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The Breeding Ecology of the Painted Stork *Mycteria leucocephala* in Central Peninsular Malaysia

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ABSTRACT

The Painted Stork (*Mycteria leucocephala*) populations in Putrajaya and Shah Alam, Peninsular Malaysia, have increased by almost 10%–13% every year. If this trend continues, it is believed that habitat overlap may occur between this species and the Milky Stork (*Mycteria cinere*a), which is currently threatened with extinction. Habitat overlap could lead them to compete for food and other necessary resources, and consequently, one species would outcompete another. However, little is known about the breeding ecology of the Painted Stork in Peninsular Malaysia. Therefore, this study aimed to evaluate the breeding ecology of the Painted Stork and examine its nesting characteristics and their effects on breeding success. Direct observations were made of colonies in the Upper Bisa Putrajaya Wetland (UBPW) and Tasik Shah Alam (TSA) during the breeding season from March to September 2016 and 2017. The peak of the breeding season was in June, and no differences were found in nesting colony parameters between study sites, including the nest diameter and nest building period, except for nest height. The average height above the ground level of TSA nests was higher than in UBPW. Human activities near the nesting site in Shah Alam may have led to the birds constructing nests higher to prevent disturbance and predation. Nest diameter and nest building period were influenced by the number of nestlings raised by parents. These findings provide new information that may be used in management programs to control Painted Stork populations and can be useful for conserving threatened species, particularly the Milky Stork.

Keywords: Breeding ecology, conservation, *Mycteria leucocephala*, nesting waterbird, Painted Stork

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INTRODUCTION

Painted Storks are exclusively piscivorous birds that occupy a high trophic level in aquatic food chains and are a prominent feature of wetlands (Kalam & Urfi, 2008). In addition to fish, their diet consists of crustaceans, molluscs and insects and is fed by tactolocation strategies (Prabhakar & Dudhmal, 2016). The Painted Stork, *Mycteria leucocephala*, uses wetlands as foraging and breeding grounds (Kaluthota et al., 2005). Wetlands provide not only ideal nesting conditions for the Painted Stork but also attract other waterbirds in the Family Ciconiidae, including the Milky Stork (*Mycteria cinerea*), Asian Openbill (*Anastomus oscitans*), Lesser Adjutant (*Leptoptilos javanicus*) and Storm's Stork (*Ciconia stormi*).

The Painted Stork's distributional range is in the Indian subcontinent (BirdLife International, 2020) and certain parts of Southeast Asia (Hancock et al., 2010). They are commonly seen in the Delhi area in north India (Kalam & Urfi, 2008). This species is listed as near threatened in the IUCN Red List (BirdLife International, 2020). In Malaysia, the Painted Stork was introduced from Sri Lanka to Zoo Negara for captive breeding in 1965, with an early population of four individuals. In 1985, Painted Storks were released from captivity in Zoo Negara and started nesting and roosting in the surrounding area, and since then, the population has continued to increase and is known to have reached 923 individuals in 2014 (Zakaria & Nor, 2019).

Painted Storks were first detected foraging far away from Zoo Negara in Putrajaya and Shah Alam in 2004. The Upper Bisa Putrajaya Wetland (UBPW) and Tasik Shah Alam (TSA) were identified as nesting locations of the Painted Stork in 2008. Besides Zoo Negara, TSA and UBPW, Saujana Golf and Bestari Jaya have also become preferred nesting sites of Painted Stork. These areas provide favourable nesting conditions for waterbirds. An uncontrolled increase in the Painted Stork population in certain areas is likely to cause this species to become a nuisance. Faeces and food left behind by waterbirds, especially in recreational areas, can attract unwanted pests that could affect human health, pollute the environment, and disturb people's daily activities (Murray & Hamilton, 2010). Therefore, wider distribution of the Painted Stork in Malaysia could cause problems due to increasing and uncontrollable populations. In addition to the environmental and human health problems caused by this species, it may threaten and interfere with the survival of local waterbirds. The spatial distributions of species are likely to overlap and cause competition for habitat, food, and other resources (Mansor & Ramli, 2017; Mansor et al., 2020). Apart from habitat loss and fragmentation, one of the most serious threats to the related endangered species, the Milky Stork, is hybridisation. A previous study has reported several incidents of the Painted Stork mating with the Milky Stork, an endangered species native to Southeast Asia (Yee et al., 2013; Baveja et al., 2019). Therefore, this study was conducted to examine the breeding ecology of the Painted Stork and to evaluate its nest characteristics and their effects on its breeding success towards the management and conservation of Malaysian storks.

