Distribution, Habitat utilization and Behaviour Ecology of Woolly-Necked Stork in Haryana, India

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Abstract

Rapid habitat degradation, the loss of wetlands, urbanization, pollution, and human disturbances are all contributing factors to the global decline in waterbird populations. The Woolly-necked Stork (*Ciconia episcopus*), a tropical stork species found throughout South and Southeast Asia, is presently listed by the IUCN as Near Threatened. Ecological data about its habitat use, distribution, and behavioral ecology are still scarce despite its widespread range, especially in areas that have been altered by humans. The current study was carried out at two significant wetland habitats in Haryana, India as Dighal Wetland and Najafgarh Jheel Bird Sanctuary between November 2024 and October 2025 in order to evaluate the Woolly-necked Stork's distribution, habitat consumption, and behavioural ecology. Direct visual surveys, scan sampling, and focal sampling methods were used to conduct field observations in wetlands, agricultural areas, and barren habitats. Behavioural activities like as feeding, resting, moving, preening, and alert were noted along with individual counts. IBM SPSS Statistics one-way ANOVA and descriptive statistics were used for the statistical analysis. The mean population at Dighal Wetland was much greater (3.75 ± 3.30) than at Najafgarh Jheel (1.58 ± 2.99) ($P = 0.001$). The most popular habitat at both locations, according to habitat analysis, was agricultural land, which accounted for 62.22% of observations at Dighal and 47.36% at Najafgarh Jheel followed by Barren land and wetlands. While resting behaviour was more common in the afternoon, feeding behaviour was the predominant activity and peaked in the morning. Despite variations in behavioural activity throughout the day, these differences were not statistically significant ($P > 0.05$). In order to maintain Woolly-Necked Stork populations in Haryana, the study emphasizes the ecological significance of agricultural landscapes and related wetlands. The results provide baseline biological data that is crucial for future conservation planning and management plans for this Near Threatened species in quickly urbanizing environments.

Keywords: Wetland ecology, Habitat use, Behaviour, Conservation, Distribution, Dighal Wetland, Najafgarh Jheel

Introduction

Globally speaking, waterbird populations are widely believed to be declining, with South America, Asia, and Africa leading the way.There are 20 species of storks in the world (family Ciconiidae), most of which are found in tropical or subtropical regions (Gula *et al*., 2023). The five to seven species of "typical" storks share straight bills and primarily black-and-white plumage, which makes them quite similar. There are six kinds of "giant" storks that have enormous bills and outstanding size (Kahl, 1987).The African Woolly-Necked Stork, which was classified as Least Concern in 2014, has never had a scientific population study conducted on it and has no prior status evaluations. Another species that underwent odd alterations in a short amount of time was the Asian Woolly-Necked Stork (*Ciconia episcopus*).The Woolly-necked Stork, is a tropical bird that is mostly found in South and South-east Asia. According to latest population estimates, it is currently regarded as “near threatened” (IUCN 2026). Its population is concentrated in India, Sri Lanka, Nepal, Myanmar, Thailand, and Indonesia (Tiwary, 2020). In contrast to South-east Asian countries like the Philippines, where these birds have experienced localized extinctions, population in India, Sri Lanka and Nepal have demonstrated relative stability or even an increase. These events may be related to habitat degradation, wetland degradation, pollution and increased hunting activities (Ghimire *et al*., 2023).The medium-sized Woolly-Necked Stork stands between 75 and 92 centimeters tall. The iris has a wine-red or deep crimson color. Its name comes from the stork's downy white neck and glossy black overall, which also includes a black "skull cap." The dark-colored plumage is contrasted with the white under-tail coverts and lower belly, it has long, red legs and a thick, blackish bill. (Hancock *et al*., 2010). It inhabits a variety of habitats in Asia, ranging from India to Indonesia and all over Africa, including marshes, woods, agricultural regions, and freshwater wetlands (Kittur and Sunder, 2021). Wetlands saw relatively few Woolly-Necked Stork sightings, with the majority being in

