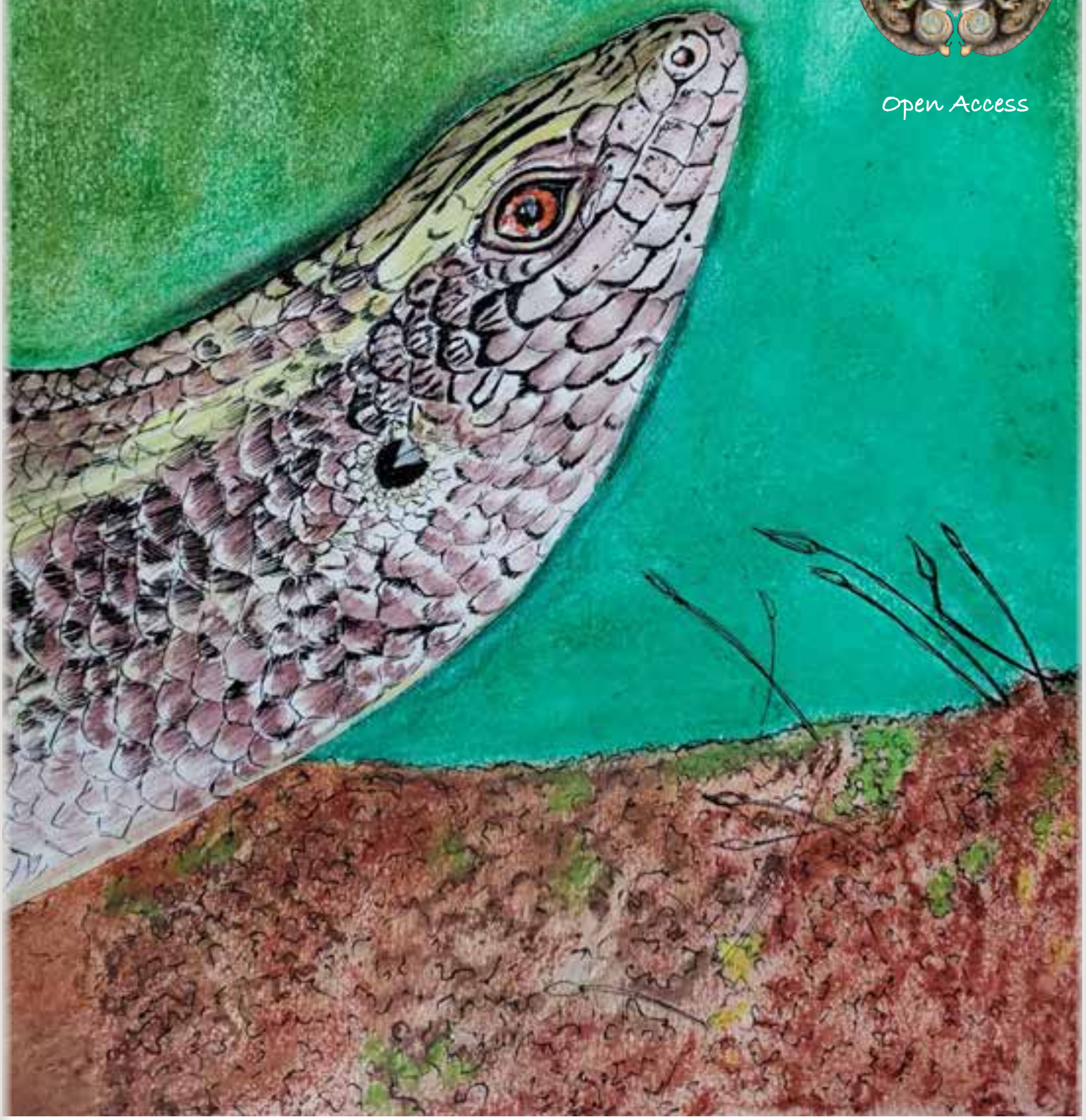
Building evidence for conservation globally

Journal of Threatened Taxa

10.11609/jott.2024.16.2. 24615-24818
www.threatenedtaxa.org

26 Februaru 2024 (Online & Print)
16(2): 24615-24818
ISSN 0974-7907 (Online)
ISSN 0974-7893 (Print)

Open Access



ISSN 0974-7907 (Online); ISSN 0974-7893 (Print)

Publisher
Wildlife Information Liaison Development Society
www.wild.zooreach.org

Host
Zoo Outreach Organization
www.zooreach.org

43/2 Varadarajulu Nagar, 5th Street West, Ganapathy, Coimbatore, Tamil Nadu 641006, India
Registered Office: 3A2 Varadarajulu Nagar, FCI Road, Ganapathy, Coimbatore, Tamil Nadu 641006, India
Ph: +91 9385339863 | www.threatenedtaxa.org
Email: sanjay@threatenedtaxa.org

For Focus, Scope, Aims, and Policies, visit https://threatenedtaxa.org/index.php/JoTT/aims_scope
For Article Submission Guidelines, visit https://threatenedtaxa.org/index.php/JoTT/about/submissions
For Policies against Scientific Misconduct, visit https://threatenedtaxa.org/index.php/JoTT/policies_various

continued on the back inside cover

Cover: Common Keeled Skink *Eutropis carinata* in oil pastels, colour pencils, & micron pen adapted from photograph by H. Byju © Pooja Ramdas Patil.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 February 2024 | 16(2): 24615–24629

ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

https://doi.org/10.11609/jott.8826.16.2.24615-24629

#8826 | Received 14 November 2023 | Final received 22 January 2024 | Finally accepted 01 February 2024

OPEN ACCESS

ARTICLE

Unearthing calf burials among Asian Elephants *Elephas maximus* Linnaeus, 1758 (Mammalia: Proboscidea: Elephantidae) in northern Bengal, India

Parveen Kaswan [1] & **Akashdeep Roy** [2]

[1] West Bengal Forest Department, Indian Forest Service, Deputy Field Director Office, Alipurduar, West Bengal 736121, India.
[2] Department of Humanities and Social Sciences, Indian Institute of Science Education and Research (IISER), Pune, Maharashtra 411008, India.
[1] parveenkaswan@gmail.com, [2] akashdeep.roy@students.iiserpune.ac.in (corresponding author)

Abstract: Rampant environmental changes and forest destruction push elephants, both Asian and African, to explore human spaces to fulfil their dietary and ecological requirements and, consequently in shared spaces many 'novel' elephant behaviors come into the limelight. Elephant calf burial is reported in African literature but remains absent from the Asian context. We report calf burials by Asian Elephants in the eastern Himalayan floodplains of the northern Bengal landscape. The study area consists of fragmented forests, tea estates, agricultural lands, and military establishments. Tea estates form the majority of elephant corridors, and we explain the burial strategy of elephants in the irrigation drains of tea estates. We present five case reports of calf burials by elephants. We aimed to understand the perimortem strategy and postmortem behavior of the Asian Elephants. The major findings reflect that the carcasses were carried by trunks and legs for a distance before being buried in a 'legs-upright-position'. We further investigated the underlying reason for calf deaths through postmortem examinations. Direct human intervention was not recorded in any of the five deaths. Through opportunistic observation, digital photography, fieldnotes, and postmortem examination reports, we suggest that the carcasses were buried in an abnormal recumbent style irrespective of the reason for the calf's death. Through long-term observation, we further report that the elephants in this region clearly avoid the paths where carcasses were buried. We discuss and connect the literature of two distinct elephant species and also compare thanatological studies of other sentient nonhuman species.

Keywords: Animal behavior, eastern Himalaya, northeastern India, sentient nonhuman species, tea estates, thanatology.

सार: बड़े पैमाने पर पर्यावरणीय परिवर्तन और वन विनाश दोनों एशियाई और अफ्रीकी हाथियों को मानव स्थानों पर आने के लिए मजबूर करते हैं। उनकी आहार संबंधी और पारिस्थितिक आवश्यकताओं को पूरा करने के लिए और, परिणामस्वरूप साझा स्थानों में हाथियों के कई अनोखे व्यवहार सामने आते हैं। अफ्रीकी साहित्य में हाथी के मृत बच्चों को दफ़नाने की बात बताई गई है लेकिन एशियाई संदर्भ में यह अनुपस्थित है। हम उत्तरी बंगाल परिदृश्य के पूर्वी हिमालयी मैदानों में हाथी द्वारा मृत बच्चों को दफ़नाने की रिपोर्ट प्रस्तुत करते हैं। अध्ययन क्षेत्र में खंडित वन, चाय बागान, कृषि भूमि और सैन्य प्रतिष्ठान शामिल हैं। चाय बागानों में अधिकांश हाथी गलियारे हैं, और हम चाय बागानों के सिंचाई नालों में हाथियों की रणनीति अथवा उनके मृत बच्चों को दफनाने की व्याख्या करते हैं। हम हाथियों द्वारा मृत बच्चों को दफनाने के पांच मामले प्रस्तुत करते हैं। हमारा लक्ष्य था की एशियाई हाथियों की पेरिमॉर्टम रणनीति और पोस्टमॉर्टम व्यवहार को समझें। प्रमुख निष्कर्ष दर्शाते हैं कि शव 'पैर-उप्पारी-स्थिति' में दफनाने से पहले कुछ दूरी तक सूंड और पैरों द्वारा ले जाया गया। हमने अंतर्निहित और पोस्टमॉर्टम जांच के माध्यम से हाथी के मृत बच्चों की मौत का कारण बताया गया। पाँचों मौतों में से किसी में भी प्रत्यक्ष मानवीय हस्तक्षेप दर्ज नहीं किया गया। विभिन्न माध्यम जैसे की - अवसरवादी अवलोकन, डिजिटल फोटोग्राफी, फील्डनोट्स और पोस्टमॉर्टम परीक्षा रिपोर्ट से हम सुझाव देते हैं कि हाथी के बच्चों की मृत्यु का कारण चाहे जो भी हो, उसे असामान्य लेटी हुई शैली में ही दफनाया गया। दीर्घकालिक अवलोकन के माध्यम से, हम आगे की रिपोर्ट देते हैं। इस क्षेत्र में हाथी स्पष्ट रूप से उन रास्तों से बचते हैं जहां शवों को दफनाया गया था। हमने दो हाथी की प्रजातियों के साहित्य को जोरते हुए चर्चा करी और अन्य संवेदनशील गैर-मानवीय प्रजातियों के थानाटोलॉजिकल अध्ययनों की तुलना भी करी।

Editor: Priya Davidar, Sigur Nature Trust, Nilgiris, India.

Date of publication: 26 February 2024 (online & print)

Citation: Kaswan, P. & A. Roy (2024). Unearthing calf burials among Asian Elephants *Elephas maximus* Linnaeus, 1758 (Mammalia: Proboscidea: Elephantidae) in northern Bengal, India. *Journal of Threatened Taxa* 16(2): 24615–24629. https://doi.org/10.11609/jott.8826.16.2.24615-24629

Funding: This study was not supported by any funding agency.

Competing interests: The authors declare no competing interests.

Author details: Parveen Kaswan is an Indian Forest Service officer. He is currently working as deputy field director of Buxa Tiger Reserve and as the director of a Vulture Conservation Breeding Centre in West Bengal. His long experience managing various wildlife divisions motivates him to study elephants, vultures, clouded leopards, and tigers. Akashdeep Roy is a senior research fellow at IISER Pune. His interdisciplinary research background for understanding human-large mammal conflict has focused on leopards, elephants, and Asiatic black bears through camera trapping, remote sensing, and telemetry. His current research focuses on elephants and their interaction with energized fences and rice beer.

Author contributions: Conceptualization, methodology: Parveen Kaswan, Akashdeep Roy. Formal analysis and investigation, writing-review and editing, supervision: Akashdeep Roy, Parveen Kaswan. Writing-original draft: Akashdeep Roy. Resources: Parveen Kaswan.

Acknowledgements: We thank the Indian Institute of Science Education and Research, Pune and the principal chief conservator of forests/chief wildlife warden of West Bengal for granting permission (Memo no: 3067/WL/4R-26/2022) to conduct this study. We are grateful to the tea garden managements and the night guards of Devpara, Chunabhati, Bharnobari, and Majherdabri for the timely intimation and cooperation regarding the calf death incidents. We are equally obliged to the divisional forest officers of Jalpaiguri division and Gorumara Wildlife Division, forest range officers of Binnaguri, Hamiltonganj, and Majherdabri ranges, and the support staff who have contributed efficiently to the production of this behavioral study. We thank the veterinary officers of Gorumara Wildlife Division and Buxa Tiger Reserve for their detailed investigation concerning the calf deaths. We also thank Suraj Kumar Dash of Wildlife Institute of India for his support in preparing the map.

INTRODUCTION

Human-induced rapid environmental change often alters non-human species' reproductive, nutritional, and physiological behavior (Chartier et al. 2011; Sih et al. 2011). Both Asian Elephants *Elephas maximus* and African Elephants *Loxodonta africana* face land-use challenges more than other species due to their substantial dietary requirements and extensive home ranges (Young et al. 2007; Kshettry et al. 2020; Roy et al. 2022). Known for their strategic planning and cooperation, these social animals also become victims of environmental modifications, and the resultant low fertility and high calf mortality rates emerge as noted unforeseen consequences (Mar et al. 2012). Realizing the slow reproductive rate in elephants, calf deaths directly influence their population dynamics. While these sentient megaherbivores constantly adapt to land-use and environmental changes to increase survival rates, they demonstrate various novel behaviors. Many such behaviors pertaining to offspring affection comes to the limelight when they frequently use the human domain. One such behavior is how they bid farewell to their deceased calves and the behavior of the herd thereafter.

The manner in which nonhumans address the dying and the dead reflects their cognition and emotional side (Hawley et al. 2018; Watson & Matsuzawa 2018; Carter et al. 2020; Fernández-fueyo et al. 2021). Animal behavior and thanatology, therefore, remain a central part of understanding the overall fitness of nonhuman species in a changing landscape (Gil et al. 2020). Most animal species, unlike humans, pay less interest to their dead conspecifics. Different species' 'weak' cognitive abilities and disease avoidance theories support this 'leaving alone' behavior (Goldenberg & Wittemyer 2019). However, cetaceans, primates, and elephants show contrasting examples of strong behavioral reactions to their deceased young ones. While such caring behavior between the mother and the offspring among different mammal species is observed (Bercovitch 2020), notably, the entire herd project affectionate behavior among elephants (McComb et al. 2006). With up to 22 months of gestation, these K-strategist species invest much emotional energy in their young ones, even after their demise.

For instance, a behavior where the elephant carcass parts were carried across a distance, covering the carcass with vegetation ("weak" burial), or observing the carcass over several hours has been covered in various scholarships concerning the African Elephants (Douglas-Hamilton & Douglas-Hamilton 1975; Goldenberg & Wittemyer 2019). Apart from elephants, burial behavior has also been observed in the termite species *Reticulitermes fukienensis* (Fernández-fueyo et al. 2021), but in no other large mammals. Calf burials by elephants are among the less-studied topics of thanatology, especially in Asia (Sharma et al. 2019), even though this practice is known to the conservation community. Elephants show a variety of behavior ranging from investigative, stationary, self-directed, social, and mourning behavior around their dead conspecifics (Hawley et al. 2018; Goldenberg & Wittemyer 2019; Watts 2019; Stephan et al. 2020).

Even though such sensory behaviors have been vastly studied, most of these research articles fail to report the exact cause of calf deaths and weakly contribute to animal thanatology. The cause of death remains a salient mediator to individual responsivity (Bercovitch 2020). We deem it urgent as the herd's behavior (especially the mother) may vary in deaths due to natural illness and accidents (injury and wounding). Calves up to five years of age experience mortality risks due to various factors such as maternal age, sex of the calf, inter-birth intervals, and whether firstborn or later-born (Mar et al. 2012; Rutherford & Murray 2020). Controlled studies have reported 43.3% of deaths due to accidents among young calves (Mar et al. 2012); therefore, the resultant behavior remains critical and dependent on the cause of death.

From an evolutionary biology standpoint, natural illness and the consequent death ultimately increase the fitness of the surviving population (Fernández-fueyo et al. 2021). Thus, an incident of calf death is expected to not to escalate the conflict against humans. However, in case of accidental deaths (attributed to humans), revenge behavior has been observed across many species such as elephants (Chalcraft 2015), primates (Watts 2019), and more recently among Orcas *Orcinus orca*. Retaliation and revenge by elephants escalate the human-elephant negative interactions (HENI) and pose a severe challenge to wildlife managers and anthropologists. However, various socio-ecological and political factors still determine the magnitude of HENI, but such factors are beyond the scope of this study. This study rather contributes to the ecological behavior of elephants, both peri and postmortem, while investigating death causes through postmortem reports of carcasses and attempting to bridge the two different elephant species and draw commonalities and contrasts between the two as far as thanatology is concerned.

While elephants occupy only 5% of their historic

home range globally, India hosts more than 60% of the global Asian Elephant population despite being one of the most populated countries in the world (Leimgruber et al. 2003; Sukumar 2006). As much as 78% of their current habitat lies outside protected areas (PAs) in heterogenous landscapes (Naha et al. 2020). With an ever-increasing human population alongside livestock and agricultural land on the one hand, and conservation efforts to increase the large mammal population on the other hand, the human-nonhuman overlap increases (Sukumar 1989; Goswami et al. 2015). The Asian Elephant is listed as 'Endangered' on the International Union for Conservation of Nature (IUCN) Red List of Threatened Species and is regarded as a sentient being for its intelligence. Many novel behaviors come to the limelight when elephants use non-forested areas more frequently. The study's novelty lies in the unique style of burial of elephant calves inside tea estates (TEs) of northern Bengal.

Along with a green cover and comparatively undisturbed passage for the pachyderms, the TEs also provide ample stretch of irrigation drains which the elephants have learnt to use differently. The irrigation drains move out excess water during the monsoon season to protect the tea bushes. However, elephants reportedly use these depressions to bury their deceased offspring. This study also presents the first photographic report of dead calf burial by elephants in the TEs.

We aimed to (1) study the cause of death of the elephant calves, (2) understand the rationale behind the unique carcass burial strategy, and (3) observe the postmortem behavior among elephants near the burial sites. We report the underlying reasons, from postmortem examination reports for the calf deaths, as well as anecdotal evidence of herd members during peri and postmortem phases. This study contributes to the existing literature on elephant behavior and thanatology through a combination of observation, analysis, and interpretation methods.

MATERIALS AND METHODS

Study area

The northern Bengal landscape is comprised of fragmented forests, tea estates, network of rivers flowing, agricultural fields, and military establishments intersected by railways and highways (Figure 1). While there has been a constant decrease in the wildlife habitat over the last few decades, the four districts of northern Bengal—Darjeeling, Kalimpong, Jalpaiguri, and Alipurduar—together host >500 elephants (MoEF & CC 2017). The land-use and landcover analysis highlights a 44% percent increase in human settlements and a seven percent decrease in the sand bed area in the last decade (Naha et al. 2019). Parallelly, Roy & Sukumar (2015) identified 59 elephant corridors, while 80% of these corridors experience a high degree of encroachment. With shrinking ecological corridors but considering peoples' tolerance (Roy et al. 2022), the elephant population increases and is 'pushed' through TEs, cited as 'natural corridors' in modern human-elephant 'conflict' literature. Exponential increase from 10,000 acres in 1866 to 50,000 acres in 1905, the tea industry has emerged as a static livelihood option to many and welcomed many migrants (Xaxa 2001). The number has grown further over the next century and currently covers approximately 1,350 km^2 of land (Kshettry et al. 2020).

Data collection

We triangulated the findings through opportunistic observation, digital photography and fieldnotes, and postmortem examination reports. These are explained below:

Opportunistic observation: The jurisdiction of wildlife divisions in northern Bengal spreads across forest villages, revenue lands, TEs, and any other area where wildlife is present. The five discussed case reports originated through opportunistic observation. This method corresponds to spontaneous observation and recording of the behavior of any natural event by the researcher or any concerned individual (Altmann 1974; Carter et al. 2020; Pokharel & Sharma 2022). The researcher then captures the event through photography, field notes, videography, or audio recording, followed by long-term observation.

Digital photography and fieldnotes: The researchers took photographs of these burial incidents, forest department officials and the tea garden management, which were later analyzed (de Silva et al. 2017; Goldenberg & Wittemyer 2019; Carter et al. 2020). The researchers and tea garden management collected evidence of elephant visitation around the burial site. All the burial sites were far from human settlements, and identifying the particular elephant herd at night was challenging for the locals. However, the researchers and tea garden management regularly monitored the specific pathways while preparing field notes to look for indirect evidence such as dung boli and footsteps.

Postmortem examination reports: Four veterinary officers conducted the postmortem report in the presence of the forest officers of respective wildlife

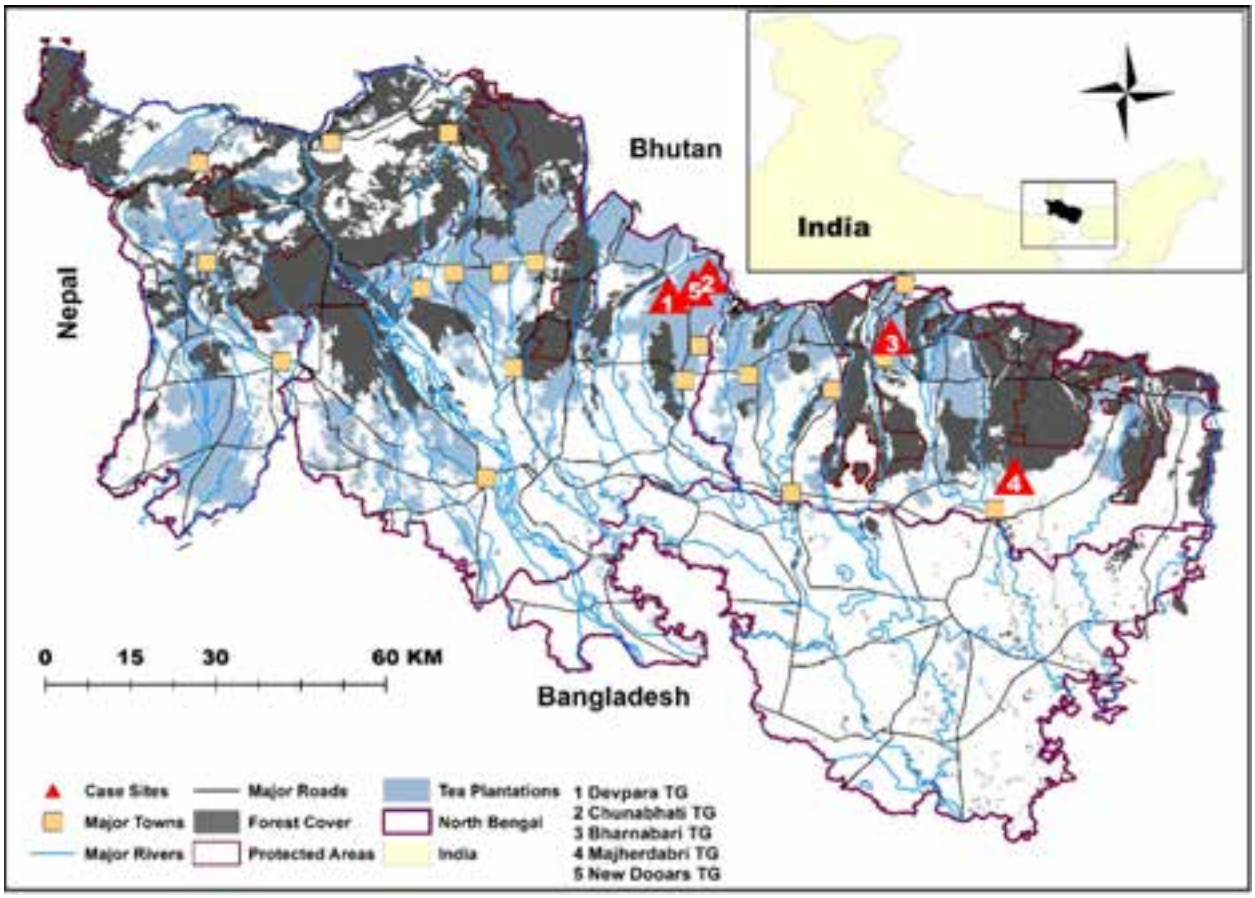


Figure 1. Map of study area showing all case sites along with major land-use types.

divisions. The postmortem report of the deceased calves reveals the reason for deaths, underlying illness, health conditions, and various parameters (see Table 1). While other research articles suspect the cause of calves' death through indirect evidence (Goldenberg & Wittemyer 2019; Sharma et al. 2019), this study gives detailed proof of the cause of death. Also, the postmortem examination report reflects the estimated time of death of the calf and deduces the 'in-transit' time and the time under the ground.