MATERIALS AND METHODS

Study Area

This study was conducted on two artificial islands in Upper Bisa, one of the five branches of the Putrajaya Wetland (UBPW) (Figure 1), and two sections of the island in Tasik Shah Alam (TSA). Islands in the UBPW that had been planted with tembusu tree (*Fagraea racemosa*) with a maximum height of 7 meters were classified as Island 1 (P1 UBPW), and islands planted with ara akar (*Ficus globosa*) with a maximum height of 9 meters were classified as Island 2 (P2 UBPW). TSA is an artificial recreational lake located in Selangor (Figure 1). The only island in this lake used as a nesting site by the Painted Stork was selected for this study; it consisted of ara akar, sealing wax palm (*Cyrtostachys renda*) and coconut (*Cocos nucifera*). The island was divided into two sections: Island 1 (P1 TSA) and Island 2 (P2 TSA), with a maximum plant height of 11.3 meters on both islands. Temperature and rainfall distributions for each month were obtained from the Malaysian Meteorological Department (MET) weather stations nearest the study area. Abiotic data were obtained from National Climate Centre stations, for the UBPW from the Serdang

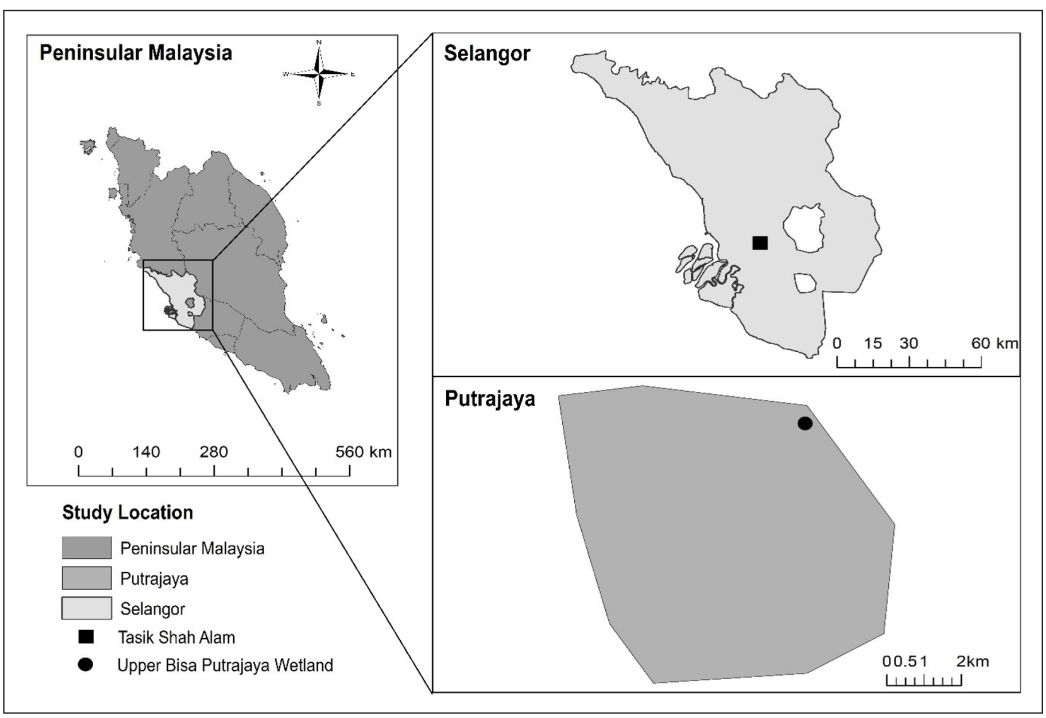

Figure 1. (Left) Map of Peninsular Malaysia, with an enlarged plan of Selangor State and Federal Territory of Putrajaya; the square (Tasik Shah Alam) and circle (Upper Bisa Putrajaya Wetland) indicate the study area

Agricultural Centre station (within a 3.52-km radius from the UBPW) and TSA from the Subang station (within an 8-km radius of TSA).

Data Collection

Data were collected during two breeding seasons of the Painted Stork, from March to September in 2016 and 2017. Direct observations of Painted Storks were made continuously from 0700 hours to 1900 hours using an HC-V380 video camera fitted with a 90× zoom lens (Panasonic, Kadoma, Japan) and a Nikon Coolpix P900 digital camera (Nikon Corporation, Tokyo, Japan). The distance between the observation point and the islands of the study area is between 33 m to 54 m. The nests were monitored for three days every week, from nest building initiation in March to all fledglings and their parents beginning to leave the nest in September. Each nest was identified and allocated a serial number to facilitate observation from the video recording. According to Meganathan and Urfi (2009), the percentage comparison method was employed, with the Painted Stork's beak length (approximately 24 cm) used as a scale to estimate tree and nest heights as the bird can be easily seen from observation points. Different aspects of breeding were recorded, such as nest building period, type of nesting tree, nest diameter and nest height above ground level. The number of nests and nestlings and nest fate at the end of the breeding season were also observed.

Nestling Development

Nestling success was classified based on the percentage of nestlings that successfully fledged from the nest. The development of each nestling was observed, and the following parameters were recorded: (1) the number of nestlings per nest, (2) the age at which the hatchling began to flap, (3) the age at which the nestling began to fly around the nest, and (4) the age at which the fledgling began to leave the nest. Each nestling was characterised based on its developmental stage: hatchling (1 to 30 days), semi-independent (31 to 85 days), and juvenile (after 85 days).

