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Diurnal activity patterns of painted storks (*Mycteria leucocephala*) in an urban artificial wetland in Malaysia

NURFARAH AIN LIMIN[1], MUHAMMAD ZULFADLI ZAINAL ABIDIN[1], NURUL NABILAH SHAMSHUL KAMAR[1], MUHAMMAD AL AMIN AMRAN[1], NUR NADIAH MD YUSOF[1,2,♥]

[1]School of Biology, Faculty of Applied Sciences, Universiti Teknologi MARA. Shah Alam 40450, Selangor, Malaysia. Tel.: +603-55435603,
♥email: nurnadiah@uitm.edu.my
[2]Institute for Biodiversity and Sustainable Development, Universiti Teknologi MARA (UiTM). Shah Alam 40450, Selangor, Malaysia

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Abstract. *Limin NA, Abidin MZZ, Kamar NNS, Amran MAA, Yusof NNM. 2024. Diurnal activity patterns of painted storks (*Mycteria leucocephala*) in an urban artificial wetland in Malaysia. Biodiversitas 25: 4878-4885.* The increasing population of painted storks (*Mycteria leucocephala*) in Malaysia poses potential risks to native waterbird species, such as the milky stork. Despite their growing presence in urban artificial lakes, such as those in Putrajaya and Selangor, our understanding of their activity patterns remains limited, highlighting the importance of this research. Therefore, this study closely investigated the diurnal activity patterns of painted storks in an urban artificial wetland in Malaysia. Stork behavior was observed using instantaneous scanning and focal sampling methods for over 20 days. Results indicated that preening was the most common activity (30%), followed by foraging (24%), vigilance (23%), walking (15%), and other behaviors (8%). Storks displayed significantly more preening in the morning, though the durations were shorter compared to the afternoon and late afternoon. They also spent more time foraging and being vigilant in the morning than at other times. Furthermore, during all sessions, the number of individuals observed in the grassy areas was much higher than in the lake or on nearby rooftops. This study provides valuable insights into the behavior of painted storks, which could inform management strategies for waterbird species in urban artificial wetlands.

Keywords: Activity budget, behavior sampling, urban ecosystem, waterbird

INTRODUCTION

Painted storks (*Mycteria leucocephala* (Pennant, 1769)) are large wading birds native to Asia, particularly in India, Sri Lanka, and Southeast Asia (Urfi 2011). They are known for their distinctive pink feathers, long yellow beaks, and black and white plumage. These birds inhabit shallow wetlands, where they primarily feed on fish, crustaceans, mollusks, and insects (Sundar 2006; Prabhakar and Dudhmal 2016). Serving as bio-indicators, painted storks reflect the health of wetlands, responding to environmental changes and accumulating pollutants through the food chain (Rahman and Ismail 2018; Zakaria et al. 2022). Understanding and conserving their behavior is essential for maintaining ecological balance.

Historically, the International Union for Conservation of Nature (IUCN) classified painted storks as near threatened due to population declines from habitat degradation, hunting, and pollution (BirdLife International 2016). However, recent assessments have revealed a positive population trend attributed to coordinated conservation efforts and breeding colony protection, resulting in their reclassification as Least Concern (LC) (BirdLife International 2023). The estimated population now exceeds 20,000 mature individuals, reducing the risk of extinction to a very low level (BirdLife International 2023).

In 1965, Malaysia's National Zoo in Kuala Lumpur introduced four painted storks from Sri Lanka as part of a breeding and conservation program (Zakaria and Nor 2019). By 2004, some of these storks began to disperse from the zoo, establishing breeding colonies in the artificial wetlands in Putrajaya, Shah Alam, and Saujana Golf Resort (Zakaria and Nor 2019). The population in both Putrajaya and Shah Alam has grown by nearly 10% to 13% annually (Zakaria et al. 2023). While this growth seems like a conservation success, it raises concerns about potential nuisances. Their excrement and food remnants, especially in recreational spots like Shah Alam Lake Garden, produce foul odors, attract pests, pollute the environment, pose public health risks, and interfere with recreational activities (Murray and Hamilton 2010).

