Assessing the status and threat to urban nesting waterbirds in Gaya Ji city, Bihar

An internship report on

Assessing the status and threat to urban nesting waterbirds in Gaya Ji city, Bihar

July- September 2025

Bihar State Biodiversity Board

Supervised jointly under the mentorship of

Prof. (Dr.) Ram Pratap Singh

Professor & Head,

Department of Life Science

Central University of South Bihar, Gaya

Shri. S. Sudhakar*, IFS*

Chief Conservator of Forest, Gaya Circle

Department of Environment,

Forest & Climate Change, Bihar

Submitted By:

Divya Kumari, Ph.D. Scholar

Department of Life Science

Central University of South Bihar, Gaya, Bihar

Acknowledgement

I am thankful to the Bihar State Biodiversity Board for providing me with this opportunity. I would like to express my sincere gratitude to the Administrative Officers of the Bihar State Biodiversity Board, **Shri Bharat Jyoti** (Chairman), **Shri S. Chandrashekar** (Secretary), **Shri Hemkant Roy** (Joint Director) and **Shri Mihir Kr. Jha** (Deputy Director) for providing the opportunity to carry out this research work and for their financial support.

I would like to thank **Prof. Kameshwar Nath Singh**, Honourable Vice Chancellor, Central University of South Bihar (CUSB), for his moral support and guidance.

I am thankful to **Shri Sathiaseelan Sudhakar**, IFS, Conservator of Forest, Gaya, for his immense support and guidance. I am grateful to **Prof. Ram Pratap Singh**, Head, Department of Life Science, CUSB, for his constant support throughout this research work and for providing the required field equipment to carry out this research work.

I express my sincere thanks to **Shri Shashikant Kumar**, IFS, Divisional Forest Officer, Gaya Division, for his support.

Last but not least, I am thankful to my colleagues, **Mr Sk Imran, Miss Trisha Mondal and Mr Sampad Samrat Senapaty** for their constructive feedback and encouragement.

Table of Contents

This report focuses on five different waterbird species nesting in the urban area of Gaya Ji city, Bihar

Description of Studied Species

Asian Openbill (*Anastomus Oscitans):* A relatively small stork species with a grayish to white body and black wings and tail with a hint of gloss. The Asian Openbill gets its name from a distinctive gap in the dull greyish-yellow bill. Asian Openbills inhabit wetland habitats including shallow marshes, flooded agricultural fields, and lakes. Mostly perform local movements after breeding, depending on water conditions.

Eastern Cattle Egret (*Ardea coromanda*): A small, white heron with a relatively short yellow bill. More often seen in rice paddies and shallow wetlands. During the breeding season, the head and breast look bright orange, and the bill is brighter. Leg colour varies from reddish or yellow during the breeding season to black during the non-breeding season. They often gather in flocks, frequently following large animals.

Black-crowned Night Heron (*Nycticorax nycticorax*): Adults are overall pale greyish with a black cap and red eyes. Juveniles are noticeably different, brown and streaky with yellow eyes. They are often crouched under overhanging branches during the day and feed nocturnally for fish, frogs and other prey.

Black-headed Ibis (*Threskiornis melanocephalus*): A large wader with a white body and bare black head and neck. Males and females look similar, and both have grayish tail feathers. It probes into mud and shallow water with its long, down-curved black bill. Found primarily around wetlands including agricultural fields.

Little Cormorant (*Microcarbo niger*): An all-black duck-like waterbird with a distinctive flattish head and a bill that is sharply hooked at the tip. Breeding adults have white plumes on the sides of the head. Like all cormorants, frequently seen swimming with its body low in the water, head and neck pointing upward, and suddenly disappearing underwater to catch fish.

Introduction

Urban regions are altered and complex landscapes, within which green or open spaces are valued both for wildlife and human well-being (Angold et al. 2006). The relationship between humans and wildlife in urban areas is complex, since different taxa respond differently to the ecological consequences of urbanisation (Kurucz, 2021; McKinney, 2008). Birds, specifically waterbirds, serve as an effective indicator of ecological health (Green and Elmberg, 2014). They represent the avian clade that can persist in urban environments by adaptation (Callaghan et al. 2019). Colonial nesting waterbirds such as storks, egrets, herons, ibis and cormorants exhibit temporal and spatial clumping of nests during breeding season (Roshnath et al. 2013). A large number of these waterbirds occupy the urban environment. Some of them forage on wetlands outside urban environments but breed and roost in crowded towns, cities and near human settlements (Roshnath and Sinu 2017).

Breeding is a crucial phase of avian life cycle. For colonial nesting waterbirds, nesting site selection is influenced by factors such as predator avoidance, proximity to feeding grounds, human disturbance, climatic conditions, availability of nesting materials and quality of nesting trees. These factors play an important role in habitat selection by these waterbirds (Kushlan, 1993; Frank et al. 2021). While urban areas provide benefits to species in terms of nesting sites, they also pose a threat to the species. Urbanization which includes habitat heterogeneity, fragmentation and habitat loss, has an adverse effect on urban bird communities (Marzluff & Ewing 2001; Panda, 2020) and can lead to loss of urban nesting sites. Many Indian cities are becoming nesting and roosting habitats, especially for tree-nesting colonial waterbirds (Mehta et al. 2024; Pomeroy and Kibuule 2021; Kumari et al. 2025). Recently, a study on the nesting ecology of the Asian Openbill showed the importance of urban landscapes for waterbirds like Asian Openbill in Gaya, India. (Kumari et al. 2025).

In addition to the conservation benefits, these colonial nesting waterbirds provide important ecosystem services. Ecosystem services are generally divided into four categories i.e regulating, provisioning, supporting and cultural. Several of the services provided by waterbirds are supporting services such as propagule dispersal or nutrient cycling, which are processes essential to ecological communities, agricultural and fishery ecosystems. Some are regulating services such as pest control, or provisioning services, which apply to resources directly exploited for food, clothing or other uses. Finally, cultural services, which apply to the recreational value or spiritual value of birds (Green and Elmberg 2014). Waterbirds can also act as bioindicators of wetland condition, because their abundance, colony occupancy, and breeding activity reflect changes in hydrology, prey availability, contamination, and human disturbance (Kushlan, 1993). In addition to habitat constraints, diet and feeding ecology are equally important for understanding whether urban habitats function as a possible breeding ground for these waterbirds. Wetland birds move large distances between habitats, exploiting food resources. The ability to locate and exploit food resources over a large area is an important adaptation. This flexibility in exploiting resources may lead to success in urban environments, as these areas are characterised by novel food opportunities (Evans and Gawlik 2020).

As we know, the majority of future urbanisation is predicted to occur in small tropical cities, which highlights the need to document and emphasise aspects of such cities that favour waterbird nesting. In Bihar, cities such as Patna, Gaya ji, Bhagalpur, Jehanabad, etc., are the prominent sites for nesting of many waterbird species. In Gaya, many waterbird species are found nesting in the anthropogenically modified areas of the city, but a lack of systematic study represents a significant knowledge gap, signifying the importance of understanding the waterbird populations and the threats they face. Therefore, this study focuses on: 1) To estimate the breeding population of colonial nesting waterbirds in the city (Gaya Ji), 2) To map the nesting sites and nesting tree’s location of waterbird species in the city, 3) To identify possible threats to the breeding population of waterbirds, and 4) To identify the feeding requirements of waterbirds through visual observation.

Figure 1: Mixed nesting colony of waterbirds in Gaya city

Gaya District, geomorphologically, the area is divided into (i) Pediplain, (ii) Ridges and Valleys, (iii) Flood plain, and (iv) Terraced alluvial plain.

Topography: The most important among the low outlying hill ranges are the Ganjas, the Bhindas, and the Jethian ranges that arise from near Bodh-Gaya and extend in the north-east direction. Out of the isolated hills, the important ones are the Barabar hills, the Hasra, the Pathra and the Chirkihills, the Brahmajoni hills, and the peak of Maher hill, having an altitude of 490 m above msl. In the south-west portion of the division, the highest peak is Dhanras (453 m). In the south-eastern portion, the hills attain a greater height, viz. Tiktikwa (623 m), Singirikhi (564 m), and others (Gaya Forest Division, 2023).

