วารสารวิจัยนิเวศวิทยาป่าไม้เมืองไทย 8(2): xxx-xxx (2567)

นิพนธ์ต้นฉบับ

ปัจจัยที่มีผลต่อการรอดของรังนกกาบบัว (*Mycteria leucocephala*) ในสวนสัตว์เปิดเขาเขียว ภาคตะวันออกของประเทศไทย

นคร สลางสิงห์ [1, 2*], วุฒิ ทักษิณธรรม[1**] และ ประทีป ด้วงแค[3]

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บทคัดย่อ

ความเป็นมาและวัตถุประสงค์: นกกาบบัวเป็นนกลุยน้ำขนาดใหญ่ที่เคยพบได้ยากในอดีต แต่ปัจจุบันพบเห็นได้ในหลายพื้นที่ของประเทศไทย อย่างไรก็ตาม พื้นที่ทำรังยังคงมีเพียงไม่กี่แห่ง สวนสัตว์เปิดเขาเขียวเป็นหนึ่งในสถานที่ที่นกกาบบัวมักเลือกทำรัง การศึกษาครั้งนี้มีวัตถุประสงค์เพื่อติดตามชั้นอายุของนกในแต่ละเดือน และปัจจัยที่ส่งผลต่อการรอดของรังนกกาบบัวในพื้นที่สวนสัตว์เปิดเขาเขียว ระหว่างปี พ.ศ. 2563-2564

วิธีการ: การสำรวจพื้นที่ทำรังของนกได้รวมถึงการบันทึกข้อมูลพิกัดรัง จำนวนรัง วันที่เริ่มสร้างรัง วันที่เริ่มฟักไข่ จำนวนตัวลูกนก วันที่พ่อแม่นกทิ้งรัง ช่วงอายุของลูกนก วันที่ลูกนกออกจากรัง และปัจจัยที่มีผลต่อการรอดชีวิตของลูกนก โดยใช้วิธีการวิเคราะห์ Mayfield เพื่อประมาณอัตราการรอดชีวิตของรัง วิธี Kaplan-Meier เพื่อประเมินความน่าจะเป็นในการอยู่รอด รวมถึง Generalized Linear Model (GLM) เพื่อวิเคราะห์ปัจจัยต่าง ๆ (อุณหภูมิ ความเร็วลม ความชื้นสัมพัทธ์ ปริมาณฝน อายุรัง และความสูงของรัง) ที่มีผลต่อการรอดชีวิตของรัง

ผลการศึกษา: นกกาบบัวเริ่มทำรังตั้งแต่ต้นเดือนสิงหาคม โดยการทำรังไม่พร้อมกัน ทำให้ช่วงอายุของลูกนกแตกต่างกัน พบการทำรังมากที่สุดในเดือนมกราคม โดยอัตราการรอดชีวิตรายวัน (Daily survival rate) ของรังนกอยู่ที่ 0.997 และอัตราการรอดชีวิตของรัง (Nest survival rate) เท่ากับ 74 % อัตราการรอดชีวิตลดลงในช่วงระยะการสร้างรังและระยะฟักไข่ แต่เริ่มคงที่ในสัปดาห์ที่แปดขึ้นไป ซึ่งใกล้เคียงกับอายุของลูกนกที่มากกว่า 16 วัน อายุของลูกนกเป็นปัจจัยสำคัญที่สุดที่ส่งผลต่อการรอดชีวิต ลูกนกที่มีอายุมากมีอัตราการรอดชีวิตที่ดีกว่า

สรุป: อัตราการรอดชีวิตของรังนกในช่วงแรกของการสร้างรังและระยะฟักไข่พบการล้มเหลวสูง ส่วนรังที่ประสบความสำเร็จมักเกี่ยวข้องกับลูกนกในรังมีอายุมากกว่า 16 วัน

คำสำคัญ: วิธีการแคปลาน และไมย์เออร์, นกลุยน้ำขนาดใหญ่, อัตราความสำเร็จของรัง

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วารสารวิจัยนิเวศวิทยาป่าไม้เมืองไทย 8(2): xxx-xxx (2567)

ORIGINAL ARTICLE

Factors Affecting the Nest Survival of Painted Stork (*Mycteria leucocephala*) at Khao Kheow Open Zoo in Eastern Thailand

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ABSRRACT

Background and objectives: The painted stork is a large wading bird that once considered as rare but now distributed across many regions in Thailand. However, suitable nesting sites remain limited, while, Khao Kheow Open Zoo is the most significant location where painted storks frequently establish nests. This study aimed to analyze the monthly age classes of painted stork chicks and to identify the factors influencing nest survival at Khao Kheow Open Zoo during 2020 and 2021.

