Breeding ecology, feeding of nestlings and nestling development of the Collared Kingfisher (*Todiramphus chloris*) in the Indian Sundarbans

Deblina Biswas, Kaushik Deuti*

Abstract - Although commonly occurring in many of the mangrove and coastal areas of the world, the breeding habits, nesting behavior, feeding, and development of nestlings of the Collared Kingfisher (*Todiramphus chloris*) had never been studied before. Our observations on the nesting behavior of this specialized bird shed light on the unique breeding habits of this species. This study was conducted in the Indian Sundarbans, from April to July 2023, by selecting one particular nesthole at Gosaba Island on an *Avicennia alba* tree trunk 1.5 m above the ground. During the middle of May, four eggs were laid, which hatched after 18 days in early June, giving birth to four blind, naked, pink-colored chicks. The development of the chicks was divided into eight stages: neonatal stage, eye-opening stage, growth stage, tail development stage, eye color changing stage, juvenile stage, collar development stage, and fledgling stage. The total time for the chicks to fly took 33 days from hatching. During this period, parents fed them crabs (70.5%), mudskippers and small fishes (12.2%), insects (11.5%), polychaetes (1.9%), reptiles and amphibians (1.9%), shrimps (1.1%), and mollusks (0.8%). Feeding observations were made for four hours (5:30-9:30 am) in the morning and two hours (4:30-6:30 pm) in the evening, and chicks were fed more food items (hourly) in the mornings than in the evenings. The adults preferred to collect these food items mostly from the muddy substratum near the nest, but at the time of high tide or after heavy rain, they preferred to collect food (like insects, mole crickets, dragonflies, etc.) from agricultural land opposite to the nesting site. However, the effect of low and high tides on the hunting activity of parents was found to be insignificant. This study in the Indian Sundarbans provides comparatively more detailed information on the nesting ecology of the species than studies made earlier in India, Bangladesh, the United Arab Emirates, and the Fiji Islands.

Key words: Sundarbans, mangroves, Collared Kingfisher, provisioned food, nestling growth.

Riassunto - Ecologia riproduttiva, alimentazione dei nidiacei e sviluppo dei nidiacei del martin pescatore dal collare (*Todiramphus chloris*) nelle Sundarbans indiane.

Sebbene la specie sia comunemente presente in molte mangrovie e aree costiere del mondo, le abitudini riproduttive, il comportamento di nidificazione, l'alimentazione e lo sviluppo dei nidiacei del martin pescatore dal collare (*Todiramphus chloris*) non erano mai stati studiati prima. Le nostre osservazioni sul comportamento di nidificazione di questo uccello specializzato hanno fatto luce sulle abitudini riproduttive uniche di questa specie. Questo studio è stato condotto nelle Sundarbans indiane, da aprile a luglio 2023, selezionando una particolare cavità-nido a Gosaba Island su un tronco di *Avicennia alba* a 1,5 metri dal suolo. A metà maggio sono state deposte quattro uova, che si sono schiuse dopo 18 giorni all'inizio di giugno, dando vita a quattro pulcini ciechi, nudi e di colore rosa. Lo sviluppo dei pulcini è stato suddiviso in otto fasi: fase neonatale, fase di apertura degli occhi, fase di crescita, fase di sviluppo della coda, fase di cambiamento del colore degli occhi, fase giovanile, fase di sviluppo del collare e fase di volo. Il tempo totale per far arrivare i pulcini all'involo è stato di 33 giorni dalla schiusa. Durante questo periodo, i genitori li hanno nutriti con granchi (70,5%), pesci saltafango e altri piccoli pesci (12,2%), insetti (11,5%), policheti (1,9%), rettili e anfibi (1,9%), gamberetti (1,1%) e molluschi (0,8%). Le osservazioni sull'alimentazione sono state effettuate per quattro ore (dalle 5:30 alle 9:30) al mattino e per due ore (dalle 16:30 alle 18:30) alla sera, e i pulcini sono stati alimentati con più cibo (ogni ora) al mattino che alla sera. Gli adulti preferivano raccogliere questi alimenti soprattutto dal substrato fangoso vicino al nido, ma al momento dell'alta marea o dopo forti piogge, preferivano raccogliere cibo (come insetti, grilli talpa, libellule, ecc.) dai terreni agricoli di fronte al sito di nidificazione. Tuttavia, l'effetto delle basse e alte maree sull'attività di caccia dei genitori è risultato insignificante. Questo studio nelle Sundarbans indiane fornisce informazioni relativamente più dettagliate sull'ecologia di nidificazione della specie rispetto agli studi effettuati in precedenza in India, Bangladesh, Emirati Arabi Uniti e Isole Fiji.

Parole chiave: Sundarbans, mangrovie, martin pescatore dal collare, cibo fornito, crescita dei nidiacei.

Zoological Survey of India, FPS Building, Indian Museum Complex, Kolkata, West Bengal, India.