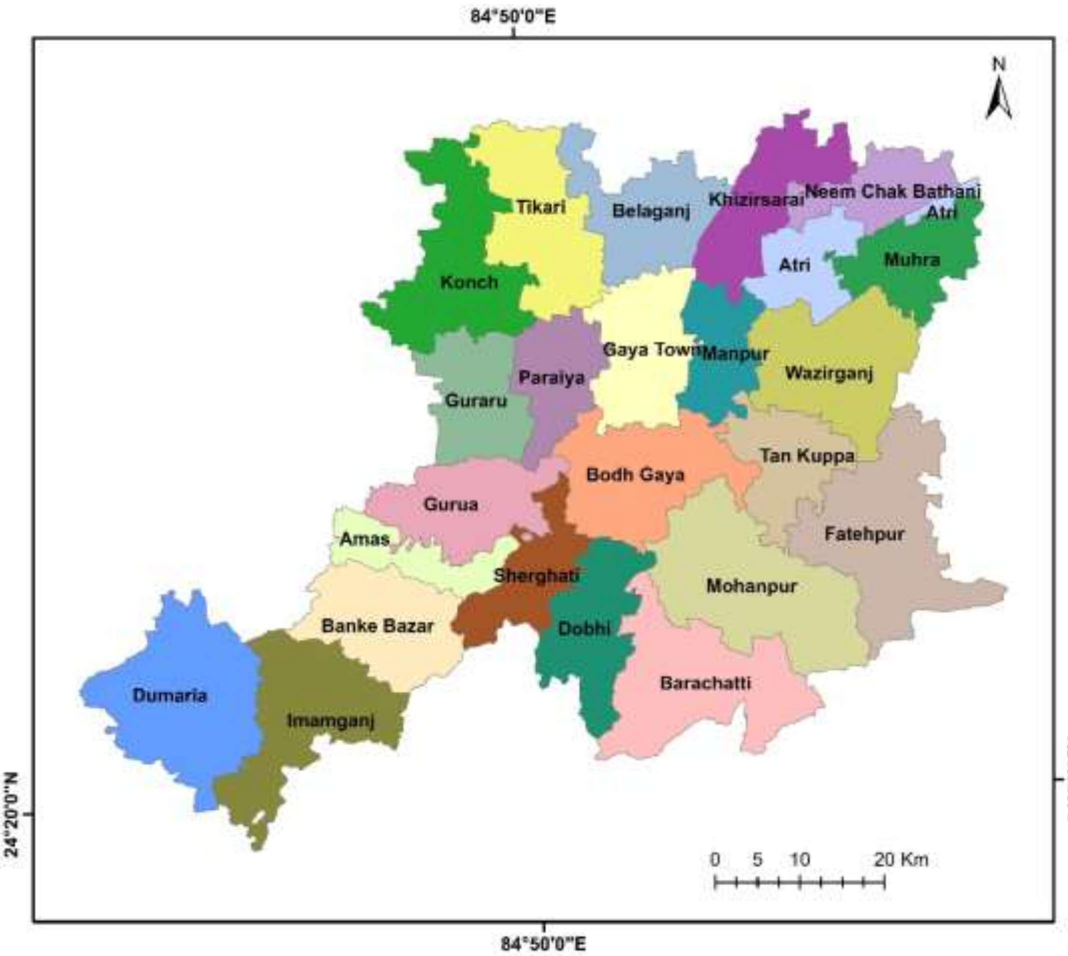


Figure 2: Map representing the Gaya district and its sub-districts

Altitude: The forests of the Division are located on the hills and undulating tract lying north of the hilly terrain. From there, a wide alluvial plain stretches away to the north, broken here and there by groups of low ranges of hills or isolated peaks springing abruptly from the level country. The altitude varies between 100 m and 700 m above the mean sea level.

Geology: The southern part of Gaya district constitutes mainly of Precambrian rocks, while the northern part is primarily covered by quaternary sediments. In the northern part of the district, most of the area is covered by the older flood plain which has a slightly higher surface than the younger flood plain, which is responsible for the splaying of the channels of Morhar and Phalgu rivers.

Rock: While the southern part of Gaya district consists mainly of Precambrian rocks, the hilly tract, as well as the inselberg in the south, are composed of Chhotanagpur Gneiss which is medium-grained and associated with small isolated patches of older rocks, viz. mica-schist, quartz mica-schist, and phyllite. The younger quartzites and mica-schists of Munger Group of Middle Proterozoic age are exposed in east of Gaya along northeast-southeast trending ridges. The Quaternary sediments overlying the Precambrian rocks are expressed as alluvial surfaces characterised by fluvial imprints like levees, channel bars, etc.

Soil: The soil varies from sandy to clayey loam, and at times to stiff clay depending on the underlying rock, topography, and degree of erosion. In the northern tract, the soil is loamy with a small proportion of sand and clay. In the southern tract, the proportion of sand is higher and the soil is sandy to sandy loam.

Climate: The tract has a continental monsoon type of climate owing to its great distance from the sea. There are three well-marked seasons in the year, namely summer, rainy, and winter. The summer season begins from the middle of March and lasts till mid-June. The peak of summer is in May. During November to May, mainly dry weather prevails with light winter rains in January.

Wind: Hot blasts of westerly winds (loo) prevail from March till mid-June generally from midday to a little before midnight. Dust storms are also common.

Rainfall: Usually, the rainy season begins in the third week of June and lasts up to September. The rainfall is at its highest occurs in July and August with an average maximum rainfall of 338.4 and 231.3 mm respectively. More than 90% of the total annual rainfall is received during the rainy season. The average annual rainfall of the district is 1105 mm.

Temperature: May is the warmest month. The temperature in May averages 34.1ºC. Sometimes the temperature can reach above 45ºC. The cold season starts in November and ends in the middle of March. In January, the average temperature is 17.7ºC, which is the lowest average temperature in the whole year (Gaya Forest Division, 2023).

Socio-economic conditions Gaya is one of the important pilgrimage places in the country and is becoming a fast international tourist centre. The total area of the district is 4,976 sq. km. It has a total population (2011 census) of 43,79,383 of which males and females are 22,66,865 and 21,12,518, respectively. The decadal change in the population is 26.08 percent. Its population density is 880 persons per sq. km. The average literacy rate of the Gaya district is 66.35 (Gaya Forest Division, 2023).

The Gaya district has significant forest cover (more than 15%) of the total geographical area (4,976 km^2). The area supports a variety of vegetation types, including deciduous forests, grasslands, and agricultural fields. The deciduous forests exhibit vertical stratification. The plantations mainly consist of timber-bearing species such as Sheesham (*Dalbergia sissoo*), Semal (*Bombax ceiba*), Gamhar (*Gmelina arborea*), and Teak (*Tectona grandis*) (Gaya Dips-2021-22).

Study Area:

The study was conducted in Gaya city, Bihar, India, which is located at a latitude of 24°47’48.696" N and a longitude of 85°0’13.86" E. It is located along the Phalgu River and is surrounded by small rocky hills (Mangla-Gauri, Shringa-Sthan, Ram-Shila, and Brahmayoni) on three sides, and the river flows on the fourth side (east). The Phalgu River, also known as the Falgu River, is formed by the amalgamation of two streams, namely, Lilajan and Mohana. As an ephemeral river, it flows only during the monsoon season, transforming into a vast expanse of dunes for the rest of the year.

The waterbird colony nests in an area of approximately 0.24 km² in the core of Gaya city. The locality features roads, government offices (including the District Collector's office, Commissioners' office, civil court, and revenue office), banks, residential buildings, towers, commercial establishments, and ponds. The Falgu River lies 0.596 km east of the nesting site (measured via Google Earth Pro). The nesting site is heavily disturbed by high traffic from vehicles and frequent pedestrian activity. The waterbirds prefer trees for nesting on these premises, highlighting the importance of this location for both people and wild birds. The waterbirds such as Asian Openbill (*Anastomus oscitans*), Black-crowned Night Heron (Nycticorax nycticorax), Eastern Cattle-Egret (Ardea coromanda), Black-headed Ibis (*Threskiornis melanocephalus*) and Little Cormorant (Microcarbo niger) are known to nest in the area (Kumari et al. 2025).

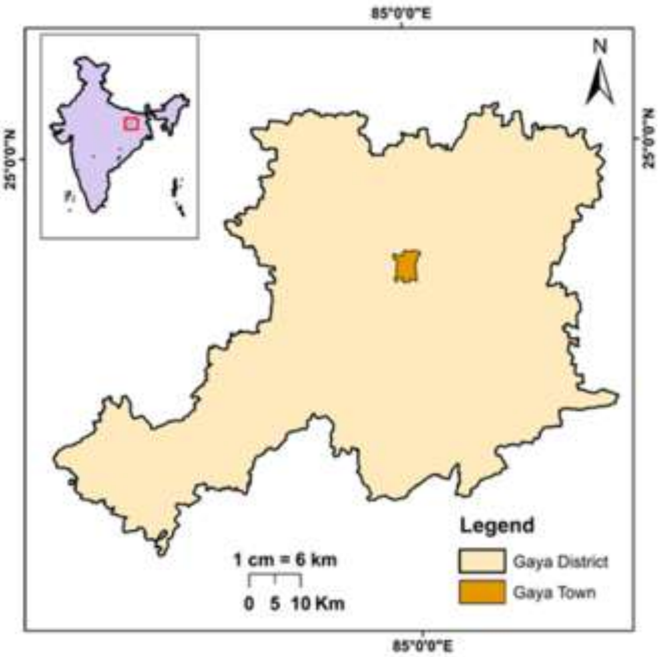


Figure 3: Map representing the study area

Objectives:

i. To estimate the breeding population of colonial nesting waterbirds in the Gaya Ji city.