Methodology: The nesting site survey involved recording various details, including nest coordinates, number of nests, start date of nest construction, egg incubation date, number of chicks, date of parent abandonment, chick age, fledging date, and factors affecting chick survival. The analysis utilized the following methods; Mayfield to estimate the nest survival rate, Kaplan-Meier to estimate survival probability over time, Generalized Linear Model (GLM) to analyze factors affecting nest survival, such as temperature, wind speed, relative humidity, rainfall, nest age, and nest height.

Main results: The painted stork began nesting in early August and varied periods among individuals, resulting age differed between the chicks. The highest nesting activity was observed in January. The study found that the daily survival rate of the nests was 0.997, and the overall nest survival rate was 74%. Survival rates declined during the nesting and incubation periods but stabilized after the eighth weeks, coinciding with chicks older than 16 days. The age of the chicks is the most critical factor affecting survival, with older chicks exhibiting higher survival rates.

Conclusion: The survival rate of nests during the early nesting and incubation periods was found to be low. Successful nests were often associated with chicks older than 16 days.

Keywords: Kaplan-Meier method, large wading bird, nest success rate

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INTRODUCTION

The Painted Stork (*Mycteria leucocephala*), a large wading bird in the family Ciconiidae (Kumar & Kanaujia, 2015), typically has a body length 93 - 102 centimeters (Wildlife Conservation Office, 2013). It is a resident species in Thailand (BirdLife International, 2023) that exhibits monogamous behavior, breeding only within a single season (Jaiyawat, 2003). The nesting sites of Painted Storks in Thailand have changed over the years. In 1990, the storks were last observed laying eggs at Thale Noi Wildlife Hunting Area in Phatthalung Province (Repaijit & Suparatwikorn, 2005). Subsequently, two nests were found in the Bung Boraphet, Nakhon Sawan (Eiam-Ampai, 2006). In 2017, nesting groups were observed in Uthai Thani Province, with one group at Uthai Rat Crocodile Farm and another at Safari World, Bangkok (Wildlife Conservation Office, 2013). Nesting activities were also documented in the Thale Noi Non-hunting Area, which was later reintroduced to the natural habitat in 2017 (Thale Noi Non-hunting Area, 2021), Khao Kheow Open Zoo (Jaiyawat, 2003; Arsaithamkul, 2019) Songkhla Zoo (Songkhla zoo, 2022), and RAMA 5 road next to the former Dusit Zoo (Reungrit, 2024).

Understanding the factors that influence bird nest survival requires consideration of three aspects: Breeding adult factors, nest predators, and other environmental factors. Breeding adult factors includes such as nest constancy (Brussee et al., 2016), the physical condition of adult birds (Öst & Steele, 2010), their age and breeding experience (Linz et al., 2013), and their defensive behaviors regarding nest protection (Remeš, 2005; Brussee *et al*., 2016). The nest predator factors involve consider in the composition and abundance of predator communities (Burr et al., 2017) and the activity patterns of these predators (Wegge & Storaas, 1990; Bêty *et al*., 2001). The other environmental factors include a broad range of variables such as the characteristics of the nesting habitat (Fuller *et al*., 2017), prevailing weather condition (Webb *et al*., 2012), temporal factors like the nesting season (Grant *et al*., 2005), nest age (Smith and Wilson, 2010), and the level of human disturbances (Uherkoch *et al*., 2015).