* Corresponding author: kaushikdeuti@gmail.com

Received for publication: 29 November 2024
Accepted for publication: 30 January 2025
Online publication: 4 June 2025

INTRODUCTION

The Collared Kingfisher, also known as white collared or mangrove kingfisher is a medium-sized coastal kingfisher of the order Coraciiformes, family Alcedinidae and subfamily Halcyoninae (Grimmett *et al.*, 2016). It has a stout black bill, blue-green upperparts with a white collar, blue wing and tail and white or buffish underparts. The species is often found in coastal wetlands, particularly in the tidal creeks and mangrove swamps (Grimmett *et al*., 2016). In India, the Collared Kingfisher is widely distributed in the states of West Bengal, Odisha, Maharashtra, Goa, Karnataka, Andaman and Nicobar Islands (Grimmett *et al*., 2016). Despite their broad distribution, basic information on their breeding biology is surprisingly poor. Literature survey reveals very little information about its life history (Ahmed, 2021).

India is home to 12 species of kingfishers, among which nine species, including the Collared Kingfisher, are found in both the Indian and the Bangladeshi Sundarbans. Although the breeding biology of this kingfisher has not been studied in the Indian Sundarbans, few studies in the Bangladesh Sundarbans depict the breeding season of the Collared Kingfisher from April to June (Ahmed, 2021). Previous studies have focused on few anatomical, physiological and ecological attributes, hunting method and niche partitioning, cooperative nesting, population status and decline due to alien intruders and molecular phylogeny of the mangrove kingfisher (Beckon, 1987; Luczon *et al*., 2010; Fitzsimons & Thomas, 2011; Borah *et al*., 2012; Campbell, 2012; Pereira, 2013; Andersen *et al*., 2015). There has been only one study on the feeding and breeding habits of the mangrove kingfisher *Todiramphus chloris* in Bangladesh (Ahmed, 2021). Therefore, studies on the breeding ecology of this species are necessary from a biological and ecological standpoint for a better understanding of the life history of the species (Woodall, 2020). Hence, this study aims to provide detailed information on nests, eggs, feeding behavior of nestlings, and nestling development on a daily basis is important.

Study area

The Sundarbans is a cluster of low-lying islands, spread across India and Bangladesh, famous for its unique mangrove swamps contributing to different biotic and abiotic factors, i.e., soil formation, hydrological cycle, climate change, and protection from natural disasters (Kathiresan & Bingham, 2001). The Indian Sundarbans consists of 102 islands of which 54 are only inhabited by humans. This study was conducted at Gosaba island (which is one of the large, inhabited islands having a lot of mangroves) of South 24 Parganas district (22.137°N, 88.836°E), Sundarbans, West Bengal, India from April to July 2023. The map of the study area was prepared using an open-source QGIS software (Fig. 1).

MATERIALS AND METHODS

From April to July 2023, we studied the feeding and breeding ecology of the Collared Kingfisher in Sundarbans, India. At first, we did random surveys using the line transect method (Gaston, 1975) in different areas of Bali and Gosaba islands in the Sundarbans to find their nests. Thus, we managed to locate three nests by following in-

