Journal of Bioresources 11 (2): 103–107, April – June 2024

JOURNAL OF BIORESOURCES

journal webpage: https://jbr.rgu.ac.in

ISSN: 2394-4315 (Print)
ISSN: 2582-2276 (Online)

RESEARCH ARTICLE

Nesting ecology of the Lesser Adjutant Stork (*Leptoptilos Javanicus* Horsfield) and prevailing threats on their survival

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Article No.: JMDJBR98; Received: 28.05.2023; Peer-Reviewed: 15.12.2023; Revised & Accepted: 10.05.2024; Published: 30.06.2024
Doi: https://doi.org/10.5281/zenodo.13915188

Abstract

The nesting ecology and threats of Lesser Adjutant Stork were studied in the areas near the Kolong river, Nagaon, Assam. The study was conducted during the post-breeding season. For determining the use of nesting habitat and trees, the height of the tree from the ground, Diameter at Breast Height (DBH) and canopy coverage area were measured. For measuring the height of the tree, Pythagoras' theorem was used through a homemade clinometer. Autocorrelation was checked by the Durbin Watson test. The Lesser Adjutants prefer upper canopy areas and areas with least vegetation and disturbance for the nest building. It was shown that the height of the tree, DBH, in the canopy coverage area is significantly in a positive association with the nest. They build their nests near wetlands, rivers, foraging nests etc. The number of nests is negatively associated with the distance to the nearest foraging areas. They prefer mostly *Bombax ceiba* tree for nesting, but also prefer *Terminalia arjuna*, and *Neolamarckia cadamba* tree for nesting. During the post-breeding season, about 6 adults, 22 juveniles, and 13 nests were recorded. A maximum of five nests were recorded in one *Terminalia arjuna*. On the basis of findings, it has been shown that human activity (road construction) is the major threat to the loss of their habitat and population. Therefore, conservation of the Lesser Adjutant stork is necessary through conservation of nest, wetlands and the mature trees like *Bombax ceiba, Terminalia arjuna* etc. for the future.

Keywords: Canopy coverage area; Conservation; Diameter at Breast Height (DBH); Nesting Colonies; Vegetation; Wetlands.

1. Introduction

Nest building is a taxonomically widespread activity, with birds and other individuals all constructing nests of some description in which to lay eggs and/or raise offspring while Nest design varies considerably between the taxa (Hansell 2000; Heenan 2013). The height of nests from the ground influences nest predation rates (Martin 1993; Lima 2009). The Lesser Adjutant Stork (*Leptoptilos javanicus* Horsfield, 1821) is one of the largest wading birds in the stork family, but the smallest of the three species of storks in the genus *Leptoptilos* (De silva et al., 2015) which is also known as Hair Crested Adjutant. This bird comes under order Ciconiformes and family Ciconiidae. It is related to the Greater Adjutant Stork. The Lesser Adjutants are widely distributed in the Indian subcontinent (De Silva et al., 2015) mostly in Assam with c.2000 birds (Choudhury, 2000). The Lesser Adjutant is listed globally and nationally as vulnerable because it has a small declining population owing to habitat loss and degradation, hunting and disturbance (Inskipp et al. 2016; BirdLife International, 2017). It is endangered in several countries and threatened throughout India and Sri Lanka through Southeast Asia and Indonesia (Saikia and Saikia, 2011). The Lesser adjutants are generally solitary. In Assam, pair formation sometimes starts in July with the male selecting the nest site prior formation, apparently by carrying twigs to the chosen site (Saikia, 1995) and in North-east India, the main period of activity occurs in November to January (Saikia, 1995). The main aims of the research were to assess the present nesting status of Lesser Adjutant and lay out an outline management to make sure long-term survival in its natural habitat. The objectives of the present study are: to estimate the number of nests of Lesser Adjutant Stork in near the Kolong river; to study the habitat preferences and distribution of Lesser Adjutant Stork in near the Kolong river; to study the association of the different parameters of nesting trees with the number of nests of the Lesser Adjutant.; to study the threats of nest and Lesser Adjutant Stork.

2. Materials and methods

2.1. Study area

The study areas are located in the Nagaon District of central Assam which is near the Kolong river. The nesting trees are found in 4 areas are:
Dimoruguri (Latitude: 26.344205°, Longitude: 92.2179°),
Niz gumutha Gaon (Latitude: 26.353328°, Longitude: 92.76063°),
Narttum Gaon (Latitude: 26.353328°, Longitude: 92.760763°)
Kacharigaon (Latitude: 26.364852°, Longitude: 92.79382°).

The study areas comprise of agricultural field, wetlands, foraging ground along with human settlement. The rice is the main crops cultivated in the region. The area consisting of different trees and vegetation. All the nesting trees were found near the main road of Nagaon District of Assam and along the National highway. The study was carrying in summer (February to April) with hot temperature and minimum precipitation.

