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Cover: Parts of *Vachellia nilotica*, medium - watercolours. © P Kritika

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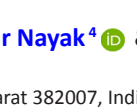

ARTICLE

Breeding ecology and nest-site characteristics of the Black-necked Stork *Ephippiorhynchus asiaticus* in Khijadiya Bird Sanctuary, a Ramsar Wetland of Gujarat, India

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Abstract: This study assessed the population status, nesting ecology, breeding phenology, and reproductive performance of the Black-necked Stork *Ephippiorhynchus asiaticus* in Khijadiya Bird Sanctuary, a Ramsar Site (No. 2492) located along the Gulf of Kachchh, India. Field surveys were conducted from July 2024 to March 2025 using stratified point counts (n = 48 points), nest monitoring, and systematic behavioural observations. All nests were constructed on *Neltuma juliflora* (syn. *Prosopis juliflora*) at heights of 3–4.5 m. Active nesting extended from early October (nest building) to late December (fledging). The mean nest attendance per visit was 62 ± 18 minutes (n = 89 visits), and partner replacement during foraging occurred in 94% of departures, indicating strong biparental coordination. Each nest produced two fledglings. Nesting sites were associated with shallow semi-perennial water (0.3–0.7 m), emergent vegetation, elevated micro-topography, and low disturbance levels. The sanctuary supported 21–23 individuals during the peak season, including breeders, non-breeders, and juveniles.

Keywords: Biparental care, breeding phenology, fledging success, nest fidelity, nesting habitat, parental investment, post-fledging care, reproductive success, waterbird conservation, wetland ecology.

સારાંશ: આ અભ્યાસમાં ભારતના કચ્છના અખાતના કિનારે આવેલ અને રામસર સ્થળ (ક્રમાંક ૨૪૯૨) તરીકે માન્યતા પ્રાપ્ત ખિજડિયા પક્ષી અભયારણ્યમાં કાળી ડોક ઢોંક (બ્લેક-નેકડ સ્ટોર્ક, *Ephippiorhynchus asiaticus*)ની સંખ્યાની સ્થિતિ, માળા બાંધવાની પારિસ્થિતિક વિજ્ઞાન, પ્રજનન પ્રવૃત્તિનો સમયગાળો તથા પ્રજનન સફળતાનું મૂલ્યાંકન કરવામાં આવ્યું હતું. જુલાઈ ૨૦૨૪ થી માર્ચ ૨૦૨૫ દરમિયાન ક્ષેત્ર સર્વેક્ષણ હાથ ધરવામાં આવ્યું હતું જેમાં પોઈન્ટ કાઉન્ટ પદ્ધતિ (કુલ ૪૮ પોઈન્ટ) દ્વારા માળાઓનું નિયમિત નિરીક્ષણ તથા વર્તણૂકના અવલોકનો લેવામાં આવ્યા હતા. તમામ માળાઓ ગાંડા બાવળ (*Neltuma juliflora*; સમાનાર્થી: *Prosopis juliflora*) વૃક્ષ પર ૩-૪.૫ મીટરની ઊંચાઈએ બનાવવામાં આવ્યા હતા. પ્રજનન પ્રવૃત્તિઓનો સમયગાળો ઓક્ટોબરની શરૂઆતમાં માળા નિર્માણથી શરૂ થઈ ડિસેમ્બરના અંતમાં બચ્ચાં ઉડવા સક્ષમ બને ત્યાં સુધી રહ્યો હતો. દરેક અવલોકન દરમિયાન માળા પર પુખ્ત પક્ષીઓની સરેરાશ હાજરી ૬૨ ± ૧૮ મિનિટ (કુલ ૮૯ મુલાકાતો) નોંધાઈ હતી. ખોરાકની શોધ દરમિયાન ૯૪% કિસ્સાઓમાં એક પક્ષી માળામાંથી નીકળ્યા પછી તેના સાથી પક્ષીએ માળાની જવાબદારી સંભાળી હતી, જે બંને માતા-પિતાની મજબૂત સંકલિત સંભાળ દર્શાવે છે. દરેક માળામાંથી બે બચ્ચાં સફળતાપૂર્વક ઉડવા સક્ષમ બન્યાં હતાં. માળા બાંધવાના સ્થળો છીછરા પાણીવાળા (૦.૩ - ૦.૭ મી.), બહારઉગી આવેલી જળવનસ્પતિ, ઊંચાઈ ધરાવતા સૂક્ષ્મ ભૂઆકાર તથા ઓછા માનવીય ખલેલવાળા વિસ્તારોમાં બનેલા હતા. પ્રજનનના મુખ્ય સમય દરમિયાન અભયારણ્યમાં પ્રજનન કરતા પુખ્ત પક્ષીઓ, અપ્રજનન પક્ષીઓ તથા કિશોર પક્ષીઓ સહિત કુલ ૨૧-૨૩ કાળી ડોક ઢોંક (બ્લેક-નેકડ સ્ટોર્ક) નોંધાયા હતા.