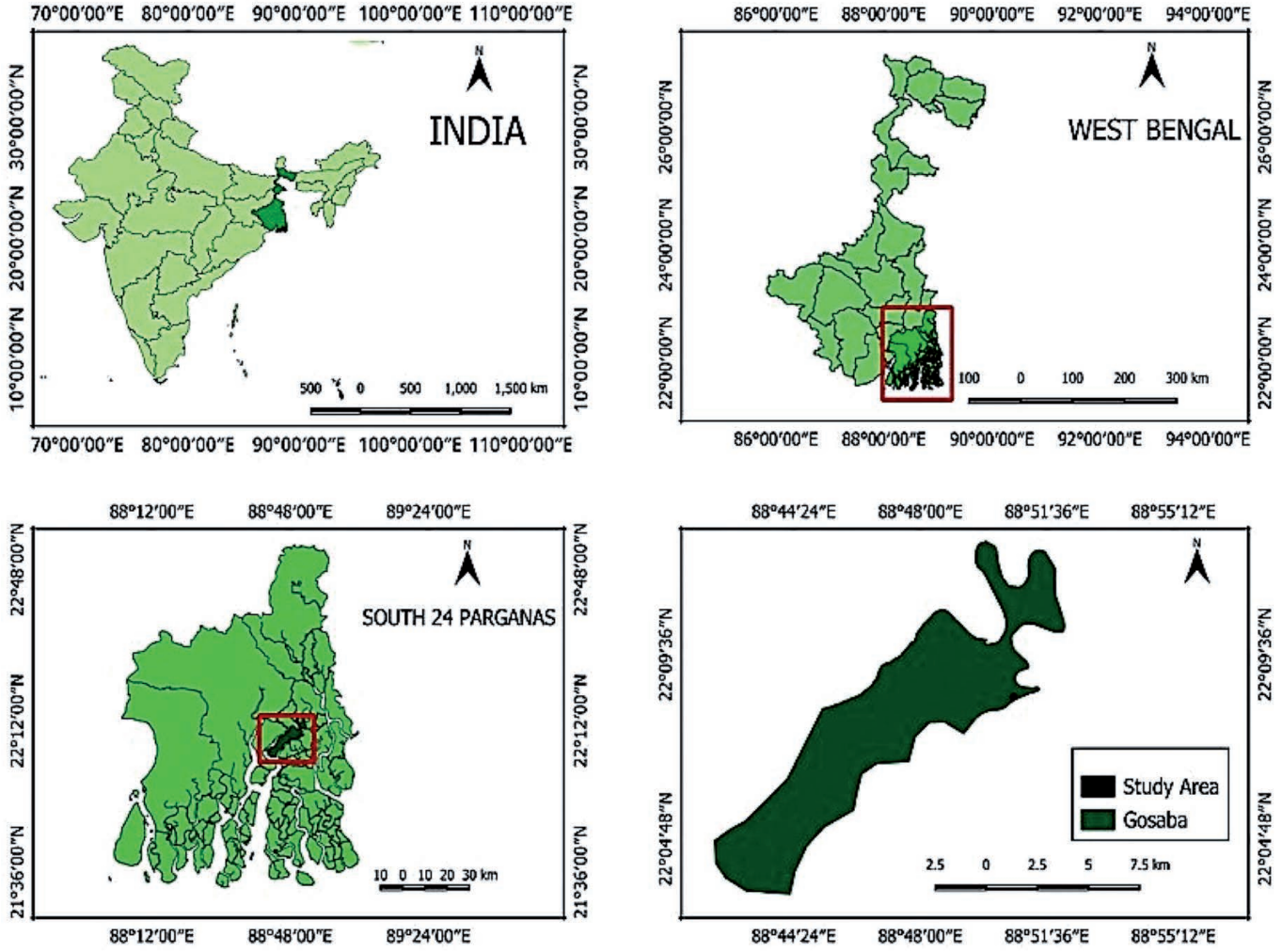

Fig. 1 – Map of study area. / Mappa dell'area di studio.

dividual adults, who were seen entering the nest hole in mangrove trees or carrying food for their nestlings. Thereafter, we selected one particular nest in the tree hole of one *Avicennia alba* mangrove tree, due to its lower height from the ground. After that, we measured different parameters like girth at breast height (GBH) of the nesting tree, its distance from the riverbank, height of the nest hole from the ground, diameter, and depth of the nesting hole with a measuring tape. We also measured egg length and egg diameter of the broken egg after hatching, using a Vernier caliper, and noted the clutch size. Over the next 33 days, we observed the feeding behavior of both parents to their nestlings, recording the time and frequency of the feeding bouts each day. These observations were made from a distance of 13-15 m from the nesting tree, without disturbing the nesting pair. However, 20 days after hatching, we approached the nest hole again and took out one nestling for a few minutes to measure its full body length, bill, wing, tarsus, and tail length using a steel ruler (0 to 300 mm). We made behavioral observations at the nest site twice a day from 05.30-09.30 h. in the morning and 16.30-18.30 h. in the evening using a Nikon Aculon 10 X 50 binocular and a Canon HS 60 X compact digital camera. A digital stopwatch was used for noting behavioral activities like calling, flying, diving, feeding, resting, and preening, and the field data was recorded using an earlier prepared datasheet.

Statistical analysis

To investigate the influence of foraging behavior, we employed a two-pronged approach. Firstly, we used the Kruskal-Wallis test to determine if the frequency of food supply to the nestlings varied significantly across different time periods. This non-parametric test was used because the data were not normally distributed. Secondly, independent samples t-tests were conducted to examine potential differences in parental hunting frequency between high and low tide periods. All data were analyzed using both Microsoft Excel and R Statistical software. The significance level was set at $p>0.05$.

RESULTS

Location of nest

The single nest we studied was located in a tree hole on the trunk of an *Avicennia alba* mangrove tree with a GBH of 81.28 cm, 2.5 m from the riverbank at a height of 1.5 m from the ground. The diameter of the nest hole was 10.16 cm and its depth was 17.78 cm (Fig. 2).

Eggs

On 28 May 2023, we observed four eggs in the nest hole. One egg was measured and found to have an egg length of 42.8 cm and an egg diameter of 25.7 cm (Fig. 2).

Feeding behavior

Both male and female parent birds fed their nestlings. Like other kingfishers, Collared Kingfishers also show a sit-and-wait foraging strategy with their keen eyesight. Every single feeding includes noticeable sit-and-wait searching, diving, and prey capturing from the mangrove habitat. That is why, in the Sundarbans, they can be termed

Fig. 2 – Location of the nest (arrow-marked) on the *Avicennia alba* plant at the edge of water and land; Four eggs inside the nest. / Posizione del nido (contrassegnato da una freccia) sulla pianta di *Avicennia alba* al confine tra acqua e terra; quattro uova all'interno del nido.

as a specialist mangrove forager feeding on different mangrove crabs, fish, insects, and mollusks (Fig. 3).

Food items and feeding frequency

According to our study in Indian Sundarbans from April to July 2023, we found that the adult pair of Collared Kingfisher fed their chicks mostly crabs - mud crabs and fiddler crabs (n=184, 70.5%) - mudskippers and small fishes (n=32, 12.2%) and Lepidopteran caterpillars constituted (n=18, 6.9%). However, adult insects like mole crickets constituted only 2.7% (n=7), dragonflies only 1.5% (n=4), and beetles only 0.4% (n=1) of the diet. Shrimps were only 1.1% (n=3)

Fig. 3 – Food items being fed to the nestlings. 1) Mud crab; 2) fiddler crab; 3) mudskipper; 4) caterpillar; 5) mole cricket; 6) dragonfly; 7) shrimp; 8) glossy mangrove snake. / Cibo somministrato ai nidiacei. 1) Granchio del fango; 2) granchio violino; 3) saltafango; 4) bruco; 5) grillo talpa; 6) libellula; 7) gambero; 8) serpente di Gerarda prevostiana.

of the diet, as were skinks (1.1%). Apart from these polychaete worms (n=5, 1.9%), mollusks (n=2, 0.8%), snakes (n=1, 0.4%) and frogs (n=1, 0.4%) were other minor food items (Fig. 4). Also, the frequency of provisioned food to the nestlings decreased with the increasing age of the nestlings (Fig. 5).