2.2. Research methods:

2.2.1. Pilot survey

Pilot survey was run before the main data collection which was done in the month of February 2023. It was performed by collecting the information about population status of Lesser Adjutant Stork and nesting habitat types, current threats and their conservation, types of nest and trees around it. Survey was done by ask questions to the local peoples living in the study area.

2.2.2. Direct count method for Nest Census

Nest search was conducted during post breeding season (February - April, 2023). The direct count method was used to count the nest and young present on the nest by direct observation and use binocular and camera for the photography of the nest. This method was suitable because of the large size of the birds. Nest were identified with the help of local people. Nests were categorized as active or apparently occupied if there was presence of young/chicks or at least one adult in the nest (Bibby et al., 2000).

2.2.3. Questionnaire survey

Questionnaire survey was done by asking question to the local residents. Respondents were selected randomly for the survey. Population status, distribution pattern, habitat, threats of Lesser Adjutant in the area were recorded based on questionnaire survey.

2.3.4. Data analysis

The data collected was categorized into tables which were used to determine the status, distribution and habitat preferences of Lesser Adjutant Stork. In this survey height and canopy of the tree and height of the nest were counted for determining the nesting habitat and tree. For measuring the height of the tree Pythagoras theorem were used where homemade clinometer were used for measuring the angle. The height of nesting trees was calculated using the formula, for level ground, (Height measurements, BC big tree):

$$\boldsymbol{H = D(tan\theta) + eye\ height}$$

Where, H= Height of the tree
D= Distance in meter from tree base to the vintage point
tan θ = Measured angle
or, for the moderately sloped ground, (Height measurement, BC big tree) (Mandal and Saikia, 2013):

$$\boldsymbol{H = D(\ tan\theta 1 + tan\theta 2\ )}$$

Where, H = Height of the tree
D = distance in meter from the tree base to the vintage point
tan θ = measured angle

When the crown diameter is being used as an intermediate variable for calculating area or cover, the plant's outline approximates an eclipse; the largest and smallest diameters have been measured to calculate the geometric mean by using the formula (Mandal and Saikia, 2013):

$$\bar{D} = \sqrt{D_1 D_2}$$

Where, $\bar{D}$ = mean diameter
D1 = largest diameter of the nest tree
D2 = smallest diameter of the nest tree

The diameter at breast height of the plant was calculated for individual tree using following formula (Mandal and Saikia, 2013):

$$D = \frac{C}{\pi}$$

Where, D = diameter of the plant to be calculated
C = circumference of the plant at breast height

Further also investigated the factors affecting nesting habitat selection of lesser adjutant such as the distance of other habitat parameters, nearest human settlements, nearest road. The nearest foraging grounds were short grassland, agricultural field, wetland, river, woodland.

2.3.5. Hypothesis

The following hypothesis were used for the nesting of Lesser Adjutant:

Null hypothesis (H_0): The number of the nest of Lesser Adjutant doesn't significantly associate with the parameters of the nesting tree.

Alternative hypothesis (H_i): The number of the nest of Lesser Adjutant Stork significantly associated with the parameters of the nesting trees.

2.3.6. Linear Regression

It was used to test whether the number of nest and the parameters of trees are associated with each other and estimating the strength association between the number of the nest and the parameters of the nesting trees. It was performed by setting the hypothesis of the number of the nest in the trees and their height, DBH, Canopy coverage area.

2.3.7. Autocorrelation

Using Durbin and Watson test (rule of thumb), variables were checked. No autocorrelation was detecting if the values lie near 2 (1.5 - 2.5) (Zach, 2021).

2.3.8. Software Use

For analysis of data MS Excel was used.

3. Results

3.1. Nesting habitat selection

Present study identified 13 active nests in 5 trees recorded in the four locations near the Kolong river (Table 1, Figure 1). Highest number of the nests were found in the *Terminalia arjuna* tree of Narttum Gaon which is taller in height, larger DBH and canopy area coverage (Table 2). The heights of nesting trees were more and matured in compare with non-nest trees which were near the nesting trees and they were randomly selected.

In the present study, three species of tree were found where lesser adjutant used mostly *Bombax ceiba* for nesting. In absence of *Bombax ceiba* (cotton tree) they used *Terminalia arjuna* (Arjun tree), and *Neolamarckia cadamba* (kadam tree).
This study recorded a total 6 adults and 22 juveniles of Lesser Adjutant Stork found in all the area in the post breeding season (Table 3). The relation between parameters of nesting tree species and number of nests was calculated by performing linear regression. The result showed that the number of nests of Lesser Adjutant were significantly and positively associated with the height (R^2=0.88, P=0.01), DBH, canopy coverage area (R^2= 0.77, P= 0.04) of the tree. According to thumb rule of Durbin-Watson test, this study showed that there was no autocorrelation because the value of DW (Durbin-Watson) lies between 1.5 to 2.5 (Table 4).