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INTRODUCTION

Wetlands designated under national and international conservation frameworks receive formal protection; however, continuous ecological monitoring is essential to detect hydrological changes, salinity fluctuations, invasive species expansion, anthropogenic disturbances, and shifts in vegetation structure and waterbird communities (Ramsar Convention Secretariat 2016; Byju et al. 2026). Monitoring programmes often emphasize migratory birds, yet the assessment of the breeding ecology of resident waterbird species is equally important. Breeding performance may reflect habitat quality, resource availability, and disturbance intensity, thereby, serving as a reliable indicator of wetland ecosystem condition (Green & Elmberg 2014; Byju et al. 2025).

The Black-necked Stork *Ephippiorhynchus asiaticus* is a large wetland-dependent bird distributed across southern and southeastern Asia and parts of Australasia (Ali & Ripley 1983; Hancock et al. 1992; Maheswaran & Rahmani 2002; Nawab & Srivastava 2009; Grimmett et al. 2011; Pathak et al. 2013; BirdLife International 2025). Although it is globally categorized as 'Least Concern' (BirdLife International 2025), the species occurs at low densities in India and exhibits scattered breeding populations (Rahmani 1989; Barman & Talukdar 1996; Sundar & Kaur 2001; Sundar 2003, 2004, 2005). It typically nests on tall trees in proximity to wetlands and demonstrates strong nest-site fidelity (Ali & Ripley 1983; Ishtiaq 1998; Sundar 2003; Ishtiaq et al. 2004; Maheswaran & Rahmani 2006).

Research on this species in India has largely focused on regions such as Keoladeo National Park in Rajasthan, Dudhwa National Park, and the Etawah–Mainpuri landscape of Uttar Pradesh (Ishtiaq 1998; Maheswaran 1998; Maheswaran & Rahmani 2002, 2006; Sundar 2003). Earlier surveys documented its limited distribution, with Rahmani (1989) reporting 141 sightings from 11 states and Sundar & Kaur (2001) recording 30 individuals across five states during field surveys conducted in 1998–1999.

In Gujarat, Khijadiya Bird Sanctuary, a protected wetland and a Ramsar site, together with its surrounding landscape, has consistently been identified as an important habitat for the species in the Saurashtra region, supporting breeding activity (Pandey & Teli 2005; Pathak et al. 2013; Gujarat Forest Department 2022). Regional assessments have also reported scattered occurrences across wetlands in the state, although confirmed breeding sites remain limited. This highlights the ecological significance of wetlands such as Khijadiya in sustaining local populations (Sundar 2003; Pathak et al. 2013; Gujarat Forest Department 2022).

While records of occurrence and occasional nesting observations are available from different parts of Gujarat, comprehensive information on breeding phenology, nest-site attributes, and reproductive success within this wetland remains limited. Considering the ecological importance of the habitat and the species' low-density breeding strategy, site-specific empirical evidence is necessary to support long-term monitoring and conservation planning. A systematic evaluation of breeding ecology in Khijadiya, therefore, contributes to effective local management and enhances broader understanding of the reproductive ecology of large wetland-dependent storks. The present study provides updated information on nesting ecology and reproductive performance of the Black-necked Stork in Khijadiya Bird Sanctuary and highlights habitat characteristics associated with successful nesting.

Study Area

Khijadiya Bird Sanctuary (6.05 km²) is located approximately 12 km north-east of Jamnagar along the southern coast of the Gulf of Kachchh, Gujarat, between 22.5167° & 22.5833° N and 70.1167° & 70.2500° E (Image 1). According to the biogeographic classification of Rodgers and Panwar (1988), the sanctuary falls within the semi-arid zone (Zone 4), specifically the Gujarat–Rajputana province (4B). The wetland complex comprises shallow freshwater impoundments on the eastern side and tidally influenced brackish to saline habitats on the western side, creating a distinct ecotonal transition between inland freshwater systems and marine-influenced environments (Gujarat Forest Department 2022). The elevation ranges approximately 5–10 m. The climate is semi-arid, with an average annual rainfall of 550–600 mm, most of which is received during the south-west monsoon period from June to September (IMD 2020).