Uncontrolled population growth may lead to habitat overlap with the local waterbird species, particularly the endangered milky stork (*Mycteria cinerea* (Raffles, 1822)) (Zakaria et al. 2023). This overlap could result in competition for habitat, food, and resources (Mansor and Ramli 2017; Mansor et al. 2020), potentially displacing one species. Furthermore, hybridization between painted storks and milky storks is a significant concern, observed both in captivity and the wild, particularly in areas impacted by habitat destruction and hunting pressures that limit mate choice (Li et al. 2006). For example, researchers have documented hybridization at the National Zoo of Malaysia. They suspect that it occurs at the Dusit Zoo in Bangkok

and Singapore Zoo, resulting in viable offspring capable of reproduction (Li et al. 2006). This genetic mixing threatens the conservation of native milky storks by diluting their genetic pool, potentially pushing the species toward extinction. Other studies have reported similar mating incidents between these two waterbird species (Yee et al. 2013; Baveja et al. 2019).

Despite the growing interest in painted storks, more comprehensive studies on their activity budgets are necessary. Most existing research has focused on specific behaviors such as foraging (Kannan and Manakadan 2007; Kalam and Urfi 2008) and nesting (Urfi 2011; Suryawanshi and Sundar 2019). However, an extensive study of the activity budget is essential for gaining insights into behavioral inconsistencies and adaptations to environmental changes, providing significant information about the ecological needs of painted storks and aiding in the development of conservation strategies for wetland habitats. This study aims to investigate the diurnal activity budget of painted storks in an artificial lake, focusing on behavioral variability in response to different observation sessions throughout the day. By elucidating these patterns, this research will contribute to a deeper understanding of the species' ecological dynamics and inform future conservation efforts.

MATERIALS AND METHODS

Study area

This study was conducted at Lake Valley, a 560-meter-long and 180-meter-wide artificial lake located in Selangor, Malaysia (3°02'46.6"N, 101°45'40.7"E) (Figure 1). Surrounded by a residential area, the lake is on a 45-acre plot of land that features two miles of running tracks, a playground, and an artificial waterfall.

Data collection

A study was conducted to investigate the diurnal activity budget of painted storks at Lake Valley from March to April 2022. Data were gathered on alternating days over 20 days. A preliminary study conducted in February 2022 helped determine the most effective observation methods based on the local environment and landscape structure. Observations were performed daily from 8:00 AM to 5:00 PM, divided into three sessions: morning (8:00-10:00 AM), afternoon (11:30 AM-1:30 PM), and late afternoon (3:00-5:00 PM).

Behavior observations

The behavior of the painted stork was recorded using instantaneous scan sampling and focal sampling methods. Binoculars were used from a distance of 50 to 100 meters to minimize disturbance. The flock size was recorded before each observation. Instantaneous scan sampling was performed five times per session at 30-minute intervals, resulting in a total of 15 scans per day. Additionally, focal sampling was conducted on two randomly selected adult storks during each session, providing detailed data on the duration of each observed behavior. Each stork was monitored continuously for 10 minutes at specified times: in the morning (8:50 AM and 9:50 AM), afternoon (12:20 PM and 1:20 PM), and late afternoon (3:50 PM and 4:50 PM). The behaviors observed through both focal and scan sampling, are summarized in Table 1. In addition to the behaviour, the locations of the observed stork – specifically whether it was situated on the grass, in the lake or on the roof of houses adjacent to the Lake Valley – were also recorded.