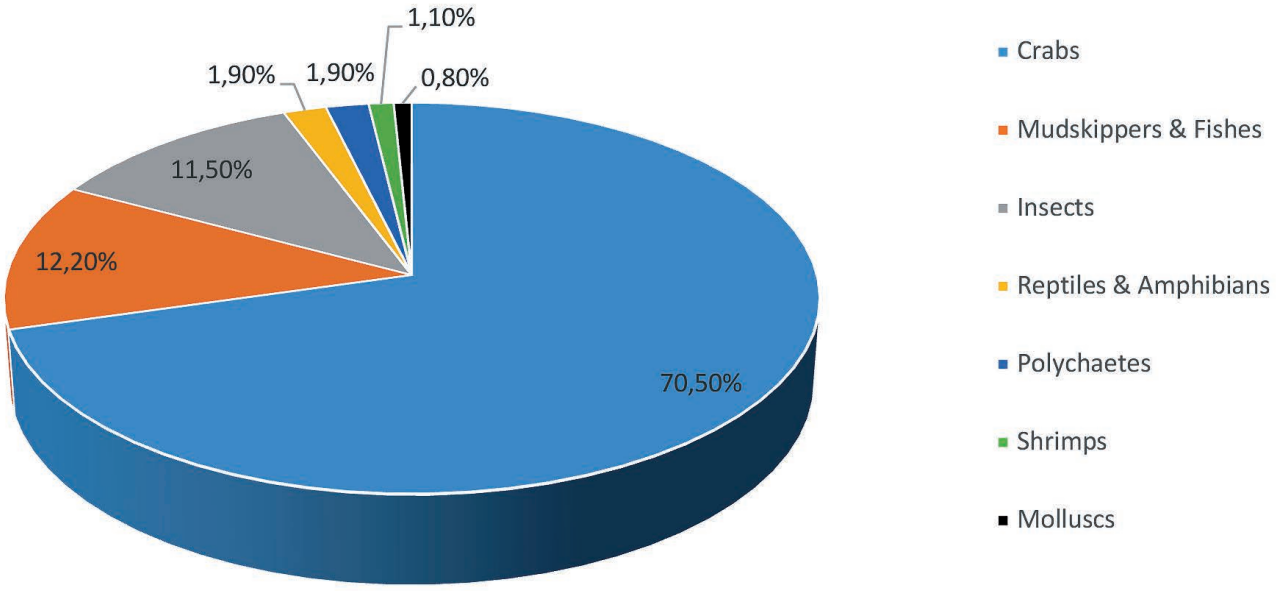

Fig. 4 – Percentage of food items fed to the nestlings. / Percentuale di alimenti somministrati ai nidiacei.