Vegetation patterns reflect the prevailing salinity gradient across the area. Saline areas support mangrove patches dominated by *Avicennia marina*, whereas freshwater zones sustain emergent macrophytes such as *Typha* spp. and *Phragmites karka*. The terrestrial fringes are mainly covered by thorn scrub vegetation dominated by *Neltuma juliflora* (syn. *Prosopis juliflora*) and *Acacia* spp. (Pandey & Teli 2005). The coexistence of dual hydrological regimes and habitat heterogeneity enhances primary productivity and increases trophic complexity, supporting fish, crustaceans, and macroinvertebrates that form the food base for

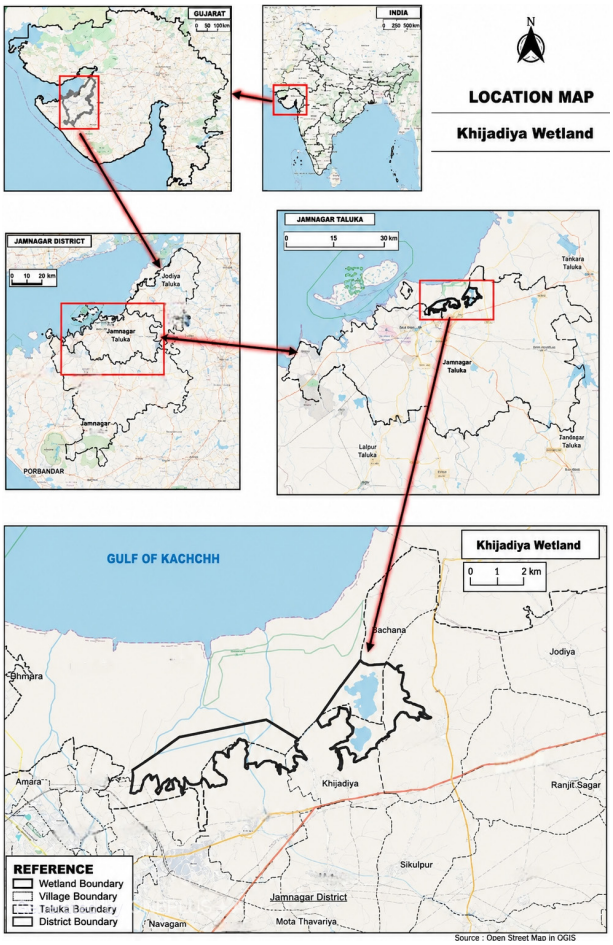

Image 1. Study area - Khijadiya Bird Sanctuary.

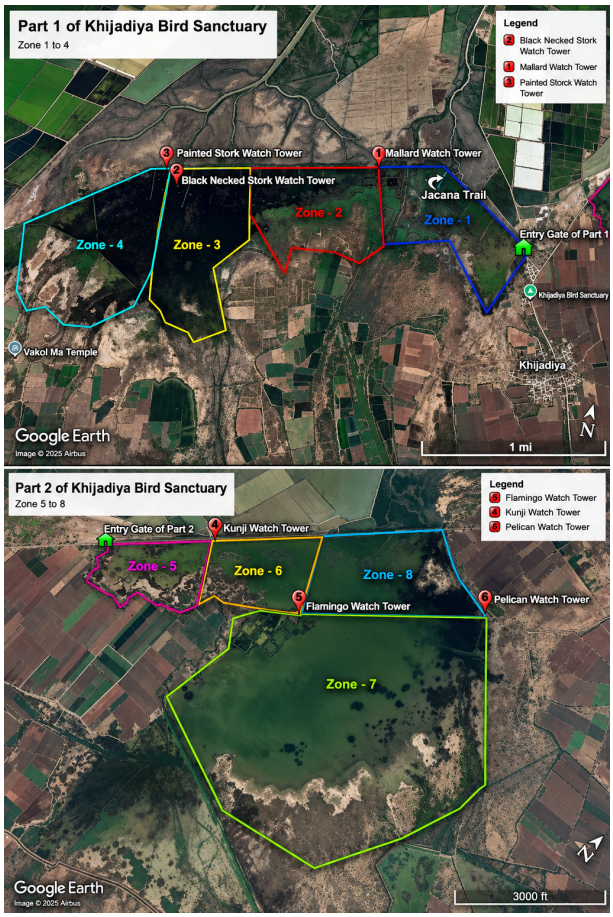

Image 2. Zone map - Khijadiya Bird Sanctuary.