RESULTS

We report five calf burial cases in different TEs in the study area (Figure 1). We present the findings in two sections, (1) internal examination through postmortem examination report and (2) external examination and field anecdotes.

Internal examination through postmortem report (see Table 1).

External examination and field anecdotes

The most surprising finding of this study is the positioning of elephant carcasses during burial. In all five cases, the legs were upright, and the head, trunk, and dorsal parts were fully buried. Due to the limited depth of the irrigation drains in TEs, the legs of the dead calves were visible above ground level (Image 1–5). We observed footsteps of herd members on both sides of the trench and over the soil covering the body, indicating a combined effort in burying the carcasses. While burying the carcass, the elephant herd vocalized for 30–40 min, as the TE night security guards reported. All the cases had minute contextual differences and are mentioned below as five different case reports:

Case 1 belongs to Devpara TE, which falls in the jurisdiction of the Gorumara Wildlife Division. The burial site's location (26.829477° N, 89.009466° E) was 350 m away from the nearest human settlement and approximately 4 km from the nearest reserve forest. It rained the night of burial, making it easier for the herd (N = 20) to bury the carcass. Loud vocalization from the herd was observed distantly. Large petechial hemorrhagic

Table 1. Details of postmortem reports of the five deceased elephant calves.

	Case 1	Case 2	Case 3	Case 4	Case 5
Forest division	Gorumara Wildlife Division	Gorumara Wildlife Division	Buxa Tiger Reserve (West)	Buxa Tiger Reserve (West)	Gorumara Wildlife Division
Date of death	12.ix.2022	17.xi.2022	19.viii.2022	27.x.2022	25.x.2023
Time of death	0200 h	1400 h	0300 h	0600 h	2300 h
Location	Debpara tea garden	Chunabhati tea garden	Bharnabari tea garden	Majherdabri tea garden	New Dooars tea garden
Age of the calf	12 months	4–5 months	10 months	6–8 months	3–4 months
Weight	350 kg	200 kg	300 kg	250 kg	160 kg
Sex	Female	Female	Male	Male	Female
Trachea	NAD	Hemorrhagic froth present	Hemorrhagic froth present	Hemorrhagic froth present	Congested
Lungs	Congested and hemorrhagic	Congested and hemorrhagic	Congested and hemorrhagic	Congested and hemorrhagic	Highly congested
Heart	Epicardium—congested and hemorrhagic	Epicardium—congested and hemorrhagic	Epicardium— congested and hemorrhagic	Epicardium—congested and hemorrhagic	Epicardium—pin point hemorrhagic and congested
Diaphragm	NAD	Congested	NAD	Ruptured	Pale colored
Nutritional status	Poor	Poor	Poor to normal	Poor to normal	Poor to normal
Reason for death	Cardio-respiratory failure due to acute catarrhal enteritis	Multiple organ failure due to acute microbial infection	Cardio-respiratory failure	Respiratory failure	Septicemia resulting from acute microbial infection along with hernia and severe gastroenteritis
Body carcass	Intact	Intact	Intact	Intact	Intact
Entry/exit wounds	No	No	No	No	No

NAD—No abnormality detected.

lesions and contusions were found on the dorsal surface of the entire vertebral region (Supplementary Appendix 1). As per long-term observation, the frequency of the elephant movement was reduced by up to 70%. Elephants have started using parallel pathways, clearly avoiding the previous path where the carcass was buried. One of the parallel routes also witnessed a human death in quick succession after the calf burial. However, such human death incidents could have resulted from other socio-ecological and circumstantial factors. Fresh elephant dung boli of different sizes were also observed near the buried carcass. The locals worshipped the deceased calf before the forest department officials took it away.

Case 2 belongs to Chunabhati TE under the Binnaguri Wildlife Squad of the Gorumara Wildlife Division. The burial site (26.860416° N, 89.072500° E) was 150 m away from the nearest human settlement and 4.5 km from the nearest forest. Subcutaneous tissues were damaged, and wide hemorrhage were observed on the dorsal side of the body (Supplementary Appendix 2). It rained heavily on the night of the incident, and the soft soil layer facilitated an easier burial process. No vocalization was reported in this case. Elephant dung boli of various sizes present indirect evidence that the herd (N = 15) also consisted of adults, sub-adults, and young adults. Although it's challenging to identify the particular herd at night, the elephants clearly avoided the pathway of the buried carcass. Now, they take alternate routes to the nearby forest after night grazing.

Case 3 corresponds to Bharnabari TE under the jurisdiction of the Hamiltonganj range of the Buxa Tiger Reserve (Supplementary Appendix 3). This burial site (26.764752° N, 89.361850° E) was 300 m from the nearest human settlement. The tea garden management and the villagers observed the unusually prolonged vocalization of an elephant herd (N = 15–20) during their entire journey inside the TE. This vocalization involved both trumpets and roars. A fracture in the right hind limb was also observed. Long-term observation on this particular pathway reflected that the elephants scarcely used this pathway, and the frequency hasn't changed after the burial incident.

This TE was declared 'sick' in 2008 as the company was at a loss and could not fully support the welfare of the tea garden residents. Moreover, the TE was shut down between 2005–08 due to loss and management failure. These socio-economic and political reasons contribute to comparatively less human density in this

Image 1. A buried carcass corresponding to case 1 of Devpara tea estate. © West Bengal Forest Department.

Image 2. A buried carcass corresponding to case 2 of Chunabhati tea estate. © West Bengal Forest Department.

Image 3. A buried carcass corresponding to case 3 of Bharnabari tea estate. © West Bengal Forest Department.

Image 4. A buried carcass corresponding to case 4 of Majherdabri tea estate. © West Bengal Forest Department.

Image 5. A buried carcass corresponding to case 5 of New Dooars tea estate. © West Bengal Forest Department.

TE, thus, facilitating easier passage for the elephants. Footsteps of herd members were recorded around the burial site, and it seemed that the herd had attempted to bury the deceased to ground level.

Case 4 belongs to Majherdabri TE under the jurisdiction of the East Damanpur range of the Buxa Tiger Reserve (Supplementary Appendix 4). The burial site's location (26.544368° N, 89.557619° E) was around 500 m away from the nearest human settlement and close to the national highway. The 'partially buried' carcass was observed by the TE workers and followed by a postmortem examination by the Forest Department. As per the postmortem report, the calf died 60–72 h before the examination. We suggest that the elephant herd must have roamed for 40–45 h before finding an appropriate trench to bury the carcass; otherwise, the carcass would've been noticed by the TE labourers earlier.

Conversely, we also report a time lag between the time of death and burial and that the carcass was dragged to the appropriate point. This forest adjoining site allowed the elephants to access the trench and

return to the forest. As the carcass was detected after almost three days, the kidneys were partially putrefied. Moreover, there were bruises and contusions on the dorsal side of the carcass—more than that in the other reported cases. Thus, it indicates that the herd carried the carcass by the trunk or the legs for a longer time.

The soil eruptions over the body of the carcass represent that rigor mortis had passed, and the gaseous components blow out of the soil before the carcass was detected. This phenomenon refers to 'postmortem flatulence' or colloquially 'burial explosion'. Rigor mortis among elephants is usually after 12 hours and remains for the next 12 hours.

Case 5 belongs to New Dooars TE under the jurisdiction of Gorumara wildlife division (Supplementary Appendix 5). The burial site's location (26.8417^{0}N, 89.0488^{0}E) was 700 m away from the human settlement. Similar to other cases, the carcass was observed by TE workers and was taken for postmortem examination after 12 hours of death. Footsteps of herd members to bury and level the soil around the carcass was observed similar to other cases.

Similar to other cases, this case was also peculiar as the elephant herd abandoned this active migratory route after burying the deceased calf. They are reported to use different parallel paths after the incident.

Overall, we also observed contusions, mainly in the neck and dorsal parts along the vertebral column in all the cases. It was accompanied by hemorrhagic fluids in the trunks of most carcasses. Other observations reveal that the mucous membrane was pale and dry, and the tongue was soiled, congested, and inflamed in all cases. The average depth of the irrigation drains was found to be 0.65 m. No body part was missing. Field observation from south Bengal shows carrying behavior by the trunk and legs (Image 6).

Image 6. An elephant carcass being carried by a herd member. © West Bengal Forest Department.

DISCUSSION

Environmental changes and land-use patterns often bring novel behavior to the limelight. This study highlights one such behavior of carcass burial by Asian Elephants in the TEs of northern Bengal. We present confirmed anecdotes of carcass burials by elephants in the northern Bengal region. We reported five similar case reports to show the carcasses' strange 'legs-upright-position' and investigated the details of such behavior. Elephants are social animals, and their cooperative behavior has been widely published in scholarly articles. However, the 'calf burial' component of thanatology remains briefly studied for African Elephants and untouched for Asian Elephants. In this section, we compare our case reports with the existing literature on thanatology in two sub-sections, namely—1) perimortem and 2) postmortem behavior.

Perimortem behavior: Calf burial and other comparisons

In a first-ever recorded photographic and postmortem examination evidence of deceased calf burials by Asian Elephants, the study contributes to the existing 'faint' knowledge about calf burials by elephants globally. Through direct and indirect evidence, this study highlights elephants helping and compassionate behavior during the burial of the carcass. A few generalities have to be made about Asian Elephants' calf burial behavior arising from the five case reports presented above.

We state that Asian Elephants carry their deceased calves to isolated locations away from humans and carnivores while searching for irrigation drains and depressions to bury the carcass. Caring for and carrying the dead offspring has been reported in both altricial (mostly primates: Chimpanzees, baboons, and macaques) (Watts 2019; Carter et al. 2020) and precocial (elephants, giraffe, and peccaries, for instance) offspring (Watson & Matsuzawa 2018; Bercovitch 2020). There are unpublished reports from the West Bengal Forest Department of an elephant cow carrying the carcass for up to two days before leaving it in an isolated location in southern Bengal (Image 6). It's worth noting that only calves are carried, and the young adults/adults are not due to non-feasibility. In most cases, these sentient beings do not leave the carcass until putrefaction starts in the deceased calf or the carcass is taken over by the Forest Department officials. Such affinity towards their offspring is attributed to oxytocin and a prolonged gestation period (Bercovitch 2020). Such hormonal

response aligns with other studies on Chacma Baboons *Papio ursinus* (Carter et al. 2020), Olive Baboons *Papio anubis*, African Elephants, and Thornicroft's Giraffe *Girafa camelopardalis* (Bercovitch 2020). Published research articles on African Elephants have reported calf burials in rare cases (Douglas-Hamilton & Douglas-Hamilton 1975), but such literature remains absent from the Asian context (Sharma et al. 2019).

Our findings also suggest that the modified land-use types, such as TEs, offer connectivity and provide extended forest cover for elephant movement. There are no irrigation drains inside the PAs, and it's exceptionally challenging to locate burial activities/sites inside the closed canopy of the semi-evergreen and moist deciduous forests of northern Bengal—quite similar to why thanatological studies have briefly touched upon the less populated African Forest Elephants *Loxodonta africana cyclotis* (Hawley et al. 2018). Through extensive patrolling by the forest guards such deceased calves are often detached from the herd to ensure normal elephant migration and the subsequent crowd management which would have occurred on seeing such 'novel' behavior. With ample irrigation drains and no forest officials, the TEs, in these cases, emerge to be a perfect land-use type for burying the carcass. In addition to such burials by elephants, the TEs of northern Bengal also witness elephant births – thus, providing a common ground for life and death.

The most interesting finding of our study was the positioning of the carcasses in a 'legs-upright-position' in the limited space in the TEs. The locals and the conservation community often perceive these burials as 'accidental'. The 'strange' positioning of the carcass could be explained for better grip for the herd member(s) to hold and lay the calf in the trench. This strategic behavior also reflects the care and affection of the herd member(s) towards the deceased conspecific. This behavior suggests that in a situation of space crunch, the herd member(s) prioritize the head for the burial before the feet. Elephants are caring social animals, and based on external examination of the carcasses, we also suggest that the calves were placed delicately by gripping one or more legs by the herd member(s). However, we observed petechial hemorrhagic lesions and contusions on the dorsal side of the carcass in all the cases. The contusions in the dorsal part suggest that the carcasses were carried from a distance to locate and bury them at a preferred location (see Image 6).

This abnormal recumbency is due to a combination of three factors. First, preexisting 'tight' irrigation drains in TEs may lead to carcasses easily being buried. Second, elephants have become bolder and use human spaces to fulfil their behavioral and dietary needs. People's tolerance towards elephants in northern Bengal is higher than in other parts of West Bengal and other Indian states (Roy et al. 2022)—presenting a healthy coexistence scenario. Third, the absence of irrigation drains and the presence of more carnivores inside the forests projects a problematic situation for the elephants to choose. Historically elephants must have buried their deceased offspring inside forests subject to trench availability, and loose soil, among other environmental factors, but we also suggest that these megaherbivores adapt to the changing socio-ecological scenario and landscapes.

Such sentient behavior in a high human density region strengthens the morale of coexistence between humans and nonhumans. Thus, their conservation quotient increases through ethics, more than the elephants' ecological role, and boosts their socio-ecological rank in society. Such exalted status of elephants is further complemented through religious reverence among various communities worldwide, including India. Births and deaths are memorialized among the local communities and hold a special place in their rural culture, as was done in the case of Devpara TE. Cases 2, 3, and 4 didn't display any such homage due to the isolated location of the carcass and religious heterogeneity in the neighborhood.

Based on anecdotal evidence from TE managers and workers, the herd made loud vocalizations and left quickly—approximately 30–40 minutes. This behavior suggests that elephants distinguish human and nonhuman spaces and avoids dissension with humans.

Vocalization remains an expected behavior among Asian and African Elephants, which was limited to the burial phase. In these cases, loud trumpets may signify mourning and preparing for inter-specific aggression (Sharma et al. 2019). A second-hand account (formal interview with the forest range officer) showed a similar case inside Jaldapara National Park (an adjoining forest in the same landscape). The elephant herd stayed there for more than four hours near the burial site, most probably because it was undisturbed by humans. His other observation adds that the same herd visited the burial site multiple times to investigate various stages of decay. This observation aligns parallel to the behavior among African Elephants (Douglas-Hamilton & Bhalla 2006; Goldenberg & Wittemyer 2019).

Besides these behaviors, we also observed the efforts of various herd members through their footprints in levelling the soil above/around the carcass – supporting the social-bonds hypothesis. Moreover, from the size of

the footsteps and dung boli, we also infer that carcass burying was a combined effort from allomothers and herd members of different age groups. Such indirect signs have been recorded in India (Sharma et al. 2019) and Africa (Goldenberg & Wittemyer 2019), even though those observations were only limited to mourning and gathering. Also, the herds operated in small numbers, parallel to previous studies on Asian Elephants (Pokharel & Sharma 2022) but contrary to African Elephants (de Silva et al. 2017). Thus, due to the absence of a hierarchical structure among Asian Elephants, we report commensurate efforts in the burial of the deceased conspecifics by the surviving herd members, unlike African Elephants, where the nonhuman agency works in hierarchical order (Sharma et al. 2019).

Postmortem behavior

Following the wildlife protocol, the forest department removed the buried carcasses and kept the records for research and training. Thus, a further comparison concerning 'visiting the carcass' cannot be made between Asian and African Elephants. In natural settings, elephants have been reported to visit the burial site at various stages of decomposition both in Africa (Hawley et al. 2018; Goldenberg & Wittemyer 2019; Rutherford & Murray 2020) and Asia (Pokharel & Sharma 2022). This case study shows the opposite behavior altogether. In all the examples, the herd fled the site within 40 minutes of burial. A formal interview with the tea garden managers shows that the elephants now use a parallel pathway and completely avoid their previous 'active' route. This observation was complemented by indirect evidence of dung boli and footsteps that the elephant herds use the parallel pathways more often than before. This behavior comes up as a new contrasting behavior to the African species who spend a lot of time investigating and exploring the elephant remains (Douglas-Hamilton & Bhalla 2006). In conclusion, the burial location plays a central role in determining the postmortem behavior among elephants, whether inside or outside the PAs.

All observations were opportunistic and must not be generalized for the entire study area or other regions of similar biogeographic and environmental conditions. We report only the cases outside PAs and the behavior thereafter. The behavior of the elephant herd inside PAs could be similar to the African species, or not. In all cases, all elephant herds avoid burial sites and take parallel routes.

All of the deceased calves were not more than 12 months of age, and similar to studies on captive elephants, wild Asian Elephants also remain susceptible to death in early years (Mar et al. 2012). All the death cases happened due to prevailing illness or natural unfavorable circumstances, including death due to falling into the irrigation drains. We restrained from putting forward the exact reason that claimed the deaths of these calves. However, we claim that irrespective of the cause of death, the elephant herd attempts to bury the carcass in an abnormal recumbency position inside TEs. Even though the nutritional status of all the calf carcasses was poor and poor-to-normal, we also step back in categorizing the deaths into natural or accidental, except in case 2 and case 5, where the elephant calves died of multiple organ failure due to acute microbial infection. Cases 1, 3, and 4 suggest deaths due to cardio-respiratory failure, which could have arisen for numerous reasons, including falling into the trench, being trampled, or suffocating to death naturally. Thus, we refrain from stating that all the deaths happened outside TEs. At the same time, we also report that all the irrigation drains where the carcasses were buried were too shallow (0.60–0.70 m) and less probable for calves to slip into and die. We also eliminate any possibility of infanticide in any of the cases as reported in other cognitive species, such as Chacma Baboons (Carter et al. 2020) and Mountain Gorillas *Gorilla beringei beringei* (Watts 2019). This remains an open platform for future research among academics researching elephant behavior and thanatology. Subsequently, we repress from commenting on whether these death cases would trigger HEC.

Even though the two distinct species separated c. 9–4.2 million years ago (Palkopoulou et al. 2018), the ancestral traits still connect the two species. We hope scholars studying thanatology come up with detailed anecdotes across various species and perform nuanced comparative thanatological studies to connect the phylogenetic continuity. We encourage science and social science evidence-based thanatological studies for not just sentient beings but also non-sentient beings and less-loved species in a changing natural and socio-political environment.

REFERENCES

Altmann, J. (1974). Observational study of behavior: Sampling methods. *Behavior* 49(3): 227–267.

Bercovitch, F.B. (2020). A comparative perspective on the evolution of mammalian reactions to dead conspecifics. *Primates* 61(1): 21–28. https://doi.org/10.1007/s10329-019-00722-3

Carter, A.J., A. Baniel, G. Cowlishaw, E. Huchard & A.J. Carter (2020). Baboon thanatology: responses of filial and non-filial group members to infants' corpses. *Royal Society Open Science* 7: 192206.

https://doi.org/10.1098/rsos.192206

Chalcraft, V.J. (2015). Essential elements for elephants, pp. 94–111. In: Kemmerer, L. (ed.). Animals and the Environment: Advocacy, activism, and the quest for common ground. Taylor and Francis, 364 pp

Chartier, L., A. Zimmermann & R.J. Ladle (2011). Habitat loss and human-elephant conflict in Assam, India: Does a critical threshold exist? *Oryx* 45(4): 528–533. https://doi.org/10.1017/S0030605311000044

de Silva, S., V. Schmid & G. Wittemyer (2017). Fission – fusion processes weaken dominance networks of female Asian Elephants in a productive habitat. *Behavioral Ecology* 28: 243–252. https://doi.org/10.1093/beheco/arw153

Douglas-Hamilton, I. & O. Douglas-Hamilton (1975). *Among the Elephants*. Collins & Harvill Press, London, 285 pp.

Douglas-Hamilton, I. & S. Bhalla (2006). Behavioural reactions of elephants towards a dying and deceased matriarch. *Applied Animal Behavior Science* 100(1–2): 87–102. https://doi.org/10.1016/j.applanim.2006.04.014

Fernández-fueyo, E., Y. Sugiyama, T. Matsui & A.J. Carter (2021). Why do some primate mothers carry their infant's corpse? A cross-species comparative study. *Proceedings of Royal Society B* 288: 20210590. https://doi.org/10.1098/rspb.2021.0590

Gil, M.A., M.L. Baskett, S.B. Munch & A.M. Hein (2020). Fast behavioral feedbacks make ecosystems sensitive to pace and not just magnitude of anthropogenic environmental change. *Proceedings of the National Academy of Sciences* 117(41): 25580–25589. https://doi.org/10.1073/pnas.2003301117

Goldenberg, S.Z. & G. Wittemyer (2020). Elephant behavior toward the dead: A review and insights from field observations. *Primates* 61: 119–128. https://doi.org/10.1007/s10329-019-00766-5

Goswami, V.R., K. Medhi, J.D. Nichols & M.K. Oli (2015). Mechanistic understanding of human-wildlife conflict through a novel application of dynamic occupancy models. *Conservation Biology* 29(4): 1100–1110. https://doi.org/10.1111/cobi.12475

Hawley, C., C. Beirne, A. Meier & J. Poulsen (2018). Conspecific investigation of a deceased forest elephant (*Loxodonta cyclotis*). *Pachyderm* 59: 97–100.