These factors can influence nest survival independently, synergistically, or interactively. For example, experienced breeders may select concealed nesting sites to minimize the risk of predator detection (Öst & Steele, 2010), while adverse weather condition can directly impact nest survival or indirectly alter the behaviors of both incubating adults and predators (Smith & Wilson, 2010). Identifying the key species-specific variables that significantly affect nest survival is essential for developing effective conservation and management strategies in avian conservation efforts (Kolada *et al*., 2009; Anteau *et al*., 2012).

This study aimed to examine the number of nests, the age-class structure of chicks in each month, nest survival, and the factors affecting nest survival for Painted stork nesting in natural areas at Khao Kheow Open Zoo.

MATERIALS AND METHODS

Study area

The study area is Khao Kheow Open Zoo, located in Chonburi Province in the eastern Thailand (Figure 1), adjacent to the Khao Kheow-Khao Chompoo Wildlife Sanctuary. The zoo's terrain includes two distinct forests types. The first type is the original forest compound, characterized by a mix of deciduous and dry evergreen forests extending along the zoo's mountain range. The second type is a landscape area featuring general trees covers and a water reservoir.

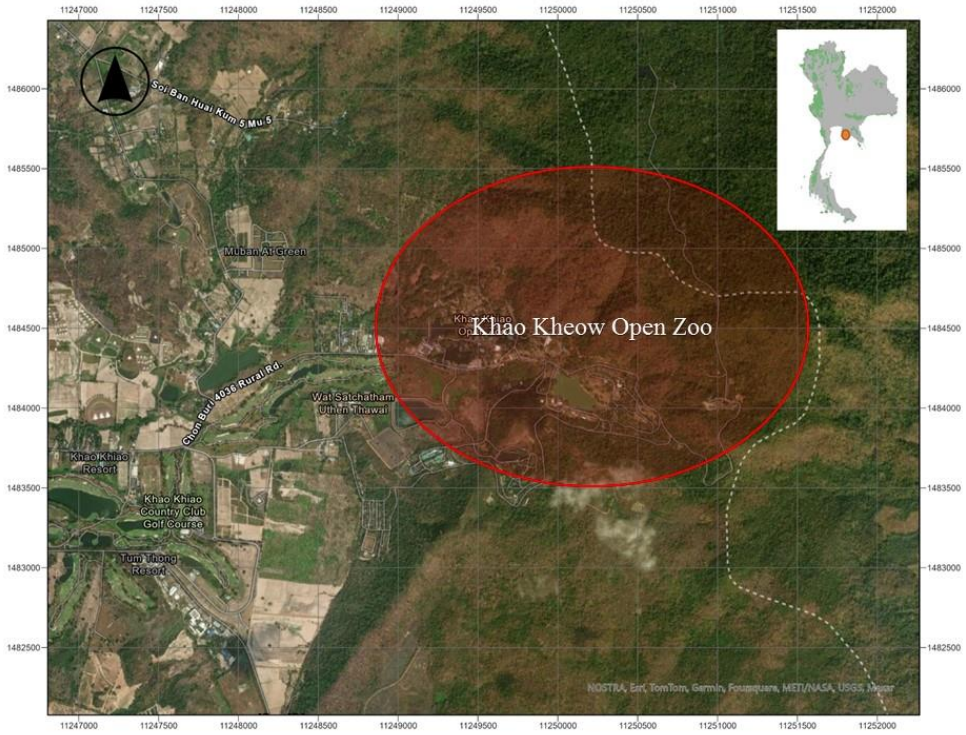

Figure 1 Map located at Khao Kheow Open Zoo

Data collection

The data collection method involved a compressive survey of the Khao Kheow Open Zoo area to identify bird nesting sites. Detail information was recorded on nesting duration, nest loss, and instances of parent bird abandonment. The location of each nest was documented using a high-magnification camera and binoculars. Nest height and tree height were measured with a range finder. Rainfall data was obtained from the Eastern Region Irrigation Hydrology Center, Royal Irrigation Department. While wind speed data was sourced from the National Hydro Informatics Data Center.

Air temperature and relative humidity data were monitored using a data logger placed within the Khao Kheow Open Zoo area.