diverse resident and migratory waterbird assemblages (Pandey & Teli 2005; Pathak et al. 2013; Gujarat Forest Department 2022).

Khijadiya Bird Sanctuary lies along the Central Asian Flyway, reinforcing its ecological importance as a staging, wintering, and breeding site for waterbirds (CMS 2014). For administrative management and ecological monitoring, the sanctuary is further divided into defined management zones (Image 2).

METHODS

Field surveys focusing on breeding ecology were conducted from July 2024 to March 2025, covering the monsoon, post-monsoon, and winter seasons. The overall field effort comprised approximately 95–120 field days. Abundance estimation was carried out using a stratified fixed point-count design (Bibby et al. 2000). A total of 48 georeferenced sampling points were established across eight management zones, maintaining a minimum spacing of 300 m to minimize spatial overlap and double counting. Counts were conducted simultaneously across survey sites within fixed time periods, with at least three observers independently surveying each survey site to minimize the possibility of double-counting individuals.

Each point was surveyed for 20–30 minutes per visit, resulting in approximately 230 survey sessions. During each survey, individuals were recorded along with group size, age class (where identifiable), behavioural observations, and associated habitat characteristics. Nest searches were conducted between October 2024 and February 2025. Confirmed nests were monitored from a distance of at least 50 m using binoculars (Nikon 10 x 50) and spotting scopes (16–48 x / 20–60 x), following standardized nest-monitoring protocols (Postupalsky 1974). Data collected from nests included nesting substrate, nest height, clutch outcome, chick survival, and patterns of adult attendance.

Behavioural observations were recorded using focal and scan sampling methods (Altmann 1974),

generating approximately 320 hours of observation data. Nest attendance duration, foraging bout length, and partner exchange frequency were quantified to construct activity budgets. Habitat assessments were conducted within a 100–150-m radius around each nest site, recording parameters such as water depth, hydroperiod, vegetation composition, canopy cover, substrate elevation, and indicators of anthropogenic disturbance.

Table 1. Summary of species abundance.

Details of birds	No. of individuals
Breeding Adults (4 pairs)	8
Juveniles (2 per nest × 4 nests)	8
Non-breeding adults (regularly seen)	5
Additional intermittent individuals	3
Total during peak season	**21**

RESULTS AND DISCUSSION

Abundance of BNS in Khijadiya

The abundance of the Black-necked Stork in Khijadiya Bird Sanctuary showed moderate seasonal variation during the study period (Table 1). Four active nests, each occupied by a breeding pair, confirmed the presence of eight breeding adults. Post-hatching monitoring recorded two chicks per nest, resulting in eight juveniles. In addition, five non-breeding adults were regularly observed across the wetland. Together, these breeding adults, juveniles, and non-breeding adults accounted for a peak seasonal population of 21 individuals. Occasional sightings of an additional 3–5 individuals outside the regularly monitored breeding and foraging areas were considered intermittent observations, likely representing transient or dispersing birds, and were therefore excluded from the confirmed peak population estimate.

Previous observations from Gujarat indicate that the Black-necked Stork generally occurs at low densities, with most records documenting solitary individuals or breeding pairs across wetlands and surrounding landscapes (Pandey & Teli 2005; Pathak et al. 2013). The observed range of 13 regularly occurring individuals, increasing to a seasonal peak of 21 with the inclusion of juveniles and transient birds, reflects the species' characteristic low-density and territorial distribution pattern. Earlier studies have similarly reported that the species maintains large home ranges and widely spaced breeding territories associated with extensive wetland systems (Ali & Ripley 1983; Sundar 2005, 2006; Maheswaran & Rahmani 2006). The presence of four breeding pairs, along with additional non-breeding individuals, suggests that the sanctuary supported breeding activities and served as an important foraging and refuge area during the study period.