3.2. Factors affecting nesting of Lesser Adjutant Stork

There were higher number of foraging areas which are river, woodland, grassland, paddy field etc. in near the nesting tree (Figure 2). Human territory and roads around the nesting trees might affect the population of stork. The number of the nest were negatively associated with the distance to the nearest foraging area (paddy field) (R= -0.788).
In the questionnaire survey many participants were varied from adult people, college students and shopkeeper. It was showed that 26.66% of college students had knowledge about the Lesser Adjutant Stork and their nest (Figure 3).

4. Discussion

The present study showed a total 13 nest recorded from the three different species of 5 trees in the study areas (Figure 4 a-i). They chose these trees on the basis of different parameters like taller in height, high canopy area and DBH and which was mature and also on the basis of other factors like foraging areas which include the river, woodland, grassland etc. Larger bird species, mostly preferred to build nests in taller (Burger, 1979) and widely branched trees (Bhattarai et al., 2021). The Lesser adjutant built their nest large, with bulky structure platform with twigs or sticks of their selected nesting trees, and also preferred trees with sparse foliage cover (for example, *Bombax ceiba*) at the nest site to make easy access during arrival and departure, similar to that of Greater adjutant (Mandal and Saikia, 2013). Therefore, trees with horizontal branches or branches slightly inclined parallel to the ground were the most preferred tree for Lesser Adjutant Stork (Bhattarai et al., 2021). In the study, the number of nests in the tree significantly correlated with tree parameters such as height, DBH, canopy coverage area.

The study showed that the Lesser Adjutant Storks were also dependent on the Kolong river. So, water quality is also important for the species which are depending on the river for fishing. In the Kolong river various fishes like *Chitala chitala, Labeo calbasu, Wallago attu, Catla catla* etc. were found and also other invertebrates were found which are eaten by the Lesser Adjutants. The Lesser Adjutant Stork also depends on wooded grassland areas, agricultural field where invertebrates are present. This proves that they prefer such places for nesting where perfect combination of food, water and shelter occurs. They do not prefer hot and humid environment. Therefore, their nests were found near the aquatic bodies.

Several threats contribute to its losses, with their importance varying across its range. The loss of nest sites through the felling of colony nest -trees is a major threat, particularly in Assam - extensive nesting colonies protected areas in the 1990s recorded drastic declines owing to the cutting down of trees and drying up of some feeding sites (Choudhury, 2000). During questionnaire survey, it was known that probably 6 years ago in these area other nesting trees were also present but it was cut down for the road construction. At that time various organizations like Laokhowa Burhachapori Wildlife Conservation Society and concerned people

protested against cutting of the nesting trees. As a result, one of the trees were saved situated in the center of the National highway. So, it was highlighting that human activity is the major threats for Lesser Adjutant Storks to becoming vulnerable status. From the local peoples, it was also known that juveniles of the Lesser Adjutant Storks died in the previous years due to hailstones. For the future survival of the Lesser Adjutants Storks, strict actions are needed to be taken to ensure protection to the population and their nest. Many organizations with government should take initiatives in Assam include nest surveys, nest replanting scheme and conservation awareness campaigns.

5. Conclusion

It is critical to understanding of nesting ecology and conservation challenges for management of threatened bird species like Lesser Adjutants. Lesser adjutant stork generally preferred upper canopy of the taller tree for nest building. The nest was found in widely branched with thin foliage cover such as *Bombax ceiba*. In the absence of *Bombax ceiba* they built their nest with the same dimension tree like *Neolamarckia cadamba* and *Terminalia arjuna*. All trees were found in the near the Kolong river. This study shows that the number of the nest of Lesser Adjutant was positively correlated with tree height, diameter of breast height and canopy coverage area. There was total 13 nest, 6 adults, 22 juveniles in the post breeding season. Conservation of Lesser Adjutant Stork is necessary because of various threats like heavy rain, hailstone and other human activity like cutting trees for the road construction.
Based on the study, a few recommendations are made which should be implemented are: Cutting down of nesting trees must be prevented (Ex. Simal trees); Insecticide, pesticide and chemical fertilizers should not be used in the agriculture fields. Wetlands inside the study area should be conserved and may be avoided from drying.

Acknowledgements

Authors are thankful to the Department of Zoology, Nowgong College (Autonomous) for providing support and guidance to conduct the study and also thankful to the respondents of the study area for cooperating in sharing the information.

Authors contributions

All the authors equally contributed in conceiving the original idea, its execution, preparation of the manuscript and the statistical analysis involved.

Conflict of interest

The Authors have no conflict of interest.