Data analysis for the study period was divided into two distinct phases: the nest-building phase and the egg incubation period. Chicks were categorized by their developmental, stage into the following age group: 1–15 days, 16–30 days, 31–45 days, and 46–60 days (Urfi, 2011). Only chicks older than 45 days were included in this classification, and a nest was considered successful if at least one chick survived (Urfi, 2011; Tiwary & Urfi, 2016).

The Mayfield Method was used to determine nest survival. This method involves calculating the number of failed nests and exposure days (Mayfield, 1961). For failures occurring between two nest visits, half of the interval length was applied (Johnson, 1979).

Daily Survival Rate (DSR) = 1 - (number of failed nests/number of exposure days)

Nest Survival = $(DSR)^d$

^{d} = average number of days in the nesting period (100 days for the Painted stork)

Kaplan-Meier, estimation was utilized to determine the proportion of subjects surviving over time following treatment (Kaplan & Meier, 1958). This method tracks the number of participants surviving over time in clinical or community trials (Lira *et al*., 2020). Survival curves were constructed under various assumptions, with probabilities of events calculated at specific times (Goel et al., 2020).

Generalized Linear Model (GLM), the model factors affecting bird nest survival were analyzed using the GLM method (Rotella *et al*., 2004). The best model was selected based on Akaike's Information Criterion (AIC), with the model having the lowest AIC value considered optimal (Etterson, 2013). The statistical significance of coefficients was assessed based on the 95 percent confidence interval of coefficients (Walsh *et al*., 2014).

RESULTS AND DISCUSSION

1. Dynamics of nest construction and fledgling emergence in Painted Storks

The observation of painted storks engaging in pairing behavior and nest construction revealed a progressive trend over the observed period. Initially, during August 2020, a modest number of nests were observed, indicative of the early stages of nesting activity. However, over subsequent months, the frequency of nest construction exhibited a consistent upward trajectory. The zenith of nest abundance was reached in January, marking a notable culmination of nesting efforts within the observed population of painted storks (Figure 2).

In a comprehensive study examining bird nest survival, data from 142 nests revealed fluctuating counts of newly constructed nests across consecutive months. Specifically,

in August, 7 new nests were documented, with a substantial increase observed in subsequent months: 33 in September, 35 in October, and 43 in November. December maintained a relatively high count with 21 new nests, followed by a marked decline in January, where only 3 new nests were observed, signifying the cessation of nest-building activity. Throughout the study period, instances of unsuccessful nests were consistently recorded, punctuating the breeding seasons. Noteworthy occurrences of unsuccessful nests were recorded in October, November, December, January, February, and March (Figure 3).