Nesting Sites and Habitat Features

Four active nests of Black-necked Stork were recorded across spatially separated management zones of Khijadiya Bird Sanctuary, reflecting the species' territorial nesting behaviour. The distribution of nests did not show clustering, which is consistent with the large breeding territories reported for this species in wetland and agricultural landscapes (Rahmani 1989; Sundar 2003; Maheswaran & Rahmani 2006).

All nests were constructed on *N. juliflora* at heights ranging 3–4.5 m and consisted of large stick platforms with shallow central depressions. Although the species commonly nests on tall native trees such as *Acacia nilotica*, *Ficus* spp., *Bombax ceiba*, *Dalbergia sissoo*, and *Ficus religiosa* (Ishtiaq 1998; Sundar 2003, 2006; Pathak et al. 2013), the present observations demonstrate adaptive use of structurally suitable invasive tree species where native nesting substrates are limited. Elevated nest placement likely reduces the risk of terrestrial predation and provides safe flight access for this large-bodied stork.

Nests were located along shallow wetland margins characterized by heterogeneous vegetation and a mosaic of open water patches. Within a 100–150-m radius around the nests, water depth ranged 0.3–0.7 m, supporting abundant prey resources such as fish, amphibians, crustaceans, and aquatic invertebrates (Gawlik 2002). The vegetation structure was diverse, with *N. juliflora* contributing approximately 35–48 % canopy cover, interspersed with emergent macrophytes including *Typha angustifolia*, *Phragmites karka*, and *Cyperus* spp., along with scattered *A. nilotica* and *Salvadora persica* on slightly elevated patches. Such shallow and structurally complex wetlands are considered suitable breeding habitats for the species because they enhance prey availability and foraging efficiency (Maheswaran & Rahmani 2002; Sundar 2005). However, because habitat availability across the sanctuary was not quantitatively compared, these observations should be interpreted as habitat associations rather than evidence of habitat selection.

Nest trees were situated on raised mounds approximately 0.5–1.2 m above the surrounding wetland

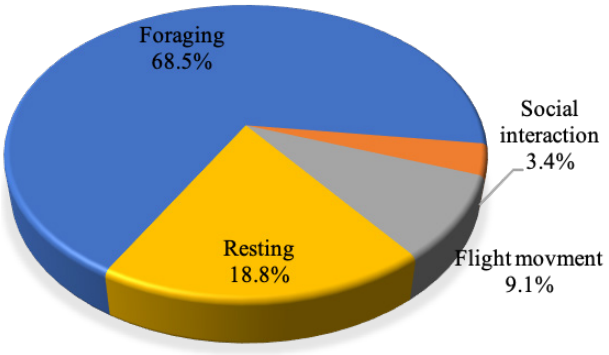

Image 3. Activity budget of Black-necked Stork (April–July).

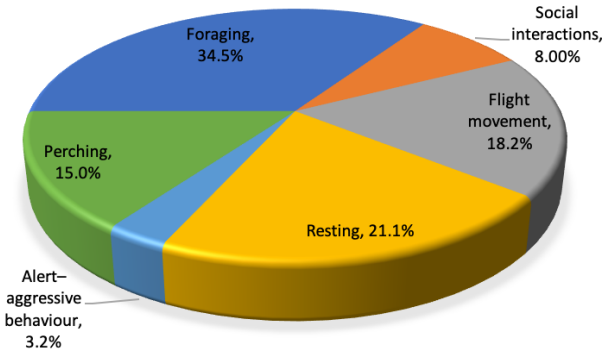

Image 4. Activity budget of Black-necked Stork (early August and late September).

surface, with mudflats and foraging pools located within 0.3–0.5 km, facilitating repeated provisioning during incubation and chick-rearing stages. Low anthropogenic disturbance within restricted-access compartments further supported nesting success, consistent with the documented sensitivity of the species to human activity near breeding sites (Rahmani 1989; Sundar 2004). Zones 1, 3, & 4 (Part 1) and Zone 6 (Part 2) recorded nests; and these locations were characterised by wetland–woodland interfaces and habitat condition. These habitat features were consistently associated with occupied nesting sites during the study period. The presence of these habitat features around nest trees in the Khijadiya Wetland Complex likely contributed to the successful breeding observed during the study period.