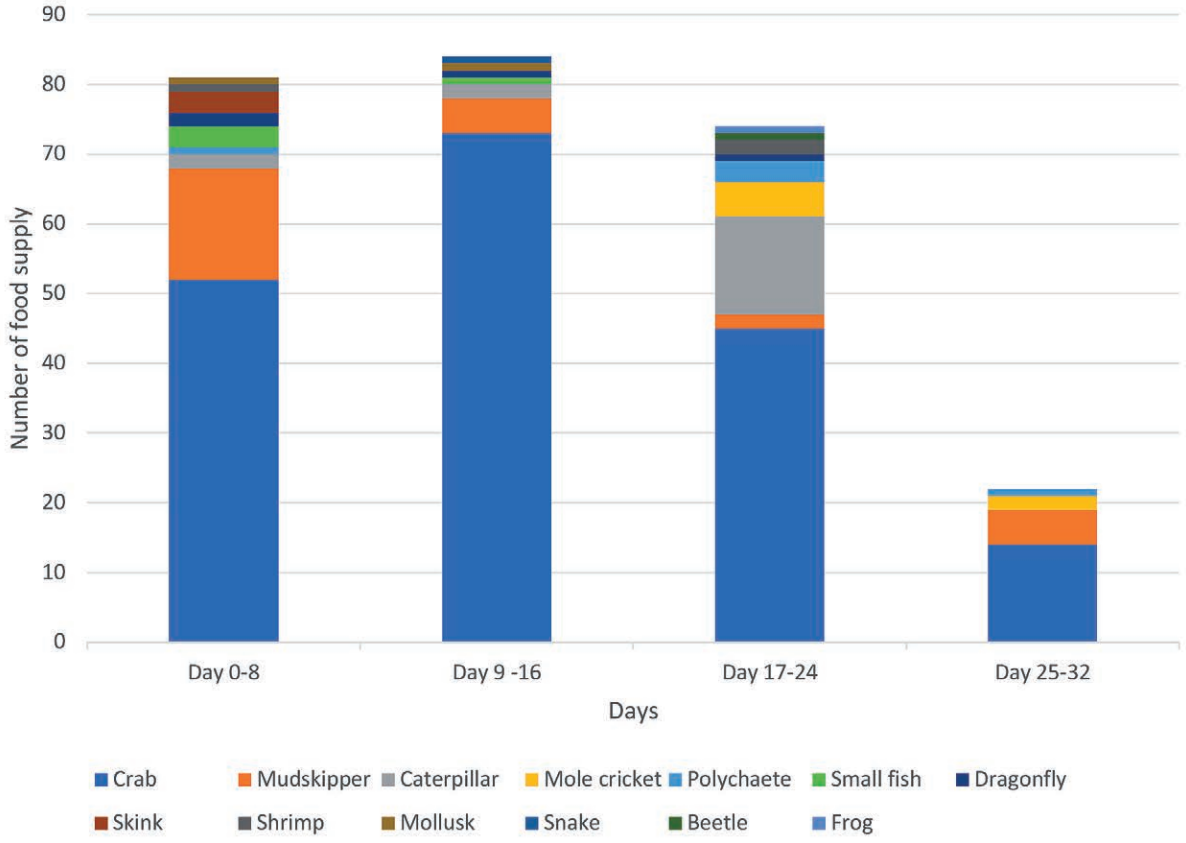

Fig. 5 – Particular live food items that were fed to the nestlings with their age in days. / Particolari alimenti vivi somministrati ai nidiacei in relazione alla loro età in giorni.

Frequency of provisioned food to the nestlings

After the eggs hatched, both parents began provisioning the hatchlings. We observed that when one parent entered the nest with food, the other waited and guarded the nest by sitting on a nearby branch of a tree or any other support near the nest hole. Also, before entering the nest hole, they sat on the nearby mud substratum and keenly observed around the nest, and then only entered the nest hole with food.

According to our behavioral observations, at the nesting site, both during morning and evening, the highest preying frequency (19.8%) of adult Collared Kingfisher was recorded during 06.30-07.30 h in the morning and the lowest preying frequency (15.7%) was recorded during 05.30-06.30h in the morning and 16.30-18.30h in the evening (Fig. 6). The frequency of food supply to the nestlings varied insignificantly at different times of the day (Kruskal-Wallis test, H=9.8, df=5, p>0.05).

They preferred to collect food mostly from the muddy substratum near the nest, but at the time of high tide or after heavy rain, they preferred to collect food (like insects, mole cricket, dragonfly, etc.) from agricultural land opposite to the nesting site. However, the effect of low and high tides on the hunting activity of parents was found to be insignificant (*t*-test, t=0.93, p>0.05).

Nestling development stages

Kingfishers are fascinating birds known for their vibrant plumage. When it comes to the development of kingfisher nestlings, after hatching, they go through several developmental stages. Here is a day-by-day observation of Collared Kingfisher chick development.

Day 1 (04.06.23) – Hatching day

Only one egg hatched in the late evening. The chick was extremely fragile and vulnerable after hatching. It was born blind, naked (devoid of any feathers), with skin that was translucent and pink in color, and completely dependent on its parents for warmth, food, and protection. The head was comparatively small as compared to the body size, but the beak had a projection, the remnant of the egg-tooth.

Day 2-7 (05.06.23-10.06.23) – Neonatal stage

At this stage, all eggs had hatched. The chicks continued to rely on their parents for warmth as they were unable to regulate their body temperature. They remained huddled together in the nest cavity. Eyes remained closed. No feather development was observed. The beak is shortened due to the dislocation of the egg tooth. The body was still naked and pink in color.

Day 8-9 (11.06.23-12.06.23) – Eye opening

One of the chick's eyes (the elder one) started to open. In this period, they spent a significant amount of time sleeping and feeding. Small skin outgrowths (Papillae) started to develop from the middle of the head down to the wings. The rest of the body was naked and pink in color, the body color changing from pink to pale blue. The beak grew thicker and stronger. Limbs were also naked and elongated.

Day 10-13 (13.06.23-16.06.23) – Development of feather

Chicks grow rapidly during this period. The eyes of all the chicks had fully opened, and thus they became more alert to their surroundings with open eyes. Their vision was not well developed initially, but it gradually improved. The eyes were blue. The feathers of the upper body parts became more prominent than on the previous days. Also, the down feathers start to grow that were white. As the nestlings grew, they started to develop pin feathers that eventually unfurl into adult feathers. No feather development was noticed on the lower part of their chin. The limbs were still naked and devoid of feathers.

Day 14-16 (17.06.23-19.06.23) – Growth stage

At this stage, chicks became more mobile and independent. Development of feathers continues, and more off-white down feathers appeared on the breast and abdomen. Off-white feathers also started to grow on the chin. During this period, their movements increased with the development of feathers on their body, and they became noisier and competitive in receiving meals from their parents.