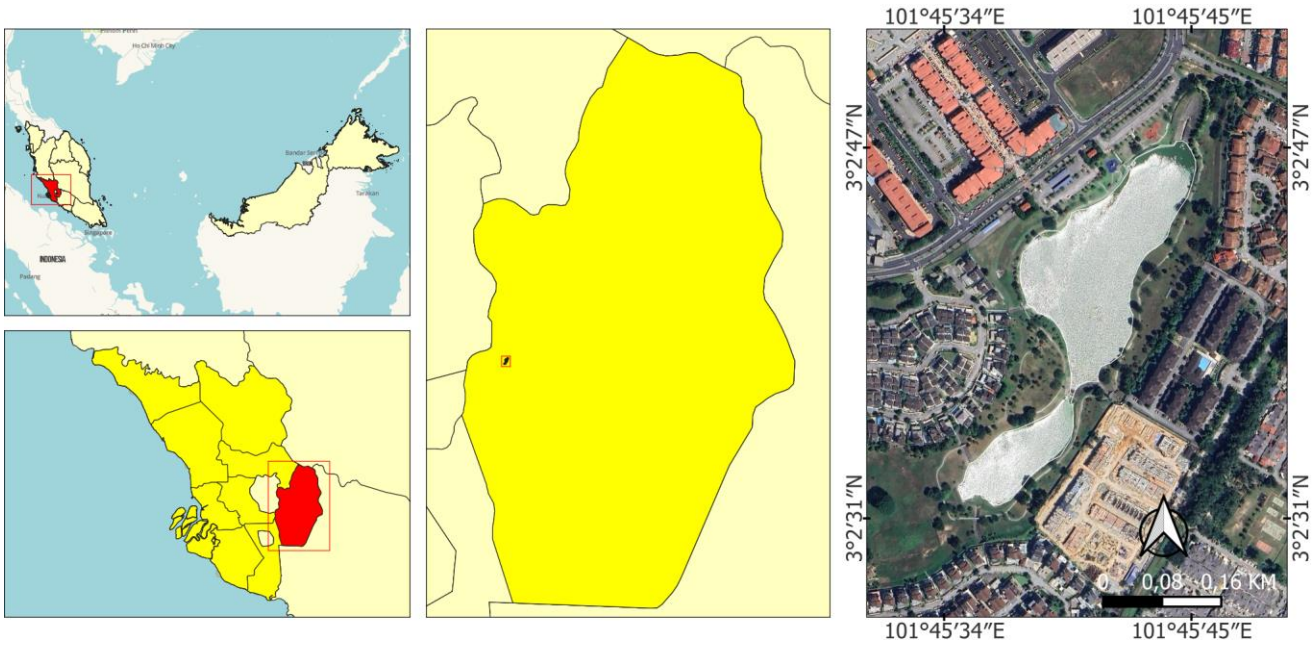

Figure 1. Location map of Lake Valley, Hulu Langat, Selangor, Malaysia

Table 1. Description of various behaviors displayed by painted stork at Lake Valley, Selangor, Malaysia (adapted from Rose et al. 2020)

Category	Definition
Foraging	Stork uses its beak to pick up items, food, and water before tilting its head back to swallow.
Resting	Stork lowers its head and positions itself on its lower body, making no visible contact with its surroundings.
Perching	Stork roosts on a horizontal object, usually a branch or roof.
Sunbathing	Stork exposes its back with wings spread or slightly opened under the sun.
Preening	Stork uses its beak to arrange feathers and clean debris on its body.
Allopreening	Stork uses its beak to arrange the feathers of other individuals.
Vigilance	Stork remains vigilant and actively scan their surroundings while freezing in any position.
Fighting	Stork pushes and beats individuals with its wings while pecking with its bill.
Socializing	Stork greets others by clattering its bill or performing a greeting display.
Threat	Stork uses an up-down motion with its wings partially open to signal a threat.
Walking	Stork takes two or more steps on the ground to move from one spot to another.
Flying	Stork flaps its wings rapidly while in the air.