Data Analysis

Data were normally distributed (by inspection with quantile-quantile plots and Shapiro-Wilk tests). Pearson correlation was used to examine the relationship of each parameter of nest characteristics (duration of nest construction, nest diameter, nest height) to the number of nestlings per nest. The correlation was also used to test the relationship between abiotic parameters (temperature and rainfalls) and the number of nests and hatchlings. One-sample t-test was used to examine the differences between two breeding colonies between UBPW and TSA, and a two-sample t-test was used to examine the differences between colonies in 2016 and 2017. All tests were performed using SPSS Software.

RESULTS

Breeding Success

The incubation period of Painted Storks at UBPW and TSA was 29 days (range 26.5–32 days; Table 1). The number of nests in both study areas increased in 2017 compared to the previous year, with a total of 122 nests recorded in UBPW (2016 = 54; 2017 = 68) and 139 in TSA (2016 = 59; 2017 = 80). Nesting success, defined as the number of breeding

Table 1
The breeding ecology of the Painted Stork in the Upper Bisa Putrajaya Wetland (UBPW) and Tasik Shah Alam (TSA)

	Upper Bisa Putrajaya Wetland		**Tasik Shah Alam**	
	2016	**2017**	**2016**	**2017**
Total number of nests	54	68	59	80
Nesting success	47	61	53	69
Nesting failed	7	7	6	11
Average incubation period	29.3	29.4	29	29.2
Minimum	27	27.5	27	26.5
Maximum	32	31.5	32	31
Average nest diameter (cm):	68.63	65.38	69.13	65.14
No nestling	53	50	62.55	53.5
Single nestling	53.25	50.5	60.78	58.7
Two nestlings	71.5	65.5	67.55	71.55
Three nestlings	96.75	95.5	85.63	76.8
Average nest building duration (day)	5.6	5.8	5.7	5.8
No nestling	4.5	4.8	4.5	4.8
Single nestling	4.5	4.8	4.5	4.8
Two nestlings	6.3	6	6.3	6
Three nestlings	7.3	7.5	7.3	7.5
Average nest height (m)	6.8	6.87	7.44	7.59
Total number of nestlings (N)	100	110	98	108
Number of nestlings per nest	2.1	1.8	1.9	1.6
Number of fledglings	96	108	97	103
Nest fates at the end of the breeding season				
Abandoned	2	4	6	12
Destroyed	14	24	39	48
Nest used by other birds				
Purple Heron	26	25	0	0
Grey Heron	9	11	14	20
Black-crowned Night Heron	2	3	0	0
Cattle Egret	1	1	0	0

pairs that successfully hatched at least one egg in each nest, was high in both study areas (UBPW = 88.52%; TSA = 87.77%). A two-sample *t*-test showed no significant difference in the number of chicks per nest between UBPW and TSA, with 1.94 chicks and 1.69 chicks per nest, respectively ($t = 1.55$, $p = 0.18$). In addition, another paired *t*-test showed no significant difference in the number of nestlings per nest between 2016 and 2017 in

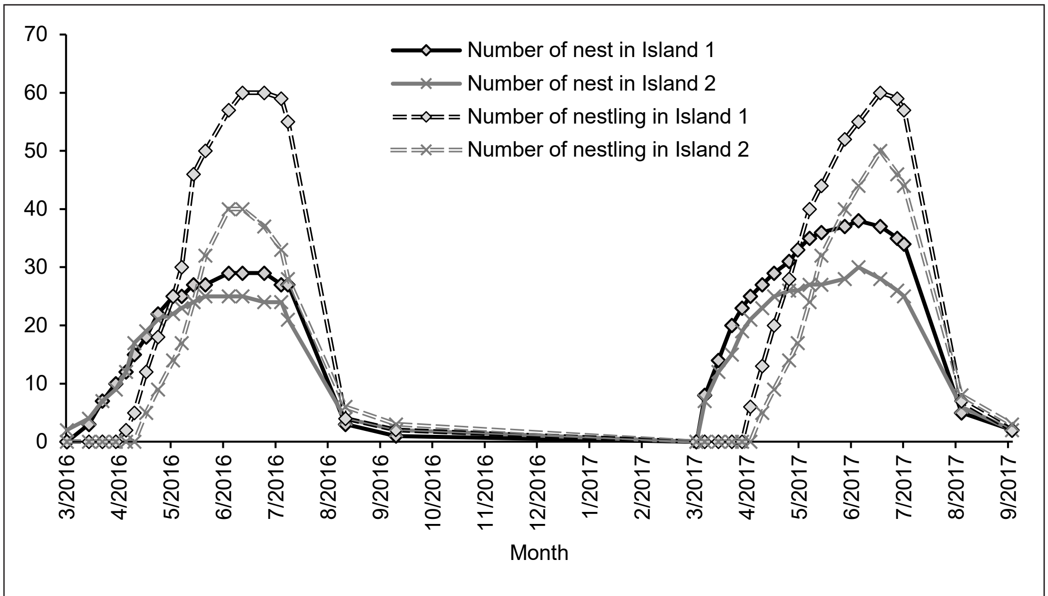

Figure 2. The number of nests and nestlings on Island 1 (Tembusu Island) and Island 2 (Ara Island) of Upper Bisa Putrajaya Wetland from 2016 to 2017