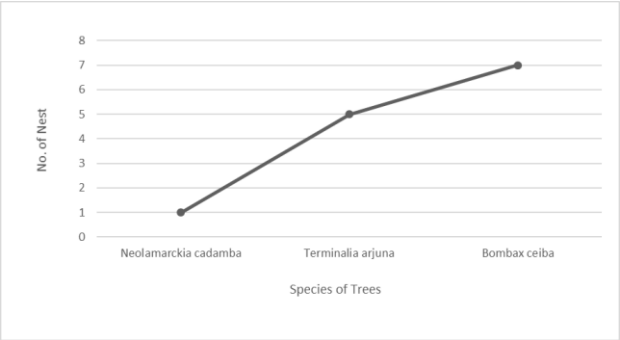

Figure 1. Number of nests in different species of trees.

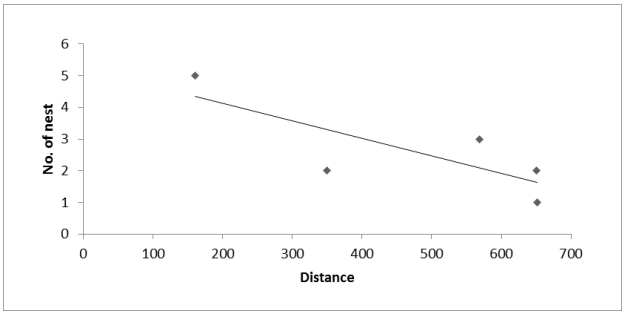

Figure 2. Linear regression between number of the nest of lesser adjutant and distance of nearest foraging areas (paddy field).

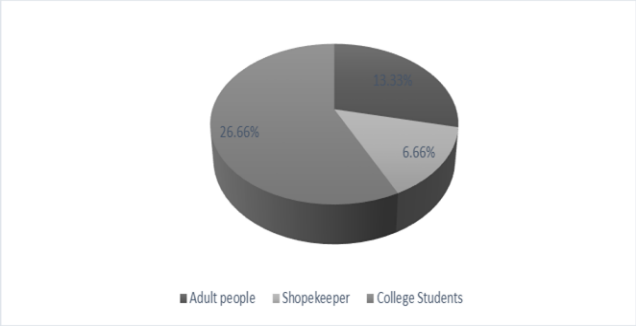

Figure 3. Participate people in questionnaire about the lesser adjutant.

Table 1. Number and character of nesting trees of Lesser adjutant in the study area.

Location	No of Trees	No. of nest	Height of Tree (meter) (Mean ±SD)	Height of Nest (meter) (Mean±SD)	DBH (cm) (Mean ±SD)	Canopy coverage area (Mean ±SD)
Dimoruguri	2	3	25.43 ± 3.91	23.89 ± 2.79	71.3 ± 12.86	44.35 ± 8.32
Niz gumutha gaon	1	3	26.34 *	25.10 ± 1.06	78.5 *	50.24 *
Narttum Gaon	1	5	30.08 *	26.34 ± 1.31	90.6 *	55.38 *
Kacharigaon	1	2	24.49 *	20.85 ± 2.55	82.2 *	45.34 *

(*single measurement, mean/SD are not applicable)

Table 2. Number of trees, nest and characters of different species of nesting trees.

Tree species	Number of trees	No of nest	Height of tree (Meter) (Mean ± SD)	Height of nest (Meter) (Mean ± SD)	DBH (cm) (Mean ± SD)	Canopy Coverage Area (Mean ± SD)
Bombax ceiba	3	7	26.34 ± 1.85	23.97 ± 2.51	78.36 ± 5.15	48.60 ± 2.82
Terminalia arjuna	1	5	30.08 *	26.34 ± 1.31	90.6 *	55.38 *
Neolamarckia cadamba	1	1	22.66 *	20.85 *	62.2 *	38.46 *

(*single measurement, mean/SD are not applicable)

Table 3. Stages of lesser adjutant in the nest of the study area.

Location	No. of Nest	Adults	Juvenile
Dimoruguri	3	2	8
Niz gumutha gaon	3	2	2
Narttum Gaon	5	1	10
Kacharigaon	2	1	2

Table 4. Linear regression showing effects of height, DBH, and canopy coverage area of nesting tree on number of nests in the study area.

Model parameters	Durbin Watson	Coefficient	R^2	t value	P-value
Height	2.18	0.48	0.882	4.75	< 0.05
DBH	1.57	0.12	0.822	3.72	<0.05
Canopy coverage area	1.94	0.20	0.778	3.24	< 0.05

Figure 4.a. Map of the study area**; b & c.** Lesser adjutant in their nest

Figure **4.d.** Lesser adjutant in their nest; **e.** Lesser adjutant's nests in Arjun tree, **f.** Foraging area of the nesting tree, **g.** Raising awareness for the conservation by local people; **h.** Measuring the parameters of trees during the study, **i.** Measuring the parameters of trees during the study.

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