Breeding Phenology and Nesting Dynamics

The pre-breeding activities and breeding of the Black-necked Stork in the Khijadiya Wetland Complex extended from early August to late December, with clear behavioural transitions marking successive phases. From April to July, the activity budget was dominated by foraging (68.5%), followed by resting (18.8%) and flight (9.1%), whereas social interaction remained minimal (3.4%) (Image 3). The predominance of feeding behaviour during this period suggests routine habitat use primarily for energy acquisition and maintenance, with no observable signs of territoriality or reproductive activity. Behaviour during this phase was largely individualistic and focused on sustenance.

A distinct behavioural shift was observed during early August to late September. Foraging activity declined to 34.5%, while resting (21.1%) and flight activity (18.2%) increased. Perching behaviour rose to 15.0%, social interactions increased to 8.0%, and alert–aggressive behaviour emerged (3.2%), although no courtship displays were recorded (Image 4). This transition may be associated with territorial establishment and pair coordination prior to active breeding. The increase in perching and vigilance behaviour suggests territory surveillance and activities associated with nesting, whereas heightened social and aggressive interactions indicate pair bonding and territorial defence. Overall, the comparison of activity budgets suggests a marked shift in behavioural patterns prior to nesting.

Active nesting occurred from early October to late December. Nest construction was recorded between 3 and 17 October, followed by nest maintenance from 19 to 22 October. Egg hatching took place between 23 and 30 October, and intensive parental care continued from 4 November to 26 December (Image 5). A total of 89 nesting visits were recorded across the four active nests, with an occupancy rate of 92.60%. The maximum continuous adult presence at nests was 5.3 hours, and the mean duration per visit was 62 ± 18 minutes (n = 89).

Egg laying predominantly occurred during September and October, consistent with previous studies from India that associate breeding onset with post-monsoon hydrological conditions and improved prey availability (Sundar 2003). The period from October to December, therefore, represented the core reproductive phase in the study area. Biparental care was consistently observed during incubation and chick-rearing, confirming the importance of coordinated parental investment during this phase.

The post-nesting phase began in late December after all four monitored nests became inactive following successful fledging. By early January, adult pairs were observed foraging alongside juveniles across the wetland. Six juveniles were recorded accompanying adults, maintaining a distance of approximately 6–18 m during foraging activities. A total of 37 independent juvenile foraging attempts and 22 begging events, followed by adult food provisioning were documented,

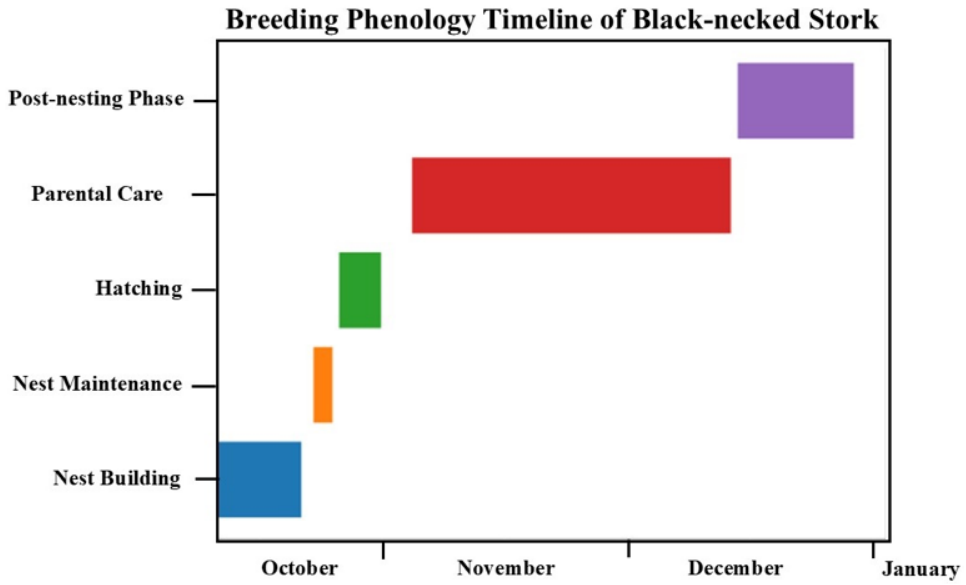

Image 5. Breeding phenology timeline of Black-necked Stork.

indicating partial dependence during the post-fledging stage. Although the monitored nests were inactive by late December, local observations suggest that nesting activity in the broader Khijadiya landscape may extend into January, reflecting spatial and temporal variation in breeding completion.