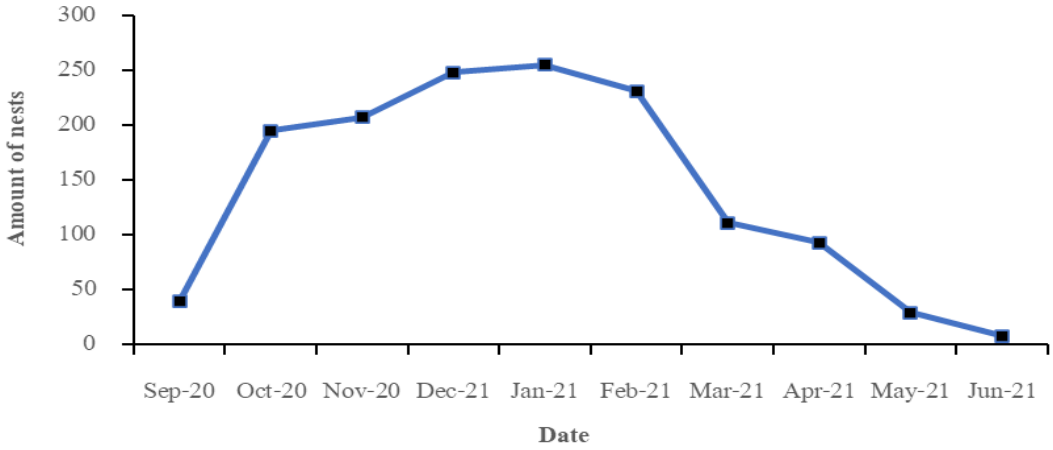

Figure 2 Monthly nest numbers during the breeding season of painted stork

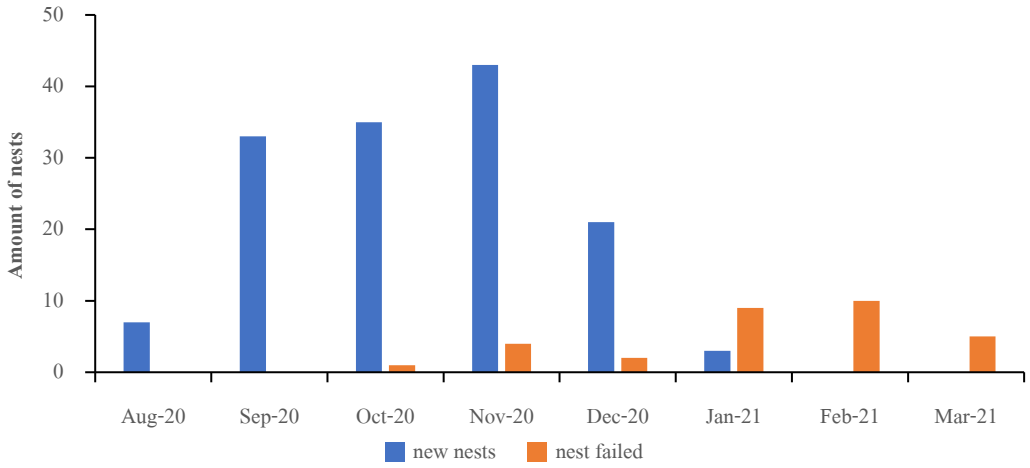

Figure 3 Monthly counts of newly built nests (n = 142) and failed nests.

The fledgling phase, a critical stage in the avian lifecycle, was meticulously studied across a sample size of 142 nests, revealing a range of fledglings per nest varying between 1 and 3. During this developmental period, characterized by the birds' immaturity, one parent bird typically assumes the role of sentinel, especially during sun-drenched days, using its wings to provide shade and shield the young within the nest. Parental care extends to feeding,

wherein regurgitated food is provided for the offspring, and the parent may reclaim any unconsumed portions. September 2020 marked the commencement of the birds' incubation period, heralding what research findings identify as the most prolonged breeding season observed in avian species. Notably, a significant proportion of young birds, hatched from eggs laid between November and December 2020, emerged predominantly in December 2020 and January 2021 (Figure 4).

A notable influx of fledglings aged 1 to 15 days was documented during December 2020 and January 2021. In January 2021, a pinnacle in the population distribution of fledglings aged 16 to 30 days was noted, with a substantial presence of birds aged 31 to 45 days persisting throughout the month. January or February 2021 witnessed the emergence of many fledglings aged 46 to 60 days, with February 2021 particularly notable for the prevalence of chicks aged 61 to 70 days, including those born in the preceding months of January and February (Figure 5)