Data analysis

Data were analyzed using IBM SPSS statistics (version 28.0). Normality was assessed using the Shapiro-Wilk test. The proportion of individual storks displaying a specific behavior was analyzed using Generalized Linear Models (GLM) with a binomial distribution and logit function, incorporating session as a fixed effect. The duration of behaviors from focal sampling, which did not follow the normal distribution, was evaluated using the Kruskal-Wallis test to determine differences across the three sessions. Post-hoc pairwise comparisons were conducted using Dunn's test with Bonferroni correction to identify significant differences between specific pairs of sessions. The abundance of painted storks across the three different sessions and locations was analyzed using GLM with a Poisson distribution and logarithm function. Statistical significance was set at $p < 0.05$.

RESULTS AND DISCUSSION

Activity pattern

Four primary behaviors were analyzed: preening, foraging, vigilance, and walking. Other behaviors were grouped under "others" due to their infrequent occurrence. Preening was the most commonly observed behavior, exhibited by 30% of the painted storks, followed by foraging (24%), vigilance (23%), and walking (15%), as illustrated in Figure 2. The remaining 8% of storks engaged in a variety of other activities, including threatening, resting, fighting, socializing, sunbathing, allopreening, perching, idling, and flying.

Behavior patterns by time of day

The observation session significantly influenced the number of storks engaged in foraging, preening, and vigilant behaviors (Table 2). A notably higher proportion of storks were observed foraging during the morning and late afternoon sessions compared to the afternoon. Conversely, preening and vigilance behaviors were more prominent in the morning and afternoon, with a significant decline in these activities during the late afternoon. In contrast, the storks' walking behavior remained consistent across all observation sessions, showing no significant variation.

Duration of behaviors

The observation session also significantly affected the duration of foraging and preening behaviors (Table 3). Painted storks spent far more time foraging in the morning than in the afternoon and late afternoon sessions. However, the duration spent on vigilance and walking behaviors showed no significant difference across the different observation sessions.

Abundance of painted storks

The abundance of painted storks varied significantly across different times of day and locations. The highest number of individuals was recorded during the late afternoon, followed by the afternoon (Table 4). The majority of painted storks were found on the grass, with fewer observed at the lake and fewest on the roof.

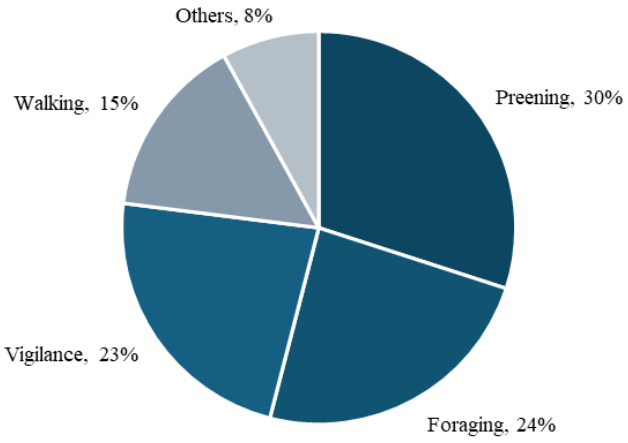

Figure 2. Percentage of painted storks observed engaging in different activity patterns at Lake Valley, Selangor, Malaysia

Table 2. Mean proportion of individual storks displaying specific behaviors during scan sampling at Lake Valley, Selangor, Malaysia, across three different sessions

Behaviors	Session	Mean proportion (SEM)	Wald test
Foraging	Morning	0.27 (0.017)^{a}	Wald = 29.79, df = 2, P ≤ 0.050
	Afternoon	0.16 (0.012)^{b}	
	Late afternoon	0.22 (0.012)^{a}	
Preening	Morning	0.28 (0.017)^{a}	Wald = 13.75, df = 2, P = 0.001
	Afternoon	0.25 (0.014)^{a}	
	Late afternoon	0.21 (0.012)^{b}	
Vigilance	Morning	0.26 (0.017)^{b}	Wald = 20.18, df = 2, P ≤ 0.050
	Afternoon	0.21 (0.014)^{b}	
	Late afternoon	0.17 (0.011)^{a}	
Walking	Morning	0.16 (0.014)^{a}	Wald = 5.81, df = 2, P = 0.055
	Afternoon	0.13 (0.011)^{a}	
	Late afternoon	0.12 (0.010)^{a}	