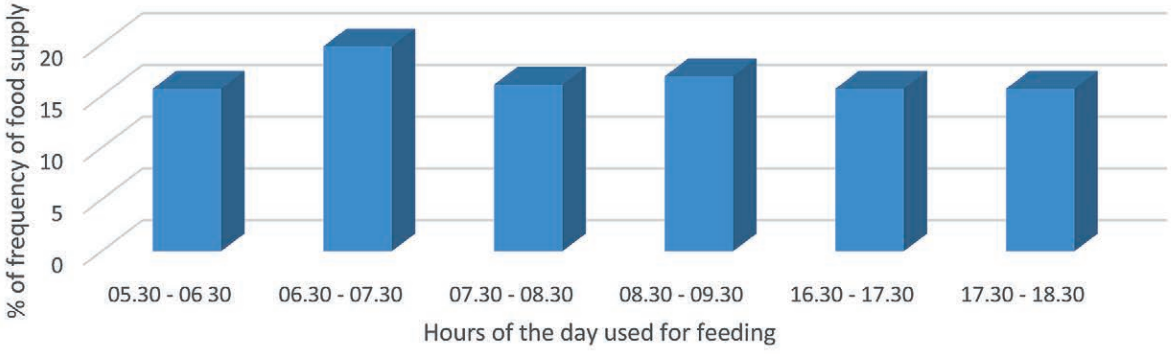

Fig. 6 – Provisioned food supply in one nest by Collared Kingfisher pair at different hours of the day during nesting period. / Rifornimento di cibo in un nido da parte di una coppia di martin pescatore dal collare in diverse ore del giorno durante il periodo di nidificazione.

Day 17-18 (20.06.23-21.06.23) – Tail development

Now they became more aware and watchful of their surroundings and started to venture inside the nest under the watchful eyes of their parents. The small tail started to grow and is blue in color. More upper and down feathers developed rapidly and became prominent. The beak became comparatively stronger than in earlier stages. Eyes were still blue in color.

Day 19-23 (22.06.23-26.06.23) – Eye color changing stage

Chicks continued to grow and develop their feathers prominently (both upper and down feathers). The flight feathers on the wings was now much longer. The color of the eyes changed from blue to black. At this stage, we took some morphological measurements of one of the nestlings:

- full body length – 12.7 cm, measured from the tip of its bill to the tip of the tail;
- tarsus length – 3.81 cm, maximum tarsus length measured from the bend of the leg to the base of the toes;
- wing length – 6.35 cm, flattened wing measured from the tip of the longest primary feather (the outermost flight feather) to the bend of the wing (carpal joint);
- bill length – 3.04 cm, measured at the point where the exposed culmen begins, i.e., where the beak becomes hard and the softest part of the gape ends;
- tail length – 1.8 cm. To measure the tail, first gently straighten and flatten the tail, then slide a ruler between the retrices and the undertail coverts until it comes to a stop at the root of the central pair of tail feathers.

All measurements were taken using different measuring techniques as per de Beer *et al*. (2001).

Day 24-28 (27.06.23-01.07.23) – Juvenile stage

Now the feathers of the chicks had completely developed and are bluish green in color (like adults) on the head and the wings. The underparts were brownish. The bill was black and well developed by now. They started to peep out from the nest hole and try to explore the outside of the nest. They also engaged in preening and wing stretching within the nest, which helps strengthen their wing muscles and prepare them for their first flight.

Day 29-31 (02.07.23-04.07.23) – Development of collar

The color of the feathers on the head, wings, and tail became prominent blue. This blue color now extended from the tip of the bill to the head. The white collar started to develop. The underparts were also white.

Day 32-33 (05.07.23-06.07.23) – Fledgling stage

The feathers were very prominent, blue on the head, wings, and tail. The white collar is now fully developed, and the underparts were also fully white. The color of the eye was now fully black. The chick was observed to fly out of the nest on its own.

An image of stages in the growth and development of feather in Collared Kingfisher chicks is given in Fig. 7.