Kshettry, A., S. Vaidyanathan, R. Sukumar & V. Athreya (2020). Looking beyond protected areas: Identifying conservation compatible landscapes in agro-forest mosaics in north-eastern India. *Global Ecology and Conservation* 22: e00905. https://doi.org/10.1016/j.gecco.2020.e00905

Leimgruber, P., J.B. Gagnon, C. Wemmer, D.S. Kelly, M.A. Songer & E.R. Selig (2006). Fragmentation of Asia's remaining wildlands: Implications for Asian elephant conservation. *Animal Conservation* 6(4):347–359. https://doi.org/10.1017/S1367943003003421

Mar, K.U., M. Lahdenpera & V. Lummaa (2012). Causes and correlates of calf mortality in captive Asian Elephants (*Elephas maximus*). *PloS ONE* 7(3): e32335. https://doi.org/10.1371/journal.pone.0032335

McComb, K., L. Baker & C. Moss. (2006). African elephants show high levels of interest in the skulls and ivory of their own species. *Biology Letter* 2(1): 26–28. https://doi.org/10.1098/rsbl.2005.0400

MoEF&CC (2017). Synchronized elephant population estimation India. Ministry of environment, forest and climate change, government of India. Available at http://www. indiaenvironmentportal.org.in/files/file/ Synchronized Elephant Population Estimation India 2017.pdf. Accessed on 5 January 2020.

Naha, D., S. Sathyakumar, S.K. Dash, A. Chettri & G.S. Rawat (2019). Assessment and prediction of spatial patterns of human-elephant conflicts in changing land cover scenarios of a human-dominated landscape in North Bengal. PLoS ONE 14(2): 1–19. https://doi.org/10.1371/journal.pone.0210580

Naha, D., S.K. Dash, A. Chettri,A. Roy & S. Sathyakumar (2020). Elephants in the neighborhood: patterns of crop-raiding by Asian Elephants within a fragmented landscape of Eastern India. *PeerJ* 8: e9399. https://doi.org/10.7717/peerj.9399

Palkopoulou, E., M. Lipson, S. Mallick, S. Nielsen, N. Rohland & S. Baleka (2018). A comprehensive genomic history of extinct and living elephants. *Proceedings of the Natural Academy of Sciences* 115(11): E2566–E2574. https://doi.org/10.1073/pnas.1720554115

Pokharel, S.S. & N. Sharma (2022). Viewing the rare through public lenses: insights into dead calf carrying and other thanatological responses in Asian Elephants using YouTube videos. *Royal Society Open Science* 9: 211740. https://doi.org/10.1098/rsos.211740

Roy, A., S.K. Dash & S. Sathyakumar (2022). A combination of cultural values and economic benefits promote tolerance towards large mammals in a hotspot of human-wildlife conflicts in eastern India. *Human Ecology* 50(2): 321–329. https://doi.org/10.1007/s10745-022-00306-8

Roy, M. & R. Sukumar (2015). Elephant Corridors in Northern West Bengal. *Gajah* 43: 26–35

Rutherford, L. & L.E. Murray (2020). Personality and behavioral changes in Asian Elephants (*Elephas maximus*) following the death of herd members. *Intergrative Zoology* 16(2): 170–188. https://doi.org/10.1111/1749-4877.12476

Sharma, N., S. Sharma, P. Shiro & K. Raman (2019). Behavioural responses of free-ranging Asian Elephants (*Elephas maximus*) towards dying and dead conspecifics. *Primates* 61: 129–138. https://doi.org/10.1007/s10329-019-00739-8

Sih, A., M.C.O. Ferrari & D.J. Harris (2011). Evolution and behavioural responses to human-induced rapid environmental change. *Evolutionary Applications* 4(2): 367–387. https://doi.org/10.1111/j.1752-4571.2010.00166.x

Stephan, C., J.J.D. Bahamboula & T.M. Brncic (2020). Responses to a poached conspecific in wild forest elephants (*Loxodonta africana cyclotis*). *Behaviour* 157: 823–833. https://doi.org/10.1163/1568539X-bja10025

Sukumar, R. (1989). Ecology of the Asian elephant in southern India. I. movement and habitat utilization patterns. *Journal of Tropical Ecology* 5(1): 1–18. https://doi.org/10.1017/S0266467400003175

Sukumar, R. (2006). A brief review of the status, distribution and biology of wild Asian Elephants *Elephas maximus*. *International Zoo Yearbook* 40(1): 1–8. https://doi.org/10.1111/j.1748-1090.2006.00001.x

Watson, C.F.I. & T. Matsuzawa (2018). Behaviour of nonhuman primate mothers toward their dead infants: Uncovering mechanisms. *Philosophical Transactions of the Royal Society B: Biological Sciences* 373(20170261): 1–11. https://doi.org/10.1098/rstb.2017.0261

Watts, D.P. (2019). Responses to dead and dying conspecifics and heterospecifics by wild mountain gorillas (*Gorilla beringei beringei*) and chimpanzees *(Pan troglodytes schweinfurthii*). *Primates* 61: 55–68. https://doi.org/10.1007/s10329-019-00735-y

Xaxa, V. (2001). Protective discrimination: why scheduled tribes lag behind scheduled castes. *Economic & Political Weekly* 36(29): 1624–1626.

Young, J., C. Richards, A. Fischer, L. Halada, T. Kull, A. Kuzniar, U. Tartes, Y. Uzunov & A. Watt (2007). Conflicts between biodiversity conservation and human activities in the central and eastern European countries. *Ambio* 36(7): 545–550. https://doi.org/10.1579/0044-7447(2007)36[545:CBBCAH]2.0.CO;2

Post Mortem Examination Report

Reference: Divisional Forest Officer, Gorumara Wildlife Division, Jalpaiguri, vide letter no. 3329/26-3/2022, Dated 12.09.2022 (Initial verbal contact by the Range Officer, Wildlife Squad III Binnaguri on 12.09.2022 morning for attending the post mortem examination).

History of the case: Carcass of one elephant calf was found and rescued from Devpara T. G. section no. 30, wildlife squad 3, Binnaguri by the R. O. Wildlife squad, Binnaguri. The carcass was found buried partially at dorsal recumbancy and according to the circumstantial evidences it appears that a herd of elephant was present there and they had partially buried the carcass inside the mud.

Description of the Animal: a) *Species: Elephas maximus*
b) *Sex:* F c) *Age:*1 yr (approx..) *d) Colour:* Greye) *Pole to tail base:*1.48 m*f) Tail length:* 0.56 mt
g) *Shoulder Height:*1.26 mt h) *Chest girth:*1.56mt i) *Neck girth:*1.08mt
j)*Trunk:*0.70mt k)*Right fore limb foot circumference:0.53 mt*

Date and Time of Detection: 12.09.2022; 11:00am approx.

Date and Time of Post Mortem: 12.09.2022; 4:00 pm onwards.

Place of Post Mortem: Bamni Camp of Gorumara beat under Gorumara south range, Gorumara national Park [N-26°49'48.0" E-088°01'46.7"]

Necropsied by:1.Dr. Sutrishna Basu, V.O., BAHC, Matiali,Jalpaiguri. 2.Dr. Satyaki Chakraborty, V.O., ABAHC, Maynaguri, Jalpaiguri.

External Examination of the Carcass:

Rigor Mortis: Partially Present **Nutritional Status:** poor

Skin: Shrunken

Eyes: Closed & opaque **Ears:**NAD **Visible Mucous Membrane:** Pale

Internal Examination:

Mouth:NAD

Subcutaneous Tissue: Wide haemorrhages found at the top of the back.

Thoracic Cavity:

Pleura: Congested **Trachea and bronchi:** NAD **Lungs:**Congested

Heart: Blood filled along with Hydropericardium

Oesophagus: NAD **Diaphragm: NAD**

Abdominal Cavity:

Peritoneum: NAD **Liver: Pale**

Spleen: Pale

Stomach: Filled with undigested feed material **Intestine: Haemorrhagic Catarrhal Enteritis**

Large Intestine &Caecum: Ulcerative foci present **Rectum: Inflammed**

Urinary Organs:

Bladder: Empty **Kidneys:** Mild Congestion

Genital Organs:

Major Findings: Large petechial haemorrhagic lesions found at the dorsal surface of the entire vertebral region.

Materials Collected for Laboratory Examination: ELE/9/1- Portion of Lung, Liver, heart, kidney & spleen in Absolute alcohol for forensic studies.**ELE/9/2-** Portion of Lung, Liver, heart, kidney & spleen in 10% formalin for histopathology.

Conclusion: According to the history and PM findings we can conclude that the above said Elehant calf was dead due to cardio-respiratory failure as a consequence of acute catarrhal enteritis.

V.O., ABAHC
Maynaguri, Jalpaiguri

V.O., BAHC
Matiali, Jalpaiguri

Post Mortem Examination Report

Name and address of sender: Divisional Forest Officer, Gorumara Wildlife Division, Jalpaiguri, vide letter NO: 4040/26-3/2018, Dated: 17/11/2022.

1) Description of animal:

a) **Species**: Asiatic Elephant
b) **Scientific Name**: *Elephas maximus*
c) Wild calf
d) **Sex**: female.
e) **Age**: 1 month approx.
f) **Body Length: Pole to tail base**= 1.22mts.
g) **Tail length**: 0.46 mt.
h) **Chest Girth**: 1.27 mts.
i) **Neck Girth**: 0.79 mt.
j) **Shoulder height**: 0.96 mts.
k) **Pole to Trunk tip length**: 0.57 mt.
l) **Right forefoot circumference**- 0.44mt.

2) **Date and time of detection:** on 17.11.2022 at about 10.20 am. (as reported by the forest personnel).

3) **Date and time of post-mortem:** on 17.11.2022 ,3.00 pm onwards.

4) **Place where animal was detected dead:** Section No- 39 B of Chunabhati Tea Garden under the jurisdiction of the wildlife Squad, Binnaguri of Gorumara Wildlife Division. (26°51'37.5"N, 89°04'21.00"E)

5) **Date and Time of Death:** approximately before 12-14 hours of Postmortem examination.

6) **Place of post-mortem:** Selka-II Compt, Khunia Beat, Gorumara North Range, Gorumara Wildlife Division.

7) **Necropsied By:** 1. Dr. Shweta Mandal, VO, BAHC, Mal service utilized at GNP .Post mortem was conducted in presence of ADFO, Gorumara Wildlife Division and other officials of Forest Department.

8) **Case History:** As reported by the Range Officer, Binnaguri WLS,Gorumara Wildlife Division on 17.11.2022 the carcass of a wild elephant calf was detected about 10.20 am(approx time) stuck inside the drain at Section No- 39 B of Chunabhati Tea garden by the patrolling staff of Binnaguri Wildlife Squad. The elephant calf was found tucked in a drain of the teagarden in dorsal recumbency with head & back totally buried inside the drain and all the four limbs extended upright. The carcass was later on shifted to the Khunia Beat ,Gorumara North Range for post mortem examination.

9) **Rigor Mortis**: passed away.

10) **Eyes:** congested conjunctiva, eyelids swollen.

11) **Ears:** blood tinged fluid coming out of the nostrils.

12) **Other natural orifices:** visible mucous membrane congested.

13) **Other Findings:** The carcass was stuck inside the drain in an abnormal recumbency with its head and back part pressed down inside the drain tightly packed with mud but the hind limbs and forelimbs out of the drain facing upwards. Foot marks of other elephants were noticed in and around the body of the dead calf. There was a bulging of mass in the ventral aspect of the abdomen adjacent to the naval area and a linear scar tissue noticed in the skin over that area.

14) Post Mortem findings:

a) ***Mouth***: mucous membrane of the mouth congested, tongue soiled with mud and protruded.

b) ***Nasal cavity***: congested.

BUXA TIGER RESERVE
(VETERINARY UNIT)
POST MORTEM REPORT OF WILD ANIMA

Case no. 18 /Vety/PM of 2022-23 Date: 20.08.22

Species	**Asian Elephant** *(Elephas maximus)*	Case Referred by	DFD, BTR (West)
		Case No.	18/Vety/BTR dated 20.08.22
Age	10 month(approx)	Vide Letter No.	Telephonic communication
Sex	Male	Locality	Vernabari tea Garden, Hemiltanganj Range, BTR (W) Div.
GPS Location at place of Death & place of necropsy (if different)	GPS location at place of death: Lat- 26.764752, Long-89.361850 PM was done at 25 miles Tower. GPS Location N26°39'37" & E89°33'15"		
Captive/Wild	Wild	Habitat	Forest of BTR
Weight	30 quintal (approx)	Weather	Sunny
Ambient Temperature	34°C	Date & Time of death	18-20 hours before P.M
		Date & Time of PM examination	20.08.22 at 1 pm onwards at broad daylight

I. HISTORY OF DEATH/ OUTBREAK

1.History	The carcass was found partially buried with fore & hind leg at upward direction.
2.Clinical Signs before death	unknown
3.Surrounding the carcass	Foot prints of elephant found surround the carcass and over the mud covering the body. Total body including head, trunk tail was found buried except four limb.
4. Other information	Body of the carcass found intact.

II. EXTERNAL EXAMINATION

Body condition index: Total Body Length : 134 cm Chest Girth : 150 cm Neck girth-99cm Tail : 61 cm Height : 97 cm Trunk : 71 cm **Tusk Details : NA** **Right Tusk Details :** 1. Convex Length : 2. Concave Length : 3. Base circumference : 4. Solid Base circumference : 5. Weight : **Left Tusk Details :** 1 Convex Length : 2 Concave Length : 3 Base circumference :	Presence of wound	Contusions present over the body.
	Number of entry wounds	Does no arise
	Description of entry wounds	
	Number of exit wounds	No

File No. 8/57 2020 WL

Memo No. 445/ED-23 Dated, Damanpur, the 30/10/2022

Annexure

Format for Reporting of Death of the Schedule -I and / or Part - II, Schedule - II Listed Species

1	Name of the Species	Indian Elephant
	a) Common Name	Elephant
	b) Scientific Name	*Elephas maximus*
2	No. of Animals reported dead	1 (One)
	a) Male	Yes
	b) Female	NA
3	Location (Please specify details like area, District, within/outside Forest etc.)	Outside the Forest Area, Majherdabri Tea Estate, Section No. - 13 adjacent to NH-31C near kalkut Basty, Cheko Beat, East Damanpur Range, Damanpur, Kalchini, District: Alipurduar. (GPS Location: 26.544368°N, 89.557619°E)
4	Date of Death / Reporting	27/10/2022 & 29/10/2022
5	Probable reasons for death	Asphyxia.
6	Details of Person who reported the incident first	Sri Sujit Kumar Barma, FR, Range Officer, East Damanpur Range
7	Action taken at the Field Level	Reported to the Deputy Field Director, Buxa Tiger Reserve (West)
8	Whether postmortem conducted or not, If yes, details.	Postmortem conducted by Dr. Liton Paul, VO, BTR in presence of Dr. Krishna Mohan, VO, Vulture Conservation Centre, Rajabhatkhawa, Dr. Nabi Kanta Jha, WBFS, ADFO, BTRW, Sri Sujit Kumar Barma, FR, RO/EDPO Range. Body Measurement was taken. After a thorough checking of the Carcass, Body was opened and Samples taken by Veterinary Doctors and burnt as instructed by the Veterinary Doctors.
9	Peliminary findings	Stumbled inside the trench of the Tea Garden and run over by a herd of the Elephants and died due to Asphyxia.
10	FIR lodged, if any (Details)	NA.
11	Details of missing body parts, if any	No.
12	Any other related information	NA

Name: Sri Sujit Kumar Barma

Designation: Forest Ranger

Signature Date: 29/10/2022

POST MORTEM REPORT OF WILD ANIMAL

Case no. Vety/PM

Date: 26.10.2023

Species	Elephant *(Elephas maximus)*	Case Referred by	DFO, Gorumara Wildlife Division
Age	3-4 months(Approx)	Vide Letter No.	Letter no -5033/26-3/2023,dt. 26.10.23 of DFO, Gorumara Wildlife Division
Sex	female	Locality	Carcass detected in one of the drains in between Section 58 and 59 inside New Dooars Tea Garden.
GPS Location at place of Death & place of necropsy (if different)	Location where the animal was found dead.(**N 26°50´30.2´´E 089°02´56´´**) Post Mortem was conducted in forest areas of Selka-I Compt,Khunia Beat, GNR.		
Captive/Wild	Wild	Date & Time of Death or found dead	Detected on 26.10.2023 at about 09.30 am. Death appeared to have occurred approximately 10-12 hours prior to post mortem examination time.
Ambient Temperature	33° C		
Habitat	Forests		
Weather	sunny		
Weight	Not taken	Date and time of PM Examination	26.10.2023 2.0 pm onwards

I HISTORY OF DEATH/OUTBREAK

1.Brief History	As per history of the Forest Officials on 26.10.2023 at about 09.30 am. carcass of a wild elephant calf was detected by the patrolling staff of Binnaguri WLS inside the New Dooars Tea Garden in one of the drains in between Section 58 and 59 The carcass was found lying in dorsal recumbency with trunk, mouth and the dorsal part of the body except the four limbs buried inside the drain. The carcass was lifted from the spot of detection and shifted to Selka-I Compatrment of Khunia Beat,Gorumara North Range. Post mortem was conducted from 2.00 pm onwards.
2.Clinical Signs before death	Not seen
3.Observation of the Surroundings of the carcass	The carcass was buried inside the drain which was approximately 0.95 mt deep and 0.50 mt wide except in that region where the calf was lying. That area appeared to be filled freshly with mud and the edges of the drain were distorted and widened and the nearby ground messed with mud. It was found in an abnormal recumbency with its entire back, head, trunk, neck and body pressed down inside the drain tightly packed with mud but all the four limbs and a portion of the ventral aspect of the abdomen out of the drain facing upwards. There was a bulging of mass in the ventral aspect of the abdomen adjacent to the naval area and a linear scar tissue noticed in the skin over that area.
4.Other relevant information	Foot marks of other elephants were noticed in and around the body of the dead calf.

II.EXTERNAL EXAMINATION

Body Condition Index Body physical parameter measured as mentioned-	Presence of Wound	No external injury seen
	Number of entry wound	_____
	Description of entry wounds	_____

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 February 2024 | 16(2): 24630–24645

ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

https://doi.org/10.11609/jott.8736.16.2.24630-24645

#8736 | Received 08 September 2023 | Final received 22 January 2024 | Finally accepted 05 February 2024

OPEN ACCESS

ARTICLE

Coexistence of Indian Pangolin *Manis crassicaudata* (Geoffroy, 1803) (Mammalia: Pholidota: Manidae) and Indian Crested Porcupine *Hystrix indica* (Kerr, 1792) (Mammalia: Rodentia: Hystricidae) in Purulia District, West Bengal, India

Debosmita Sikdar [1], Shwetadri Bhandari [2] & Sanjay Paira [3]

[1] Presidency University, 86/1 College Street, Kolkata, West Bengal 700073, India.
[2,3] Sarisha Wildlife and Ecology Society (WNE), Sarisha, Nabasan Road, Diamond Harbour, 24 PGS (S), West Bengal 743368, India.
[1] Present address: Aswini Plaza, Sarat Sarani, near Bandel Church, Post and District- Hooghly, West Bengal 712103, India.
[1] debosmitasikdar18@gmail.com (corresponding author), [2] wildlifenecology2014@gmail.com, [3] sanjaypaira9933@gmail.com

Abstract: The Indian Pangolin *Manis crassicaudata* and the Indian Crested Porcupine *Hystrix indica* are subject to extensive poaching in Purulia District (West Bengal, India), diminishing their populations, and making the study difficult. Applying methodologies that include local sightings, field observations, camera trapping, and quadrate analysis, these species were observed to co-occur in rocky cavities in Ajodhya hills at several locations. Evidence for this included fresh pangolin tail drag marks, claw prints, footprints, scales, porcupine quills, teeth marks, and faecal matter in the same locations within the study area. Quadrate analysis showed that the trees housing the target prey species of the Indian Pangolin as well as the trees bearing fruits favoured by the Indian Crested Porcupine, occurred at maximum frequency within the Quadrate area. We hypothesise that pangolins and porcupines co-occupy rocky cavities for protection from poachers, who can easily break into more typical burrows and set traps in front of them. This may be an example of adaption to poaching, which demonstrates the necessity of conservation measures to alleviate severe anthropogenic pressure.

Keywords: Ajodhya hills, camera trapping, co-inhabitation, diurnal surveys, perception study, poaching, quadrate analysis, rocky cavity.

Editor: S.S. Talmale, Zoological Survey of India, Pune, India.

Date of publication: 26 February 2024 (online & print)

Citation: Sikdar, D., S. Bhandari & S. Paira (2024). Coexistence of Indian Pangolin *Manis crassicaudata* (Geoffroy, 1803) (Mammalia: Pholidota: Manidae) and Indian Crested Porcupine *Hystrix indica* (Kerr, 1792) (Mammalia: Rodentia: Hystricidae) in Purulia District, West Bengal, India. *Journal of Threatened Taxa* 16(2): 24630–24645. https://doi.org/10.11609/jott.8736.16.2.24630-24645

Funding: The project was approved and funded by the Government of West Bengal, Directorate of Forests, Office of the Divisional Forest Officer, Purulia Division [Approval letter no. 2552/26-1(WL)] and the Sarisha Wildlife and Ecology Society (WNE) India.

Competing interests: The authors declare no competing interests.

Author details: Debosmita Sikdar is presently a student at Presidency University, Kolkata. Is a JNCASR (Jawaharlal Nehru Centre for Advanced Scientific Research) summer research fellow, 2023. Worked on understanding alarm behaviour in *Etroplus suratensis* (a cichlid). Worked as project intern at WNE-India, on Sloth Bear and Pangolin conservation. Also, is currently working on understanding the change in sea snake distribution due to global warming, at the Marine Ecology Laboratory, Presidency University, Kolkata. Shwetadri Bhandari is the founder and president of the Sarisha Wildlife and Ecology Society (WNE), India. Presently working on Pangolin conservation with the funding support from CWS (Centre for Wildlife Studies) and Elephant conservation with forest department and funding support from WTI (Wildlife Trust Of India). Sanjay Paira works as a wildlife biologist at Sarisha Wildlife and Ecology Society (WNE), India. He is a specialist in herpetofauna.

Author contributions: DS—Formal analysis, software, data curation, writing-original draft, writing-review & editing, visualization. SB—Conceptualization, Methodology, validation, resources, supervision, funding acquisition, writing-review & editing. SP—Investigation, resources, project administration, supervision.

Acknowledgements: The authors profoundly acknowledge their gratefulness to the Forest Department of Purulia District, West Bengal, India, for provision of all permits and logistics for conducting the survey. We also extend our gratitude to the Local community of the Mohultarn village for their cooperation during the community interviews, the members of the Sarisha Wildlife and Ecology Society (WNE-India) and the teammates at the fieldwork, for their unwavering enthusiasm and supportive attitude.

INTRODUCTION

Indian pangolins and porcupines have not been extensively studied due to their shyness, nocturnal habits, affinity for inhabiting inaccessible places, and difficulty of spotting them in the wild (Saltz & Alkon 1989; Karawita et al. 2018). Current studies of pangolin conservation come from South Africa (Heath & Coulson 1997; Shepherd et al. 2017). Our study concentrated on the Ajodhya Hills, Purulia, West Bengal, India where Indian Pangolins *Manis crassicaudata* and Indian Crested Porcupines *Hystrix indica* are known to be present as well as poached, with the goal of providing insights into how these species interact and adapt to excessive poaching.