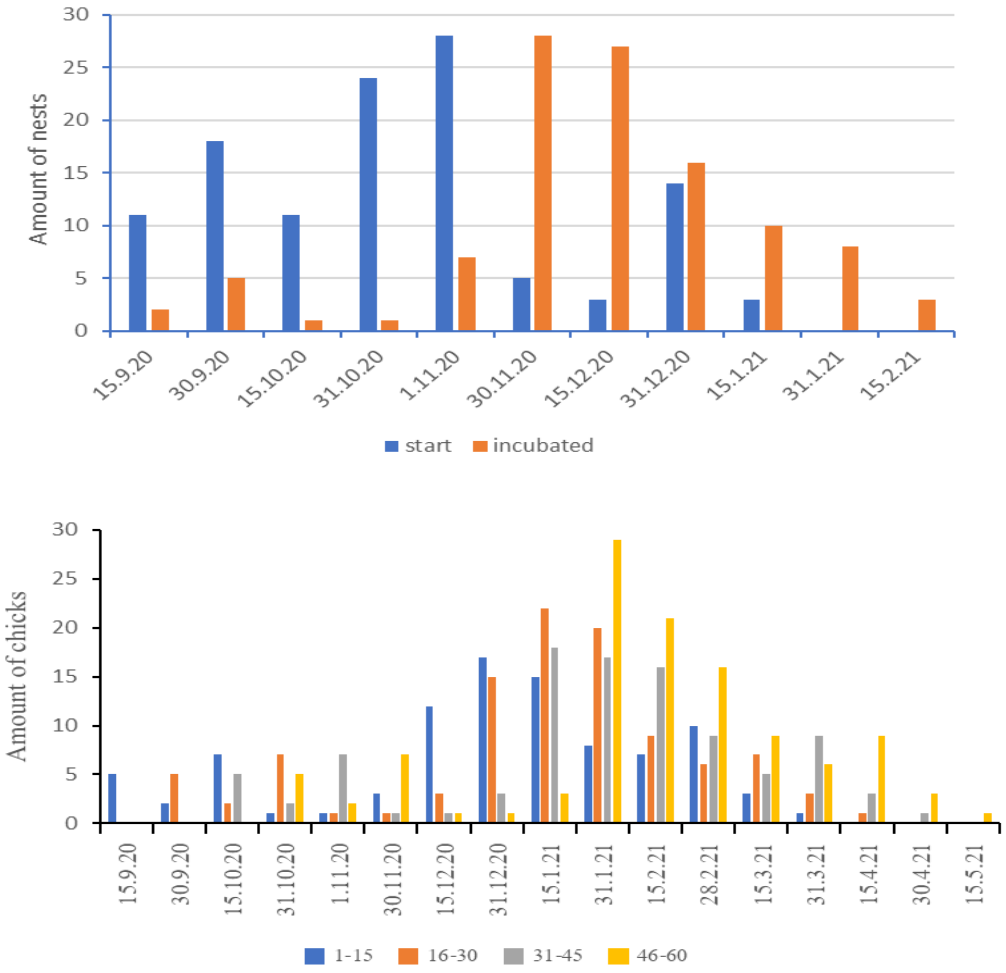

Figure 5 Distribution of fledglings across different age groups.

2. Environmental conditions and developmental phases of Painted Stork chicks

For chicks aged 1 to 15 days, the prevailing ambient temperature averaged 26 °C, with a typical low of 20 degrees Celsius and a peak of 33 °C. Monthly average rainfall stood at 21 millimeters, accompanied by a relative humidity of 68 %. As chicks matured to 16 to 30 days, the temperature profile remained consistent, averaging 26 °C, with a minimum of 20 °C and a maximum of 34 °C. This phase notably experienced no recorded rainfall, with relative humidity registering at 63 %. Chicks aged 31 to 45 days encountered a slightly elevated average temperature of 27 °C, with a corresponding low of 21 °C and a maximum of 34 °C. Rainfall during this interval diminished to an average of 5 millimeters per month, while relative humidity was maintained at 70%.

Transitioning to the 46 to 60 days age group, the ambient temperature increased to an average of 29 °C, with a minimum of 23 °C and a maximum of 35 °C. Monthly rainfall averaged 24 millimeters during this stage. The comprehensive nesting and incubation phase, encompassing nest construction, egg laying, and nurturing until fledglings reach independence, spans an average duration of 147 days. Remarkably, the longest recorded nest persisted for approximately 270 days, while the shortest duration recorded was approximately 85 days.

3. Survival of Painted stork nestling

The fledglings of Painted Storks exhibit a remarkable daily survival rate of 0.997 and nest survival of 74 %, while a nest success rate of 0.73 or 73 % by nest success divides total nests (104 successful nests from 142 nests). During the bird breeding season, precipitation levels varied significantly between heavy and light rain periods. This variability affected the duration of nest construction, as demonstrated by the Wilcoxon signed-rank test ($p < 0.05$). Nest-building time was notably longer during the rainy season from August to October, averaging 38.5 days (SD ±30). In contrast, the average nest-building time decreased to 21.7 days (SD ±20) during low precipitation, November to January.