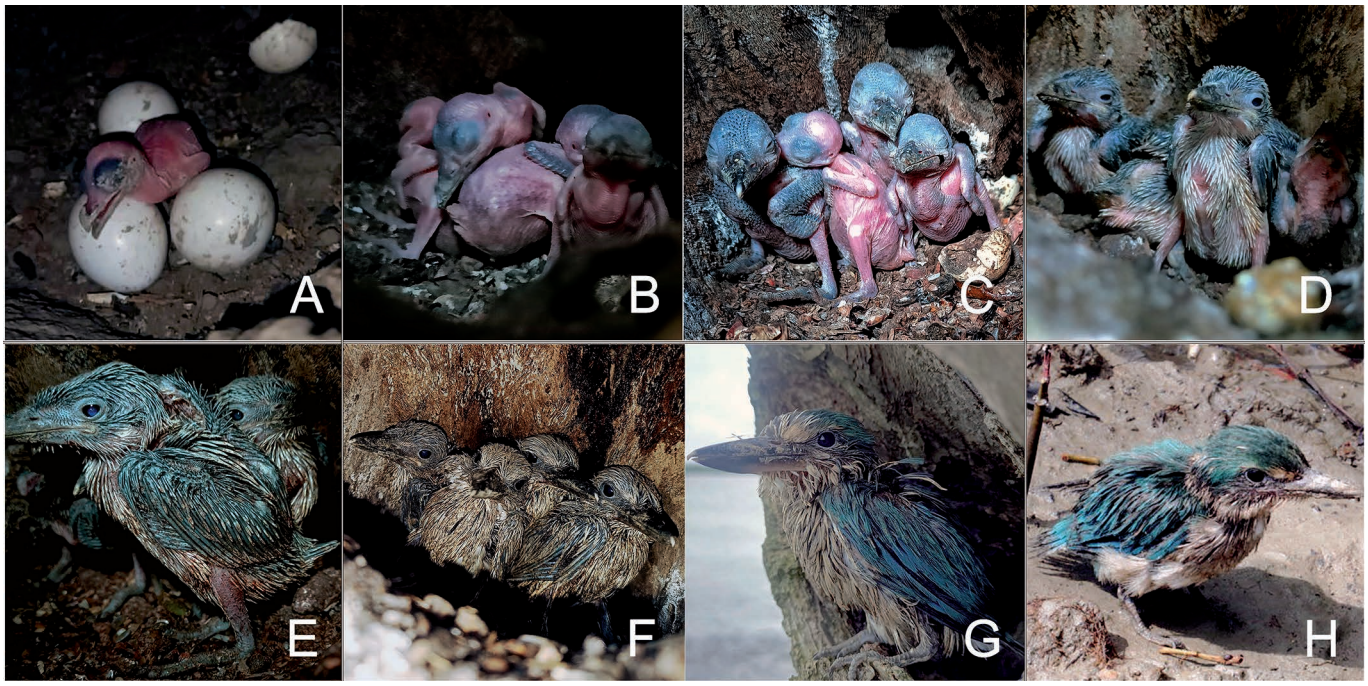

Fig. 7 – Nestling development of Collared Kingfisher in Indian Sundarbans. A) Hatching day; B) neonatal stage; C) eye-opening stage; D) feather development stage; E) tail development stage; F) eye-color changing stage; G) juvenile stage; H) development of collar at fledgling stage. / Sviluppo dei nidiacei di martin pescatore dal collare nelle Sundarbans indiane. A) Giorno della schiusa; B) stadio neonatale; C) fase di apertura degli occhi; D) fase di sviluppo delle penne; E) fase di sviluppo della coda; F) fase di cambiamento del colore degli occhi; G) stadio giovanile; H) sviluppo del collare allo stadio di nidiaceo.

DISCUSSION AND CONCLUSIONS

This study in the Indian Sundarbans provides the first detailed insights into the breeding habits, nesting behavior, and feeding patterns of the Collared Kingfisher, including information on its nestling development, prey preferences, and foraging strategies within this unique ecosystem.

The study in Bangladesh Sundarbans from April to June, 2017 and 2018 (Ahmed, 2021) reported crab (Paddler crab and Ghost Crab) to constitute 62% of the diet of nestlings, while minnows and small fishes constituted 12% of the diet. These percentages are similar to our study; however, in the Bangladesh study (Ahmed, 2021), shrimps constituted 9% of the nestling diet as compared to 1.1% in our study.

Due to heavy rains on certain days, the parents could not feed the nestlings properly. On those days when feeding was possible during both mornings and evenings, it was observed that the diet of nestlings consisted mostly of crabs, 64.5% in the morning hours and 75.8% in the evening hours, followed by mudskipper and fish, 15.7% in the morning hours and 5.2% in the evening hours. The Collared Kingfisher parents provisioned the nestlings with insects at a rate of 14.2% in the morning hours and 12% in the evening hours, Polychaete worms 2.3% in the morning and 1.7% in the evening, Reptiles and Amphibians 0.8% in the morning and 1.7% in the evening. Shrimps were provisioned to the nestlings only in the morning at a rate of 2.3%, and Mollusks were provisioned to the nestlings only in the evening at a rate of 3.4% (Fig. 8).

In the Bangladesh study, the nest hole was also in the trunks of mangrove trees like *Exoecaria agallocha* and *Avicennia* sp, just like our study, and also the clutch size (four eggs) was similar. The incubation period was also similar, 17-20 days in the Bangladesh study and 18 days in our study, as was the nestling period, 25-30 days (Ahmed, 2021), while 33 days in our study.

Borah *et al.* (2012) studied the food items in the diet of adult Collared Kingfishers in Odisha, India, and reported that they consumed about 55% insects and 45% crabs.

Pereira (2013) reported that the Collared Kingfisher nested in the hollows of older and larger mangrove trees in the United Arab Emirates (UAE), while Ali & Ripley (1983) from India, also reported nest holes in tree trunks or in mud nest of tree ants, sometimes in termite mound. Ali & Ripley (1983) also reported that fiddler and other crabs, mudskippers (*Periophthalmus*), grasshoppers, lizards and centipedes were in the diet of adult Collared Kingfishers, and that they nested in April-May.

In the Southern hemisphere, Beckon (1987) reported the nesting month as October for the Collared Kingfisher from the Fiji Islands. This is natural as the summer season starts from August to September in the southern Hemisphere. Beckon (1987) also reported nests in a single hole of a dead tree trunk while Fitzsimons & Thomas (2011) reported grasshoppers, crickets, lizards (skinks),