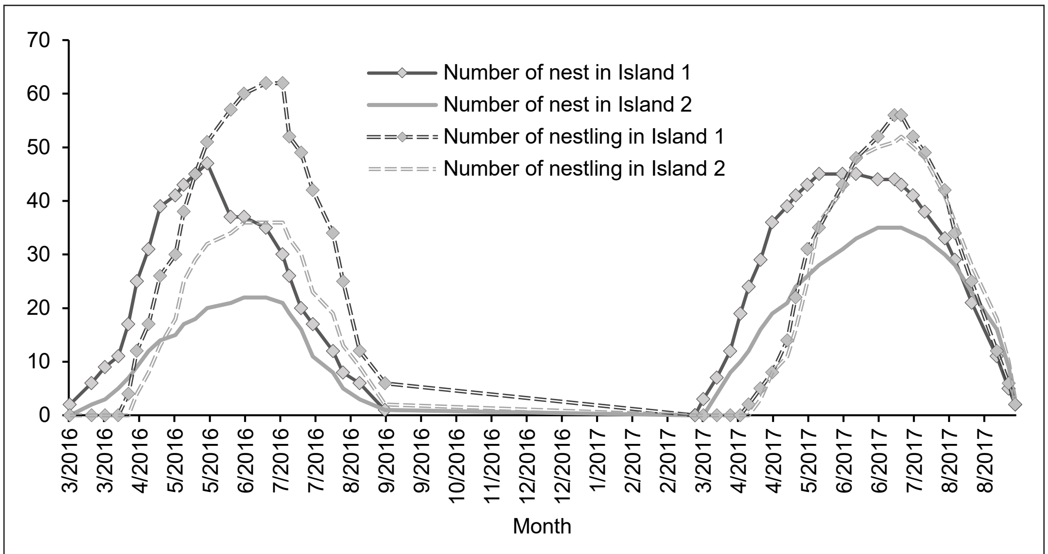

Figure 3. The number of nests and nestlings on Island 1 and Island 2 of Tasik Shah Alam from 2016 to 2017

UBWP, while TSA showed a significant difference in the number of nestlings per nest ($p > 0.05$; UBPW, $p = 0.3$; TSA, $p = 0.03$; Table 1). The number of nestlings per nest in UBPW was 2.13 (n = 100) in 2016 and 1.8 (n = 110) in 2017. In TSA, a total of 1.85 nestlings (n = 98) per nest were recorded in 2016 and 1.57 (n = 108) in 2017. Hatchling fatality was very low in both years, with a survival rate of 97.14% (n = 204), with four deaths in 2016 and two deaths in 2017 at UBPW, while the survival rate of nestlings at TSA was 97.19% (n = 200) with one death recorded in 2016 and five deaths in 2017. Correlation analysis showed a positive relationship between the number of nests on each island in 2016 and 2017 and the number of offspring per nest ($r = >0.5$), with the average number of nestlings peaking in June in UBPW (Figure 2) and TSA (Figure 3).

Nest Diameter and Duration of Nest Building Based on Clutch Size

Nest diameter did not differ between sites. Nest diameter in UBPW and TSA was directly proportional to the number of nestlings. The average diameter of the nest in UBPW was 67.0 cm, while in TSA, it was 67.14 cm, with an average nest-building period in UBPW of 5.7 days and 5.8 days in TSA (Table 1). The size of the Painted Stork nest was related to the number of nestlings produced by the breeding pair, with nest diameters ranging from 44 to 93.7 cm in UBPW and from 40 to 110 cm in TSA. Figure 4 shows that the diameter of nests with three nestlings was the largest, with an average of 88.67 cm (UBPW = 96.13 cm; TSA = 81.22 cm), compared to nests with two nestlings which averaged 69.03 cm (UBPW = 68.5 cm; TSA = 69.55 cm), while parents with only one successfully raised nestling had nests with the smallest size, with the average being 55.81 cm (UBPW = 51.88 cm; TSA = 59.74 cm).