agricultural fields (Kittur and Sunder, 2020).These stork are adapted to a variety of environment, including grasslands, crop fields, and coastal regions on both continents. They use a variety of watery habitats, such as reservoirs, marshes and rivers.The majority of wetlands in Jhajjar and Rohtak were communal water-bodies that saw heavy year-round use from humans and animals. (Kittur and Sunder, 2021). According to studies, they prefer natural wetlands for foraging although they also exploit agricultural fields, marshes, and flooded pastures (Tiwary, 2020). The most frequent factor contributing to habitat deterioration, urbanization, is spreading quickly across the world. Natural Ecosystem is being fragmented, isolate and degraded as a result of urbanization. Consequently, urbanization is regarded as posing a serious threat to wildlife. In fact, 20% of all bird species worldwide are found in urban regions, according to a recent global research, indicating that despite the threat that urbanization poses to biodiversity, urbanized surroundings nevertheless have great conservation significance (Thabethe, 2018). The population of the species has been adversely affected by habitat loss and fragmentation, primarily in South-east Asia, where there has been a noticeable reduction in recent years and it is believed to be threatened. Developing effective conservation strategies for this species is severely hampered by the lack of baseline data on its ecology and distribution as well as a deeper knowledge of the relative risks (Tiwary, 2020). Compared to other stork species, ecological research on the Woolly-necked Stork is still very scarce despite its extensive range. There are relatively few studies that address population trends, habitat usage, and behavioral ecology in an integrated way; instead, existing research has frequently concentrated on single characteristics like dispersion records or habitat associations. Furthermore, site-specific, field-based research in diverse settings where natural and human-modified habitats coexist is lacking.

Materials and Methods

Study Area

Haryana is located between latitudes 27°39′ and 30°35′ N and longitudes 74°28′ and 77°36′ E. The state is pleasant in the winter and extremely heated in the summer (around 45°C). The state's hottest months are May and June, while its coldest months are December and January. The average rainfall is about 354.5 mm, and the climate is semi-arid to arid (Kumar and Rana, 2024). The current study was carried out at the two sites namely Dighal wetland and Najafgarh jheel (Fig 1).

Dighal Wetland

Dighal occupies 30.57 km2 and is situated at latitude 28° 44' N and longitude 76° 36' E. This location is mostly recognized for its significance for bird viewing and is a potential Important Bird Area (IBA) since it is surrounded by several marshes, lakes, and migratory bird routes (Anjali and Rana, 2021) (Fig 2).

Najafgarh Jheel Bird Sanctuary

The Najafgarh Jheel Bird Sanctuary (28.498N, 76.946E) is a division of the Sahibi River that is situated on the Delhi-Haryana border and is thought to be about 7 km long. The 298-acre Najafgarh Jheel Bird Sanctuary is located in the Gurugram District of Haryana, India, and includes the villages of Kherki-Majra and Dhankot. The Jheel is one of the most contaminated because untreated sewage flows into it, yet it is nevertheless a vital home for numerous plant and bird species (Kumar and Rana, 2021, 2024) (Fig 2).