The breeding season can be divided into two distinct periods: the first, characterized by heavy rainfall from August to October (Phase 1), and the second, with minimal rainfall extending from November to January (Phase 2) (Figure 6). During Phase 1, when birds began nesting, 21.3% rate of unsuccessful nesting was observed. However, in Phase 2, when nesting began, the rate of unsuccessful nests increased to 32.8%. The nest survival was analyzed using the Kaplan-Meier method, which encompasses the observation of various occurrences, including the appearance and disappearance of nests from the initiation of nest construction by birds to the hatching of eggs and until the young ones reach an age between 1 and 45 days.

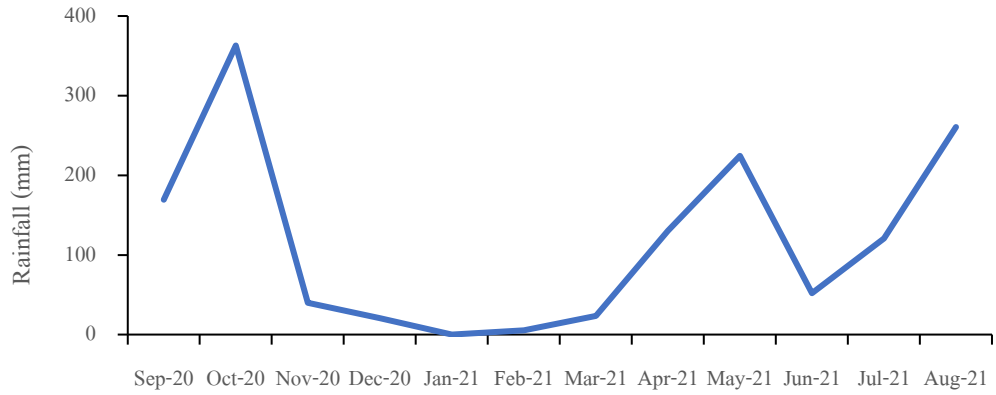

Figure 6 Monthly rainfall in 2020 and 2021 during the study period

The nest survival diagram illustrates a rapid decline in survival rates during the early stages of nest formation and the incubation period, followed by stabilization around the eighth week (nestling age over 16 days) (Figure 7). The weekly and cumulative Kaplan-Meier survival proportion for Painted Storks offers invaluable insights into the survival trends of fledgling storks during their critical developmental phases. This meticulously collected and analyzed dataset provides a comprehensive overview of the likelihood of survival for Painted Storks over ten weeks. Throughout the observed timeframe, the survival proportions exhibit a gradual decline, reflecting the myriad challenges and hazards encountered by the fledglings as they progress through their early life stages. In the initial week, the survival proportion is notably high at 0.979, indicating a robust likelihood of survival shortly after hatching. However, as subsequent weeks unfold, this proportion steadily diminishes, reaching 0.774 by the tenth week (Table 1).