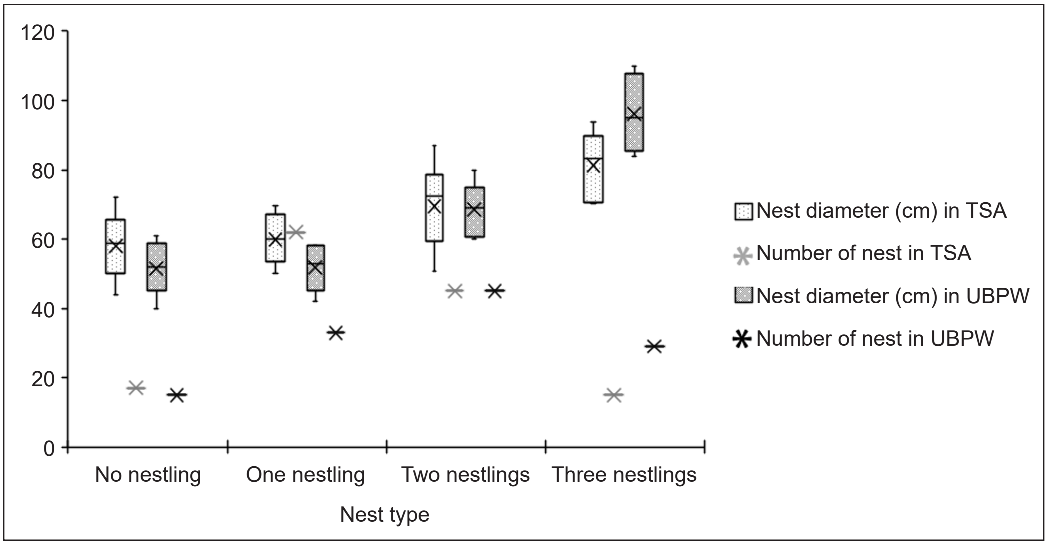

Figure 4. Number of nests by diameter and number of offspring

The nest-building duration of the Painted Stork was the same in both study areas, but it was based on the number of nestlings per nest (Table 1). Pairs raising three nestlings took longer to build their nest, on average, 7.4 days compared to 6.15 days for pairs with two nestlings and only 4.65 days for pairs with one nestling. In UBPW, 36.89% of the nests found during observations had two nestlings (n = 122), while in TSA, nests with only one nestling were more common (44.6%, n = 139).

Above-Ground Nest Site Selection

Our observations indicated that nest site selection by the Painted Stork was not random and that the type of tree and human presence influenced nest site preference in TSA. The average nest height above ground level in UBPW was lower than in TSA (Table 1). The average height was 6.84 m in UBPW and 7.56 m in TSA (Table 2). In the latter location, all nests were built above ground on trees at more than 49% of the tree height (Figure 7). Nests at less than 49% of tree height were found only in UBPW (Figure 6). Most nests (54 nests) found in UBPW were at 50%–74% of tree height, followed by 49 nests at 75%–100% of tree height, while most nests (78 nests) found in TSA were at 75%–100% of tree height (Figure 5).

Table 2
Maximum and minimum nest height above ground level at each study location

Location	Island	Minimum height (m)	Maximum height (m)
UBPW	P1	1.96	7.9
	P2	5.13	11.5
TSA	P1	11.3	7.25
	P2	10.2	7.93

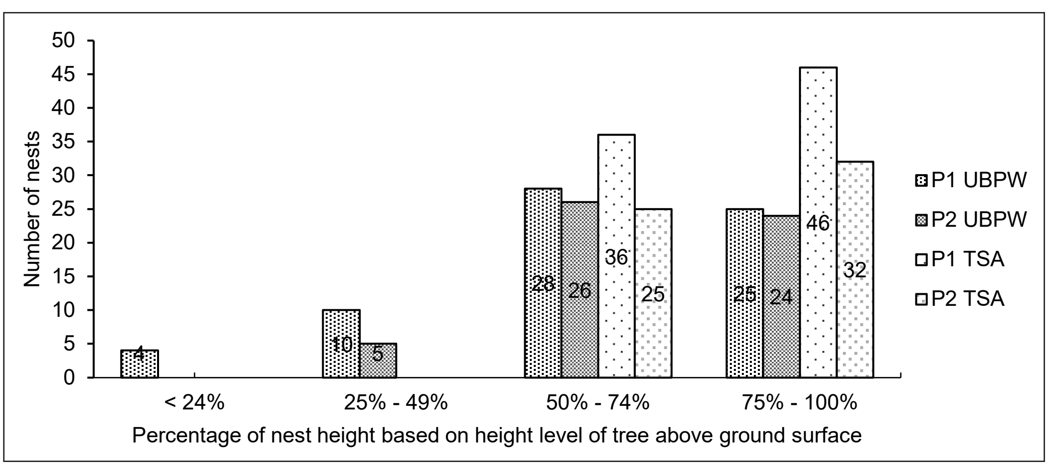

Figure 5. The number of nests above ground level based on nest position on the tree as a percentage of tree height