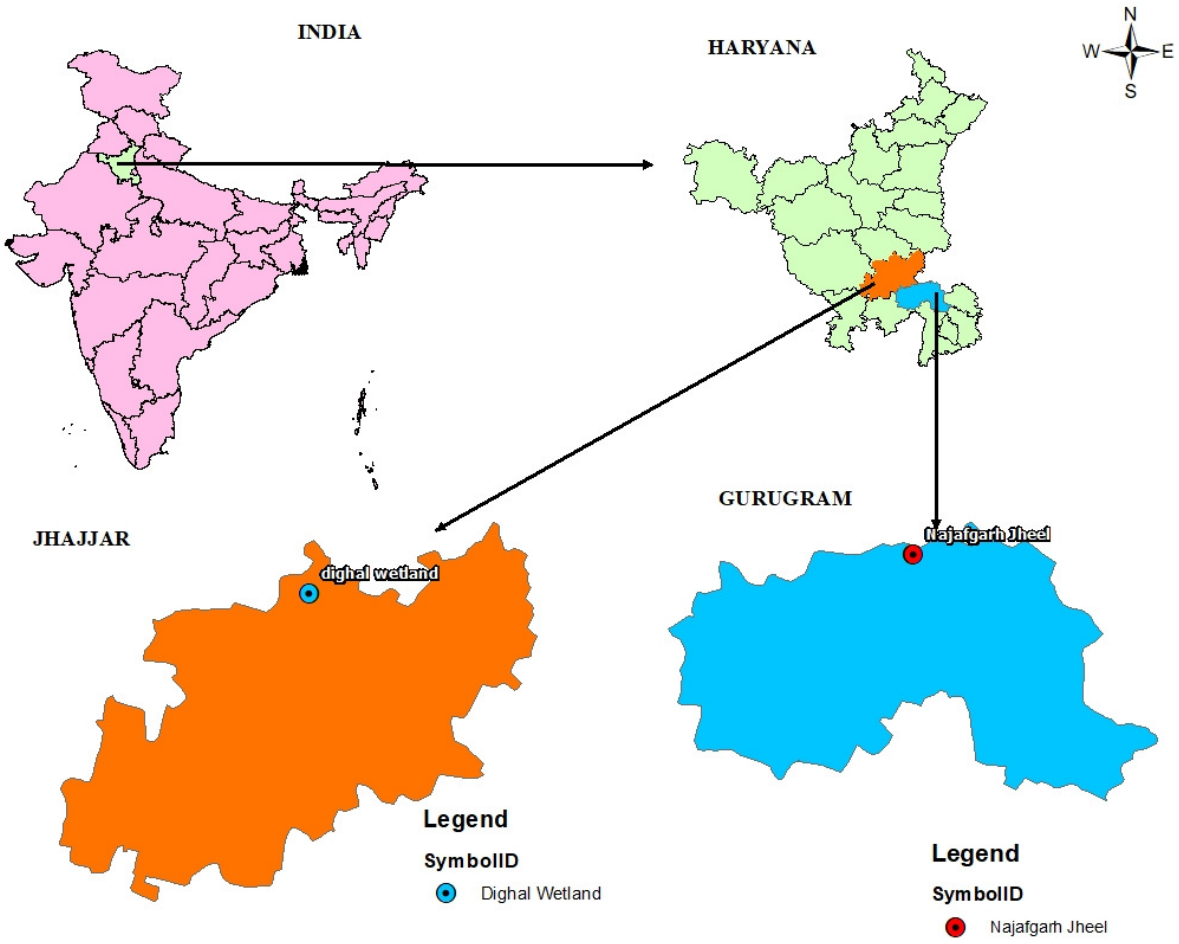

Fig 1: Map showing location of various study sites.

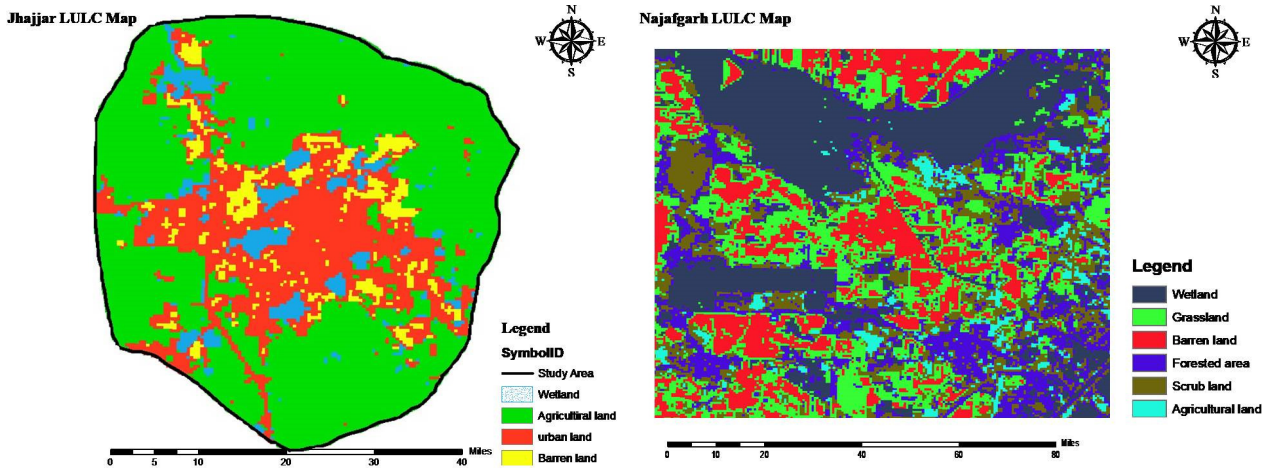

Fig 2: Map showing Land Use and Land Cover (LULC) of major habitat classes at Dighal wetland and Najafgarh Jheel.