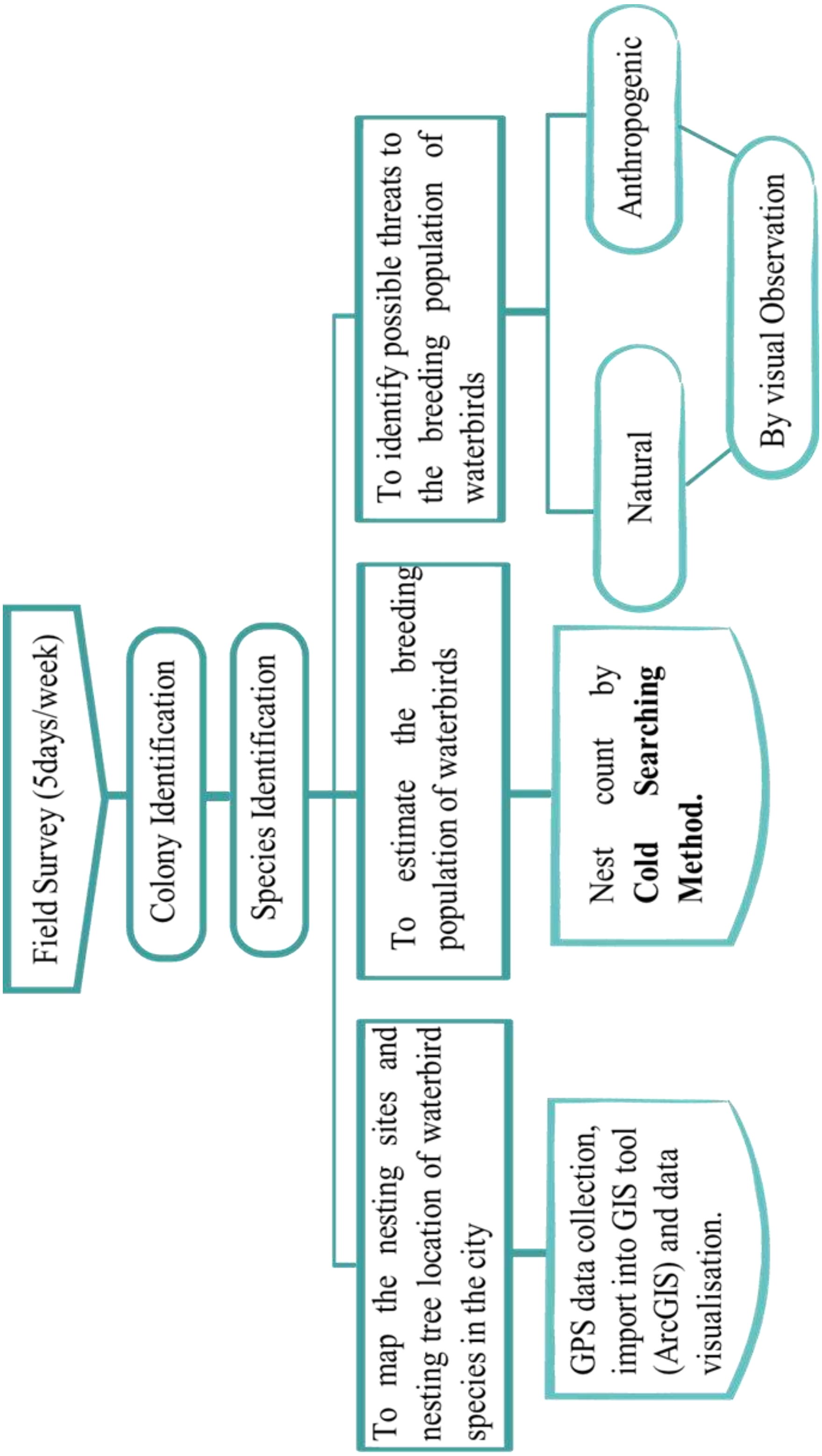
ii. To identify the nesting requirements of waterbirds nesting in Gaya Ji city.

iii. To identify possible threats to the breeding population of waterbirds in Gaya Ji city.

iv. To identify the feeding requirements of waterbirds through visual observation.

Methodology

A schematic representation of the methodology is given below:



Objective 1

To estimate the breeding population of colonial nesting waterbirds in the Gaya Ji city.

In this objective, we aim to estimate the breeding population size of nesting waterbirds in the city. To estimate the breeding population, a field survey was conducted using the **cold searching method** (Sutherland et al., 2004) in Gaya Ji (the second largest city of Bihar) during the nesting period between July to September in each month at the study location.

Methodology:

A pilot survey was conducted in the city following a simple random walk method. The survey was conducted in July, coinciding with the breeding season of the waterbirds. Further to the pilot survey, detailed field observations were carried out from July to September. The colony was checked for nest count once a month. Nesting bird species were identified using field guide (Grimmett et al. 2016) and the number of nests on each nesting tree was counted using the **cold searching method**, ensuring minimal disturbances to the nesting birds. The Observation was performed using binoculars (Celestron 8×40), and active nests were identified by the presence of adult birds, their eggs, or chicks (assuming that each active nest has a pair, a male and a female bird). Based on the highest number of nests counted at each site from July to September, the breeding population of the waterbirds was estimated (Figure 4).

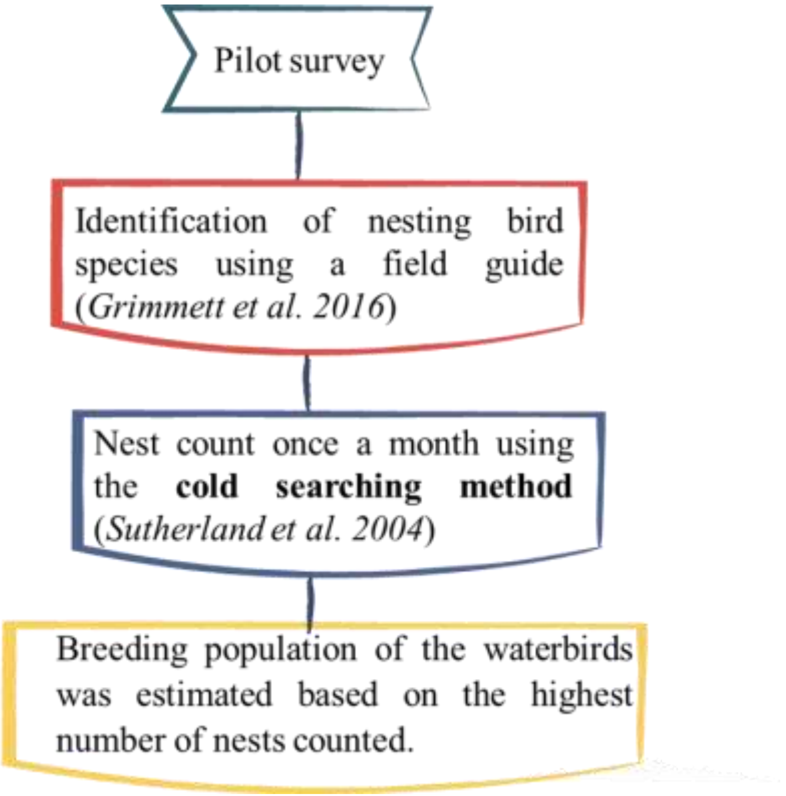


Figure 4: Flowchart depicting the step-wise method used to estimate the breeding population of colonial nesting waterbirds in the city.

Results

Breeding population of colonial nesting waterbirds in the city

The study focused on a detailed analysis of five waterbird species: Asian Openbill, Cattle Egret, Black-crowned Night Heron, Little Cormorant and Black-headed Ibis. The number of nesting individuals per species ranged from 30 (Black-headed Ibis) to 3786 (Asian Openbill). Of the total individual species (n = 5058), the highest abundance was observed for the Asian Openbill, accounting for 74.8 % of the total species population. Followed by 16 % of Cattle Egret, 7.7% of Black-crowned Night Heron, 0.7% of Little Cormorant and 0.6% of Black-headed Ibis. Nesting species represented 04 families. Species-wise data is presented in Table 1.

Serial no.	Species participating in the heronries	Family	Scientific name	No. of individuals
1	Asian Openbill	Ciconiidae	*Anastomus oscitans*	3786
2	Cattle Egret	Ardeidae	*Ardea coromanda*	814
3	Black-crowned Night Heron	Ardeidae	*Nycticorax nycticorax*	388
4	Little Cormorant	Phalacrocoracidae	*Microcarbo niger*	40
5	Black-headed Ibis	Threskiornithidae	*Threskiornis melanocephalus*	30

Table 1: Waterbird species participating in the heronries with scientific name and number of nesting individuals.

Figure 5: Asian Openbill with the chicks in the nest

Figure 6: Black-headed Ibis nests located on the Madras Thorn

Figure 7: Eastern Cattle Egret collecting twigs from the mango tree

Objective 2

To identify the nesting requirements of waterbirds nesting in the Gaya Ji city.

In this objective, we aim to investigate the nesting requirements of waterbirds inhabiting the urban environments of Gaya Ji city, Bihar. This study provided insights into specific habitat characteristics, including nesting tree species, height, girth at breast height (GBH) and canopy area that directs nesting preferences of these species. The results will aid in urban biodiversity conservation strategies for the nesting population of waterbirds.