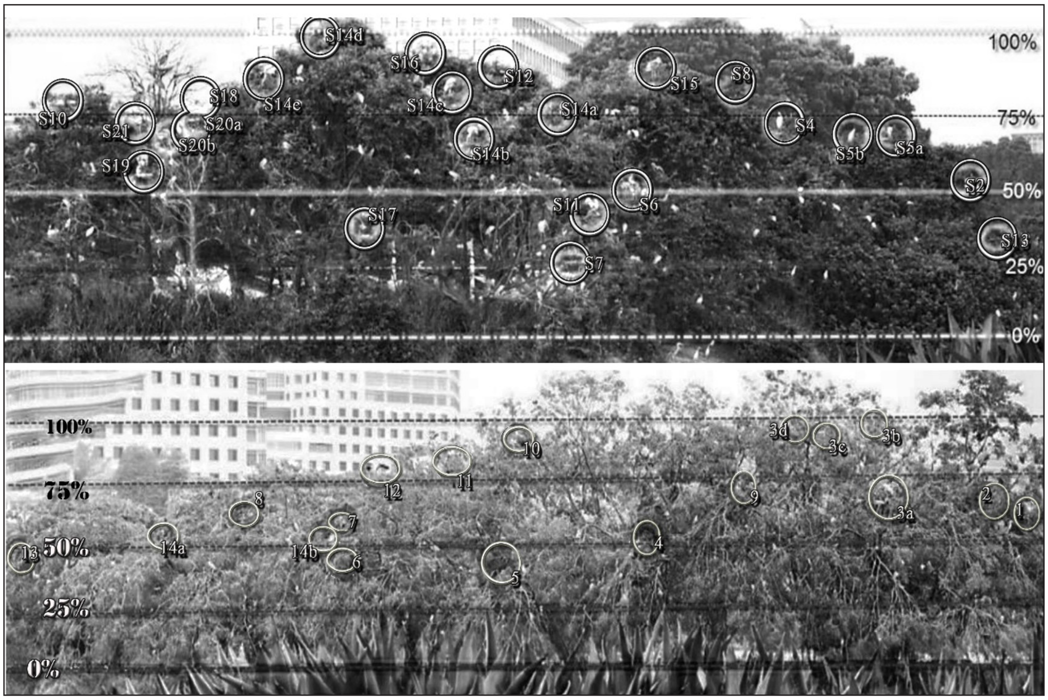

Figure 6. Position of Painted Stork nests as a percentage of tree height in Island 1 (top) and Island 2 (bottom) in UBPW

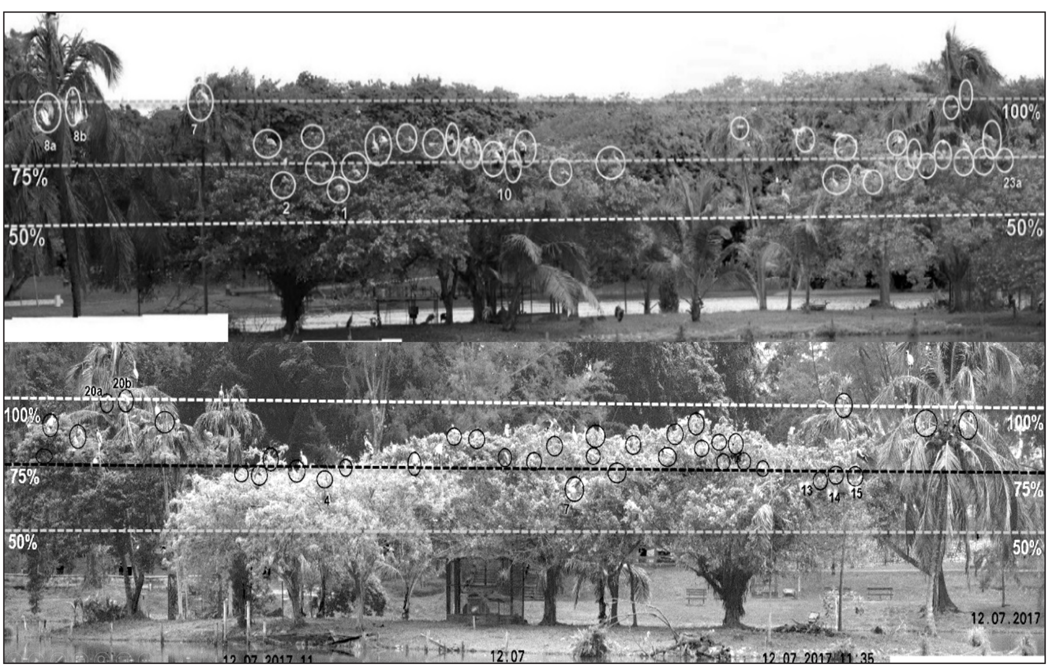

Figure 7. Position of Painted Stork nests as a percentage of tree height in Island 1 (top) and Island 2 (bottom) in Tasik Shah Alam

Nest Fate

Painted Stork was observed to have peak nesting season during both April and July in TSA and UBWP. At the end of the breeding season, while some Painted Stork nests in UBPW were destroyed or abandoned, others were observed to have been taken over by four other waterbird species, the Purple Heron (*Ardea purpurea*), Grey Heron (*Ardea cinerea*), Black-crowned Night Heron (*Nycticorax nycticorax*), and Cattle Egret (*Bubulcus ibis*). Nests in TSA also experienced the same fates, but only the Grey Heron was seen to take over some Painted Stork nests while the other nests were destroyed or abandoned by their owners.