The Indian Pangolin has been assessed as 'Endangered' according to the IUCN Red List of Threatened Species (Mahmood et al. 2019). It has also been listed in the Appendix I of the CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) and a Schedule I species under the Wildlife (Protection) Amendment Act, 2022, to safeguard it from the extensive poaching.

The Indian Crested Porcupine has been accessed as 'Least Concern' on the IUCN Red List (Amori et al. 2021), and is protected under the Schedule I of the Wildlife (Protection) Amendment Act, 2022 to illegalize its poaching.

Description

As the species name *crassicaudata* suggests, the Indian Pangolin is characterized with a prehensile thick (crassus) tail (cauda), with adults weighing up to 16 kg and having a length of approximately 148 cm (Mahmood et al. 2019). Sharp keratinous scales cover the dorsal and lateral surfaces of its body, both dorsal & ventral surfaces of the tail, and over the limbs. It has 11–13 rows of overlapping scales round the mid body with a terminal scale on its ventral side of tail (Mohapatra & Panda 2014). It has curved claws in its forelimbs which are used to dig into termite mounds and ant nests, following which the ants and termites are licked up by its long, sticky saliva-coated tongue. When threatened, it either flees or curls up into a tight ball, depending entirely on its scales, for protection (Chao et al. 2019).

The Indian Crested Porcupine weighs approximately 11–18 kg (Prater 2005) and has a body length of 70–90 cm (Prater 2005). Its body is covered with two types of keratinous quills—a longer and slender type which masks the shorter and thicker ones underneath. When threatened, it raises its quills with the help of a muscle attached to the base of its quills and tries to scare away the threat. It has long claws for digging, sharp incisors, and a keen sense of smell.

Distribution

According to Mohapatra et al. (2015), the Indian Pangolin is found in southern Asia from northern and southeastern Pakistan throughout the Indian subcontinent south of the Himalaya, to northeastern India and Sri Lanka. In India, it is distributed across states like Andhra Pradesh, Bihar, Chhattisgarh, Delhi, Gujarat, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Odisha, Rajasthan, Tamil Nadu, Uttarakhand, Uttar Pradesh, and West Bengal and has also been reported to be present in Bangladesh, Pakistan, Nepal, and Sri Lanka.

The Indian Crested Porcupine is found in most countries of southwestern, southern and central Asia, including Afghanistan, Armenia, China, Georgia, India, Iran, Iraq, Israel, Lebanon, Nepal, Pakistan, Saudi Arabia, Sri Lanka, Turkey, and Yemen.

Habitat and Diet

The Indian Pangolin is mainly fossorial and is known to excavate burrows in the soil, as well as inhabit crevices of boulders (Mahmood et al. 2019). There are two types of burrows: the resting burrow, where it rests during the day, and the feeding burrow, which it digs to uncover prey (Karawita et al. 2018). The most preferred dietary choices of the Indian Pangolin are the red ants and the termites (Supplemental Images 1A, 1B, 1C, 1D), which are found within its habitat (Karawita et al. 2018; Mahmood et al. 2019).

The Indian Crested Porcupine is semi fossorial and digs burrows or lives in rocky caves. However, it is not an expert climber and spends most of its lifetime on or under the ground. It can be found in rocky hillsides, forests, grasslands, and even agricultural fields where it goes for eating potatoes (Saltz & Alkon 1989), fruits, tubers, roots, etc. Its habitat choice is dependent on the presence of abundant food resources (like fruit trees) and rocky cavities or proper substrate to make the digging of burrows practically possible (Saltz & Alkon 1989).

Behaviour

The Indian Pangolin sleeps in burrows during the daytime and forages at night (Karawita et al. 2018). A study conducted on Indian Pangolins in captivity at the Nandankanan Zoo, India, revealed that they show peak activity between 2000 h and 2100 h (Mahmood et al. 2019). It is also arboreal and can climb trees using its

forelimbs, hindlimbs, and the prehensile tail which acts as an 'extra limb' (Mahmood et al. 2019). It is myrmecophagous (Beca et al. 2022) and termitophagous (Chao et al. 2019) and known to prefer the ant species *Camponotus confucii*, *C. compressus*, and termite species *Odontotermis obesus*, as shown by a study conducted in the Potohar Plateau, Pakistan (Mahmood et al. 2013).

The Indian Crested Porcupine has been found to feed preferably on underground bulbs, such as potatoes (Saltz & Alkon 1989), and fallen fruits from trees and is considered a 'generalist herbivore'. It has been found to consume a greater variety of food items in the summer season, compared to that in the winter season; the reason can be attributed to the fact that it shows greater activity in summer than in winter (Corsini et al. 1995) thus exploring more area from the burrow for foraging in the summer, hence the diversification in its diet (Akram et al. 2017). Its activity radius was found to be greater in the late summer (when forest is already enriched with nutrient sources) than in the early summer (when nutrient sources become available initially) (Saltz & Alkon 1989). Therefore, it can be predicted that higher the concentration of food resources in an area or near the living burrow, the greater the preference of the porcupine to inhabit there, to get a variety of food sources. It is known to remain in proximity to its burrow during the brightly moonlit nights (to avoid predators) and its habitation is closely linked with the 'forage availability'. It leaves its burrow shortly before sunset and returns only at sunrise (Corsini et al. 1995).

MATERIALS AND METHODS

Study area

The current study was conducted in the Gajaburu Hills (Supplemental Image 2) near Mohultarn Village in the Sirkabad Beat, Arsha Range of the Purulia Division Forest Department, West Bengal, India. The global positioning system (GPS) coordinates of the place are 23.24^0 N, 86.22^0 E. Six sites were selected within the study area as the focal sites.

Study design

The study was conducted from November 2022–April 2023. These months were chosen for the study so that the behaviour of the target animals could be monitored in the duration of winter season, as well as partly in the summer season, for preventing any bias of the behaviour towards a particular season. The first requirement was identification of potential sampling sites, which was accomplished with the help of perception study of local people and rigorous field surveys in November 2022. Quadrate analysis was added as a part of the study to further validate if the chosen sampling sites could support the co-existence of the pangolin and the porcupine. The data was collected by taking photographs of animal prints and by collecting quills, faecal matter, and scales.

Community interviews and Perception study

Community interviews are one of the most cost-effective methods to determine pangolin and porcupine distribution in regions where their population has declined overtime and to further access their current population status. Most surveys that used this method, reported successful recognition of target species by the locals who were interviewed (Willcox et al. 2019). The locals in Purulia recognize the Indian Pangolin as 'Soorjomukhi' and they could easily identify and describe it. We interviewed local hunters and local people living in the Mohultarn village to study their perception, which helped us in identification of the priority sites for pangolin and porcupine burrow distribution and how to distinguish these burrows from those of other burrowing animals present in the associated habitats. However, for the validation of the statements made by the local people, we cross checked the information provided by the locals with the available scientific records and observations mentioned in the existing scientific literature.

Diurnal field surveys

The field surveys were conducted for a period of six months, from November 2022–April 2023. In November 2022, field surveys were undertaken once each week (four times). Following this, field surveys were conducted twice each month for the rest of the five months from December 2022–April 2023 (10 times). Each in-person field survey was limited to four to five hours (with recesses) at a time, to prevent manual error in data collection due to fatigue. The frequency of field surveys was reduced from four in November 2022 to two in the rest of the months because the initial time-consuming process of identifying the potential sampling sites within the study area was completed in November 2022. Accordingly, six potential sites were identified within the study area. In total, 14 field surveys were conducted during the whole study period.

The site selection criteria included the detection of recent claw marks, tail drag marks, footprints, faecal samples (dung), quills, bite marks, feeding signs (broken

ant nests and termite mounds), scratch marks, and burrows of our target animals (Indian Pangolin and Indian Crested Porcupine). To determine if the burrows had been occupied most recently, we checked for the absence of leaves and cobwebs (Willcox et al. 2019) and by looking for the presence of fresh soil or fresh activity signs of the pangolin and porcupine near the burrow entrance (Waseem et al. 2020).

In November 2022, the field surveys were conducted randomly (to prevent bias) on a day of each week, with a minimum of seven days gap before the next survey, to remove the effects of any human interference. During December 2022–April 2023, the surveys were focussed on collection of data from already identified sites, setting of camera traps and performing quadrate analysis. These surveys were undertaken with a gap of approximately 14 days between each survey. For example, if the first survey in December was performed on the Friday of the first week of December, the second survey in December was performed on the Friday of the third week of December. Following this, the next survey was conducted on the Friday of the first week in January 2023, and again on the Friday of the third week in January 2023.

The surveyors who comprised of seven trained individuals and two experienced local villagers (employed as para-biologists (Karawita et al. 2018) to guide us to the actual field sites (during the daytime)) were divided into three groups: Group A—two trained individuals and a local villager; Group B—two other trained individuals and the other local villager; Group C—three trained individuals. Each group was placed in-charge of two sampling sites (six in total).

Camera trapping

Once the potential habitats and feeding signs of the pangolin and the porcupine were detected, camera traps (Cuddeback X-Change™ Color model 1279) (Supplemental Image 3) were set at those selected sampling sites (six in number) targeting the entrance of resting burrows, feeding burrows, termite mounds, ant nests, edge of a rivulet, and in places where fresh bites and feeding signs were observed. Installation of camera traps was done separately and following a routine which was different with respect to the capturing of photographs of animal signs using the Nikon D3400 camera (Refer to 'Data collection and capturing photographs' of materials and methods section).

The six selected sampling sites where field surveys were conducted, were also chosen as the six camera trap stations. The exact GPS coordinates (taken using GPS Map Camera Application in Xiaomi Redmi Note 8) of these six stations were noted as follows:

Site 1: 23.23^0 N 86.27^0 E, Site 2: 23.20^0 N 86.28^0 E, Site 3: 23.22^0 N 86.26^0 E, Site 4: 23.25^0 N 86.24^0 E, Site 5: 23.24^0 N 86.27^0 E, Site 6: 23.21^0 N 86.28^0 E.

Twelve camera traps were required during the entire study period. During the first four field surveys in November 2022, no camera traps were set. The first set of six camera traps were installed (during the day) on the Friday of the first week of December 2022 at the six different sampling sites (coordinates mentioned above) in the study area. The six camera traps remained in the field for a period of 14 days, following which those were removed from the six sampling sites on the Friday of the third week of December 2022. Then, as the first set of six camera traps were removed, the second set of another six camera traps were re-installed at the six sampling sites on the Friday of the third week of December 2022. The second set remained installed for 14 days, after which they were removed on the Friday of the first week of January 2023, and again the initial first set of six camera traps were re-installed on the same day. This process of installation and removal of camera traps were followed till the Friday of the third week of April 2023, resulting in 132 days of camera trap data. The timings of camera trap installation, removal and re-installation were strictly maintained between 1200 and 1400.

Quadrate method

Quadrate method (25 × 25 m) was used for vegetation analysis at the six selected sites where camera traps were set, in the study area.

The collection of quadrate data was first performed in the first week of November 2022. Following this, three technical replicates (data provided as supplementary material) of the quadrate data were obtained on three separate days— Friday of the first week of December 2022, Friday of the first week of February 2023, and Friday of the first week of April 2023, with a gap of one month between the technical replicates. This was done to monitor any change (if at all) of the vegetation cover at the sampling sites in the study area, during the study. Collection of quadrate data was part of the workflow of the diurnal field surveys conducted at the frequency as mentioned in the "diurnal field surveys" section.

Two sampling sites were placed under one group of team members (consisting of three members in each team). Each sampling site also corresponded to a quadrate area (25 × 25 m). Therefore, there were six quadrate areas, with each group responsible for taking quadrate data from two sites. For each quadrate area, three biological replicates (of the species of trees) were

counted on the same day, by the three team mates independently and separately, to prevent the possibility of bias in counting due to influence of the result of counting obtained by one teammate over the others.

For the data collection of quadrate analysis, the type of trees and number of each type of tree was noted down, from six quadrate areas, considered in the six sites within the study area. Three technical replications of the data collection were done at each of the six sites, thus resulting in 18 datasets (refer to supplementary material) for each type of tree.

Data collection and capturing photographs

Data collection was done from six selected sites within the study area and included the capturing of photographs (Image 1A) (using Nikon D3400 digital camera) of rocky burrows, termite mounds, ant nests, feeding signs, fresh prints of body parts on ground, and trees within the quadrate areas. Also, faecal matter and detached body parts such as quills (of Indian Crested Porcupine) and scales (of Indian Pangolin) (Images 1B,C) were collected.

Data collection and capturing of photographs was conducted on all six sampling sites, during every diurnal field survey. Data was collected during one random day in each week in November 2022, with a gap of minimum seven days (four data collections in November); followed by data collection in the Friday of the first week of December 2022, then in the Friday of the third week of December 2022, then in the Friday of the first week of January 2023, followed by the Friday of the third week of January 2023, and so on, till April 2023. Therefore, data collections were done twice each month from December 2022–April 2023 (10 times), accounting for total 14 data collection rounds.

Data analysis

The statistical analysis of the data obtained through

Image 1. Indian Pangolin and its scales found in study area: A—Individual detected in one of the six sampling sites in our study area | B—ventral surface of a scale found detached from the body | C—dorsal surface of the scale found detached from the body. © Shwetadri Bhandari.

quadrate method was performed using Microsoft Excel and R version 4.3.0.

The Mean ± SEM values of the number of trees commonly occurring within the quadrates, were used for plotting the graph. The commonly occurring trees were further divided into two groups:

1) The Favoured group—trees favoured by Indian Pangolin and Indian Crested Porcupine within the quadrate areas, and

2) The Unfavoured group—trees unfavoured by Indian Pangolin and Indian Crested Porcupine, within the quadrate areas.

Ethical considerations

The project was undertaken and executed only after the provision of required permits for the fieldwork, by the Forest Department of West Bengal, Purulia Division (Approval letter number: 2552/26-1(WL); date of approval: 06/09/2022). The surveys were carried out by following all the instructions of the forest rangers. The two villagers (anonymised for the sake of research integrity) were involved in the surveys as para-biologists, only after informing them thoroughly about our survey goals, in their colloquial language, without using scientific jargons, and only when they voluntarily consented for contribution in the study. Absolute care was taken to maintain silence during the surveys and to leave the areas without any major changes after the surveys.

The data collection was non-invasive, involving perception study, surveys, camera trapping, quadrate analysis, and collection of faecal matter. Additionally, since the Indian Pangolin and the Indian Crested Porcupine are nocturnal and exhibit movements in their habitats at night, the in-person data collection and surveys were done during the day. Camera traps were hidden out of view of the animals and set in such a way, to prevent any interaction of the camera traps with any animals. Certain body parts like quills (of the Indian Crested Porcupine) and scales (of the Indian Pangolin) were collected only when those were left on the ground after their natural detachment from the animal bodies.

RESULTS

Signs of pangolin and porcupine presence

Rocky cavities were detected at multiple locations in the Gajaburu hills, where the evidence of the Indian Pangolin and the Indian Crested Porcupine sharing their living space were detected. However, we have depicted the evidence observed at only one rocky cavity (henceforth called 'focal rocky cavity') in the Results section because results captured by camera at this site had maximum clarity. At sites other than the six focal sites, the rocky cavities were at such an angle of the terrain, that although the evidence was visible, photographing those up close was not logistically possible, without hampering the evidence.

In Image 2A, the focal rocky cavity is clearly visible, with the fresh and recent tail drag marks, footprints, and claw prints (the magnified views of these have been shown in Images 2B,C, respectively of the Indian Pangolin, in the sandy soil layer at the entrance of the focal rocky cavity. Interestingly, further inwards from the sandy soil layer, towards the focal rocky cavity, the detached quills of the Indian Crested Porcupine (Image 2D) were also detected. Additionally, a boulder was found approximately 2–3 m from the focal rocky cavity, on which we spotted fresh dung (faecal sample) of the Indian Crested Porcupine. This indicates recent co-usage of the same rocky cavity by both the Indian Pangolin and the Indian Crested Porcupine.

Habitat suitability

A Karam *Neolamarckia cadamba* tree was detected (Image 3A) within 5 m of the focal rocky cavity, where co-existential evidence of the Indian Pangolin and Indian Crested Porcupine was detected. The Karam tree was observed with a termite mound growing on the lower part of its trunk and red ants were spotted all over its trunk and branches. Another huge and well-developed termite mound was detected (Image 3B) approximately 7 m from the focal rocky cavity and 3 m from the Karam tree. It shows that this site with termite mounds and presence of red ants in proximity to the rocky cavity, is the preferred habitat for the Indian Pangolin, due to the abundant food sources nearby.

Numerous fallen Bael fruits were found already cracked open, and their inner contents eaten by the Indian Crested Porcupine (Image 4A). We further spotted the teeth (incisor) marks of the Indian Crested Porcupine (Image 4B) on a Bael *Aegle marmelos* fruit. The left-side teeth marking (marked in red towards left edge in Image 4B) possibly shows the porcupine having tried to drag its incisors across the hard outer covering of the fruit, thus trying to pry it open. The right-side teeth marking (marked in red towards right edge in Image 4B) possibly shows the porcupine having tried to get a firm hold of the fruit with its teeth, while trying to fracture the hard covering of the Bael fruit, to feed on the meat inside it. Again, this feeding evidence was detected near our focal

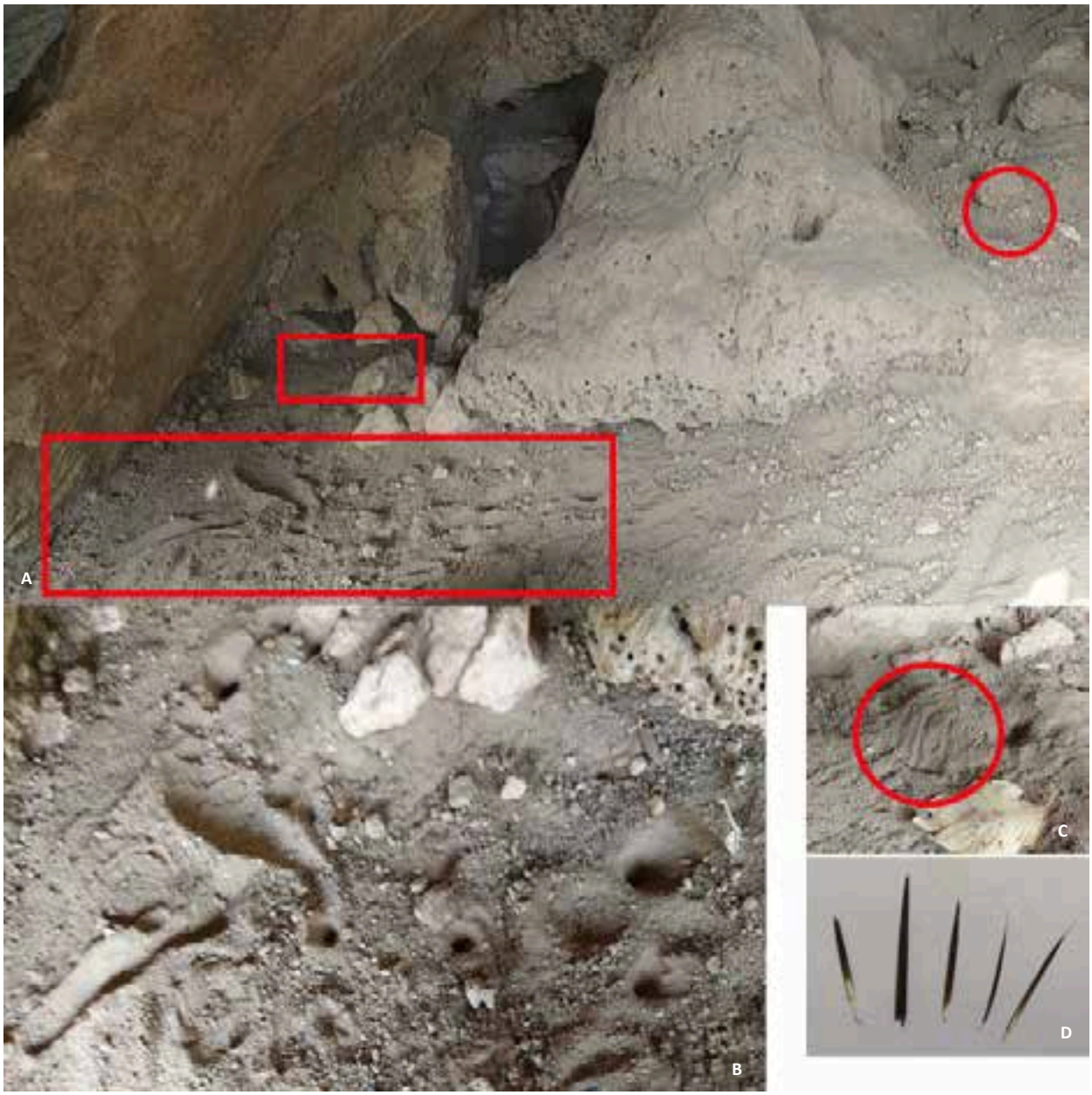


Image 2. Signs of pangolin and porcupine presence: A—focal rocky cavity with position of tail drag marks, footprints (bigger red rectangle) and claw prints (red circle) of Indian Pangolin, and detached quills (smaller red rectangle) of the Indian Crested Porcupine, at the entrance | B—magnified view of the entrance of focal rocky cavity with tail drag marks (towards left) and footprints (towards right) of the Indian Pangolin | C—magnified view of the entrance of focal rocky cavity with claw prints (shown in red circle) of the Indian Pangolin | D—detached quills of the Indian Crested Porcupine collected from the entrance of the focal rocky cavity. © Debosmita Sikdar.

rocky cavity, indicating that our considered site also has nutrient sources for the Indian Crested Porcupine, which therefore has an affinity to stay in this habitat, which is further proved by the presence of fresh dung of the Indian Crested Porcupine on a boulder (Image 4C) at that place.

Quadrate analysis

The results of all six quadrates were combined in a single table (Table 1) and graph (Figure 1) to visualize the relationship between the types of trees most commonly spotted in the quadrates (plotted on the x-axis) versus the total number of each type of tree counted in the quadrates (plotted on the y-axis) considered, where the focal rocky cavities were present, as well as camera traps

were set. Among the eight types of commonly occurring trees, there were four types of trees which occurred most frequently in the quadrate areas namely: Tendu *Diospyros melanoxylon*, Bael *Aegle marmelos*, Karam *Neolamarckia cadamba*, and Sisu *Dalbergia sissoo*. These four trees were grouped under 'the Favoured group' (Refer to 'Data analysis' sub-section under 'Methods' section). The remaining four trees namely: White Siris *Albizia procera*, Indian Plum or Kul *Ziziphus mauritiana*, Banyan *Ficus benghalensis*, and Palash *Butea monosperma* are grouped under 'the Unfavoured group' (Refer to 'Data analysis' sub-section under 'Methods' section).