Methodology:

To study habitat characteristics of the species, all possible nesting trees were identified using a field guide. Nesting location characteristics (tree species, height, canopy area, and girth at breast height) of the selected nesting trees were measured. To determine the canopy area, radii in four directions from the centre of the nesting tree were measured, and the average of these radii was taken. The area of the circle was then calculated to estimate the canopy area. For tree height measurement, a range finder (Diamondback HD 2000 Laser Rangefinder) was used, and the height was measured using the **Sine method** (Larjavaara & Muller-Landau, 2013). GBH was measured using a measuring tape, at 1.37 m above the ground, which is the standard height for measuring GBH (Figure 8). The locations (latitude and longitude) of all nesting trees were recorded using a handheld Global Positioning System (GPS, Garmin eTrex 22x). To assess whether nesting-tree characteristics (height, girth at breast height, and canopy area) and nest height differ among waterbird species. We first checked the normality of the data. Since the data was not normally distributed, we applied a non-parametric Kruskal-Wallis test, followed by Dunn's test for post-hoc pairwise comparisons, and visualised the data with violin plots

(Figure 10). We used Spearman's rank correlation to evaluate the relationship between the number of nests and tree characteristics (height, GBH and canopy area) of nesting trees.

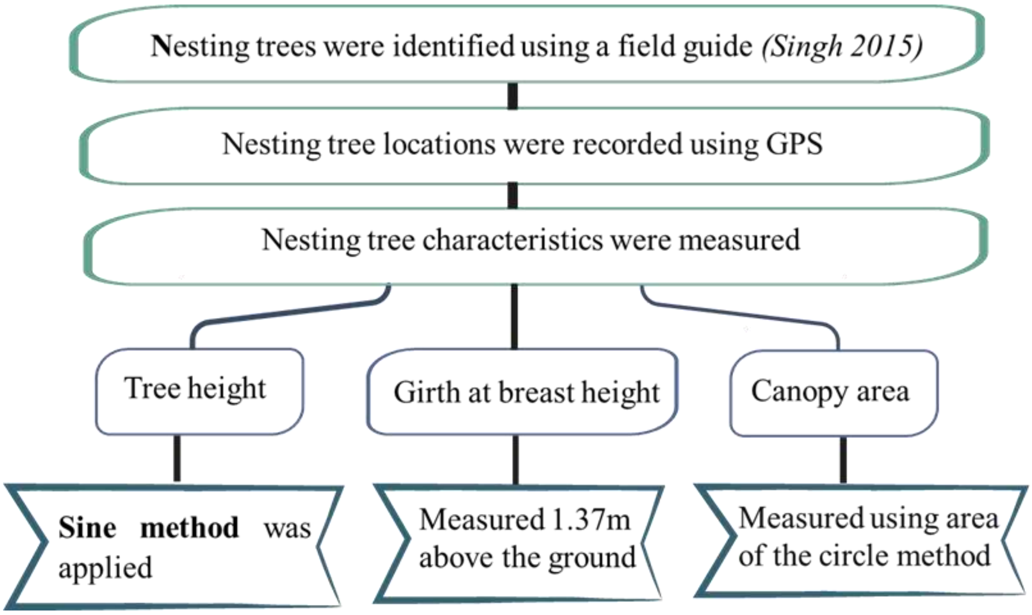


Figure 8: Flowchart depicting the step-wise method used to estimate the breeding population of colonial nesting waterbirds in the city.

Results

Tree species used by waterbirds

A total of 27 tree species were utilised as nesting trees by the five focal waterbird species within the study area (Table 2). Among these, Peepal (*Ficus religiosa*), Neem (*Azadirachta indica*), and Cluster fig (*Ficus racemosa*) were the most commonly used tree species, holding 22.5%, 14.3% and 8.5% of total observed nests (n = 2529), respectively. Other tree species supporting nests included Wood Apple (*Aegle marmelos*), Tamarind (*Tamarindus indica*), Kapok (*Ceiba pentandra*), Jamun (*Syzygium cumini*), Kadamb (*Neolamarckia cadamba*), Yellow Gulmohar (*Peltophorum pterocarpum*), Scholar tree (*Alstonia scholaris*), Gulmohar (*Delonix regia*), False Ashoka (*Polyalthia longifolia*), Mango (*Mangifera indica*), Banyan (*Ficus benghalensis*), Shisham (Dalbergia sissoo), Amaltas (*Cassia fistula*), Kasod (*Senna siamea*), Moringa (*Moringa oleifera*), White Champa (*Plumeria alba*), Madras Thorn (*Pithecellobium dulce*), Pakar (*Ficus virens*), Gamhar (*Gmelina arborea*), Arjuna (*Terminalia arjuna*), Indian Mahogany (*Swietenia mahagoni*) Rain tree (*Samanea saman*), Eucalyptus (*Eucalyptus camaldulensis*)and Sagwan (*Tectona grandis*) (Table 2;3;4;5). Nest distribution varied among bird species, with Asian Openbill nests predominantly abundant within the studied species.

Normality tests (Shapiro-Wilk) showed non-normal distributions for tree height ($p < 0.02$), GBH ($p < 0.0001$), and canopy area ($p < 0.0001$). A Kruskal-Wallis (non-parametric test) indicated a significant difference in tree height (**χ^2=29.6, df=4 and $p < 0.0001$**) and GBH (**χ^2=21.2, df=4 and p = 2.82588E-4**) but not with canopy area (**χ^2=7.05, df=4 and p = 0.133**) among 5 waterbird species. Post-hoc pairwise comparisons (Dunn's test) showed a statistically significant difference ($P \leq 0.05$) in tree height between AOB and CE, CE and NH, and CE and CO and in GBH between AOB and CE, CE and NH. This indicates that species CE selected nesting trees that were shorter than those used by species AOB, NH and CO, and with lower GBH than those used by species AOB and NH (Table 6). GBH and canopy area showed a moderate, statistically significant positive correlation (Spearman, $r = 0.38$, $p < 0.0001$) and (Spearman, $r = 0.30$, $p < 0.0001$), respectively, suggesting that trees with greater GBH and canopy area were more likely to have higher nest densities.

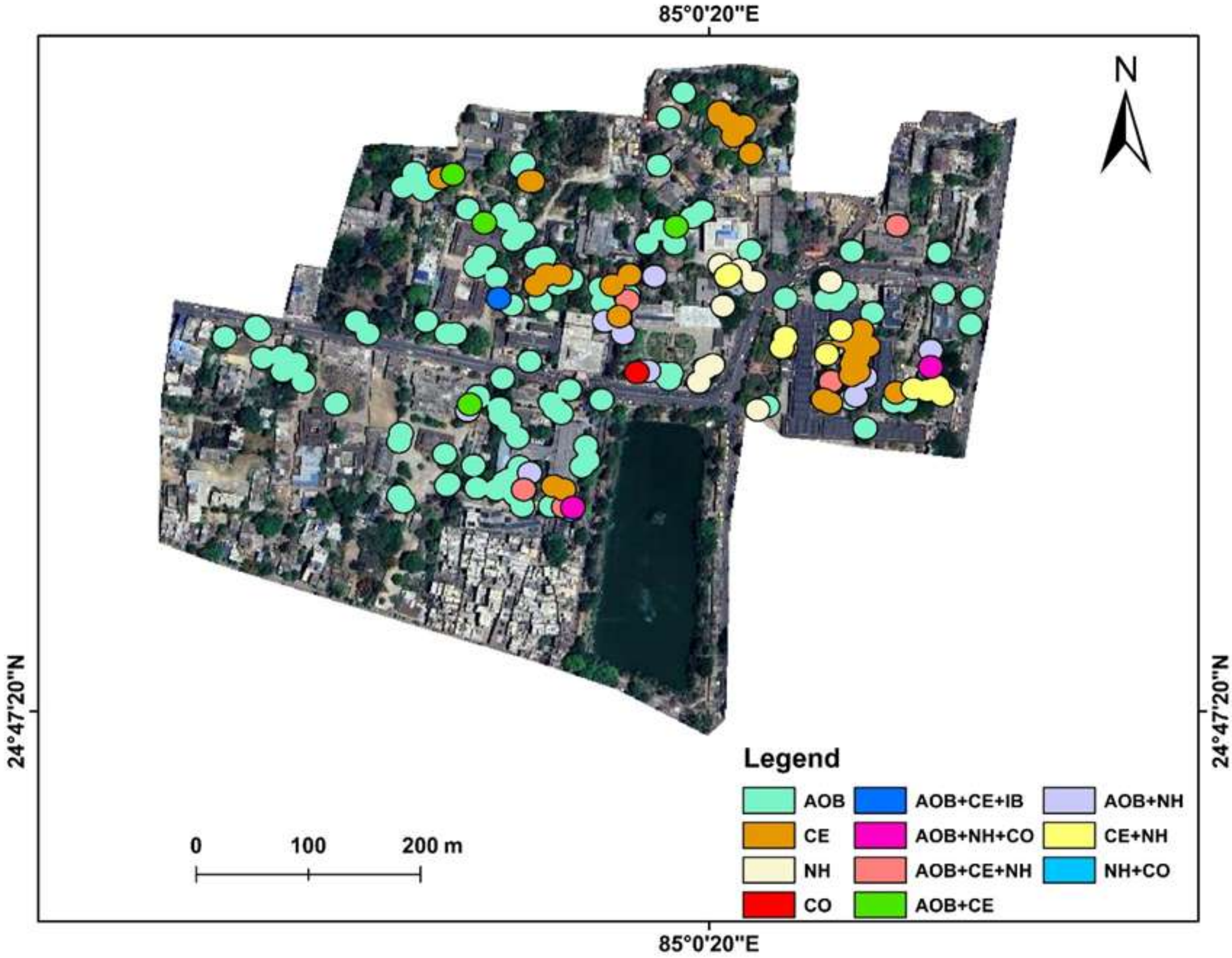


Figure 9: Spatial distribution of nesting tree species used by waterbird species in the study area, indicated by different colours.