Methodology

The current study examined the distribution, habitat use, and behavioral behaviors of Woolly-necked Storks at Dighal Wetland and Najafgarh Jheel from November 2024 to October 2025. The study sites included a variety of habitat types that offer the species appropriate places to feed and rest, such as wetlands, agricultural regions, and barren lands. Throughout the study period, fortnightly visits were conducted on a regular basis in the morning, afternoon, and evening. In order to accurately identify and describe the species and its behavioral activities, data was collected by direct observation usingNikon Coolpix digital camera P950 and Nikon 10x50 binoculars. Visual scanning of individuals observed at various habitats within the study sites was used to record population counts.Scan sampling and focal sampling methods were used to make behavioural observations. Feeding, resting, movement, preening, and alert behavior were among the behaviours noted during the study. Descriptive statistics, such as percentage values, mean ± standard error (SE), and 95% confidence intervals, were used to examine the collected data. To identify significant variations in population distribution, habitat usage, and behavioral activities throughout several time blocks of the day, one-way Analysis of Variance (ANOVA) (Anjali & Rana 2022, 2024; Sony & Rana, 2025) was used. $P < 0.05$ was used to determine statistical significance. IBM SPSS Statistics was used for all statistical analyses.

Results

The Woolly-Necked Stork's mean population was higher at Dighal wetland (3.75 ± 3.30) than at Najafgarh Jheel (1.58 ± 2.99), suggesting that the species was more abundant in Dighal wetland during the study period. The distribution of storks at the two study locations varied significantly ($P = 0.001$; $F = 4.72$) according to the statistical analysis, indicating that the wetlands' resource availability and habitat characteristics varied significantly. Better food possibilities, appropriate nesting and roosting sites, and relatively less anthropogenic disturbance may all contribute to the higher prevalence of Woolly-Necked Storks at Dighal Wetland. The large confidence interval numbers show how the population changed throughout the course of the study period (Table1).

With a mean abundance of 2.33 ± 0.49, the species used agricultural land the most at Dighal Wetland (62.22%), followed by barren land (26.66%) and wetland habitat (11.11%). The species in Dighal Wetland clearly preferred a particular environment, as evidenced by the statistically significant difference in habitat usage ($P = 0.004$; $F = 6.63$). Similar to this, at Najafgarh Jheel, the largest percentage of Woolly-Necked Storks were found on agricultural land (47.36%), closely followed by barren ground (42.10%), and wetland habitat (10.52%) (Fig 3). At Najafgarh Jheel, however, the variance across habitat types was statistically non-significant ($P = 0.37$; $F = 1.02$), indicating more equal habitat usage at this location.Overall, the results show that at both research sites, agricultural land was the Woolly-necked Stork's preferred habitat. The presence of food supplies including insects, amphibians, tiny reptiles, and other prey items in farmed fields and other damp areas may be the cause of this predilection (Table2).

Feeding activity peaked in the morning (22.5 ± 3.08), fell in the afternoon (16.5 ± 2.27), and then slightly increased in the evening (19.5 ± 2.67). This implies that during the cooler parts of the day, the species favored active foraging. The afternoon had the highest level of resting behavior (18.0 ± 2.53), suggesting a decrease in activity during warmer hours, probably as a means of conserving energy. Movement activity was significantly higher in the morning (7.00 ± 0.96) and evening (8.08 ± 1.13) than in the afternoon (5.83 ± 0.80). While alert behavior varied very little during the day, preening behavior stayed mostly consistent throughout all time blocks.The most common behavioral activity was feeding, which was followed by resting, movement, preening and alert behavior. Since all of the P-values were higher than 0.05, the statistical analysis revealed no discernible variation in behavioral activity between the various time blocks of the day. This suggests that while there were minor differences in behavioral frequencies between the morning, afternoon, and evening hours, these differences were not statistically significant (Table3) (Fig 4).