Note: Different superscript letters (^{a,b}) in the same column indicate significant differences in behaviors between sessions ($p < 0.05$)

Table 3. Median duration (s) spent by painted storks during focal sampling across three different sessions at Lake Valley, Selangor, Malaysia

Behaviors	Session	Median	Kruskal-Wallis, H
Foraging	Morning	68.50^{a}	$H_2 = 6.83$, df = 2, p = 0.033
	Afternoon	0.00^{b}	
	Late afternoon	22.00^{ab}	
Preening	Morning	5.00^{a}	$H_2 = 7.01$, df = 2, p = 0.030
	Afternoon	80.00^{b}	
	Late afternoon	64.00^{b}	
Vigilance	Morning	234.50	$H_2 = 2.12$, df = 2, p = 0.347
	Afternoon	183.00	
	Late afternoon	159.00	
Walking	Morning	89.50	$H_2 = 0.48$, df = 2, p = 0.786
	Afternoon	76.50	
	Late afternoon	73.00	

Note: Different superscript letters (^{a,b}) in the same column indicate significant differences in behaviors between sessions ($p < 0.05$)

Table 4. Mean abundance of painted storks by session and location

Parameters		Mean (SEM)	Wald test
Session	Morning	2.25 (0.087)^{a}	$\chi^2 = 123.019$, df = 2, $p < 0.05$
	Afternoon	3.00 (0.100)^{b}	
	Late afternoon	3.84 (0.113)^{c}	
Location	Lake	2.47 (0.091)^{a}	$\chi^2 = 1071.495$, df = 2, $p < 0.05$
	Grass	6.44 (0.147)^{b}	
	Roof	0.18 (0.024)^{c}	

Note: Different superscript letters (^{a,b,c}) in the same column indicate significant differences ($p < 0.05$)

Discussion

Foraging behavior has emerged as a primary behavior among painted storks, aligning with patterns documented in various avian species (Bonter et al. 2013). This includes multiple species of ducks (Zimmer et al. 2011), wintering hooded cranes (*Grus monacha* (Temminck, 1835)) (Li et al. 2015), grey crowned cranes (*Balearica regulorum* (E.T.Bennett, 1834)) (Nagwere 2014), herring gulls (*Larus argentatus* (Pontoppidan, 1763)) (Enners et al. 2018), African jacanas (*Actophilornis africanus* (J.F.Gmelin, 1789)) (Ameha and Afework 2018), milky storks (*M. cinerea*) (Rahman et al. 2020), black-necked cranes (*Grus*

nigricollis (Prjevalsky, 1876)) (Zhang et al. 2020), Asian woolly-necked storks (*Ciconia episcopus* (Boddaert, 1783)) (Ghimire et al. 2022), and seabirds (*Puffinus puffinus* (Brunnich, 1764)) (Darby et al. 2022). This study found that foraging was most prevalent in the morning and late afternoon, aligning with findings that other bird species often increase foraging activities during these times (Bonter et al. 2013; Nagwere 2014; Kumar and Rana 2021). The higher occurrence of late afternoon foraging likely reflects the storks' need to maximize energy intake before nightfall to avoid starvation overnight, as well as a response to low predation risk (Bonter et al. 2013). These findings have practical implications for understanding and managing avian populations.

Water turbidity significantly affects painted storks, like other visual predators, influencing their ability to detect and capture prey, as noted in seabirds (Darby et al. 2022). They rely heavily on clear water conditions to efficiently locate prey. The clearer water conditions in the morning make prey more detectable and cause fish to swim closer to the surface due to lower oxygen concentrations, which may lead to increased foraging behavior (Urfi 2011). Additionally, the storks may heighten morning foraging activity to accumulate energy for mating, nesting, and other daily activities (Ameha and Afework 2018; Yousaf et al. 2020). Early morning foraging also aids in avoiding predators, allowing for successful feeding (Yousaf et al. 2020). Similar patterns emerged in wading birds, which actively forage near dawn due to minimal human presence (Goss-Custard et al. 2019).