Tree species	**Number of trees**	**Nest number**
Wood Apple *(Aegle marmelos)*	3	52
Tamarind *(Tamarindus indica)*	2	25
Kapok *(Ceiba pentandra)*	5	64
Jamun *(Syzygium cumini)*	4	33
Kadamb *(Neolamarckia cadamba)*	2	11
Yellow Gulmohar *(Peltophorum pterocarpum)*	13	143
Peepal *(Ficus religiosa)*	19	461
Scholar tree *(Alstonia scholaris)*	8	94
Gulmohar *(Delonix regia)*	8	104
False Ashoka *(Polyalthia longifolia)*	14	135
Mango *(Mangifera indica)*	14	157
Cluster fig *(Ficus racemosa)*	15	204
Banyan *(Ficus benghalensis)*	6	147
Neem *(Azadirachta indica)*	10	151
Shisham *(Dalbergia sissoo)*	5	44
Amaltas *(Cassia fistula)*	1	2
Kasod *(Senna siamea)*	1	9
Moringa *(Moringa oleifera)*	1	8
White Champa *(Plumeria alba)*	1	2
Madras Thorn *(Pithecellobium dulce)*	1	14
Pakar *(Ficus virens)*	1	19
Gamhar *(Gmelina arborea)*	1	5
Arjuna *(Terminalia arjuna)*	1	9

Table 2: Tree species used by Asian Openbill for nesting in Gaya city, Bihar

Tree species	Tree Number	Nest number
Neem *(Azadirachta indica)*	24	200
Yellow Gulmohar *(Peltophorum pterocarpum)*	6	45
Mango *(Mangifera indica)*	4	26
Jamun (Syzygium cumini)	3	16
Scholar tree (Alstonia scholaris)	3	13
Banyan *(Ficus benghalensis)*	2	25
Gulmohar *(Delonix regia)*	2	10
False Ashoka *(Polyalthia longifolia)*	2	5
Cluster fig *(Ficus racemosa)*	2	12
Wood Apple *(Aegle marmelos)*	2	10
Indian Mahogany *(Swietenia mahagoni)*	1	1
Shisham *(Dalbergia sissoo)*	1	6
Madras Thorn *(Pithecellobium dulce)*	1	30
Peepal *(Ficus religiosa)*	1	8

Table 3: Tree species used by Eastern Cattle Egret for nesting in Gaya city, Bihar

Tree species	Tree number	Nest number
Eucalyptus (Eucalyptus camaldulensis)	1	9
Rain tree *(Samaneasaman)*	2	20
Jamun (Syzygium cumini)	1	1
Gulmohar *(Delonix regia)*	1	9
Shisham *(Dalbergia sissoo)*	1	1
Neem *(Azadirachta indica)*	5	13
Banyan *(Ficus benghalensis)*	3	8
False Ashoka *(Polyalthia longifolia)*	4	7
Scholar tree (Alstonia scholaris)	3	11
Yellow Gulmohar *(Peltophorum pterocarpum)*	8	27
Peepal *(Ficus religiosa)*	8	88

Table 4: Tree species used by Black-crowned Night Heron for nesting in Gaya city, Bihar.

Bird species	Tree species	Tree number	Nest number
Little Cormorant	*Peepal (Ficus religiosa)*	2	14
Little Cormorant	*Yellow Gulmohar (Peltophorum pterocarpum)*	1	4
Little Cormorant	*Sagwan (Tectona grandis)*	1	2
Black-headed Ibis	*Madras Thorn (Pithecellobium dulce)*	1	15

Table 5: Tree species used by Little Cormorant and Black-headed Ibis for nesting in Gaya city, Bihar

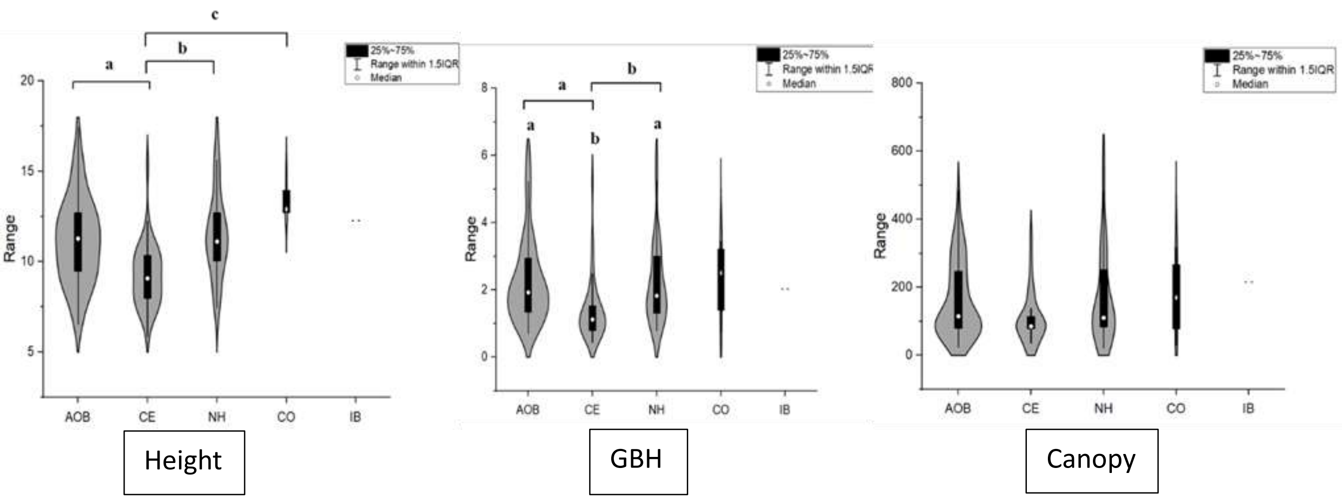


Figure 10: Tree height, girth at breast height (GBH), and canopy area of nesting trees used by five colonial waterbird species. Letters (a,b,c) showed the significant difference in tree architecture in nesting tree species.

Species	Height (m±sd)	GBH (m±sd)	Canopy (m±sd)
Asian Openbill	11.1 ± 2.4	2.2 ± 1.3	156.7 ± 111.6
Little Cormorant	13.3 ± 1	2.3 ± 1.2	172.1 ± 123.2
Eastern Cattle Egret	9.2 ± 1.8	1.4 ± 0.9	106.4 ± 75.4
Black-crowned Night Heron	11.5 ± 2.4	2.2 ± 1.3	164 ± 140.8
Black-headed Ibis	12.3	2.0	215.9

Table 6: Average tree height, girth at breast height (GBH), and canopy area of nesting trees.

Nesting Height, Of the five waterbird species counted in the study area, the species Asian Openbill, Eastern Cattle Egret, Black-crowned Night Heron, Little Cormorant, and Black-headed Ibis exhibited average nesting heights of 9.7, 7.5, 10.9, 12.7, and 8.2 metres, respectively (Table 7). Among the recorded species, the Little cormorant had the highest nest height, followed by the Black-crowned Night Heron, Asian Openbill, Black-headed Ibis and Eastern Cattle Egret (**Table 7**). Species vertical position relative to the tree's height:

Little Cormorant = Black-crowned night heron > Asian Openbill > Cattle Egret > Black-headed Ibis

The majority of species prefer the upper canopy of the tree rather than the lower branches. Black-headed Ibis was the lowest-nesting species relative to tree height, which might suggest competition pressures, as the Ibis nesting tree had mixed species nesting of Asian Openbill and Cattle Egret.

The Kruskal-Wallis test result showed a significant difference in nest height between species. Post-hoc pairwise comparisons (Dunn's test) showed a statistically significant difference (Sig = 1) in nest height between NH-CE, NH-IB, NH-AOB, CE-CO, CE-AOB, CO-IB, and CO-AOB. NH had significantly higher tree height than CE, IB and AOB. CO had significantly higher nest height than CE, AOB and IB. Overall, ***the Cattle egret chooses a lower nest height than the Asian Openbill, Black-crowned Night Heron and Little Cormorant***.

Species	Average Tree Height (m±sd)	Average Nest Height (m±sd)	Relative Nest Height
Asian Openbill	11.1 ± 2.4	9.7±2.03	0.87
Black- crowned Night Heron	11.5 ± 2.4	10.9±2	0.94
Eastern Cattle Egret	9.2 ± 1.8	7.5±1.6	0.82
Little Cormorant	13.3 ± 1	12.7±2.6	0.95
Black-headed ibis	12.3	8.2±0.2	0.67

Table 7: Average tree height in relation to average nest height used by nesting waterbird species

Objective 3

To identify possible threats to the breeding population of waterbirds in the Gaya Ji city.