Table1: Distribution of Woolly-necked Stork at Dighal wetland and Najafgarh Jheel from November 2024 to October 2025.

Study site	Woolly-necked Stork	P-value	F-value

	Mean ±SE	95% CI (Min- Max)		
Najafgarh Jheel	1.58 ±2.99	-29.5-32.6	**0.001**	**4.72**
Dighal wetland	3.75 ±3.30	-27.3-34.8		

Table2: Habitat wise number of individuals of Woolly-necked Stork at Dighal wetland and Najafgarh Jheel from November 2024 to October 2025.

Habitat	**Number of individuals of Woolly-necked Stork**					
	Dighal wetland			**Najafgarh Jheel**		
	%	**Mean ±SE**	**95% CI (Min- Max)**	**%**	**Mean ±SE**	**95% CI (Min- Max)**
Agricultural land	62.22%	2.33 ±0.49	1.23-3.42	47.36%	0.75 ±0.37	-0.06-1.56
Wetland	11.11%	0.41±0.22	-0.08-0.92	10.52%	0.16 ±0.16	-0.20-0.53
Barren land	26.66%	1.00 ±0.36	0.18-1.81	42.10%	0.66 ±0.35	-0.11-1.44
P-value	0.004			0.37		
F-value	6.63			1.02		

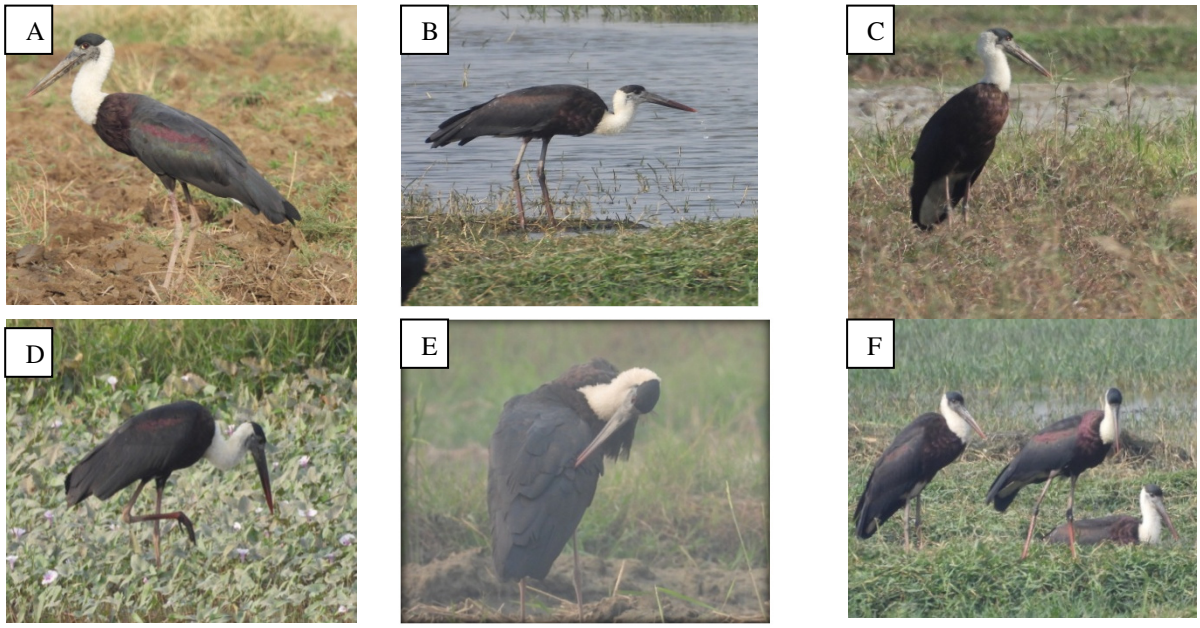

Fig 3: Habitat utilization and different Behaviour of Woolly-Necked Stork recorded during the study period- (A) Agricultural land, (B) Wetland, (C) Barrenland, (D) Feeding, (E) Preening, (F) Resting, (G) Movement, (H) Nesting, (I) Alert

Table3: % of time spent by Woolly-necked Stork to perform various behavioural activities at study site from November 2024 to October 2025 in different time blocks of a day (morning, afternoon and evening).