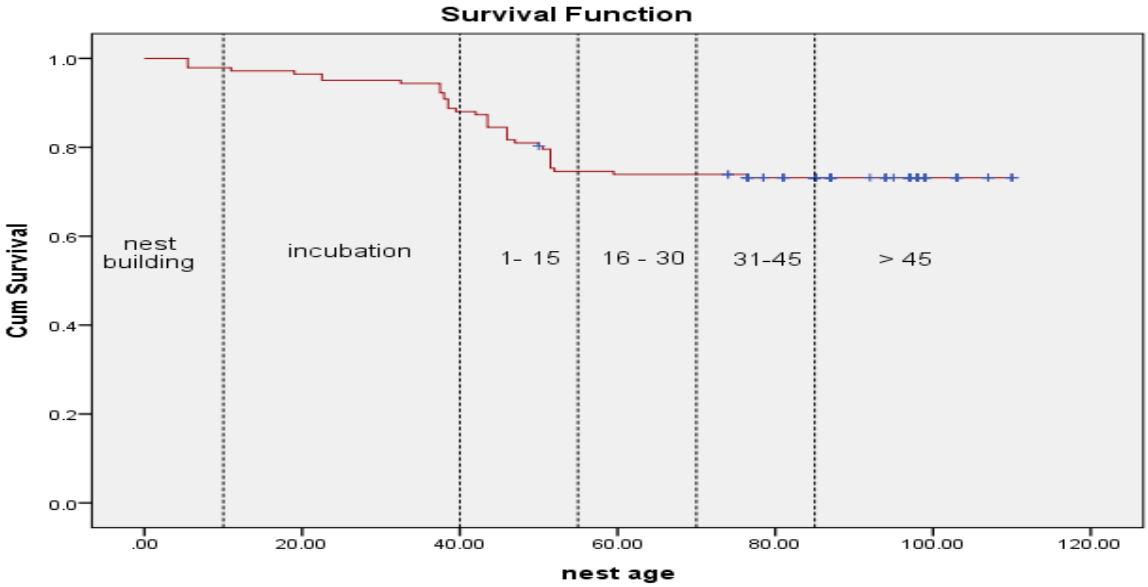

Figure 7 Nest survival during nest formation and chick development

Table 1 Weekly and Cumulative Kaplan-Meier Survival Proportion for Painted Stork

Week	Survival Proportion	Std. Error
1	0.979	0.012
2	0.972	0.014
3	0.965	0.015
4	0.951	0.018
5	0.944	0.019
6	0.894	0.026
7	0.824	0.032
8	0.774	0.140
9	0.774	0.140
10	0.774	0.140

4. Factors Influencing the Nest Survival

Various factors may influence nest survival, including average air temperature, average wind speed, average relative humidity, average precipitation, nest age, and nest height. These relationships can be analyzed using statistical models such as generalized linear models (GLMs). Models with the lowest Akaike Information Criterion (AIC) values are considered the most appropriate for analyzing nest survival. The table below (Table 2) presents the top 10 models with the lowest AIC values from a total of 63 models analyzed.

Table 2 Models of factors Influencing the nest survival

Model	AIC
Nest age	20.092
Nest age * nest height	21.427
Temperature average * nest age	22.044
Humidity average * nest age	22.073
Precipitation average * nest age	22.073
Wind speed average * nest age	22.081
Humidity average * nest age * nest height	23.379
Temperature average * nest age * nest height	23.419
Wind speed average * nest age * nest height	23.422
Precipitation average * nest age * nest height	23.427

This study identified a significant positive correlation between the survival of painted stork nests and nestling age, particularly noteworthy once chicks reached 16 days. Another study conducted in different regions highlighted environmental influences on nest survival, with nestling age, annual rainfall, and winter temperatures notably affecting survival rates, which stabilized notably after chicks surpassed 20 days of age (Tiwary & Urfi, 2016). Adverse environmental factors like strong winds further contributed to nest failures (Urfi et al., 2007). The vulnerability of younger nestlings, especially those under ten days old, led to higher mortality rates (Jovani & Tella, 2004). Nest survival has emerged as crucial for avian breeding success, with nest losses being a primary cause of reproductive failure across species (Martin, 1993), particularly during extreme weather events such as cold spells in December and January, resulting in nest mortality due to hypothermia (Tiwary & Urfi, 2016).

Environmental variables such as temperature and rainfall critically influence nesting success and nestling development, with high temperatures during the early stages reducing survival rates and rainfall patterns in tropical semi-arid regions influencing breeding timing, food availability, and fecundity (Bourne et al., 2020; França et al., 2020). Moreover, environmental conditions affected nest construction and parental behaviors, influencing provisioning rates and post-fledging survival (Facey et al., 2020). Humidity levels during incubation impacted water loss and embryonic mortality, thus affecting nest productivity (Van der Pol et al, 2013; Bobek et al, 2018).

CONCLUSION

The painted stork began nesting in the Khao Kheow Open Zoo area in August. Due to asynchronous nesting, the age of the chicks varies. Analysis of factors affecting nest survival indicated that nests with chicks older than 16 days had higher survival. Conversely, nests with chicks younger than 16 days, may be more vulnerable to hypothermia from adverse weather conditions and may have lower survival.

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