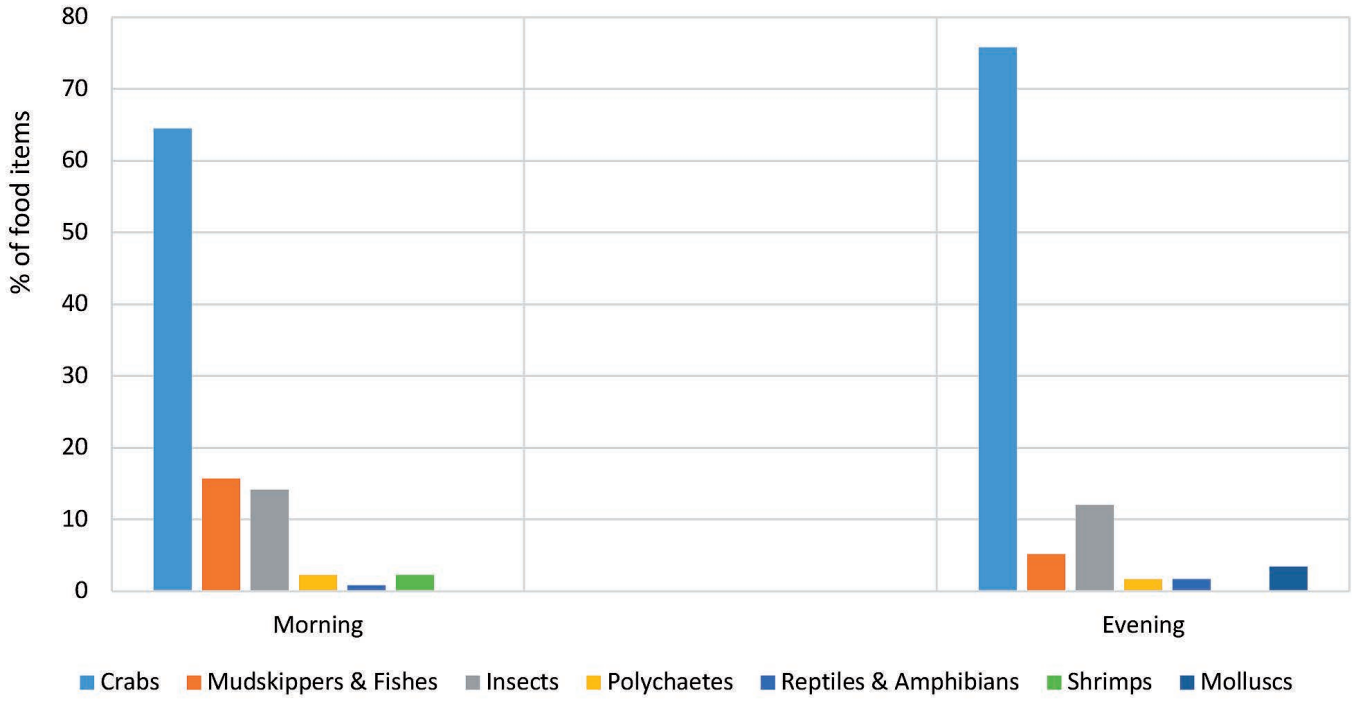

Fig. 8 – Percentage of food fed to the nestlings during mornings and evenings. / Percentuale di cibo somministrato ai nidiacei durante la mattina e la sera.

young birds, crabs, fish, geckos, earthworms, large insects, shrimps, mudskipper, cicadas, beetles, carpenter bees, wasps, spiders, frogs, snakes, mice, the eggs and nestlings of small birds in the diet of adult Collared Kingfisher from the Fiji Islands.

The studies on nesting ecology of Collared Kingfisher in Bangladesh (Ahmed, 2021), Fiji (Beckon, 1987; Fitzsimons & Thomas, 2011), Odisha (Borah *et al*., 2012), UAE (Pereira, 2013) provided only minimal information regarding their nesting habits, nestling development, feeding of nestlings.

This study underscores the critical importance of detailed, species-specific ecological research, particularly in vulnerable ecosystems like the Sundarbans. By understanding the feeding patterns and dietary needs of Collared Kingfishers during the breeding season, this research provides crucial baseline data for conservation efforts. Furthermore, the study demonstrates the impact of environmental factors, such as high and low tides, on parental foraging success and subsequent nestling nutrition. These findings contribute valuable data to our understanding of Collared Kingfisher ecology and emphasize the importance of long-term monitoring and research in this unique and dynamic ecosystem.

ACKNOWLEDGEMENTS

We are grateful to the people of the Indian Sundarbans for their help during field work and to Aninda Majumder for help with field photography and photo-editing. We thank Santanu Mitra for the identification of crabs and mudskippers, Rajmohana Keloth for the identification of the mole cricket, and Prasenjit Dawn for the identification of the dragonfly from the photographs. We are also extremely grateful to the anonymous reviewers who helped us to upgrade the manuscript tremendously. We remain grateful to Director, Zoological Survey of India for permitting us to conduct this study. This study was financed by the University Grants Commission of the Government of India as a fellowship to the first author.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

While conducting this study, no individuals of the Collared Kingfisher (adults as well as nestlings) were harmed or disturbed in any way. As the study area is not under any protected area zone, no permission was required for this study. Therefore, we authors consented to participate equally in this study.

CONSENT FOR PUBLICATION

The authors hereby provide consent for the publication of the manuscript detailed above, including all images or data contained within the manuscript.

AVAILABILITY OF DATA AND MATERIAL

The authors give consent to the readers to access the data and materials for citation used in this paper.

COMPETING INTERESTS

The authors have declared no conflict of interest.

FUNDING

This study was financed by the University Grants Commission of the Government of India as a fellowship to the first author.

CONTRIBUTIONS

Deblina Biswas, responsible for field data collection, data analysis and interpretation of the data, creating figures and writing the original manuscript draft. Kaushik Deuti, responsible for conceptualization of the study, supervising the field study, reviewing and editing the manuscript.

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