Of the Painted Stork nests taken over by the four waterbird species in UBPW, 41.8% were occupied by the Purple Heron, 41% by the Black-crowned Night Heron, 16.4% by the Grey Heron, and 1.64% by the Cattle Egret, while 31.15% of the nests were destroyed and 4.92% were left empty (Figure 8). On the other hand, more than half (62.6%) of the Painted Stork nests in TSA were destroyed by their owners, while the Grey Heron took over 24% of the nests, and the rest (12.95%) were abandoned.

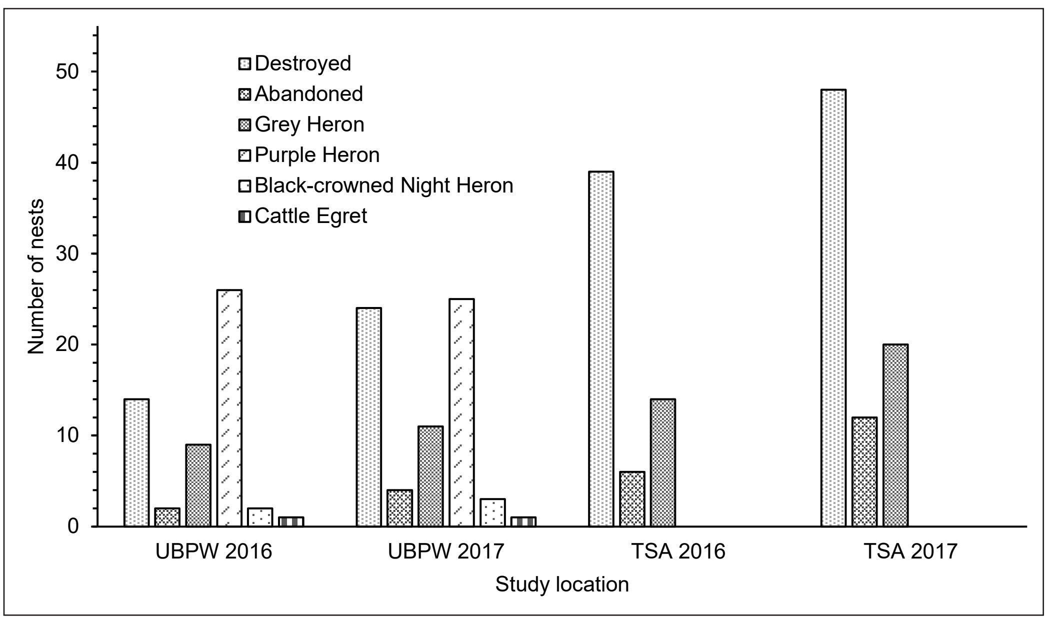

Figure 8. The fate of Painted Stork nests in the two study areas

Abiotic Conditions

Table 3 shows that June's highest number of nests and nestlings occurred. There was a highly significant positive relationship between the number of nests and the highest average temperature (UBPW: r = 0.815; TSA: r = 0.776; p <0.01), while there was a negative relationship between the number of nests and average rainfall distribution and between the number of juveniles and average rainfall distribution.

Table 3
Average temperature, rainfall, number of nests and number of nestlings by month in the UBPW and TSA in 2017

Month	Average highest temperature (°C)		Average lowest temperature (°C)		Average rainfall (mm)		Number of nests		Number of nestlings	
	UBPW	TSA	UBPW	TSA	UBPW	TSA	UBPW	TSA	UBPW	TSA
January	29	30	24	24	189	208	0	0	0	0
February	30	31	24	24	181	189	0	0	0	0
March	31	32	24	24	319	310	26	13	0	0
April	31	32	25	25	381	360	54	56	29	5
May	31	32	25	25	307	282	63	81	76	54
June	31	32	25	25	171	165	65	84	110	92
July	30	31	25	24	146	155	40	71	64	97
August	30	31	24	24	167	177	10	44	18	53
September	30	31	24	24	213	219	3	3	5	5
October	30	31	25	24	270	273	0	0	0	0
November	30	30	24	24	312	318	0	0	0	0
December	29	30	24	24	251	270	0	0	0	0

DISCUSSION

We found that the Painted Stork in Peninsular Malaysia began nesting in mid-March in Malaysia, after the monsoon season, which occurs between November and March (METMalaysia). This study also shows that the number of nests and nesting success is reduced when rainfall increases. This result is similar to Urfi's (2011a) findings for the nesting season of the Painted Stork in Sri Lanka, likely because Malaysia and Sri Lanka are located at similar latitudes. The monsoon season is unsuitable for nesting as heavy rains affect the incubation process, which requiring high temperatures for embryo development. Although the rainy season is not suitable for breeding birds, the water rises causes an increase in fish populations by the end of the monsoon season in February, thus sufficient as a food resource for the Painted Stork to start nesting and breeding (Urfi et al., 2007). Such strategies and adaptations could ensure their population's success (Mansor et al., 2015).