Trees such as *Dalbergia sissoo*, which provide humid conditions in their roots for supporting the formation of ant nests and termite mounds, are often found within the habitat of the Indian Pangolin (Mahmood et al. 2013). Also, the Karam tree that was found in our focal site, bore termite mounds and red ants on it. Therefore, the presence of Karam and Sisu tree in our quadrates (containing the focal rocky cavity), favours the presence of the Indian Pangolin in the area.

Additionally, we observed that the Indian Crested Porcupine had fed on Bael fruits. Also, the Tendu tree produces sweet fruits, which local people often collect for eating. Although, we have not found evidence of the Indian Crested Porcupine having fed on Tendu fruits, yet scientific literature suggests that it prefers eating fruits, bulbs, tubers, and roots of plants, even potatoes from agricultural fields (Saltz & Alkon 1989). Therefore, the presence of Bael and Tendu trees in the quadrates (containing the focal rocky cavity), favours the presence of the Indian Crested Porcupine in the area.

Thus, the trees which housed the target prey species of the Indian Pangolin (red ants and termites) and the trees bearing fruits favoured by the Indian Crested Porcupine, occurred at maximum frequency within the quadrate area, which already contained the focal rocky cavity. This overlapping of favoured food sources of the pangolin and porcupine in the same area, is an indication that both the species may co-inhabit in the area, and occupy the same living burrow, as indicated

Table 1. Results of the quadrate analysis. The trees - *Diospyros melanoxylon, Aegle marmelos, Neolamarckia cadamba,* and *Dalbergia sissoo* - occurred at maximum frequency within the quadrate areas.

	Types of trees most commonly spotted in the quadrates	No. of trees of each type counted in the quadrates (Mean±SEM)
1.	White Siris *Albizia procera*	12±0.28
2.	Indian Plum or Kul *Ziziphus mauritiana*	15±0.63
3.	Banyan *Ficus benghalensis*	2±0.25
4.	Palash *Butea monosperma*	9±0.44
5.	Tendu *Diospyros melanoxylon*	29±0.78
6.	Bael *Aegle marmelos*	21±0.86
7.	Karam *Neolamarckia cadamba*	26±1.27
8.	Sisu *Dalbergia sissoo*	23±0.70

Image 3. Habitat suitability signs for the Indian Pangolin: A—Karam tree with termite mounds on its trunk, found near the focal rocky cavity within the quadrate area | B—termite mound observed near the focal rocky cavity within the quadrate area. © Debosmita Sikdar.

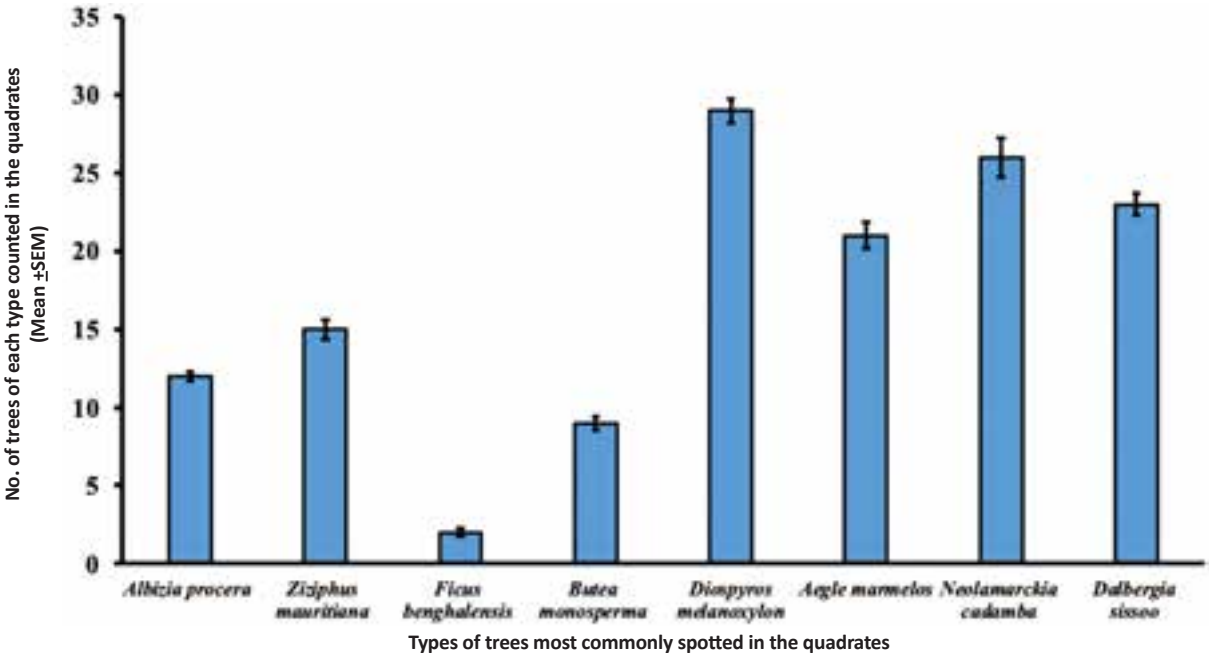


Figure 1. Graphical representation of result of quadrate analysis.
The two trees (*Neolamarckia cadamba* and *Dalbergia sissoo*) which housed the target prey species of the Indian Pangolin (red ants and termites) and the two trees (*Diospyros melanoxylon* and *Aegle marmelos*) which bear fruits favoured by the Indian Crested Porcupine, occurred at maximum frequency within the quadrate areas.

by the indirect evidence near the entrance of our focal rocky cavity.

Statistical analysis of quadrate data

The dataset for the Favoured group was analysed using R version 4.3.0 to check for normal distribution of the dataset, using the Shapiro-Wilk normality test. However, the original dataset did not show normal distribution (Shapiro-Wilk Normality test: W = 0.958, P = 0.016 as P <0.05; so, log transformation of the dataset was taken and then the dataset showed normal distribution (Shapiro-Wilk normality test: W = 0.972, P = 0.112) as P >0.05.

Similarly, the original dataset for the Unfavoured group did not show normal distribution (Shapiro-Wilk normality test: W = 0.938, P = 0.002) as P <0.05. Even the subsequent log transformations of the original dataset could not yield normal distribution of data (Shapiro-Wilk normality test: W = 0.796, P = 2.227e-08), and (Shapiro-Wilk normality test: W = 0.707, P = 1.902e-10) respectively, as P <0.05.

The datasets of the Favoured and Unfavoured groups were analysed using a non-parametric test called Wilcoxon signed-ranks test, by taking into consideration the original datasets of both groups. The null hypothesis was: There is no significant difference between number of trees of Favoured group and number of trees of Unfavoured groups in the quadrates considered at focal sites. The alternate hypothesis was: there is significant difference between number of trees of Favoured group and number of trees of Unfavoured groups in the quadrates considered at focal sites.

After running the analysis, the alternate hypothesis was accepted (Wilcoxon signed-ranks test: W = 100, P <2.200e-16) as P < 0.05. This indicates that at the quadrate areas, the trees which contain the food sources of both the Indian Pangolin and the Indian Crested Porcupine, are significantly different in number, with respect to those trees which do not contain food sources of both animals. Thus, the presence of trees of the Favoured group in an area facilitates the co-inhabitation of both animals and has significant potential for supporting the presence of both the Indian Pangolin and the Indian Crested Porcupine simultaneously, as evidenced by the data collected from our focal sites.

DISCUSSION

According to the report of the 2002 census of wild animals in southern West Bengal, conducted by the West Bengal Forest Department, only 42 pangolins were found in the Purulia district (Samanta et al. 2021). The possible reason for their scanty population is that the

Image 4. Existential evidence of Indian Crested Porcupine: A—*Aegle marmelos* fruits found near the focal rocky cavity, cracked open and inner contents fed by the Indian Crested Porcupine | B—*Aegle marmelos* fruit recovered near the focal rocky cavity with biting marks (made by incisors) of the Indian Crested Porcupine | C—dung of the Indian Crested Porcupine found on a boulder near the entrance of the focal rocky cavity. © Debosmita Sikdar.

Indian Pangolin is extensively hunted and poached for its meat (Hughes 2014), which is consumed locally and as a luxury food; and scales which are internationally traded (Mohapatra et al. 2015). The scales combined with other materials are used in traditional Chinese medicine, to promote blood circulation, stimulate lactation, reduce swelling, expel pus (Xu et al. 2016) and cure rheumatism (Hughes 2014).

The scales of an average adult Indian Pangolin weigh about 3.5 kg in total. According to a report, in 1996 the pangolin scales were sold for INR1000/kg in Mizoram, which increased to INR12,000– INR13,000/kg in 2013 (Mohapatra et al. 2015). According to another report from 2006–2007, the scales were sold for USD $132/kg at wholesale markets, and USD $160/kg at retail markets, which have increased four-fold at the wholesale markets and six-fold at the retail markets (Xu et al. 2016).

There was a report on pangolin spotting in the Ajodhya Hills, in the Purulia District, West Bengal on 12 August 2021 by a camera trap survey, and there were also reports of rescue of two Indian Pangolins by the forest department of Purulia from poachers at Bararola and Serengdi village adjacent to the Ajodhya Hills on 22 August 2021 and 28 August 2021, respectively (Samanta et al. 2021).

The techniques employed by the poachers for entrapping a pangolin include the digging up of muddy burrows or driving them out by smoking or flushing them out with water, pitfall trapping, and using hunting dogs. Then the captured pangolins are killed by boiling them in water or knocked unconscious by hitting with a club. The scales are then either peeled off the pangolin or it is entirely skinned (Mohapatra et al. 2015). Banerjee (2022) discusses about the traditional 'Shikar' or hunting ritual carried out in the Ajodhya Hills, Purulia on 'Baishakhi Purnima', the full moon day in summer, wherein the Santhal (local tribe) men wander in the forests and kill wild porcupine, pangolin, deer, monkey, wild boar, and bear.

The Indian Crested Porcupine is also subject to extensive poaching to obtain its meat, and quills, which are used for making traditional medicines. Lupo & Schmitt (2005) state the porcupines were hunted using spears. However, the porcupines are recently hunted using special traps called 'fibre purse' or 'bag trap', which is set in front of the burrow of the animal. These special traps are built in a specific way, consisting of fibres or ropes hanging down from a layer of rocks on the top. Then, the hunters frighten the porcupine and force it to move into the trap, wherein quills of the porcupine get entangled in the dangling fibres, and when trying to pull away and escape, the rocks fall on its delicate body, thus injuring and immobilising the porcupine, which gets subsequently poached

The Indian Pangolin and the Indian Crested Porcupine in Purulia, coexist in the same rocky cavity. From the perspective of the Indian Pangolin, it protects itself by staying in the rocky cavity occupied by the porcupine, by making it difficult for the poachers to break or dig open a hard rocky cavity, as opposed to a soft, muddy burrow. Additionally, by occupying pre-formed rocky cavities, the pangolin can save the energy that it would have spent in digging a burrow in the soil, thus, more energy is available for foraging, mating, and offspring rearing.

From the perspective of the Indian Crested Porcupine, it gains huge advantage of co-inhabiting with the Indian Pangolin by decreasing its probability of getting poached by 50%. When the porcupine co-exists with a pangolin, then considering that both Indian Pangolin and Indian Crested Porcupine have overlapping time period of peak activity at night, the probability that the porcupine exits the burrow at a specific time is one-half of the probability of exiting the burrow when it was the lone occupant of the burrow. Thus, the probability of the porcupine getting entrapped in the 'fibre purse', is reduced by half (50%) with respect to probability of being poached when it occupied the burrow alone.

A study from southwestern Sri Lanka, had reported the co-occupancy of the 'same habitats' by burrowing animals such as the Indian Pangolin, the Greater Bandicoot Molerat *Bandicota indica* and the Indian Crested Porcupine *Hystrix indica* (Karawita et al. 2018). The general trend being observed in case of the co-inhabitancies, is that these behaviours are exhibited mostly in the areas involving high human-wildlife interactions.

CONCLUSION

The present study undertaken at the Purulia District of West Bengal, India, depicts that the Indian Pangolin and the Indian Crested Porcupine may coexist and share the same habitat. The reason for such behaviour, can be attributed to help them in coping up with extreme anthropogenic intrusion in their niche. An immediate necessity for their conservation also arises to diminish their population decline, caused by extensive poaching.

Future Work

IUCN estimates predict that the global Indian Pangolin population is likely to decrease by over 50% in the next 20 years (Waseem et al. 2020). Moreover, among all the Asian Pangolins, the Indian Pangolin is the least studied in terms of their abundance, population status, burrow characteristics and habitat preference (Karawita et al. 2018). This lack of proper quantitative data about the Indian Pangolin in India, Nepal, and Bangladesh, hampers understanding of the behaviour and ecology of the species. Future research and thorough surveys on pangolin populations are needed to shed light on this aspect.

It is important to determine if the Indian Pangolin shows such behaviours in presence of any other animals, whether it co-inhabits with other animals during the breeding, offspring rearing seasons and study their behaviours in other types of habitats, especially in the tropical wet rainforests. The study of these activities are essential to formulate effective conservation strategies for the 'Endangered' Indian Pangolin.

REFERENCES

Akram, F., O. Ilyas & A. Haleem (2017). Food and feeding habits of Indian crested Porcupine in Pench tiger reserve, Madhya Pradesh, India. *Ambient Science* 4(1): 62–66.

Amori, G., R. Hutterer, B. Kryštufek, N. Yigit, G. Mitsainas & L. Palomo (2021). *Hystrix indica* (amended version of 2016 assessment). The IUCN Red List of Threatened Species 2021: e.T10751A197516522. https://doi.org/10.2305/IUCN.UK.2021-1.RLTS.T10751A197516522.en. Accessed on 16 February 2024.

Beca, G., L.E. Valentine, M. Galetti & R.J. Hobbs (2022). Ecosystem roles and conservation status of bioturbator mammals. *Mammal Review* 52(2): 192–207. https://doi.org/10.1111/mam.12269

Banerjee, A. (2022). Bodding's Santal Medicine and Connected Folklore vis-à-vis Vidyasagar's understanding of Anthropological Study. *Journal of the Asiatic Society* 63(4): 131–154.

Chao, J.T., H.F. Li & C.C. Lin (2019). The role of Pangolins in ecosystems, pp. 43–48. In: Challender, D.W.S., H.C. Nash & C. Waterman (eds.). *Pangolins: Science, Society and Conservation*. Academic Press, Elsevier, London, 658 pp.

Corsini, M.T., S. Lovari & S. Sonnino (1995). Temporal activity patterns of crested Porcupines *Hystrix cristata*. *Journal of Zoology* 236(1): 43–54. https://doi.org/10.1111/j.1469-7998.1995.tb01783.x

Heath, M.E. & I.M. Coulson (1997). Preliminary studies on relocation of Cape Pangolins *Manis temminckii*. *South African Journal of Wildlife Research* 27: 51–56. https://doi.org/10.10520/EJC117030

Hughes, J.E. (2014). Thinking (with) the Indian Pangolin: A human-animal perspective on India's colonial and princely histories. Nehru Memorial Museum and Library, Teen Murti House, New Delhi, India, 45 pp.

Karawita, H., P. Perera, P. Gunawardane & N. Dayawansa (2018). Habitat preference and den characterization of Indian Pangolin (*Manis crassicaudata*) in a tropical lowland forested landscape of southwest Sri Lanka. *PLoS ONE* 13(11): e0206082. https://doi.org/10.1371/journal.pone.0206082

Mohapatra, R.K., S. Panda, M.V. Nair, L.N. Acharjyo & D.W.S. Challender (2015). A note on the illegal trade and use of pangolin body parts in India. *TRAFFIC Bulletin* 27(1): 33–40.

Lupo, K.D. & D.N. Schmitt (2005). Small prey hunting technology and zooarchaeological measures of taxonomic diversity and abundance: Eehnoarchaeological evidence from central African forest foragers. *Journal of Anthropological Archaeology* 24(4): 335–353. https://doi.org/10.1016/j.jaa.2005.02.002

Mahmood, T., K. Jabeen, I. Hussain & A.R. Kayani (2013). Plant Species Association, Burrow Characteristics and the Diet of the Indian

Pangolin, *Manis crassicaudata*, in the Potohar Plateau, Pakistan. *Pakistan Journal of Zoology* 45(6): 1533–1539.

Mahmood, T., D. Challender, A. Khatiwada, S. Andleeb, P. Perera, S. Trageser, A. Ghose & R. Mohapatra (2019). *Manis crassicaudata*. The IUCN Red List of Threatened Species 2019: e.T12761A123583998. https://doi.org/10.2305/IUCN.UK.2019-3.RLTS.T12761A123583998.en. Accessed on 16 February 2024.

Mahmood, T., R.K. Mohapatra, P. Perera, N. Irshad, F. Akrim, S. Andleeb, M. Waseem, S. Sharma & S. Panda (2019). Indian Pangolin Manis crassicaudata (Geoffroy, 1803), pp. 71–88. In: Challender, D.W.S., H.C. Nash & C. Waterman. *Pangolins: Science, Society and Conservation*. Academic Press, Elsevier, London, United Kingdom, 658 pp.

Mohapatra, R.K. & S. Panda (2014). Husbandry, behaviour and conservation breeding of Indian Pangolin. *Folia Zoologica* 63(2): 73–80. https://doi.org/10.25225/fozo.v63.i2.a4.2014

Prater S.H. (ed.) (2005). *The Book of Indian Animals.* Bombay Natural History Society, Oxford University Press, Mumbai, India, 324 pp.

Saltz, D. & P.U. Alkon (1989). On the spatial behaviour of Indian Crested Porcupines (*Hystrix indica*). *Journal of Zoology* 217(2): 255–266. https://doi.org/10.1111/j.1469-7998.1989.tb02486.x

Samanta, S., S. Mahato & A. Mukherjee (2021). Documentation of the globally threatened Indian Pangolin and its threats from Ajodhya Hills, Purulia, West Bengal, India. *Zoo's Print* 36(12): 65–66.

Shepherd C.R., E. Connelly, L. Hywood & P. Cassey (2017). Taking a stand against illegal wildlife trade: the Zimbabwean approach to Pangolin conservation. *Oryx* 51: 280–285. https://doi.org/10.1017/S0030605316000119

Waseem, M., B. Khan, T. Mahmood, H. S. Hussain, R. Aziz, F. Akrim, T. Ahmad, R. Nazir, S. Hameed & M. N. Awan (2020). Occupancy, habitat suitability and habitat preference of endangered Indian Pangolin (*Manis crassicaudata*) in Potohar Plateau and Azad Jammu and Kashmir, Pakistan. *Global Ecology and Conservation* 23: e01135. https://doi.org/10.1016/j.gecco.2020.e01135

Willcox, D., H.C. Nash, S. Trageser, H.J. Kim, L. Hywood, E. Connelly, G. Ichu, J.K. Nyumu, C.L.M. Moumbolou, D.J. Ingram & D.W.S. Challender (2019). Evaluating methods for detecting and monitoring pangolin (Pholidata: Manidae) populations. *Global Ecology and Conservation* 17: e00539. https://doi.org/10.1016/j.gecco.2019.e00539

Xu, L., J. Guan, W. Lau & Y. Xiao (2016). An overview of pangolin trade in China. *TRAFFIC* September 2016: 1–10.

Quadrate Analysis Data

The Favoured Group

Name of tree	*Diospyros melanoxylon*	*Aegle marmelos*	*Neolamarckia cadamba*	*Dalbergia sissoo*
No. of trees of each type	33	25	32	21
	34	22	30	22
	32	23	29	23
	27	19	27	25
	25	18	25	28
	27	19	25	26
	35	29	21	22
	32	27	23	23
	31	28	23	22
	28	21	35	28
	26	21	33	27
	28	21	36	28
	31	18	22	23
	30	17	19	23
	33	17	20	23
	26	20	22	19
	25	20	21	19
	26	21	22	20
Mean	**29.389**	**21.444**	**25.833**	**23.444**
Standard deviation	**3.310**	**3.650**	**5.393**	**2.955**
SEM	**0.780**	**0.860**	**1.271**	**0.696**

Colour coding for Quadrate data collected at the six focal sites (in order):

- Three technical replicates from Focal site 1
- Three technical replicates from Focal site 2
- Three technical replicates from Focal site 3
- Three technical replicates from Focal site 4
- Three technical replicates from Focal site 5
- Three technical replicates from Focal site 6

The Unfavoured Group

Name of tree	*Albizia procera*	*Ziziphus mauritiana*	*Ficus benghalensis*	*Butea monosperma*
No. of trees of each type	12	15	2	10
	11	14	2	8
	12	15	1	9
	11	21	1	8
	12	19	1	8
	11	18	1	7
	13	12	3	7
	12	10	2	8
	10	13	2	7
	11	14	2	13
	13	13	3	11
	12	15	2	10
	12	13	0	8
	15	15	0	8
	12	14	0	8
	10	15	3	10
	13	16	3	12
	11	18	3	12
Mean	**11.833**	**15.000**	**1.722**	**9.111**
Standard deviation	**1.200**	**2.657**	**1.074**	**1.875**
SEM	**0.283**	**0.626**	**0.253**	**0.442**

Colour coding for Quadrate data collected at the six focal sites (in order):

- Three technical replicates from Focal site 1
- Three technical replicates from Focal site 2
- Three technical replicates from Focal site 3
- Three technical replicates from Focal site 4
- Three technical replicates from Focal site 5
- Three technical replicates from Focal site 6

R Code Sheet for Statistical Analysis of Quadrate data

```
R version 4.3.0

[Workspace loaded from ~/. RData]

> library(readxl)
> Pangolin_Porcupine <- read_excel ("Pangolin-Porcupine.xlsx",
+     sheet = "Favoured")
> View (Pangolin_Porcupine)
> shapiro.test (Pangolin_Porcupine$Number)

        Shapiro-Wilk normality test

data:  Pangolin_Porcupine$Number
W = 0.95757, p-value = 0.01615
> LOGFAV=log (Pangolin_Porcupine$Number)
> shapiro.test (LOGFAV)

        Shapiro-Wilk normality test

 data:  LOGFAV

W = 0.97228, p-value = 0.1125
```