In this study, we aimed to identify possible threats to the breeding population of waterbirds inhabiting the urban environments of Gaya Ji city, Bihar. This will aid in understanding both anthropogenic and natural threats to the nesting waterbirds within the study area, and will help in developing site-specific management and conservation plans. The current study documented potential threats to the waterbirds caused by anthropogenic activities.

Methodology:

To identify the possible threats field survey was conducted following a **random sampling method** (Sutherland et al. 2004), once a week from July to September (13 visits) in each nesting location of the birds. Prior to field observations, a standard datasheet was prepared listing all the potential threats to the nesting birds. During surveys across the study area, each identified nesting site was visited and assessed for the presence or absence of these threats. Threats were recorded on the datasheet, and photos were taken. Minimum disturbance to nesting birds was maintained for observation.

Results

Major threat to waterbirds in the urban city (Gaya)

1. **Tree cutting**

The present study documented **three** tree canopy cutting incidents which resulted in the loss of 38 active nests of bird species (28 nests of Asian Openbill, 6 nests of Cattle Egret and 4 nests of Black-crowned Night Heron). The majority of the nests include chicks and eggs (Figure 11).

Figure 11: Tree canopy pruning at a nesting tree at Civil Court, Gaya Ji, resulting in the loss of active nests of the nesting species.

2. **Collision with building walls**

Birds suffer internal haemorrhages, damage to eyes, skull or instant death. In this study, we found **three** cases of collision with buildings (Figure 12).

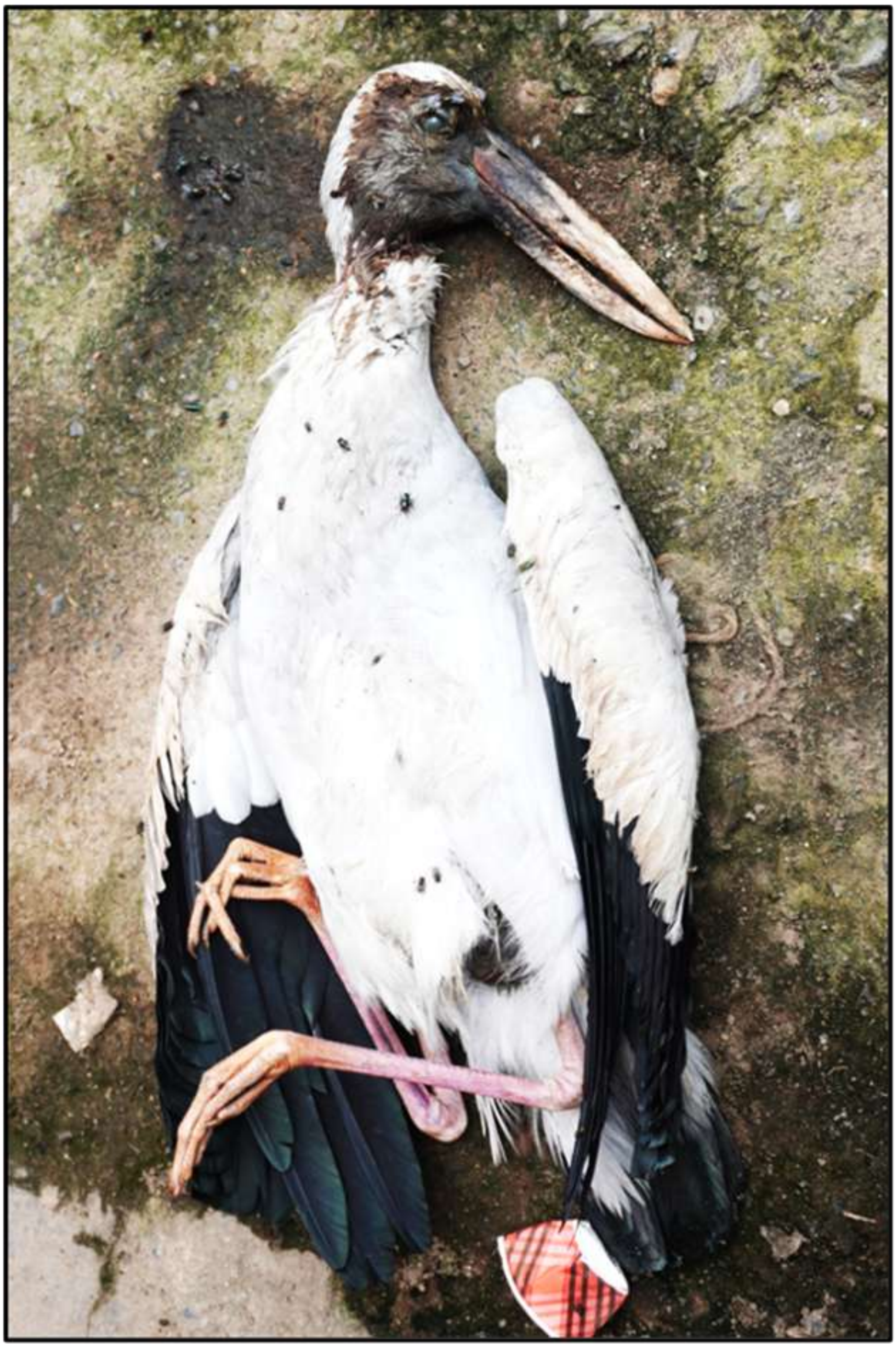


Figure 12: Bird mortality resulting from collision with a building wall at Civil Court, Gaya Ji, Bihar.

3. **Construction near nesting sites**

Construction activity was observed near nesting sites in areas surrounding Jila Parishad, the collectorate building, and Prabhavati Hospital (Figure 13).

Figure 13: Construction near nesting site at Prabhavati Hospital, Gaya

4. **Entanglement with mesh thread**

Birds often become entangled in mesh threads; as a result, these birds remain suspended from trees, sometimes unnoticed until they are either rescued by people or succumb to their injuries and die. In this study period, we found **seven cases** of entanglement with mesh thread (Figure 14).

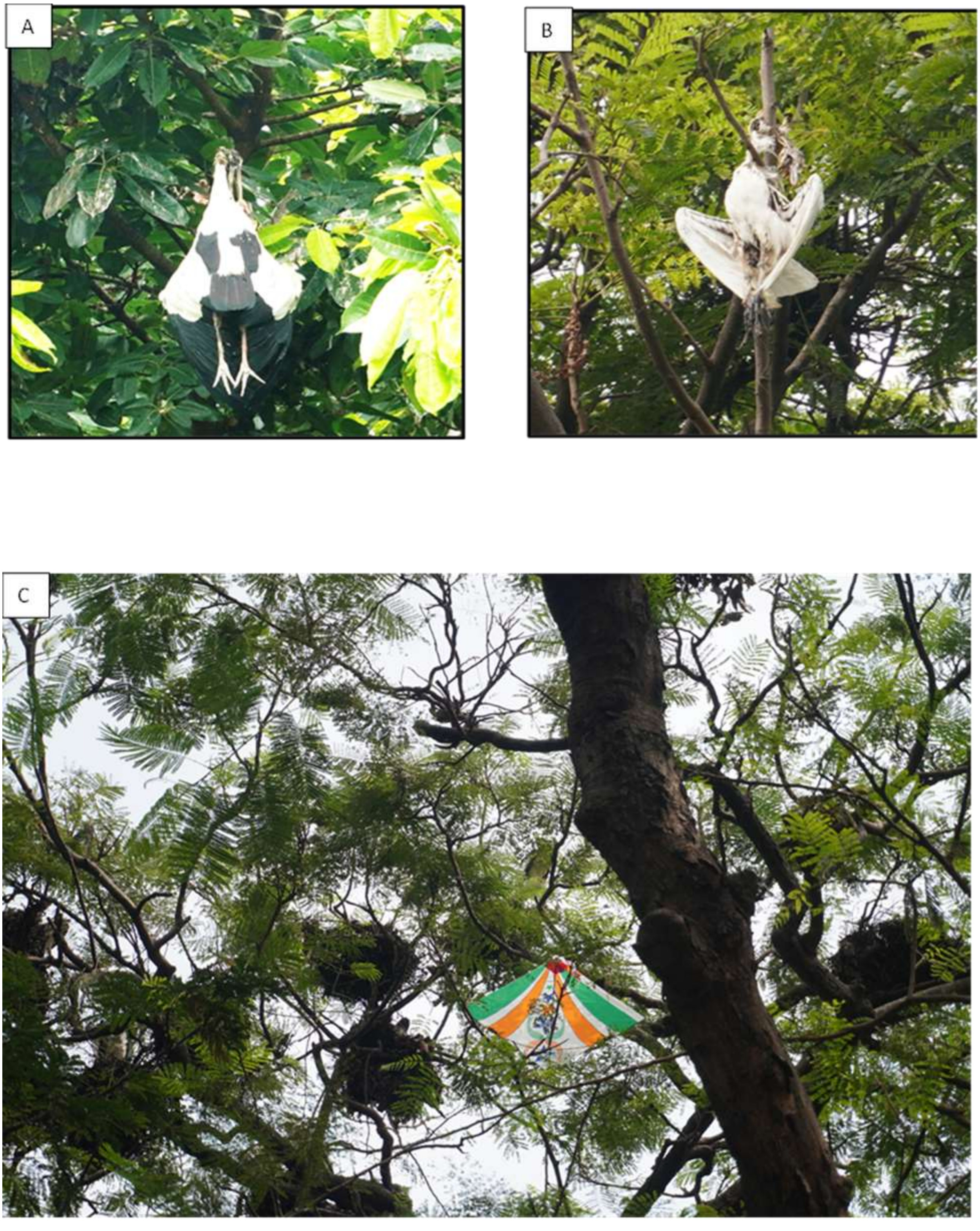


Figure 14: (A, B) Entanglement of a bird in synthetic mesh thread on a nesting tree; (C) kite along with the thread near the nests, indicating potential anthropogenic threat.