The Painted Stork nests were built on trees in UBPW, and TSA is mostly at 50%–100% of the tree's height, facilitating landing and avoiding threats from predators (Urfi, 2011b). Hatching failure is not influenced by nest height. This study provides observational evidence for this; some nests built at 75% of the tree's height were left empty by parents after incubating for almost a month and a half. Hatching success, nesting success, nest size, the number of nestlings per nest, and parental care are not affected by the height of the nest on the tree (Lambrechts et al., 2012), but they are influenced by biotic factors, including predation and egg viability and abiotic factors such as the weather and disturbance caused by humans (Urfi, 2010). Although nesting success is not guaranteed by nest site selection, it is influenced by interference by humans or other animals. In this study, the lowest nest in TSA was 5.16 m from the ground, possibly due to human activities such as kayaking. In contrast, no human activities were observed in UBPW, and the lowest nest was 1.96 m from the ground, similar to the nest placements recorded by Urfi (2011b), who found nests as low as the water surface in the Delhi Zoo. It suggests that human presence influences nest height in breeding colonies of the Painted Stork. Anthropogenic activities force storks to change their foraging area and increase their energy requirement for flight and food searching (Prabhakar & Dudhmal, 2016).

This study showed that trees with a larger branch diameter were preferred as nesting sites by Painted Storks in both colonies. Painted Storks were observed to build their nests on islands planted with the tembusu tree (*Cyrtophyllum fragrans*), which has branches with a larger diameter than ara akar (*Ficus globosa*). Larger branches are believed to ensure the safety of nests and support the weight of the nest and nestlings (Urfi & Kalam, 2006). The most preferred tree was tembusu, followed by coconut and ara akar; the least preferred tree was sealing wax palm (*Crytostachy renda*). Both ara akar and sealing wax palm can support only one nest per branch, unlike tembusu and coconut tree, which can support more than one nest per branch.

The results of this study show that nest-building duration was related to the diameter of the nest and the number of nestlings per nest. The volume of the clutch, as well as the size of the incubating parent, determines the surface area and size of the nest for structural support of the parent and their nestlings (Heenan & Seymour, 2011). The positive relationship between nest size and clutch size shows that females alter the size of their nests to accommodate eggs and hatchlings based on the number of eggs they plan to lay (Slagsvold, 1989; Àlvarez & Barba, 2008). The construction of a larger nest indicates the nest quality with high breeding success and may also be due to the need to prepare an extra space for storing prey as food supplies (Korpimäki, 1985; Vergara et al., 2010). Moreover, cooperation between partners in which the female builds the nest while the male looks for nest material and biparental incubation strategy contribute to nesting success (Daud et al., 2022).

The results showed that the number of nests in the Putrajaya and Shah Alam colonies was inversely proportional to the amount of rainfall. In June, the average rainfall decreased by 44.3% to 171 mm in the Putrajaya colony, but the number of nests continued to increase to 65, and a total of 110 Painted Storks had 155 successful hatchlings. The last breeding season occurred in September, when the average rainfall increased by 27.54%, from 172 mm in August to 216 mm in September. There were no more nesting Painted Storks in both study areas in October and after the monsoon season began in Peninsular Malaysia. Environmental factors, such as rainfall and temperature, play an important role in nest building and parent and nestling activity (Sparks & Tryjanowski, 2005; Daud et al., 2022) and can affect nesting success, nestling development and nesting density throughout the breeding season, especially in the early stages of the breeding phase (Ismail & Rahman, 2013). The weather can also affect the hatching rate and nestling mortality at the end of the breeding season (Jovani & Tella, 2004; Novoa et al., 2008). At the end of the breeding season, Painted Stork nests were observed either destroyed, abandoned or have been taken over by other species. Due to its robust size, certain species, such as herons and egrets, may re-use the nest. While nest abandonment at the end of the breeding season is normal behaviour in most birds, why storks destroy their nest is still uncertain. It was observed that Milky Stork in Kuala Gula destroyed their nest after failing to hatch the eggs (Faiq, pers. comm.). Future studies should focus on the detailed breeding biology of storks, including Milky Storks, to help us to understand the potential of wetlands as conservation sites for storks and other waterbirds.

CONCLUSION

We found that the peak of the breeding season of Painted Stork was in June, and no differences were found in nesting colony parameters between study sites, including the nest diameter and nest building period, except for nest height. The selection of nesting location is the main successful nesting strategy of the Painted Stork. These findings provide information about the breeding activities of the Painted Stork in Peninsular Malaysia and highlight the importance of wetlands as nesting sites for waterbirds. These findings provide useful information that may be used in management strategies to control Painted Stork populations and can be useful for conserving related threatened species, the Milky Stork.

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