The proximity of the study area to running tracks and playgrounds suggests that increased human activity later in the day may be a determining factor in the observed reduction in foraging in the afternoon (Prabhakar and Dudhmal 2016). Consequently, storks may prefer the morning hours to compensate for potential disruptions (Wang et al. 2011). Disturbances to foraging areas can lead to reduced prey availability, forcing storks to seek food elsewhere (Rahman et al. 2020). This aligns with the idea that human activity disrupts animal behavior, forcing birds to alter their feeding routines (Thomas et al. 2003; Yasué 2005; Wilson et al. 2020) and mimicking predation threats (Zimmer et al. 2011). Prolonged exposure to disturbances, such as human activities and the presence of other animals, particularly during mating season, can negatively impact storks' fitness due to reduced foraging time (Kalam and Urfi 2008). Supporting this, Mainwaring et al. (2014) found that high disturbance levels during foraging lead to reduced food intake, ultimately affecting bird well-being and reproductive health. Temperature also plays an integral role in daily feeding patterns; in hotter areas, birds often reduce their noon activity to minimize metabolic consumption, which may contribute to the lack of afternoon foraging (Bonter et al. 2013). The observed pattern of increased morning and late afternoon foraging supports the hypothesis that storks, like other birds, adjust their feeding routines in response to environmental and anthropogenic factors to survive in their ecosystems (Yousaf et al. 2020).

The study found that preening, the most frequently observed behavior, surpassing even foraging, plays a crucial role in the ecological context of birds. This finding is consistent with the research of Zakaria et al. (2022) for painted storks and other waterbirds, like greater flamingos (*Phoenicopterus roseus* (Pallas, 1811)) and grey-crowned cranes (Nagwere 2014; Kumar and Rana 2021). Preening, a behavior synonymous with grooming, serves integral functions such as feather maintenance and removal of dirt and ectoparasites (Nagwere 2014; Ameha and Afework 2018; Zakaria et al. 2022; Bush and Clayton 2018, 2023). A study found that the presence of Northern fowl mites significantly increased hens preening activity, leading to more skin lesions (Murillo et al. 2020). The higher frequency of preening in the morning and afternoon sessions may reflect the need to maintain feather conditions by removing moisture and dew, which aids in thermoregulation for optimal flight performance throughout the day (Surmacki and Hill 2014). Preening is also a form of maintenance or comfort behavior in birds (Jumilawaty and Dalimunthe 2018; Engel et al. 2019). Similar findings in African jacanas revealed increased preening in the morning to maintain their feathers in prime condition (Ameha and Afework 2018). Additionally, the study was conducted at the beginning of the breeding season, suggesting that frequent morning preening may promote stocks as suitable mates (Zolnierowicz et al. 2016). The low-risk predation and disturbances in the morning likely provide more opportunities for self-care behaviors like preening (Brynychová et al. 2020). Furthermore, preening frequency tends to increase with larger flock size, a phenomenon known as social facilitation (Keeling et al. 2017).

Interestingly, the reduced preening observed in the late afternoon may indicate a shift in priorities as the storks prepare for nocturnal activities or respond to decreasing daylight. Although storks spent the most time preening in the morning, they allocated longer durations to preening in the afternoon and late afternoon, potentially linked to increased preening and stress, as noted in other studies in hens (Engel et al. 2019) and pink-footed geese (Clausen et al. 2020). This may indicate frustration or stress, serving as a displacement behavior in response to environmental stressors like human disturbance, similar to findings in laying hens (Engel et al. 2019; Kozak et al. 2019). This topic was not directly addressed in the current study, emphasizing the need for future research on the health and stress levels of painted storks.