5. **Regurgitated food samples of waterbirds contain rubber bands**

Of the **65 regurgitated pellets** collected from the study area, **11**(n=13) contained rubber bands with different colours (pink, red, yellow and green) (Figure 15). These constitute 17% of the total collected sample. The frequency of the coloured band was pink (30.7%), yellow (46.1%), green (7.6%) and red (15.8%).

Figure 15: Regurgitated food sample of Cattle Egret and Black crowned night heron with rubber bands

6. **Natural threats**

We also recorded some natural threats, which include storms and heavy rain that remove nests, causing chick mortality. Predators like street dog crows, black kites, and shikra were observed near the nesting trees (Figure 16).

Figure 16: Regurgitated food sample of Cattle Egret and Black-crowned Night Heron with rubber bands

Objective 4

To identify the feeding requirements of waterbirds through visual observation

Understanding the feeding requirements of waterbird populations through visual observation is essential, as it provides direct information on prey selection, foraging behaviour, and habitat use for foraging by these species during the breeding season.

Methods

The feeding needs of birds were assessed through direct field observations. To investigate the diet fed to chicks by these waterbirds **Photo-sampling method** was used, which offers a non-invasive tool to accurately and efficiently investigate the diet composition (Gaglio et 2017). Observations were conducted during morning hours (6:30 am to 9:30 am) in the months of August and September. The identification of the feeding samples was based on visual observation.

Results

In terms of diet composition, five prey groups, namely fish, molluscs, frogs, crabs, and insects, were observed as the main diet for waterbirds. Based on the observation, the Insecta class was the most abundant, which accounts for a total of 50% of the total regurgitated sample, followed by Osteichthyes (17%), Malacostraca (11%), amphibians (9%), Gastropods (4%), other 9% are constituted by Reptilia, Clitellate and Arachnida. Fishes were also determined to be an important diet for waterbirds, such as black-crowned night heron and cormorants. Meanwhile, worms and insects were mainly consumed by the Cattle egret (Figure 17). Crabs and molluscs were observed in the diet of the Asian Openbill.

Figure 17: Regurgitated food sample of waterbirds observed under the nesting trees

4. Discussion

4.1 Breeding population

This study provided a comprehensive assessment of waterbird diversity across Gaya city, Bihar, highlighting the importance of these birds in supporting rich biodiversity in the city. The study specifically recorded the breeding of five waterbird species, namely the Asian Openbill, Eastern Cattle Egret, Black-crowned Night Heron, Little Cormorant, and Black-headed Ibis. A total of 2529 nests were found on 189 trees of 27 species in a human-dominated landscape of area 0.24 km^2. Similar to this, a study of heronry birds in the urban environment of the North Kerala region of peninsular India found 174 trees of 22 species hosted 1,928 heronry bird nests in the urban habitats, and the maximum number of nests and nesting trees were encountered on the roads of urban areas (Roshnath and Sinu 2017).

4.2 Nesting tree selection

These waterbirds utilise a diverse range of native and exotic tree species for nesting. Several old and tall trees favoured for nesting activities were of *Ficus* species, including *Ficus religiosa*, *Ficus benghalensis*, *Ficus virens* and *Ficus racemosa*, which accounted for 15% of the total nesting tree species. Ficus tree species were maintained across the city despite their large size due to religious beliefs. Such religious beliefs have also been observed to benefit waterbird populations in other parts of South Asia as well (Koju et al. 2020; Mehta et al., 2023). The Asian Openbill was the most abundant species in the study area, nesting in 23 tree species, which made up 74.8 % of the nests of the studied species, followed by Eastern Cattle Egret, Black-crowned Night Heron, Little Cormorant and Black-headed Ibis. The peepal tree, with its spread-out canopy, was the most preferred nesting tree for all species, as the maximum number of nests of the species were found on the Peepal tree (*Ficus religiosa*), except for the Eastern Cattle Egret, which had a maximum percentage of nests (50%) on the neem tree (*Azadirachta indica*). These waterbird species occupy nests at different average heights ranging from 7.5 to 12.7 metres.

4.3 Identified Threats

This study also observed threats that were common to habitat and breeding waterbirds, such as tree canopy cutting, construction around nesting sites, death due to entanglement, etc. Some of the threats, including proximity to human settlements and urban expansion, were also mentioned by Roshnath and Sashikumar (2019) in their studies on conservation challenges of the heronries in Kerala. Entanglement by mesh thread was also observed in species such as the Black kite, Crow, Rose-ringed Parakeet, Rock Pigeon, Barn Owl, Asian Koel and White-throated Kingfisher (Babu et al. 2015).

4.4 Dietary Observations

The dietary data obtained through visual observations of feeding behaviour provided important insights into the food selection and trophic interaction of the breeding population (Fauzi N A et al. 2024). Often, noninvasively found dietary samples such as regurgitated pellets, faeces, and regurgitated fish samples are the preferred source of information (Oehm et al. 2017). The specific prey consumed by the observed population may reflect both availability in the local environment and species-specific foraging adaptations. In the present study, 50% of the sample were from the class Insecta, followed by Osteichthyes (17%) (Figure 18) Previous studies reported that small frogs were the most common vertebrates found in the regurgitated pellets of Cattle egret, and the most common food in their diet was grasshoppers (Hanebrink & Denton, 1969). The observed population consumes pest insects like grasshoppers and snails that affect plant health and agricultural productivity, that showed the ecosystem services provided by these waterbird species.

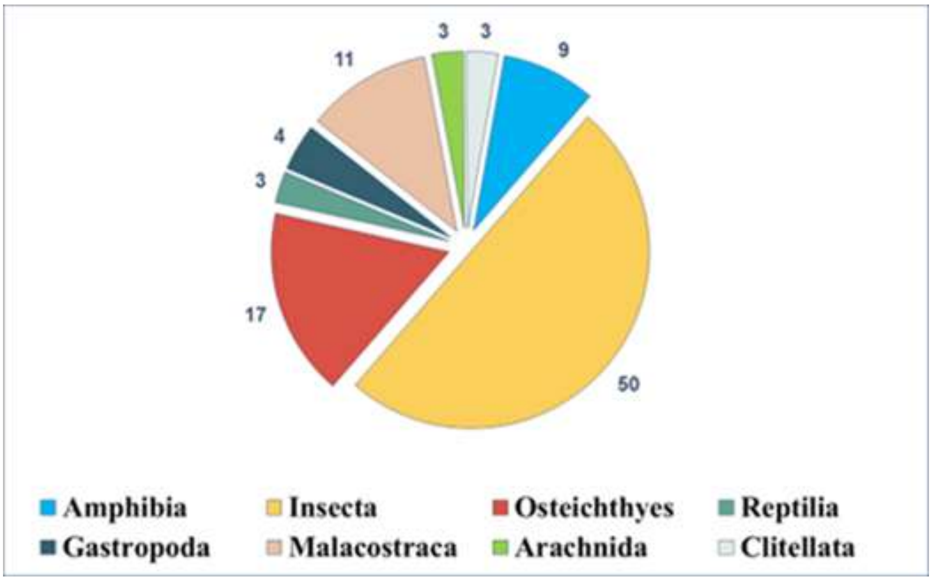


Figure 18: Percentage of different food sample collected under nesting trees

In India, one of the most important factors influencing the food cycles of birds is the monsoon (Urfi, 2011). Many bird species time their breeding to coincide with peak food abundance, ensuring that energetic demands during chick-rearing are met by high prey availability. In the case of the Asian Openbill, which survives on a diet of Apple Snails (genus Pila). These storks arrive in an area at the commencement of rains, and this period coincides with the re-emergence of snails from dry season torpor (Hancock et al. 1992). These findings highlight that spatial variation in food resources can impact both nest site selection and breeding success, highlighting the importance of sustaining productive foraging habitats within and around nesting areas.

Suggested Action Plan/ Recommendations

1. **Protection of Habitat**

- To protect old native trees, especially Banyan, Peepal, Mango, and other large Ficus species, which provide a large canopy area for nesting of these waterbirds.
- Avoid felling or heavy pruning of trees during the breeding season (July–September).
- Plant native tree species in government areas, along roads, and around fields near government offices to provide nesting habitats for these species.