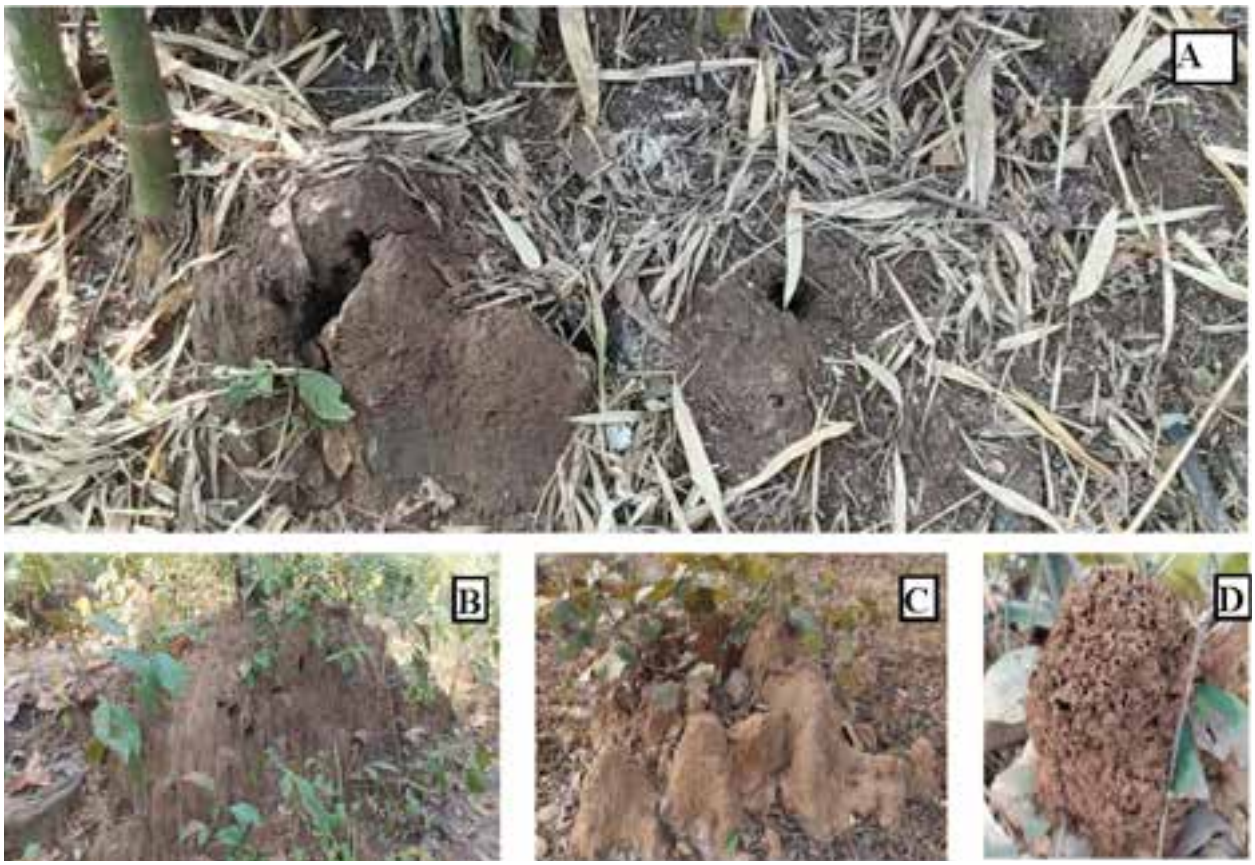
The Favoured group's dataset was log transformed to make the dataset parametric or normally distributed (Shapiro-Wilk normality test, P>0.05).

```
> library(readxl)
> Pangolin_Porcupine <- read_excel ("Pangolin-Porcupine.xlsx",
+     sheet = "Unfavoured")
> View (Pangolin_Porcupine)
> shapiro.test (Pangolin_Porcupine$Number)

        Shapiro-Wilk normality test

data:  Pangolin_Porcupine$Number
W = 0.93847, p-value = 0.001587
> LOGVAL=log (Pangolin_Porcupine$Number)

> shapiro.test (LOGVAL)

        Shapiro-Wilk normality test

data:  LOGVAL
W = 0.79605, p-value = 2.227e-08
 > LOGVAL1<-log (Pangolin_Porcupine$`log (Number)`+1)
> shapiro.test (LOGVAL1)

        Shapiro-Wilk normality test
 data:  LOGVAL1
W = 0.70663, p-value = 1.902e-10
```

The Unfavoured group's dataset was non-parametric i.e., not normally distributed (Shapiro-Wilk normality test, P<0.05). Two types of log transformations were performed to normalize data distribution but couldn't be done.

```
> library(readxl)
> Pangolin_Porcupine <- read_excel ("Pangolin-Porcupine.xlsx",
+     sheet = "Combined")
> View (Pangolin_Porcupine)
> wilcox.test (Pangolin_Porcupine$Number)

        Wilcoxon signed rank test with continuity correction
data:  Pangolin_Porcupine$Number
V = 10011, p-value < 2.2e-16
alternative hypothesis: true location is not equal to 0.
```

Non-parametric test (Wilcoxon signed-ranks test, P<0.05) performed between the Favoured group and Unfavoured group, here named "Combined" group.



Supplemental Image 1 (A–D). Termite mounds found in study area. In addition to the six focal sites, termite mounds were found at various other locations within the study area, indicating the presence of the Indian Pangolin. © Debosmita Sikdar.

Supplemental Image 2. Picture of Study area. A view of the Gajaburu hills in Purulia District, West Bengal, India, where the Study was conducted. © Debosmita Sikdar.

Supplemental Image 3. Picture of Camera trap. The picture shows the type of Camera traps that were used in the study for monitoring the activities of the Indian Pangolin and the Indian Crested Porcupine. © Debosmita Sikdar.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 February 2024 | 16(2): 24646–24657
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.8799.16.2.24646-24657
#8799 | Received 21 October 2023 | Final received 24 December 2023 | Finally accepted 10 January 2024
OPEN ACCESS
ARTICLE

Avifaunal assemblage patterns in Bharathapuzha River Basin, Kerala, India

Pazhayattuparambil Narayanan Anoop Raj [1], Avadhoot Dilip Velankar [2] & Padmanabhan Pramod [3]

[1,3] Salim Ali Centre for Ornithology and Natural History, South India Centre of Wildlife Institute of India, Anaikatty (Post), Coimbatore, Tamil Nadu 641108, India.
[1] Manipal Academy of Higher Education (MAHE), Madhav Nagar, Manipal, Karnataka 576104, India.
[1] Siddharth Foundation, No 26, Abbas Garden, TVS Nagar, Coimbatore, Tamil Nadu 641025, India.
[2] 12, Saisanket CHS, Ganeshwadi, Panchpakhadi, Thane, Maharashtra 400601, India.
[1] anupnarayanan1@gmail.com (corresponding author), [2] avadhoot.velankar@gmail.com, [3] neosacon@gmail

Abstract: Bharathapuzha, the second largest west-flowing river in the Western Ghats, originates from the northern and southern parts of the Palghat gap and debouches into the Arabian Sea at Ponnani. This river is exposed to high levels of anthropogenic pressures. This study looks into avifaunal assemblage patterns and the factors influencing the structure of bird communities in different ecological zones of the Bharathapuzha River Basin. The syntropic birds and flocking birds contribute variations in the bird community assemblage in the river basin. For the water-dependent and water-associated birds, mudflats, water flow, riverside vegetation, and distance from the forest were found to be the influencing factors in the migratory season. The study also emphasized the importance of protecting these river-associated habitats for the conservation of birds.

Keywords: Anthropogenic pressures, bird community, environmental factors, mudflats, Nila River, riverine birds, riverside vegetation, water flow, water-associated birds, water-dependent birds.

Editor: H. Byju, Coimbatore, Tamil Nadu, India.

Date of publication: 26 February 2024 (online & print)

Citation: Raj, P.N.A., A.D. Velankar & P. Pramod (2024). Avifaunal assemblage patterns in Bharathapuzha River Basin, Kerala, India. *Journal of Threatened Taxa* 16(2): 24646–24657. https://doi.org/10.11609/jott.8799.16.2.24646-24657

Funding: Kerala State Biodiversity Board.

Competing interests: The authors declare no competing interests.

Author details: Anoop Raj is a doctoral student of Manipal Academy of Higher Education, Manipal and affiliated with SACON. He is a researcher in bird ecology with a wildlife biology science background. He is working on riverine bird communities of the Western Ghats for his Ph.D. Dr. Avadhoot Dilip Velankar is an independent researcher. His area of specialization is primatology. Dr. Padmanabhan Pramod is a senior principal scientist and head of the nature education programme at SACON. He has 27 years of research experience in the bird community, biodiversity assessment, and applied ornithology.

Author Contributions: ARPN - Study design, Field surveys, Data analysis and Preparation of manuscript, PP – Study design, Review, Preparation of manuscript, ADV – Data analysis, Preparation of manuscript.

Acknowledgements: I acknowledge the Kerala State Biodiversity Board for the funding through the doctoral fellowship programme. Also extending gratitude to Mrs. Nila, Mrs. Sheena, and Mr. Subhash for their constant support in data collection. I thank Mr. Anoop N.R. for his comments in improving the manuscript.

INTRODUCTION

Bird species respond rapidly to any changes in the environment (Bühning-Gaese 1997; Waide et al. 1999; Donald et al. 2001; Suárez-Seoane et al. 2002; Benton et al. 2003; McCracken & Tallowin 2004; Batáry et al. 2007). The avian species diversity, richness, and abundance are determined by various factors such as migration, natality, mortality, and availability of food and niches (Fitzherbert et al. 2008; Jayapal et al 2009). Many researchers have attempted to study bird communities in the different habitats in the Western Ghats (Daniels 1989; Pramod 1995, Karanth et al. 2016) which provided useful information about the distribution trends. Most of these studies focused on forest ecosystems in the protected area network. Understanding the pattern of distribution of birds and their drivers in highly disturbed ecosystems outside the protected area network is less attempted (Garcia et al. 2010; Anand et al. 2010; Chandran & Vishnudas 2018; Variar et al. 2021).

From the origin to the mouth, the Bharathapuzha River passes through various landscapes and topographic conditions. Most ecosystems in the river basin are located outside the protected area network and are vulnerable to anthropogenic pressures. Deforestation in the hill region, construction of check dams, indiscriminate sand mining, the spread of weeds and invasive plants inside the river channel, expansion of monoculture plantations, encroachment and water pollution are the major threats to the river (John et al. 2019). In this study, we attempted to understand the pattern of avifaunal assemblage in the Bharathapuzha river basin which is highly disturbed due to anthropogenic pressures which destroyed the riverine habitats, water quality, and natural water flow.

MATERIAL AND METHODS

Study area

Bharathapuzha is a 6th-order river (Strahler 1964) having a large extent of production landscape in the basin (Jacob & Narayanaswami 1954; John et al 2019). The total area of the river drainage basin is 6186 km^2, which includes 50 watersheds and 290 mini watersheds. Twenty-five percent of the river drainage basin comes under various protected areas (Raj & Azeez 2010; John et al. 2019). Silent Valley National Park, one of the important biodiversity hotspots in the country falls in this river basin. This river originates from the Thirumurthi hills of Anamalai and flows towards the west through the Palghat Gap until it drains into the Arabian Sea. Chitturpuzha, Kalpathipuzha, Gayathripuzha, and Thoothapuzha are major tributaries of this river which originates from the Western Ghats. These rivers play a crucial role in maintaining the water flow in the river.

Study design

Field surveys were conducted in 453 km stretches of the river between the elevation gradient of 621–0 m. The intensive sampling area was selected using stratified sampling techniques. The area was stratified into three ecological zones based on the river flow, geomorphology, and ecological setting of the river. Thus, the sampling locations were classified into the upper reaches (headwaters), middle reaches (tributary), and lower reaches (main course and estuary) of the river which are henceforth termed ecological zones (Abell et al. 2008). Considering the extent of area available in these zones, the sampling locations and sampling efforts were distributed. Sampling was done in one non-migratory (April to October 2018) and two migratory seasons (November 2017–February 2018, and November 2018–February 2019). The riverine area in the basin was gridded into 1 km^2 grids. From these, 70 grids along the river channel were selected through random sampling for intensive study (Figure 1). In each grid, data on birds and associated environmental parameters were collected through 4-point counts (each 15-minute long) using the fixed width point count method (Reynolds et al. 1980). Thus, for the three seasons together, a total of 840-point counts of bird data collection were conducted from the sampling area. Observations were done 0600–1100 h and 1530–1900 h. Bird identification was done using field guides and photographs (Ali & Ripley 1983; Ali 1999; Karmierczak 2000; Grimmett et al. 2014).

Data preparation

Data collected from 70 grids in three seasons (two migratory, one non-migratory) were tabulated and organized as 210 samples. Contingency tables were created as samples vs. species with abundance values as scores using the pivot table function in the spreadsheet package. Samples with no detection were removed from the tables.

Bird group categories

The bird species recorded during the study period were classified into three groups as water-dependent birds (WDB), water-associated birds (WAB), and non-water-associated birds (NWAB).

Water-dependent birds (WDB) are the birds that use water as their most preferred habitat. This includes the

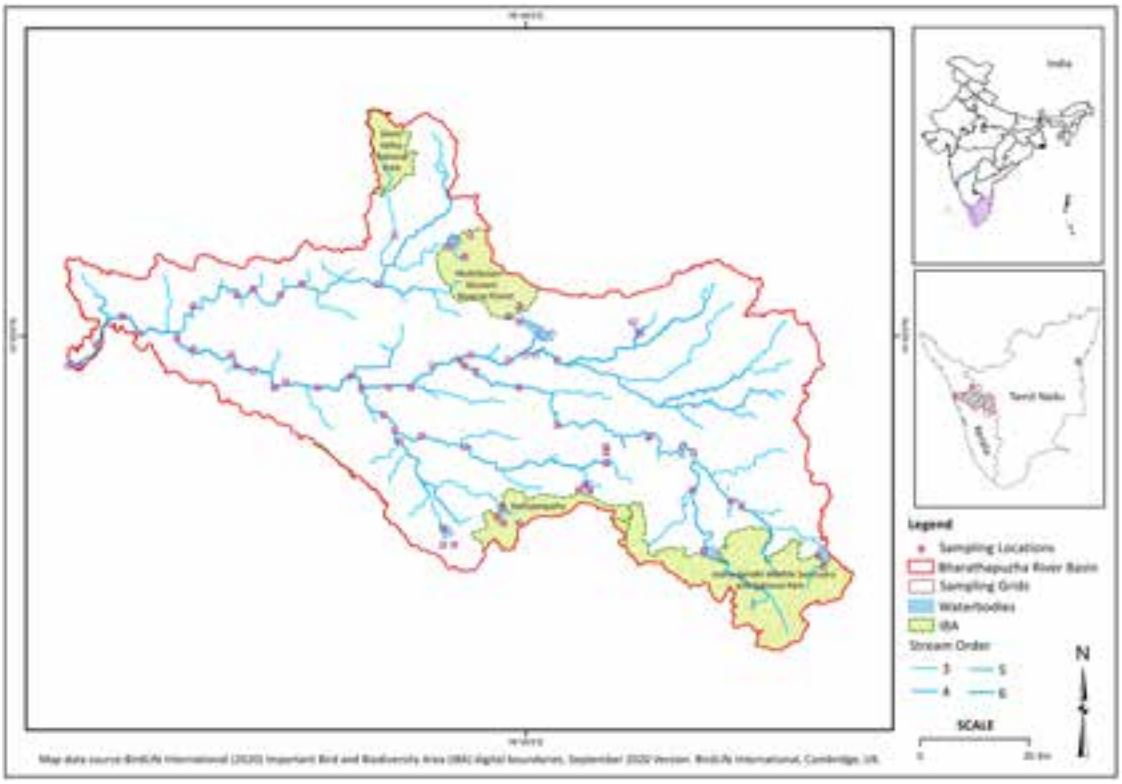


Figure 1. Location map of Bharathapuzha River Basin showing streams and sampling locations.

taxonomic groups such as Anseriformes, Suliformes, and a few members of Charadriiforms.

Water-associated birds (WAB) include the taxonomic groups such as Pelecaniformes, Ciconiiformes, Gruiformes, Charadriiformes, and a few members of Coraciiforms, Passeriformes, and Accipitriformes.

Non-water-associated birds (NWAB) are the birds that don't use riverine habitats as primary habitats. Galliformes, Podicipediformes, Cuculiformes, Caprimulgiformes, Accipitriformes, Strigiformes, Trogoniformes, Bucerotiformes, Coraciiforms, Piciformes, Falconiformes, Psittaciformes, and Passeriformes come under this category.

Environmental parameters

Data on 17 environmental parameters were collected. The parameters such as check dams, waste dumping, and artificial perches were recorded as presence and absence. Area of water channel, water flow, riverside vegetation, mudflats, sandbanks, rocks and barren land recorded in percentage (%) in a unit area by visual estimation. The canopy cover was recorded using the *Canopeo* (Patrignani et al. 2015). The distance from the nearest forest, agricultural land, and human settlements was collected on a km scale using the Google Earth Pro application. The temperature and rainfall data were collected from the Worldclim database for the study period.

Analysis

To assess the community structure and its variation across ecological zones and seasons, non-metric multidimensional scaling (nMDS) was performed (Kruskal 1964; Borcard et al. 2011). For nMDS, the contingency table was prepared using one nonmigratory and migratory season data. Analysis was performed separately for WDB, WAB, and NWAB. Bray-Curtis dissimilarity index being sensitive to differences in abundances and does not rely on absences has been used extensively in community ecology (Schroeder & Jenkins 2018; Lorenzón et al. 2019). Hence, a distance matrix with Bray-Curtis dissimilarities was used for nMDS ordination. To determine if the clusters shown in nMDS ordination are statistically significant, ANOSIM was also performed using the Bray-Curtis dissimilarity matrix (Anderson & Walsh 2013). ANOSIM was performed using ecological zone and season as grouping variables.

Similarity Percentage (SIMPER) analysis was employed to further assess the contribution of the species to the dissimilarities between the grouping

variables (Clarke 1993; White et al. 2005; Asefa et al. 2017).

To test the impact of environmental parameters on the community structure of WDB and WAB in migratory and non-migratory seasons, distance-based redundancy analysis was used (Legendre & Anderson 1999). First, a global model was performed by incorporating all non-auto-correlated environmental variables. Linear dependencies for all environmental variables were checked by computing variance inflation factors (VIF) for each variable. The variable reduction was performed using the forward selection method (Boccard et al. 2011) by including variables with VIF below 10. A most parsimonious model was computed using the environmental variables within $\alpha = 0.05$ during the forward selection method. The proportion of variation explained by each variable was calculated by adjusting the R^2 value with the R^2 value of the global model as the threshold.

All statistical analysis was performed in R statistical language (v4.3.2) with R Studio IDE (v2023.06.0). Vegan, a community ecology package was used to perform ordination and significance testing (Oksanen et al. 2013). Ordination graphs were generated using the package ggplot2 (Wickham 2016).

RESULTS

Bird assemblage patterns across ecozones and season

The study recorded 235 species of birds while employing the sampling protocols. There were 23 species of WDB, 49 species of WAB, and 163 NWAB recorded from the river basin.

Water dependent birds

Ordination shows that the avifaunal community in the middle reaches is not distinct and completely overlaps within the upper and middle reaches (Figure 2). Some WDBs distinctly favored sites from either upper or lower reaches (nMDS: stress = 0.15, non-metric R^2 = 0.97). The variation between ecological zones was more significant than within ecological zones (ANOSIM: R = 0.132, p <0.05). However, the bird community variation observed between migratory and non-migratory seasons was not significant (ANOSIM: R = 0.007, p <0.7).

Little Cormorants *Microcarbo niger*, Black-headed Gull *Chroicocephalus ridibundus*, Brown-headed Gull *Chroicocephalus brunnicephalus*, White-breasted Waterhen *Amaurornis phoenicurus*, Palla's Gull *Ichthyaetus ichthyaetus*, and Oriental Darter *Anhinga melanogaster* contributed to the community variation in the lower and middle reaches. Along with the above-mentioned bird species, the presence of River Tern *Sterna aurantia* and Lesser Whistling Duck *Dendrocygna javanica* contributed to the community variation in

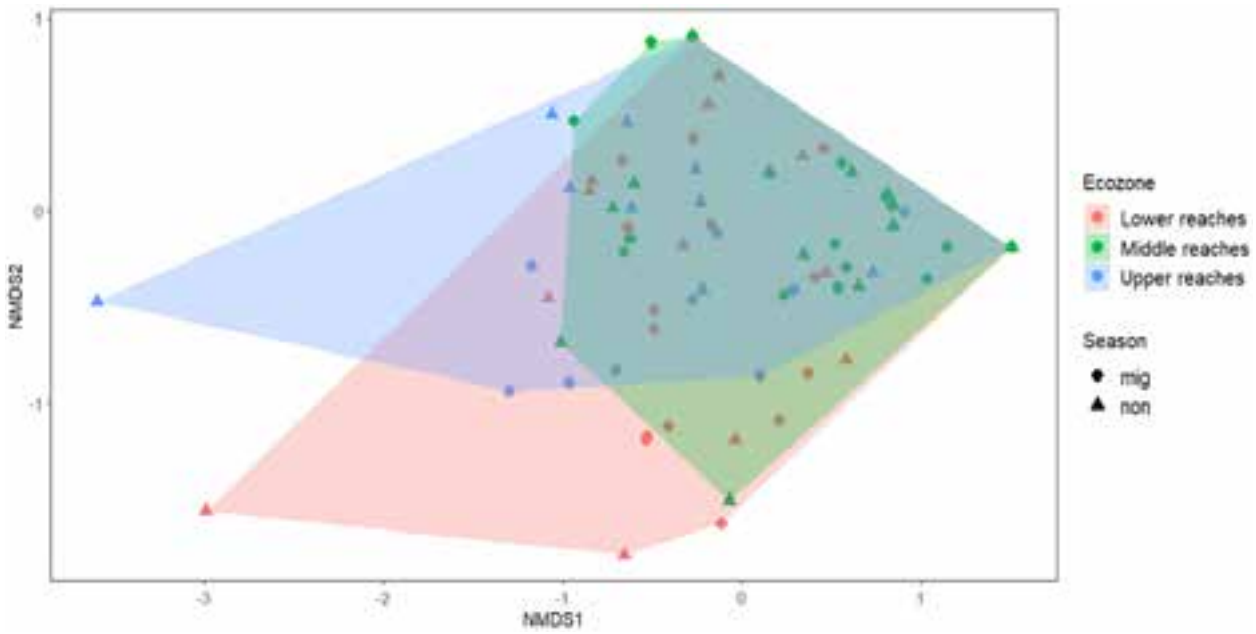


Figure 2. Non-metric multidimensional scaling (nMDS) for water-dependent birds (mig: migratory season; non: non migratory season).

the lower and upper reaches. Little Cormorant, White-breasted Waterhen, River Tern, and Lesser Whistling Duck contributed to the community variation between the middle and upper reaches.

Water associated birds

The lower reaches and middle reaches have many sites with similar species composition, however, many sites recorded very distinct composition (nMDS: Stress = 0.219, Non-metric R^2 = 0.94) (Figure 3). Similarly, several sites in the middle and lower reaches were similar in composition to the upper reaches. Also, lower and upper reaches have sites with unique compositions specific to the respective ecological zones. The variation between ecological zones is more significant than within ecological zones (ANOSIM: R = 0.159, p <0.05). While considering the lower reaches and upper reaches separately, the sites with unique compositions are more. Due to this, species composition between seasons is significantly different (ANOSIM: R = 0.039, p <0.05).