Breeding phenology observed in the present study follows a seasonal progression beginning with behavioural transitions during August–September and culminating in active nesting from October to December. Similar breeding patterns have been reported from semi-arid regions of India, where nesting typically begins after the monsoon when wetlands are replenished, and prey resources increase (Sundar 2005; Maheswaran & Rahmani 2006). Pre-breeding behavioural changes, including increased perching, heightened alertness, and enhanced pair interactions, suggest behaviours consistent with territorial establishment and pair coordination before nest construction, a pattern commonly documented for large stork species (Hancock et al. 1992). However, these behavioural functions were inferred from field observations and were not directly tested in the present study.

Reproductive Performance and Breeding Success

Post-hatching monitoring confirmed that all four nests saw the emergence of two chicks each, while three had early emergence, and one followed later. The number of chicks remained stable through late December, and by 20–21 December, individuals had reached near pre-fledgling size, suggesting healthy growth and high early survival. No instances of predation, chick mortality, or nest abandonment were recorded during the monitoring period. All four nests successfully produced fledglings, resulting in eight juveniles from four breeding pairs and yielding a 100% fledgling success rate (Table 2).

Table 2. Summary of breeding parameters and reproductive success of the Black-necked Stork.

Parameter	Value	Notes
Total active nests	4	All nests were monitored throughout the season
Total breeding pairs	4 pairs (8 adults)	A total of 13 individuals were observed, but only 4 pairs nested
Successful nesting attempts	4	No nest failure recorded
Failed nesting attempts	0	No predation, abandonment, or damage
Total fledglings	8 juveniles	2 fledglings per nest
Fledging success	2 fledglings per nest	Successful breeding outcomes were observed during the study period
Evidence of predation	None observed	

The recorded clutch size was two eggs per nest, which is slightly lower than previously reported clutch sizes of 3–4 eggs for the species, where typically 1–3 chicks fledge per successful nest (Ishtiaq 1998; Maheswaran 1998; Sundar 2003). Rare cases of higher fledging output, including four fledglings from individual nests, have also been documented (Sundar et al. 2007). However, in most studies, two surviving chicks per

successful nest represent the common reproductive output. The present findings, therefore, fall within the lower but ecologically consistent range of productivity reported for the species.

Compared with earlier studies from Uttar Pradesh, where breeding success showed considerable variation and many nests failed to produce fledglings (Sundar 2003), all monitored nests in Khijadiya successfully produced fledglings during the study period. The habitat characteristics associated with these occupied nests may have contributed to the observed breeding outcomes. Reproductive performance in the sanctuary aligns with evidence that breeding success in the Black-necked Stork is strongly influenced by stable hydrological conditions, adequate prey availability, and secure nesting substrates near wetlands (Sundar 2005; Maheswaran & Rahmani 2006). The semi-perennial wetland regime and relatively low disturbance levels were characteristics of the areas surrounding occupied nests and may have contributed to sustained parental investment throughout incubation and chick-rearing.

Post-fledging observations further confirmed prolonged parental care, with juveniles accompanying adults and displaying begging behaviour prior to independent dispersal. Such extended dependency and gradual attainment of independence are characteristic of large stork species and reflect adaptive strategies that enhance juvenile survival during early life stages.

CONCLUSION

The findings suggest that Black-necked Storks utilized Khijadiya Bird Sanctuary for breeding and foraging during the study period and provided baseline information on nesting ecology and breeding performance within the wetland complex. Occupied nests were associated with shallow wetlands, structurally suitable nesting trees, and relatively low anthropogenic disturbance. These habitat characteristics coincided with successful breeding during the study period. Similar observations have been reported in earlier ecological studies, which emphasize the role of protected wetland complexes in sustaining viable breeding populations of the species. Although the study provides valuable insights into the breeding ecology of the Black-necked Stork in Khijadiya Bird Sanctuary, the findings are based on observations from a limited number of nests during a single breeding season. Consequently, the results should be interpreted as indicative rather than definitive, and long-term monitoring across multiple breeding seasons will be necessary to evaluate interannual variation in nesting ecology, habitat use, and reproductive performance. Continued protection of wetland hydrology, conservation of existing nesting trees, and effective regulation of human activities within the sanctuary will be essential to ensure the long-term persistence and conservation of this species in the region.

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