Time block	Number of observation days	Activities				
		Feeding	Resting	Movement	Preening	Alert
Morning	**12**	22.5±3.08	11.8±1.69	7.00±0.96	5.00±0.69	3.58±0.52
Afternoon	**12**	16.5±2.27	18.0±2.53	5.83±0.80	5.83±0.80	3.66±0.54
Evening	**12**	19.5±2.67	12.7±1.79	8.08±1.13	5.75±0.79	3.83±0.54
Total	**36**	19.5±1.56	14.2±1.23	6.97±0.58	5.52±0.43	3.69±0.30
P-value		**0.30**	**0.08**	**0.27**	**0.70**	**0.94**

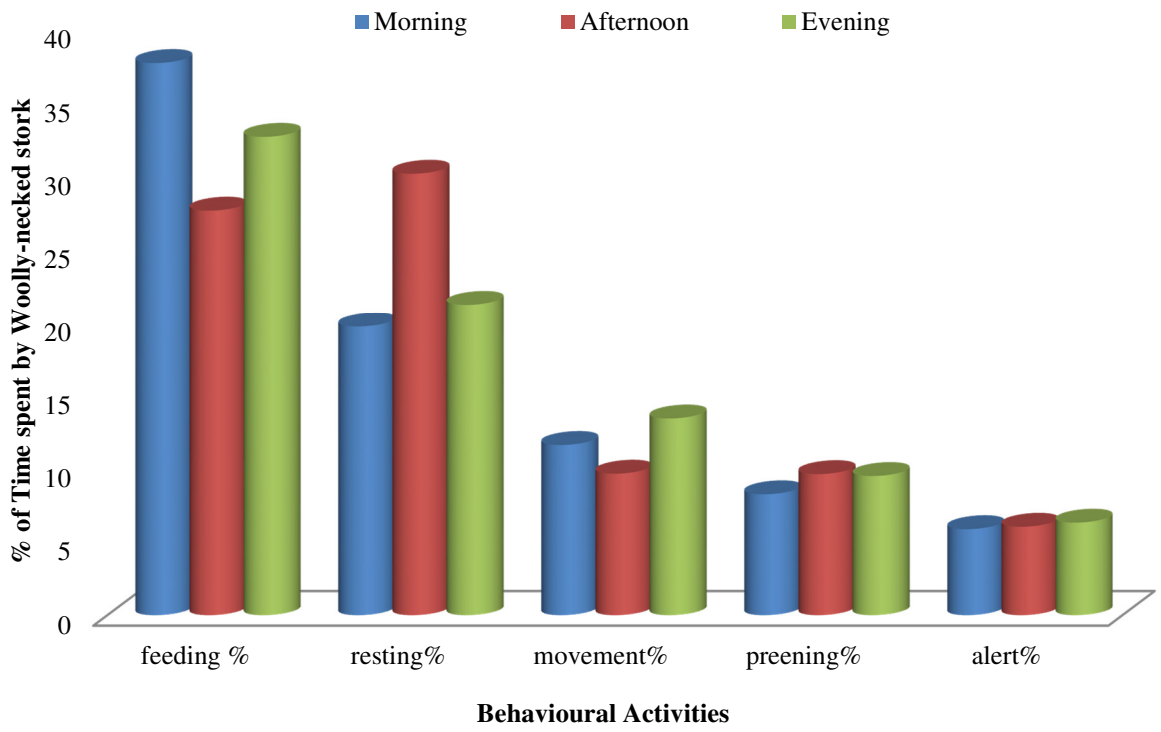

Fig 4: % of time spent by Woolly-Necked Stork on different behavioural activities in between different time blocks of a day.