2. **Urban Planning**

- Developmental city plans should encourage a bird-friendly construction layout so that they can include some green spaces to promote urban coexistence of these waterbirds without disturbances.
- Protection of adjacent wetlands and foraging grounds near urban and peri-urban areas near the city.

3. **Systematic monitoring**

- Seasonal monitoring of nesting sites is needed.
- This will help understand the population dynamics of nesting waterbirds, as continued urbanisation, infrastructure expansion, and climate change pose a substantial threat to the long-term viability of such colonies.
- Study nest site fidelity of these birds in urban areas.

4. **Increasing public awareness to reduce bird-human conflict**

- Responsible disposal of rubber bands and Manjha (kite thread).

5. **Urban Heronry – a potential waterbird nesting heritage site**

   In the Gaya district within Gaya town block, the area covering 0.24 km^2 needs to be protected as a 'waterbird nesting heritage site' due to its significance for bird nesting and related ecosystem aspects, considering the following ecological factors:

- The portion of this area includes the habitat of several local migratory birds such as the Asian Openbill, Black-necked Ibis and Eastern cattle egret. In addition to these species, numerous other birds, like Black-crowned Night Heron, Intermediate Egret, Little Egret, and Little Cormorant, were observed nesting in this area in substantial numbers during the monsoon season.
- This nesting site is located within a government area in an urban landscape and has been considered a traditional nesting site for these waterbirds for many years.
- The area is not designated as a protected area under the Wildlife Protection Act of 1972. Therefore, its conservation is recommended under the category of Other Effective Area-based Conservation Measures (OECM), as designated internationally for biodiversity conservation.
- The site also features a pond, "**Digghi Talab**", in which several waterbird species can be seen roosting during the breeding season.
- The area is rich in native, old tree species, such as peepal and banyan, which provide an appropriate nesting site for these species and act as microhabitats within an urban area.

References

Angold, P., Sadler, J., Hill, M., Pullin, A., Rushton, S., Austin, K., Small, E., Wood, B., Wadsworth, R., Sanderson, R., & Thompson, K. (2005). Biodiversity in urban habitat patches. The Science of the Total Environment, 360(1–3), 196–204. https://doi.org/10.1016/j.scitotenv.2005.08.035

Babu, S., Subramanya, S., & Dilawar, M., 2015. Kite flying: Effect of Chinese manja on birds in Bangalore, India. Indian BIRDS 10 (1): 13–18.

Callaghan, C.T., Major R. E., Wilshire, J. H., Martin, J. M., Kingsford, R. T., Cornwell,W. K. (2019) Generalists are the most urban-tolerant of birds: a phylogenetically controlled analysis of ecological and life history traits using a novel continuous measure of bird responses to urbanization. Oikos 128: 845–858.

eBird. (2026). eBird: An online database of bird distribution and abundance. Cornell Lab of Ornithology. https://ebird.org

Evans, B. A., & Gawlik, D. E. (2020). Urban food subsidies reduce natural food limitations and reproductive costs for a wetland bird. Scientific Reports, 10(1), 14021. https://doi.org/10.1038/s41598-020-70934-x

Fauzi, N. A., Munian, K., Mahyudin, N. a. A., & Norazlimi, N. A. (2025). Ecological insights on the feeding behaviour of waterbirds in an Important Bird and Biodiversity Area of South West Johor Coast, Malaysia. Biodiversity Data Journal, 13, e141250. https://doi.org/10.3897/bdj.13.e141250

Frank, S. J. D., Gopi, G. V., & Pandav, B. (2021). Heronry distribution and site preference dynamics of tree-nesting colonial waterbirds in Tamil Nadu. PeerJ, 9, e12256. https://doi.org/10.7717/peerj.12256

Gaglio, D., Cook, T. R., Connan, M., Ryan, P. G., & Sherley, R. B. (2016). Dietary studies in birds: testing a non-invasive method using digital photography in seabirds. Methods in Ecology and Evolution, 8(2), 214–222. https://doi.org/10.1111/2041-210x.12643

Gaya Dips-2021-22. District Industrial Potential Survey with District Development Plan Gaya 2021-2022. Patna; 2021. Available from: https://www.scribd.com/document/806988521/Gaya-Dips-2021-22

Gaya Forest Division. (2023). Preliminary working plan report of Gaya Forest Division under Gaya Forest Circle, Bihar (Period: 2023-2024 to 2032-2033). Bihar Forest Department.

Green, Andy & Elmberg, Johan. (2014). Ecosystem Services Provided by Waterbirds. Biological reviews of the Cambridge Philosophical Society. 89. 105-122. 10.1111/brv.12045.

Grimmett, R., Inskipp, C., & Inskipp, T. (2016). Field Guide to Birds of the Indian Subcontinent: India, Pakistan, Sri Lanka, Nepal, Bhutan, Bangladesh and the Maldives. Bloomsbury Publishing.

Hancock, J., Kushlan, J. A., & Kahl, M. P. (1992). Storks, ibises and spoonbills of the world. A&C Black.

Hanebrink, E. L., & Denton, G. (1969). Feeding Behavior and Analysis of Regurgitated Food Collected from the Cattle Egret Bubulcus ibis and the Little Blue Heron Florida caerulea. ScholarWorks - UARK (University of Arkansas at Fayetteville), 23(1), 74–79. https://scholarworks.uark.edu/jaas/vol23/iss1/13

Koju R, Mahajan B, Gosai KR et al (2020) Ciconiiformes nesting on trees in cereal-dominated farmlands: importance of scattered trees for heronries in lowland Nepal. Waterbirds 42:355–365.

Kumari, D., Mondal, T., Imran, S. et al. (2025). Nesting ecology of the Asian Openbill (Anastomus oscitans) in an urban landscape: a case study from Gaya, India. Discov Sustain 6, 1210. https://doi.org/10.1007/s43621-025-02118-4

Kurucz, K., Purger, J. J., & Batáry, P. (2021). Urbanization shapes bird communities and nest survival, but not their food quantity. Global Ecology and Conservation, 26, e01475. https://doi.org/10.1016/j.gecco.2021.e01475

Kushlan, J. A. (1993). Colonial waterbirds as bioindicators of environmental change. Colonial Waterbirds, 16(2), 223–251.

Larjavaara, M., & Muller-Landau, H. C. (2013). Measuring tree height: a quantitative comparison of two common field methods in a moist tropical forest. Methods in Ecology and Evolution, 4(9), 793–801. https://doi.org/10.1111/2041-210x.12071

Marzluff, J. M., & Ewing, K. (2001). Restoration of Fragmented Landscapes for the Conservation of birds: A General Framework and Specific Recommendations for Urbanizing Landscapes. Restoration Ecology, 9(3), 280–292. https://doi.org/10.1046/j.1526-100x.2001.009003280.x

McKinney, M. L. (2002). Urbanization, biodiversity, and Conservation. BioScience, 52(10), 883. https://doi.org/10.1641/0006-3568(2002)052

Mehta, K., Koli, V. K., Kittur, S., & Sundar, K. S. G. (2024). Can you nest where you roost? Waterbirds use different sites but similar cues to locate roosting and breeding sites in a small Indian city. Urban Ecosystems, 27(4), 1279–1290. https://doi.org/10.1007/s11252-023-01454-5

Oehm, J., Thalinger, B., Eisenkölbl, S., & Traugott, M. (2017). Diet analysis in piscivorous birds: What can the addition of molecular tools offer? Ecology and Evolution, 7(6), 1984–1995. https://doi.org/10.1002/ece3.2790

Panda, B. P., Mahapatra, B., & Sahoo, A. A., & Ray, S. S., & Parida, S. P. & Pradhan, A. (2020). Habitat Use of Urban and Periurban Birds in a densely populated City of Eastern India.Asian Journal of Conservation Biology, 9. 290-297.

Pomeroy, D & Kibuule, M. (2021). The rise and fall of the Marabou Stork in Uganda. SIS Conservation, 3, 3-6.

R, Roshnath & Shashikumar, C. (2019). Conservation Challenges of the Heronries in Kerala. Journal of the Bombay Natural History Society. 116. 63-67. https://doi.org/10.17087/jbnhs/2019/v116/131385

Roshnath R, Sinu PA. Nesting tree characteristics of heronry birds of urban ecosystems in peninsular India: implications for habitat management. Curr Zool. 2017 Dec;63(6):599-605. https://doi.org/10.1093/cz/zox006

Sundar, K. G., & Kittur, S. (2013). Can wetlands maintained for human use also help conserve biodiversity? Landscape-scale patterns of bird use of wetlands in an agricultural landscape in north India. Biological Conservation, 168, 49–56. https://doi.org/10.1016/j.biocon.2013.09.016

Sutherland, W. J., & Newton, I. (2004). Bird Ecology and Conservation: A Handbook of Techniques. Oxford University Press.

Urfi, A.J. (2011). Food and Foraging. In: The Painted Stork. Springer, New York, NY. https://doi.org/10.1007/978-1-4419-8468-5_6