Cattle Egret *Bubulcus ibis*, Brahmini Kite *Haliastur indus*, Little Egret *Egretta garzetta*, Green Bee-eater *Merops orientalis*, Indian Pond Heron *Ardeola grayii*, Asian Openbill *Anastomus oscitans* contributed maximum to the bird community variation between lower and middle reaches. A similar pattern was seen in the lower and upper reaches. Along with the other bird species White-throated Kingfisher *Halcyon smyrnensis* also contributed to the variation between middle and upper reaches. The presence of other species like Red-wattled Lapwing *Vanellus indicus*, Black-headed Ibis *Threskiornis melanocephalus*, Large Pied Wagtail *Motacilla maderaspatensis*, Common Sandpiper *Actitis hypoleucos*, Intermediate Egret *Ardea intermedia*, Chestnut-headed Bee-eater *Merops leschenaulti*, and Marsh Sandpiper *Tringa stagnatilis* had different abundances between ecological zones which resulted in dissimilarities evident in nMDS and ANOSIM.

Non-water associated birds

The lower reaches, middle reaches, and upper reaches are distinct in species compositions (nMDS: Stress = 0.19, Non-metric R^2 = 0.96) (Figure 4). However, most of the sites in the middle are similar in composition

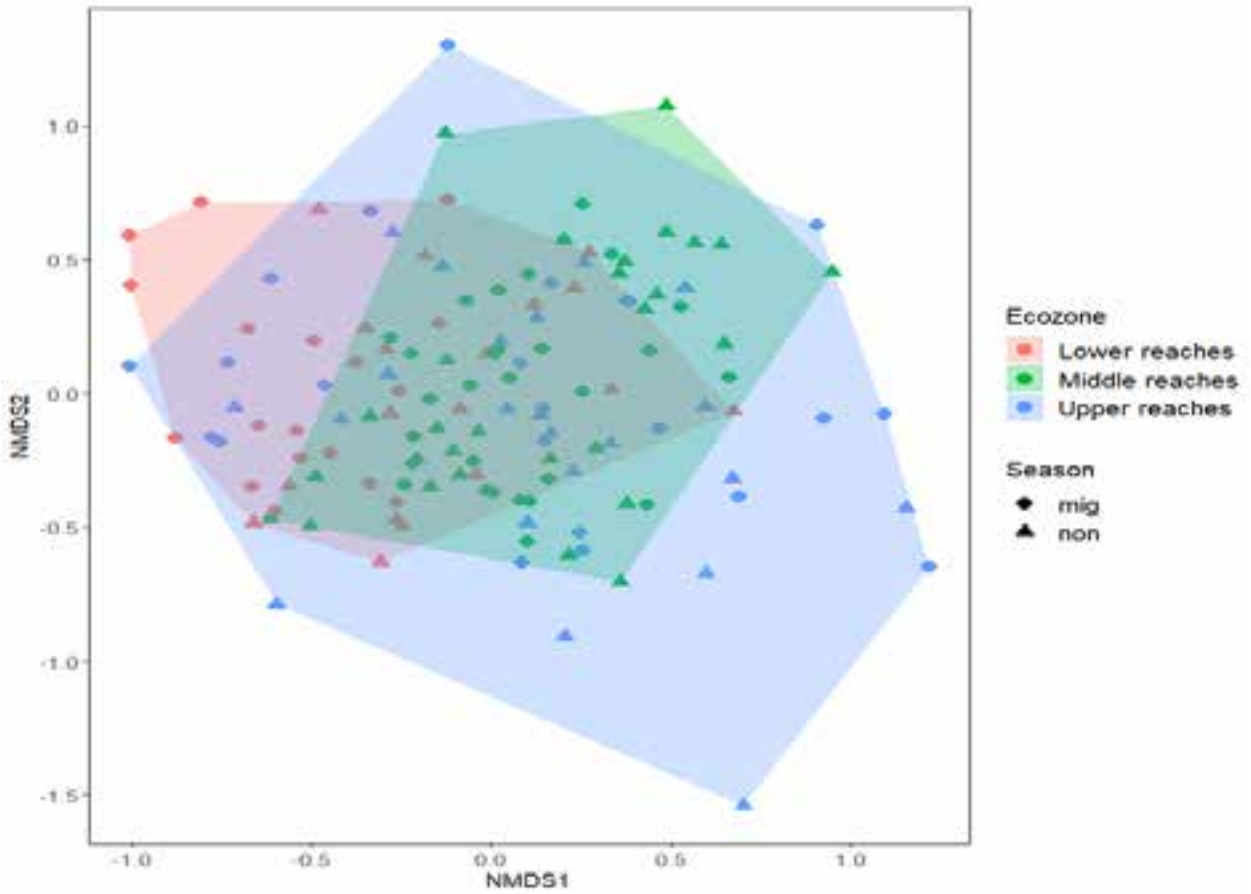


Figure 3. Non-metric multidimensional scaling (nMDS) for water-associated birds (mig: migratory season; non: non migratory season).

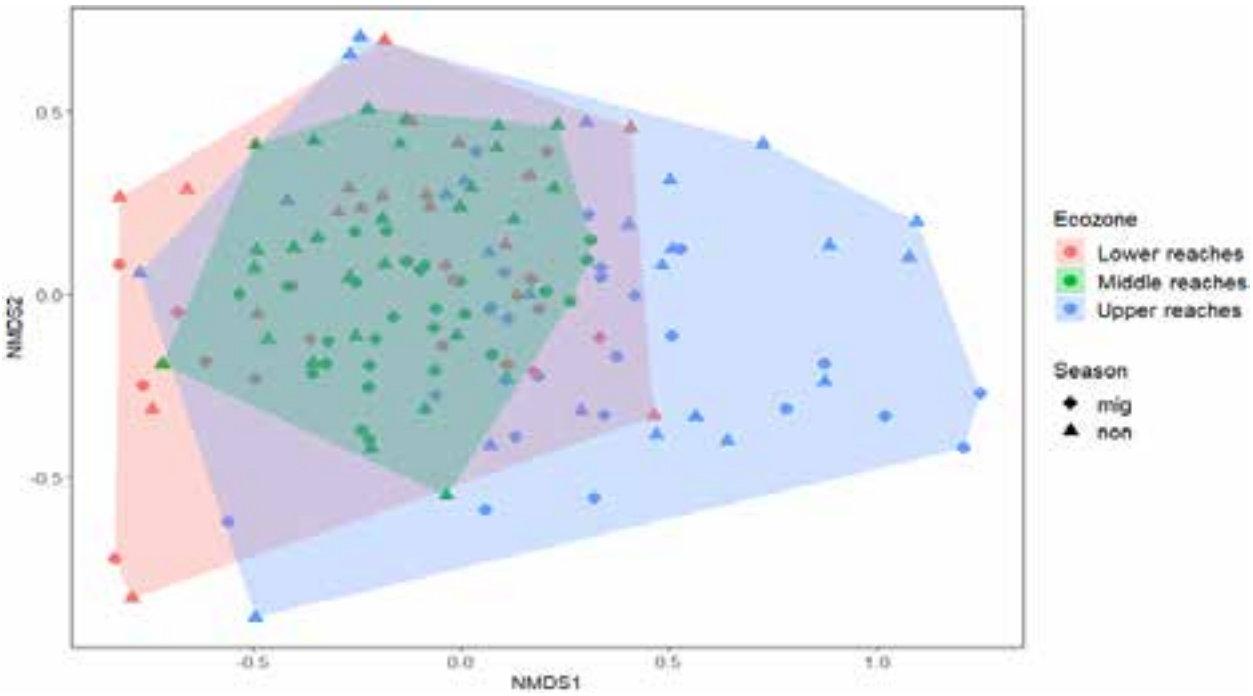


Figure 4. Non-metric multidimensional scaling (nMDS) for non-water associated birds (mig: migratory season; non: non migratory season).

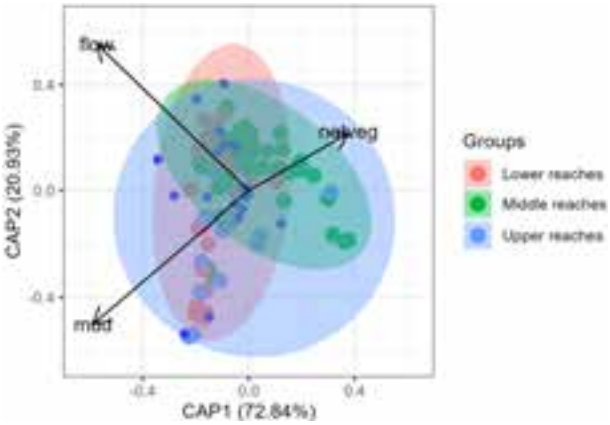


Figure 5. Distance-based redundancy analysis (db-RDA) for water-dependent birds in the migratory season.

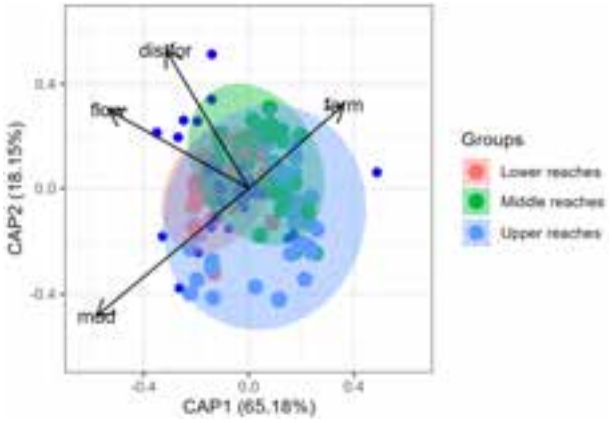


Figure 6. Distance-based redundancy analysis (db-RDA) for water-associated birds in the migratory season.

with upper and lower reaches. Lower and upper reaches have more unique sites with NWABs than with WDBs and WABs. The variation between ecological zones is higher than within ecological zones (ANOSIM: R = 0.154, p <0.05). Some sites have unique seasonal assemblages of birds. This made composition in the migratory seasons, and seasonal variation significant (ANOSIM: R = 0.053, p <0.05).

In non-river-associated birds, differential abundances of synanthropic species were found to be contributing factors to dissimilarity between ecozones. House Crow *Corvus splendens*, Asian Palm Swift *Cypsiurus balasiensis*, Rock Pigeon *Columba livia*, Common Myna *Acridotheres tristis*, Yellow-billed Babbler *Turdoides affinis*, Large-billed Crow *Corvus macrorhynchos* and Barn Swallow *Hirundo rustica* contributed to the bird community variation between the lower and middle reaches; middle and upper reaches; and lower and upper reaches. The abundance variation of Black Kite *Milvus migrans* and Purple-rumped Sunbird *Leptocoma zeylonica*, also contributed much to these variations.

Factors Influencing Bird Community structure in Bharathapuzha river basin

Selected environmental parameters were analyzed using distance-based redundancy analysis (Db-RDA) for WDBs and WABs during the migratory season and non-migratory seasons. The results are given below.

Water-depended birds in migratory season

Db-RDA for WABs during migratory season showed that the constrained axis explained the significant variation (CAP1 Eigenvalue = 1.87 Proportion explained = 78.0%, CAP2 Eigenvalue = 0.52 Proportion explained = 21.9%) (Figure 5). Forward selection of environmental

Table 1. Table 1. Forward selection of variables and adjusted R^2 for distance-based redundancy analysis (db-RDA) of water-dependent birds in the migratory season.

	Variables	R^2	R^2Cum	AdjR^2Cum	F	p value
1	Mudflats	0.048893593	0.04889359	0.04055055	5.8604059	0.016*
2	Water flow	0.023191219	0.07208481	0.05566153	2.8241889	0.047*
3	Check dams	0.011114354	0.08319917	0.05864200	1.3577732	0.251
4	Altitude	0.011698160	0.09489733	0.06228101	1.4346392	0.209
5	Farmland	0.009676843	0.10457417	0.06387300	1.1887671	0.287
6	Barren land	0.017266246	0.12184042	0.07350136	2.1431422	0.100
7	Riverside vegetation	0.026095423	0.14793584	0.09270946	3.3076214	0.039*
8	Sandbank	0.010357548	0.15829339	0.09536205	1.3166793	0.247
9	Temperature	0.006612920	0.16490631	0.09400213	0.8393903	0.391
10	Area of water channel	0.005256994	0.17016330	0.09113123	0.6651722	0.530
11	Distance from forest	0.004208018	0.17437132	0.08704521	0.5300614	0.660
12	Rocks	0.003517995	0.17788931	0.08210943	0.4407600	0.641
13	Waste dumping	0.003243874	0.18113319	0.07676781	0.4040647	0.646
14	Rainfall	0.003320936	0.18445412	0.07140816	0.4112761	0.740
15	Perches	0.002203425	0.18665755	0.06465618	0.2709098	0.863
16	Distance from human settlements	0.002033782	0.18869133	0.05757074	0.2481724	0.776

Table 2. Forward selection of variables and adjusted R^2 for distance-based redundancy analysis (db-RDA) of water-dependent birds in the non-migratory season.

	Variables	R^2	R^2Cum	AdjR^2Cum	F	p value
1	Altitude	0.04512	0.04512	0.02744	2.55158	0.072
2	Area of Water channel	0.03282	0.07794	0.04314	1.88627	0.172
3	Distance from forest	0.04089	0.11883	0.06799	2.4132	0.107
4	Temperature	0.03344	0.15227	0.08578	2.01166	0.108
5	Water flow	0.01454	0.16681	0.08349	0.87254	0.353
6	Farmland	0.0166	0.18341	0.08342	0.99612	0.315
7	Riverside vegetation	0.01542	0.19882	0.08198	0.92355	0.356
8	Check dam	0.01229	0.21111	0.07683	0.73204	0.459
9	Barren land	0.00748	0.21859	0.0657	0.44006	0.572
10	Mudflats	0.00529	0.22388	0.0514	0.30674	0.679
11	Sandbanks	0.00452	0.2284	0.0355	0.25777	0.709
12	Distance from human settlement	0.00437	0.23276	0.01865	0.24464	0.64
13	Sewage	0.003	0.23576	-0.0008	0.16473	0.75
14	Waste dumping	0.00221	0.23796	-0.0222	0.1187	0.846
15	Rain fall	0.0026	0.24057	-0.0442	0.13703	0.855
16	Rocks	0.00106	0.24163	-0.0695	0.05473	0.967

variables revealed that the Area of mudflats (R^2 = 0.048, F = 5.86, p <0.05), area of water flow (R^2 = 0.02, F = 2.82, p <0.05) and riverside vegetation (R^2 = 0.02, F = 3.30, p <0.05) to be affecting species composition in sites with 9.4% variation explained in Table 1.

Water-depended birds during the non-migratory season

Db-RDA for WDBs during migratory season showed no constrained or unconstrained axis explaining significant variation. Forward selection of environmental variables also didn't show significant variation between bird community and environmental variables (Table 2).

Water-associated birds in Migratory season

Db-RDA for water-associated birds during migratory explained that the constrained axis showed significant variation (CAP1 Eigenvalue = 2.51 Proportion explained = 65.1%, CAP2 Eigenvalue = 0.70, Proportion explained = 18.15%) (Figure 6). Forward selection of environmental variables revealed that the area of mudflats (R^2 = 0.05, F = 8.13, p <0.05) and area of water flow (R^2 = 0.02, F = 3.39, p <0.05), distance from forest (R^2 = 0.05, F = 8.13, p <0.05), and distance from farm (R^2 = 0.05, F = 8.13, p <0.05) weakly affected species composition in ecological zones with 9.4% variation explained in Table 3.

Water-associated birds in Non-migratory season

Db-RDA for WABs during migratory season showed that only one constrained axis explained significant variation (CAP1 Eigenvalue = 0.46 Proportion explained = 46.7%, MDS1 Eigenvalue = 3.02 Proportion explained = 13.88%) (Figure 7). Forward selection of environmental variables revealed that the area of mudflats (R^2 = 0.05, F = 8.13, p <0.05) weakly affects species composition in ecological zones with 3.2% variation explained in Table 4.

DISCUSSION

Bharathapuzha river basin has 262 species of birds with a significant number of residents and migrants which are distributed throughout the basin (Raj et al. 2023). This indicates the diversity of productive and heterogeneous habitats in the river basin.

This study showed that the bird species composition varied significantly between the ecological zones. This could be because of habitat heterogeneity, seasonal movement patterns, population changes, availability of food and space and climatic conditions in the ecological zones. Similar observations on bird communities were explained earlier by many (Meyer & Turner 1992; Namgail et al. 2017; Gonz´alez-Gajardo et al. 2009;

Table 3. Forward selection of variables and adjusted R^2 for distance-based redundancy analysis (db-RDA) of water-associated birds in the migratory season.

	Variables	R^2	R^2Cum	AdjR^2Cum	F	p value
1	Mudflats	0.04575	0.04575	0.03873	6.52025	0.006*
2	Water flow	0.03512	0.08087	0.06725	5.15865	0.003*
3	Distance from forest	0.01891	0.09978	0.07963	2.81522	0.029*
4	Farmland	0.0182	0.11798	0.09145	2.74392	0.033*
5	Temperature	0.00924	0.12723	0.09417	1.39808	0.2
6	Riverside vegetation	0.00831	0.13553	0.09594	1.2586	0.234
7	Rainfall	0.01154	0.14707	0.10114	1.75851	0.123
8	Distance from human settlement	0.01035	0.15742	0.10516	1.58428	0.166
9	Perch	0.00667	0.16409	0.10531	1.02164	0.355
10	Altitude	0.00599	0.17008	0.10473	0.91724	0.379
11	Barren land	0.00499	0.17508	0.10306	0.76294	0.504
12	Waste dumping	0.00372	0.1788	0.09996	0.56611	0.644
13	Area of Water channel	0.00345	0.18224	0.09651	0.52276	0.675
14	Sewage	0.0035	0.18574	0.09306	0.52864	0.64
15	Check dam	0.00285	0.18859	0.08882	0.42777	0.829
16	Sandbanks	0.00258	0.19117	0.08422	0.38617	0.818
17	Rocks	0.00119	0.19236	0.07794	0.17628	0.981

Table 4. Forward selection of variables and adjusted R^2 for distance-based redundancy analysis (db-RDA) of river-associated birds in non-migratory season.

	variables	R^2	R^2Cum	AdjR^2Cum	F	p value
1	Mudflats	0.04636	0.04636	0.03192	3.20881	0.026*
2	Sandbanks	0.03052	0.07688	0.04848	2.14872	0.09
3	Riverside vegetation	0.02782	0.1047	0.06274	1.98887	0.091
4	Rock	0.0219	0.1266	0.07115	1.57952	0.168
5	Water flow	0.01709	0.14369	0.07463	1.23718	0.276
6	Barren land	0.02022	0.16391	0.08167	1.47528	0.177
7	Distance from human settlement	0.01327	0.17718	0.08118	0.9675	0.243
8	Distance from forest	0.01141	0.18859	0.07857	0.82981	0.537
9	Check dam	0.01118	0.19977	0.07559	0.81019	0.538
10	Perch	0.01081	0.21058	0.07209	0.7808	0.495
11	Rainfall	0.00853	0.21911	0.06573	0.61199	0.68
12	Area of water channel	0.00867	0.22778	0.0593	0.61734	0.671
13	Temperature	0.00585	0.23363	0.04913	0.41207	0.797
14	Farmland	0.00597	0.2396	0.03874	0.41588	0.828
15	Waste dumping	0.00795	0.24754	0.03049	0.54923	0.685
16	Sewage	0.00417	0.25171	0.01695	0.28391	0.892
17	Altitude	0.00223	0.25394	0.00028	0.1495	0.978

Runge et al. 2015; Yang et al. 2022).

The bird community includes various species of flocking birds, colonial breeding birds and synanthropic birds. Their contribution to the variation was more visible due to the relatively high abundance. The high abundance of synanthropic species such as Red-vented Bulbul, Red-whiskered Bulbul, House Crow, and Black Drongo is considered as an indicator of human influence or urbanization (Plass & Wunderle 2013: Kurucz et al. 2021). They were found to be in high abundance in the upper reaches indicating that the habitats in the upper reaches are under anthropogenic pressure (John et al. 2019). Black Kite, Brahmini Kite, Cattle Egret, Rock Pigeon and House Crow were found in large numbers in the lower reaches. This indicates that the lower reaches of the river is highly urbanised and the generalist species thrive in the region.

The resident birds also contributed to the changes in the species composition. This could be because of their tolerance and adaptation to local fragmentation and disturbance (Rendón et al. 2008; Donaldson et al. 2016). Areas in the lower reaches provide wintering sites for many long-distance migrant birds. Black-headed Gull, Brown-headed Gull, and Pallas' Gull were found in high abundance in the lower reaches. This indicates that these migrant birds are highly dependent on the large waterbodies of the lower reaches.

Environmental factors influencing the water-dependent and water-associated birds in the Bharathapuzha river basin.

The area of mudflats, area of water flow, riverside vegetation, distance from forest, and distance from farmland are the environmental parameters that have positively influenced the WDB and WAB bird communities' distribution. Various studies indicate the importance of mudflats and the area of water flow on the WAB communities (Bellio & Kingsford 2013; Aarif et al. 2014; Clemens et al. 2014; Murray & Fuller 2015; Luo et al. 2019).

Mudflats are one of the important ecosystems which determine the characteristics of the river channel. In the Bharathapuzha river basin, from the upper reaches to the lower reaches, mudflats are seen everywhere in various degrees. In some locations, mudflats form due to the natural flow of water, whereas in some areas it is created due to the check dams. In the upper and lower reaches, relatively more extensive mudflats are available for the WDB and WAB for foraging and resting. These mud flats are one of the most productive ecosystems and are reported to have high levels of benthic and soil biota (Dittmann 2008; Dissanayake 2019). The mud flats in the river basin are prone to high anthropogenic threats due to encroachment and sand mining. River-side farming is a common practice in the Bharathapuzha river basin.

The farmers here use these mudflats for farming during the summers. This extensively reduces the space and food availability of birds. Destruction or disappearance of these habitats can decrease the diversity of WDB and WAB. The study strongly recommends the protection and management of existing mudflats in the riverine area.

The area of water flow represents the percentage of water in the river channel. Bharathapuzha is a perennial river. The water level reduces drastically during the summers. Though the water is less in the river channel, the flow is continuous. The anthropogenic activities in the river have drastically interrupted the water flow. The construction of dams and check dams in various places has altered the natural flow. The large waders (herons, egrets, and storks) and shorebirds (plovers and sandpipers) prefer the shallow flowing water in the lower reaches. But the deep divers like kingfishers are seen mostly in the middle reaches. The ducks and cormorants prefer the stagnant water in the dams and check dams. This indicates that the changes in the water levels in the river channel influence the bird community. The study highlights the importance of maintaining the flow of the river to protect the birds and ecosystem in the river basin.