Vigilance was observed less frequently compared to foraging and preening, with higher levels recorded during the morning and afternoon sessions. This pattern suggests that vigilance in painted storks is heavily influenced by factors such as predation risk, human presence, and flock size (Atkins et al. 2019; Tarakini et al. 2020). The increased vigilance in the morning may be due to heightened human activity at breeding grounds, supporting the idea that painted storks became more alert in response to perceived threats, similar to woolly-necked storks (Ghimire et al. 2021). Elevated vigilance is often associated with higher stress levels in birds, thereby diverting attention from important activities like feeding and resting (Tätte et al. 2019; Blackburn et al. 2024a,b). When faced

with disturbances or potential threats, birds typically spend less time foraging and more time on vigilance (Inger et al. 2006; Klett-Mingo et al. 2016; Carr and Golinski 2021; Novčić 2023). The present study's findings align with this observation, showing that storks allocated less time foraging and more vigilance when agitated. The reduced vigilance observed in the late afternoon, despite potential predation threats, may be attributed to the protective effect of flocking behavior, which decreases the likelihood of an individual being targeted by predators (Yousaf et al. 2020). Although vigilance was less frequent compared to foraging and preening, its duration was longer, consistent with studies suggesting that birds in urban environments exhibit increased vigilance (Tätte et al. 2019). This suggests that the relationship between vigilance and urbanization may vary depending on the species and context. Furthermore, environmental and social factors, such as prey abundance and social dynamics within flocks, play a crucial role in influencing vigilance behavior in waterbirds (Zhang et al. 2021; Munday and Rose 2022).

Walking behavior remained constant across different observation sessions, indicating that it is less influenced by temporal changes compared to foraging, preening, and vigilance. This stable pattern suggests walking may serve as a baseline activity, not strongly affected by the time of day or other external factors, and can be used to assess more variable behaviors like foraging and preening.

Research findings provide valuable insights into the habitat preferences of painted cranes. Their abundance varies significantly by time of day and location, with the highest numbers recorded in the late afternoon. This may be attributed to increased availability of food sources or changes in habitat preferences (Table 4). Storks were predominantly observed in grassy areas rather than the lake or roofs, potentially reflecting a preference for habitats that offer better foraging opportunities or shelter. This adaptability demonstrates painted storks' versatility as a species (Kittur and Sundar 2020). Bird communities are often associated with vegetative complexity, where forbs and bushes enhance bird diversity (Jahan et al. 2022). The complex vegetation likely provides shelter and protection, contributing to the storks' habitat preference. However, other studies have shown that stork abundance can vary with seasons, while location and year may not necessarily indicate ecosystem quality (Kittur and Sundar 2020). The observed patterns of habitat use and abundance suggest that painted storks are highly adaptable and capable of utilizing a variety of environments effectively. For instance, a study conducted in Maduru Oya National Park, Sri Lanka, found that waterbirds were abundant in diverse habitats such as grass, open water, mud, and on exposed rocks or dead trees/logs (Dilrangi et al. 2021).

In conclusion, painted storks display a range of behaviors, including foraging, preening, vigilance, and walking. This behavior varies depending on time and location, demonstrating the species adaptability to different environmental and human-induced factors. Foraging activity peaked in the morning and late afternoon, likely to maximize energy intake before sunset. Preening, the most frequent behavior, plays a crucial role in feather maintenance and thermoregulation, with heightened activity in the morning and longer durations in the afternoon, potentially reflecting stress responses to environmental factors. Although vigilance occurred less frequently, it lasted longer, indicating sensitivity to potential threats like predation and human disturbances. Consistent walking behavior across sessions suggests a baseline activity less influenced by external factors. Variations in stork abundance and habitat preference further illuminate their adaptability, emphasizing the importance of habitat complexity. These findings enhance our understanding of painted storks' behavior and underscore the need for continued research on the impact of environmental disturbances on their behavior and overall well-being. As this species serves as one of the bioindicators of environmental health, the behavior of painted storks can reflect broader ecological changes, which could ultimately facilitate in improving management practices for wetland habitats.

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