recent trends in populations of Critically Endangered Gyps vultures in India. Bird Conservation International, 34, e1.

Schabo, D. G., Heuner, S., Neethling, M. V., Rosner, S., Uys, R., & Farwig, N. (2017). Long-term data indicates that supplementary food enhances the number of breeding pairs in a Cape Vulture Gyps coprotheres colony. Bird Conservation International, 27, 140-152.

Shultz, S., Baral, H. S., Charman, S., Cunningham, A. A., Das, D., Ghalsasi, G. R., Goudar, M. S., Green, R. E., Jones, A., Nighot, P., Pain, D. J., & Prakash, V. (2004). Diclofenac poisoning is widespread in declining vulture populations across the Indian subcontinent. Proceedings of the Royal Society B, 271(Suppl. 6), S458-S460.

Swan, G., Naidoo, V., Cuthbert, R., Green, R. E., Pain, D. J., Swarup, D., Prakash, V., Taggart, M., Bekker, L., Das, D., Diekmann, J., Diekmann, M., Killian, E., Meharg, A., Patra, R. C., Saini, M., & Wolter, K. (2006). Removing the threat of diclofenac to Critically Endangered Asian vultures. PLoS Biology, 4(3), e66.