Discussion

The current study offers significant information about the Woolly-necked Stork's behavioral ecology, habitat utilization, and population status in the studied area. Asian Woolly-necked Storks frequently use wetlands, agricultural fields, riverbanks, irrigation canals, and peri-urban environments for nesting and foraging, according to earlier research. They exhibit remarkable behavioral plasticity and a high degree of tolerance to human disturbance, as seen by their frequent nesting near roads, villages, telecom towers, and other artificial buildings. In environments that have been altered by humans, a preference for taller nesting substrates may further lower the danger of predation and promote successful reproduction (Sadik and Datta, 2025; Roshnath *et al*., 2026). Similar observation from South Africa reported strong selection towards urban and rural residential habitats, suggesting adaptability to areas associated with human activity. Additionally, prior research has indicated that species with more generalist behavior and behavioral adaptability are better effective in developed settings. The use of mosaic landscapes with green areas scattered throughout may be related to natural prey resources, food availability, and habitat variability (Gula and Downs, 2026). These findings are consistent with earlier studies showing once thought to be timid and limited to natural wetlands, woolly-necked storks have successfully established breeding populations in residential and semi-urban areas of KwaZulu-Natal. Their utilization of urban green spaces, additional food sources, and a variety of microhabitats demonstrates a high degree of ecological adaptation and behavioral flexibility, which may help the species continue to spread in shifting environments (Gula and Down, 2026). According to Kittur and Sundar (2020), Wetland-associated farmlands are important for foraging activities, as evidenced by the species' stronger relationship with agricultural landscapes.The species exhibited a stronger correlation with the agricultural landscapes that surround the wetlands, indicating the ecological significance of altered habitats in sustaining Woolly-necked Stork feeding activities. The species may find favorable feeding possibilities in agricultural fields with damp soil and shallow water conditions. Similar findings also showed that unprotected wetlands located in agricultural landscapes are regularly used by Woolly-necked Stork, according to higher resolution observations. Additionally, analyses revealed that a sizable portion of Woolly-necked Stork lived in human-modified environments in Asia and Africa, utilizing a range of man-made elements such gardens, mobile phone towers,

residential backyards, irrigation canals, village trees, crop fields, and fallow fields (Sundar, 2020; Kakati *et al*., 2022). Artificial structures like electric pylons and communication towers are increasingly being used for nesting, according to recent studies. The majority of nests were found in agricultural fields and wetlands, underscoring the significance of wetland–agriculture mosaics for foraging and breeding. Additionally, the species demonstrated excellent nest-site fidelity, tolerance to human disturbance, and a preference for elevated nesting surfaces, which may lower the danger of predation and improve breeding success (Gula, 2024; Tere *et al*., 2025). There are very few long-term ecological and environmental studies on tropical stork species, particularly in Asia, which emphasizes the need for more field-based studies on population trends, habitat usage, and dispersion (Gula *et al*., 2023), the findings of the present study further support this observation. Similar findings were documented from Nepal (Ghimire *et al*., 2022), where habitat appropriateness and nesting ecology were found to be crucial elements for Asian Woolly-necked population conservation strategy. Overall, the current study offers significant information about the behavioural ecology, habitat use, and population status of Asian Woolly-Necked in the study region. The species demonstrated a significant usage of marsh and agricultural habitats, underscoring the ecological significance of both environments for the species' survival. Further evidence of the species' adaptation to habitats altered by humans came from behavioural investigations. However, local populations may be adversely affected in the future by growing anthropogenic disturbances, habitat modification, and the loss of nesting and feeding places. For the species to survive over the long run, wetlands, agricultural mosaics, and adequate nesting sites should be conserved. To gain a better understanding of Asian Woolly-Necked population dynamics, breeding ecology, and habitat requirements in northern India, more long-term ecological research across several seasons and geographies are required.

Conclusions

The Woolly-Necked Stork primarily prefers agricultural land for feeding, roosting, and other daily activities, according to the current study on habitat utilization, distribution, and behavioural ecology. Because there were food sources, shallow water areas, and wide spaces that were conducive to movement and prey detection, agricultural fields offered favorable foraging chances. Wetlands and adjacent bodies of water were also used by the species. However, occupancy and activity in agricultural areas were significantly higher. The distribution and abundance of the species were affected by seasonal variation, with variations noted based on environmental factors and the availability of resources. Feeding was the most common activity, followed by resting, preening, moving, and interacting with others, according to behavioural observations. The Woolly-Necked Stork effectively adapted to human-modified environments, especially agricultural ecosystems, in order to survive. The Woolly-Necked Stork demonstrated adaptive behaviour and effectively used agricultural ecosystems and other human-modified landscapes to survive.

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Competing Interest

The authors declare no competing interests.

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