Riverside vegetation includes the vegetation patches seen on the riverside, inside the river channel, and the floating vegetation on the water. The egrets and herons are seen foraging in these habitats. The White-breasted Waterhen and Purple Moorhen were found nesting on floating vegetation. In many locations, the vegetation inside the water channel was created due to anthropogenic activities such as sand mining and check dam construction. Several bird species use this as a breeding and foraging ground. Large flocks of Cattle Egrets and little cormorants are seen in such vegetation. Apart from the birds, otters also are observed to use this area as their shelter which is prone to periodical fires in summer.

Distance from forest and distance from farmland shows a weak statistical significance in its effect on the bird communities. The lower reaches of the Bharathapuzha River are dominated by paddy cultivation. Most of the WAB depend on these habitats for foraging.

CONCLUSION

The present study, recommends a systematic survey of the check dams and their effectiveness in the river basin. A regulation on check dam construction has to be brought into action and unwanted check dams should be removed to ensure the water flow. No significant correlations between most variables and birds were found in our study in the non-migratory season. The non-migratory season data collection was conducted from April 2018 to September 2018, in which the Kerala flood occurred. The flood in the Bharathapuzha River affected largely on the microhabitats and riverine ecosystems which in turn reflected on the environmental parameters collected during the survey. The recent trend in changes in rainfall patterns, floods and droughts in the river basin may affect the bird communities. Seasonal variation in river channels and resource availability needs to be studied in detail. In the present study, most of the study locations fell outside the protected area network. The bird diversity in the river basin shows the importance of the non-protected areas in biodiversity conservation (Raman & Sukumar 2002; Raman & Mudappa 2003; Raman 2006; Anand 2010; Raj et al. 2023). To protect these habitats which support bird diversity new strategies such as land-sharing with local communities are required which ensure effective biodiversity conservation over a large landscape like the Bharathapuzha river basin.

REFERENCES

Aarif, K.M., S.B. Muzaffar, S. Babu & P.K. Prasadan (2014). Shorebird assemblages respond to anthropogenic stress by altering habitat use in a wetland in India. *Biodiversity and Conservation* 23: 727–740. https://doi.org/10.1007/s10531-014-0630-9

Abell, R., M.L. Thieme, C. Revenga, M. Bryer, M. Kottelat, N. Bogutskaya & P.P. Petry (2008). Freshwater ecoregions of the world: a new map of biogeographic units for freshwater biodiversity conservation. *Bioscience* 58(5): 403–414. https://doi.org/10.1641/B580507

Ali, S. (1999). *Birds of Kerala*. Kerala Forests and Wildlife Department, Thiruvananthapuram, 520 pp.

Ali, S. & S.D. Ripley (1983). *A Pocket Guide to the Birds of the Indian Subcontinent*. Bombay Natural History Society, Bombay, 354 pp.

Anand, M.O., J. Krishnaswamy, A. Kumar & A. Bali (2010). Sustaining biodiversity conservation in human-modified landscapes in the Western Ghats: remnant forests matter. *Biological Conservation* 143(10): 2363–2374. https://doi.org/10.1016/j.biocon.2010.01.013

Anderson, M.J. & D.C. Walsh (2013). PERMANOVA, ANOSIM, and the Mantel test in the face of heterogeneous dispersions: what null hypothesis are you testing? *Ecological Monographs* 83(4): 557–574. https://doi.org/10.1890/12-2010.1

Asefa, A, A.B. Davies, A.E. McKechnie, A.A. Kinahan & B.J. van Rensburg (2017). Effects of anthropogenic disturbance on bird diversity in Ethiopian montane forests. *The Condor: Ornithological Applications* 119(3): 416–430. https://doi.org/10.1650/CONDOR-16-81.1

Batáry, P., A. Báldi & S. Erdős (2007). Grassland versus non-grassland bird abundance and diversity in managed grasslands: local, landscape and regional scale effects, pp. 45–55. In: Hawksworth, D.L. & A.T. Bull (eds). Vertebrate Conservation and Biodiversity. Topics in Biodiversity and Conservation, *Springer* (5): 871–881.

https://doi.org/10.1007/978-1-4020-6320-6_4

Bellio, M. & R.T. Kingsford (2013). Alteration of wetland hydrology in coastal lagoons: Implications for shorebird conservation and wetland restoration at a Ramsar site in Sri Lanka. *Biological Conservation* (167): 57–68. https://doi.org/10.1016/j.biocon.2013.07.013

Benton, T.G, J.A. Vickery & J.D. Wilson (2003). Farmland biodiversity: is habitat heterogeneity the key? *Trends in Ecology & Evolution* 18(4): 182–188. https://doi.org/10.1016/S0169-5347(03)00011-9

Borcard, D., F. Gillet & P. Legendre (2011). *Numerical Ecology with R*. Springer, New York, 688 pp.

Bühning-Gaese, K. (1997). Determinants of avian species richness at different spatial scales. *Journal of Biogeography* 24(1): 49–60. https://doi.org/10.1111/j.1365-2699.1997.tb00049

Chandran, K. & C.K. Vishnudas (2018). A comparative study of mixed-species bird flocks in a shaded coffee plantation and natural forest in Wayanad, Kerala. *Indian Birds* 14: 97–102.

Clarke, K.R. (1993). Non-parametric multivariate analyses of changes in community structure. *Australian Journal of Ecology* 18: 117–143. https://doi.org/10.1111/j.1442-9993.1993.tb00438

Clemens, R.S., A. Herrod & M.A. Weston (2014). Lines in the mud; revisiting the boundaries of important shorebird areas. *Journal for Nature Conservation* 22(1): 59–67. https://doi.org/10.1016/j.jnc.2013.09.001

Daniels, R.J.R. (1989). Conservation strategy for the birds of the Uttara Kannada District. Ph.D. thesis. Indian institute of science, Bangalore, 238 pp

Dittmann, S. (2008). Biodiversity and habitat characteristics of intertidal and estuarine mudflats of the Fleurieu Peninsula and Gulf St Vincent. Report for the Department for Environment and Heritage and Adelaide Mount Lofty Ranges Natural Resources Management Board, 52 pp.

Donald, P.F., R.E. Green & M.F. Heath (2001). Agricultural intensification and the collapse of Europe's farmland bird populations. Proceedings of the Royal Society of London. Series B: *Biological Sciences* 268(1462): 25–29. https://doi.org/10.1098/rspb.2000.1325

Donaldson, L., A.J. Woodhead, R.J. Wilson & I.M. Maclean (2016). Subsistence use of papyrus is compatible with wetland bird conservation. *Biological Conservation* 201: 414–422. https://doi.org/10.1016/j.biocon.2016.07.036

Dissanayake, N.G. (2019). Biodiversity and ecological functioning of mudflat macrofauna in the Anthropocene. PhD thesis. Griffith University, Australia, 221 pp. https://doi.org/10.25904/1912/1396

Fitzherbert, E.B., M.J. Struebig, A. Morel, F. Danielsen, C.A. Brühl, P.F. Donald & B. Phalan (2008). How will oil palm expansion affect biodiversity? *Trends in Ecology & Evolution* 23(10): 538–545. https://doi.org/10.1016/j.tree.2008.06.012

Garcia, C.A., S.A. Bhagwat, J. Ghazoul, C.D. Nath, K.M. Nanaya, C.G. Kushalappa & P. Vaast (2010). Biodiversity conservation in agricultural landscapes: challenges and opportunities of coffee agroforests in the Western Ghats, India. *Conservation Biology* 24(2): 479–488. https://doi.org/10.1111/j.1523-1739.2009.01386.x

Gonz´alez-Gajardo, A., P.V. Sepúlveda & R. Schlatter (2009). Waterbird assemblages and habitat characteristics in wetlands: influence of temporal variability on species habitat relationships. *Waterbirds* 32: 225–234. https://doi.org/10.1675/063.032.0203

Grimmett, R., C. Inskipp & T. Inskipp (2014). *Birds of Indian Subcontinent*. Oxford University Press, 528 pp.

Jacob, K. & S. Narayanaswamy (1954). The Structural and Drainage Pattern of the Western Ghats in the Vicinity of Palghat Gap. Proceeding of National Institute of Science India 20(1): 101–118.

Jayapal, R, Q. Qureshi & R. Chellam (2009). Importance of forest structure versus floristics to composition of avian assemblages in tropical deciduous forests of Central Highlands, India. *Forest Ecology and Management* 257(11): 2287–2295. https://doi.org/10.1016/j.foreco.2009.03.010

John, J., N.R. Chithra & S.G. Thampi (2019). Prediction of land use/cover change in the Bharathapuzha river basin, India using geospatial techniques. *Environmental Monitoring and Assessment* 191: 1–15. https://doi.org/10.1007/s10661-019-7482-4

Karanth K.K., V. Sankararaman, S. Dalvi, A. Srivathsa, R. Parameshwaran, S. Sharma, P. Robbins & A. Chhatre (2016). Producing Diversity: Agroforests Sustain Avian Richness and Abundance in India's Western Ghats. *Frontiers in Ecology and Evolution* 4: 111 . https://doi.org/10.3389/fevo.2016.00111

Karmierczak, K. (2000). *A Field Guide to the Birds of India*. Pica Press, U.K., 351 pp.

Kurucz, K., J.J. Purger & P. Batary (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

Kruskal, J.B. (1964). Multidimensional scaling by optimizing goodness of fit to a nonmetric hypothesis. *Psychometrika* 29(1): 1–27.

Legendre, P. & M.J. Anderson (1999). Distance-based redundancy analysis: testing multispecies responses in multifactorial ecological experiments. *Ecological Monographs* 69(1): 1–24. https://doi.org/10.1890/0012-9615(1999)069[0001:DBRATM]2.0.CO;2

Lorenzón, R.E., A.H. Beltzer, P.F. Olguin, E.J. León, L.V. Sovrano, C.E. Antoniazzi & A.L. Ronchi-Virgolini (2019). Temporal variation of bird assemblages in dynamic fluvial wetlands: seasonality and influence of water level and habitat availability. *Revista de Biología Tropical* 67(6): 1131–1145. https://doi.org/10.15517/rbt.v67i6.36734

Luo, K., Z. Wu, H. Bai & Z. Wang (2019). Bird diversity and waterbird habitat preferences in relation to wetland restoration at Dianchi Lake, south-west China. *Avian Research* 10(1): 1–12. https://doi.org/10.1186/s40657-019-0162-9

McCracken, D.I. & J.R. Tallowin (2004). Swards and structure: the interactions between farming practices and bird food resources in lowland grasslands. *Ibis* 146: 108–114. https://doi.org/10.1111/j.1474-919X.2004.00360.x

Meyer, W.B. & B.L. Turner (1992). Human population growth and global land-use/cover change. *Annual Review of Ecology and Systematics* 23(1): 39–61.

Murray, N.J. & R.A. Fuller (2015). Protecting stopover habitat for migratory shorebirds in East Asia. *Journal of Ornithology* 156: 217–225. https://doi.org/10.1007/s10336-015-1225-2

Namgail, T, J.Y. Takekawa, S. Balachandran, E.C. Palm, T. Mundkur, V.M. Vélez, D. J. Prosser & S.H. Newman (2017). Himalayan thoroughfare: migratory routes of ducks over the rooftop of the world, pp. 30–44. In: *Bird Migration Across the Himalayas: Wetland Functioning amidst Mountains and Glaciers*. Cambridge University Press, 440 pp. https://doi.org/10.1017/9781316335420.005

Oksanen, J.F., G. Blanchet, R.K.P. Legendre, P.R. Minchin, R.B. O'hara & G.L. Simpson (2013). Community ecology package "Package vegan." version 2.6-4. 1–295. https://CRAN.R-project.org/package=vegan.

Patrignani, A. & T.E. Ochsner (2015). Canopeo: A powerful new tool for measuring fractional green canopy cover. *Agronomy Journal* 107(6): 2312–2320. https://doi.org/10.2134/agronj15.0150

Plass, E.O.V. & J.M. Wunderle (2013). Avian distribution along a gradient of urbanization in northeastern Puerto Rico. *Ecological Bulletins* (54): 141–156.

Pramod, P. (1995). Ecological studies of bird communities in Silent Valley and neighbouring forests. PhD hTesis, University of Calicut.

Raj, P.A., A.D. Velankar & P. Pramod (2023). Diversity and distribution of birds in the Bharathapuzha River Basin, Kerala, India. *Journal of Threatened Taxa* 15(11): 24169–24183. https://doi.org/10.11609/jott.8573.15.11.24169-24183

Raj, P.N. & P.A. Azeez (2010). Land use and land cover changes in a tropical river basin: a case from Bharathapuzha River basin, southern India. *Journal of Geographic Information System* 2(4): 185–193. https://doi.org/10.4236/jgis.2010.24026

Raman, T.R.S. (2006). Effects of habitat structure and adjacent habitats on birds in tropical rainforest fragments and shaded plantations in the Western Ghats, India. *Biodiversity and Conservation* 15: 1577–1607. https://doi.org/10.1007/s10531-005-2352-5

Raman, T.R.S. & R. Sukumar (2002). Responses of tropical rainforest birds to abandoned plantations, edges and logged forest in the Western Ghats, India. *Animal Conservation* 5: 201–216. https://doi.

org/10.1017/S1367943002002251

Raman, T.R.S. & D. Mudappa (2003). Bridging the gap: sharing responsibility for ecological restoration and wildlife conservation on private lands in the Western Ghats. *Social Change* 33: 129–141. https://doi.org/10.1177/004908570303300309

Rendón, M.A., A.J. Green, E. Aguilera & P. Almaraz (2008). Status, distribution and long-term changes in the waterbird community wintering in Doñana, southwest Spain. *Biological Conservation* 141(5): 1371–1388. https://doi.org/10.1016/j.biocon.2008.03.006

Reynolds, R.T., J.M. Scott & R.A. Nussbaum (1980). A variable circular-plot method for estimating bird numbers. *The Condor* 82(3): 309–313.

Runge, C.A., J.E.M. Watson, S.H.M. Butchart, J.O. Hanson, H.P. Possingham & R.A. Fuller (2015). Protected areas and global conservation of migratory birds. *Science* 350: 1255–1258. https://doi.org/10.1126/science.aac9180

Schroeder, P.J. & D.G. Jenkins (2018). How robust are popular beta diversity indices to sampling error? *Ecosphere* 9(2): e02100. https://doi.org/10.1002/ecs2.2100

Strahler, A.N. (1964). *Quantitative Geomorphology of Drainage Basin and Channel Networks*, pp. 439–476. In: Chow, V.T. (ed.). *Handbook of Applied Hydrology*. McGraw Hill Book Company, New York.

Suárez-Seoane, S., P.E. Osborne & J. Alonso (2002). Large-scale habitat selection by agricultural steppe birds in Spain: identifying species–habitat responses using generalized additive models. *Journal of Applied Ecology* 39(5): 755–771. https://doi.org/10.1046/j.1365-2664.2002.00751.x

Variar, A.S., N.R. Anoop, P.A. Vinayan, P.A. Ajayan, N.S. Sujin, A. Ali, P.K. Prasadan, M. K. Smija & S. Babu (2021). Resident birds show different patterns in species composition and functional diversity in differently managed coffee plantations in the Western Ghats, India. *Ornithological Science* 20(2): 185–199. https://doi.org/10.2326/osj.20.185

Waide, R.B., M.R. Willig, C.F. Steiner, G. Mittelbach, L. Gough, S. Dodson, I. Dodson, G.P. Juday & R. Parmenter (1999). The relationship between productivity and species richness. *Annual review of Ecology and Systematics* 30(1): 257–300. https://doi.org/10.1146/annurev.ecolsys.30.1.257

White, J.G., M.J. Antos, J.A. Fitzsimons & G.C. Palmer (2005). Non-uniform bird assemblages in urban environments: the influence of streetscape vegetation. *Landscape and urban planning* 71(2–4): 123–135. https://doi.org/10.1016/j.landurbplan.2004.02.006

Wickham, H. (2016). *GGPLOT2: Elegant Graphics for Data Analysis*. Springer-Verlag New York, 182 pp.

Yang, X., Z. Duan, S. Li, C. Zhang, M. Qu, G. Hua & D. Yu (2022). Factors driving the abundance of wintering waterbirds in coastal areas of Guangdong Province. *Frontiers in Ecology and Evolution* 9. 808105. https://doi.org/10.3389/fevo.2021.808105

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 February 2024 | 16(2): 24658–24693

ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

https://doi.org/10.11609/jott.8347.16.2.24658-24693

#8347 | Received 29 December 2022 | Final received 11 January 2024 | Finally accepted 15 February 2024

OPEN ACCESS

ARTICLE

Desmids of Brahmaputra valley, a major southern Asian river basin

Soumin Nath [1] & **Partha Pratim Baruah** [2]

[1,2] Department of Botany, Gauhati University, Guwahati, Assam 781014, India.
[1] gautamnath237@gmail.com (corresponding author), [2] ppbaruah@gauhati.ac.in

Abstract: Inadequate information on the diversity and dispersion of desmids has led to incomplete floristic data in the northeastern region of India. The present study focuses on contributing to the information on the diversity and geographical distribution of desmid in water bodies of the Brahmaputra River basin of the Indian subcontinent. During the period 2019–2022, desmid flora of 91 waterbodies were studied. Two-hundred-and-thirty-one taxa belonging to five families and 25 genera were recorded, out of which 94 were new records for the northeastern India. Desmidiaceae was the dominant family with 195 species and with 69 species *Cosmarium* was the dominant genus.

Keywords: Biomonitoring, Brahmaputra River basin, *Cosmarium*, Charophyta, Desmid diversity, floristic data, geographical distribution, new records, northeastern India, water bodies.

Editor: Karthick Balasubramanian, Agharkar Research Institute, Pune, India. **Date of publication:** 26 February 2024 (online & print)

Citation: Nath, S. & P.P. Baruah (2024). Desmids of Brahmaputra valley, a major southern Asian river basin. *Journal of Threatened Taxa* 16(2): 24658–24693. https://doi.org/10.11609/jott.8347.16.2.24658-24693

Funding: Self-funded.

Competing interests: The authors declare no competing interests.

Author details: Dr. Partha Pratim Baruah is currently working as a professor in Department of Botany, Gauhati University, Assam, India. His thrust of research includes algal taxonomy, phycoremediation, phytoremediation, wetland, and wildlife ecology. He has completed seven national and international research projects till date. Mr. Soumin Nath is currently working as an assistant professor in Department of Botany, Dudhnoi College, Dudhnoi, Goalpara, Assam, India and pursuing his Ph.D. in the field of "Algal Taxonomy" in Gauhati University under the guidance of Prof. Partha Pratim Baruah.

Author contributions: SN—Conceptualization, visualization, investigation, writing- original draft. PPB—Supervision, conceptualization, writing- review & editing.

Acknowledgements: The authors are thankful to the head, of the Department of Botany, at Gauhati University for providing the laboratory facilities created by MoEF&CC (Govt. of India), DST-FIST, and UGC-SAP for conducting the research.

INTRODUCTION

The Indo-Malaya/northern Australia desmid floral region (Coesel 1996) which covers the entire southeastern Asian river basins is one of the 10 desmid floral regions (Krieger 1933, 1937) of the world. The Brahmaputra which originates in Tibet Himalaya and flows through India and Bangladesh up to the Bay of Bengal has the longest and largest river basins in the region covering an area of 2,900 km which includes altogether 180 watersheds, 24 major tributaries, and around 16,037 numbers of large to medium lentic water bodies up to the maximum size of 2,500 ha (Dadhwal et al. 2014). The prevailing eco-climatic conditions is concomitant with the humble and less destructive life styles of the aboriginal people help to maintain the pristine environments in the majority of the water bodies excluding those in urbanised centres/ towns that lead to support a rich desmid flora therein.

Desmids are eukaryotic unicellular creatures belonging to the class Zygnematophyceae of phylum Charophyta under kingdom Plantae (Lewis & McCourt 2004; Komal et al. 2021). All desmids consist of two symmetrical 'semi cells' joined by an isthmus (Das & Keshri 2012) and the majority possess beautiful cell-wall ornamentations (Brook 1981).

The members of this group not only prefer to grow and flourish in pure and less populated water but also quickly respond to the slightest change in pH or nutrient content in the substratum (Borics et al. 1998; Fehér 2003), which makes them ecologically sensitive and are therefore, considered as one of the indicators of good water quality. Recently, the information on desmids is seen to be documented as baseline data for any ecological and biomonitoring investigation in aquatic systems and the conservation of the same as well (Aquino et al. 2017; Paul et al. 2017) in the line of work of Coesel (1998) who proposed to determine the nature conservation value (NCV) based on parameters like species richness, presence of rare taxa, and the occurrence of taxa signifying ecosystem maturity.

Though a good number of workers (Baruah et al. 2009, 2013, 2020; Deka & Sarma 2011; Adhikary & Jena 2012; Bordoloi & Baruah 2015; Nath & Baruah 2020) have documented algal flora in different regions of Brahmaputra river basin in recent days, exclusive information on diversity and distribution of desmids is very much limited from this floristically wealthier sandwich region between Indo-Burma and Himalaya biodiversity hotspots (Bordoloi 1983; Deka et al. 2011; Yasmin et al. 2011; Phukan & Bora 2012; Baruah & Baruah 2013; Das 2020). The present endeavour was therefore undertaken to explore and document the hidden wealth of desmid flora in different lentic and lotic aquatic ecosystems of the Brahmaputra River basin of the Indian subcontinent.

MATERIALS AND METHODS

Sample collection and Identification

A total of 91 waterbodies (Table 1) were randomly explored in the entire reach of the mighty Brahmaputra River (Figure 1) for the collection of desmid samples. The collection of desmids was done by filtering technique using plankton net of mesh size 25 µm from January 2019 to December 2022. The samples were examined freshly under different magnifications (20X, 40X, and 60X) of the compound microscope (Euromex Delphi X Observer series) and photomicrographs were taken with the help of a digital camera (Euromex 20MP). Image view software was used for micrometric measurements of desmids. The remaining samples were preserved in Lugol's iodine solution for further investigations. Identification of desmids were done by following monographs of Croasdale et al. (1983), Prasad & Misra (1992), Lenzenweger (1996, 1997, 1999, 2003), John et al. (2005), Ahmed et al. (2007), and Das & Keshri (2016). Updated nomenclature of the species was given by following Guiry & Guiry (2022) and was systematically arranged following Ruggiero et al. (2015).

RESULTS

In the present study, 231 taxa of desmids belonging to 25 genera, under five families, and two orders were recorded from the selected water bodies of the entire Brahmaputra River basin located under the Indian subcontinent. Desmidiaceae was reported to be the dominant family with 195 species, of which *Cosmarium* was recorded as the dominant genus with 69 species.

Systematic Enumeration

Phylum: Charophyta
Class: Zygnematophyceae
Subclass: Zygnematophycidae
Order: Desmidiales
Family: Closteriaceae
Genus: *Closterium*

Closterium abruptum West 1892: 719, pl. IX [9]: fig. 1

Cells elongate, 8–9 times longer than broad, slightly curved at the centre but more curved towards the extremities, having 64–70° of arc, cell wall smooth, one girdle band present, chloroplast with 2–3 pyrenoids, cells 171–245 µm long and 22–25 µm broad,

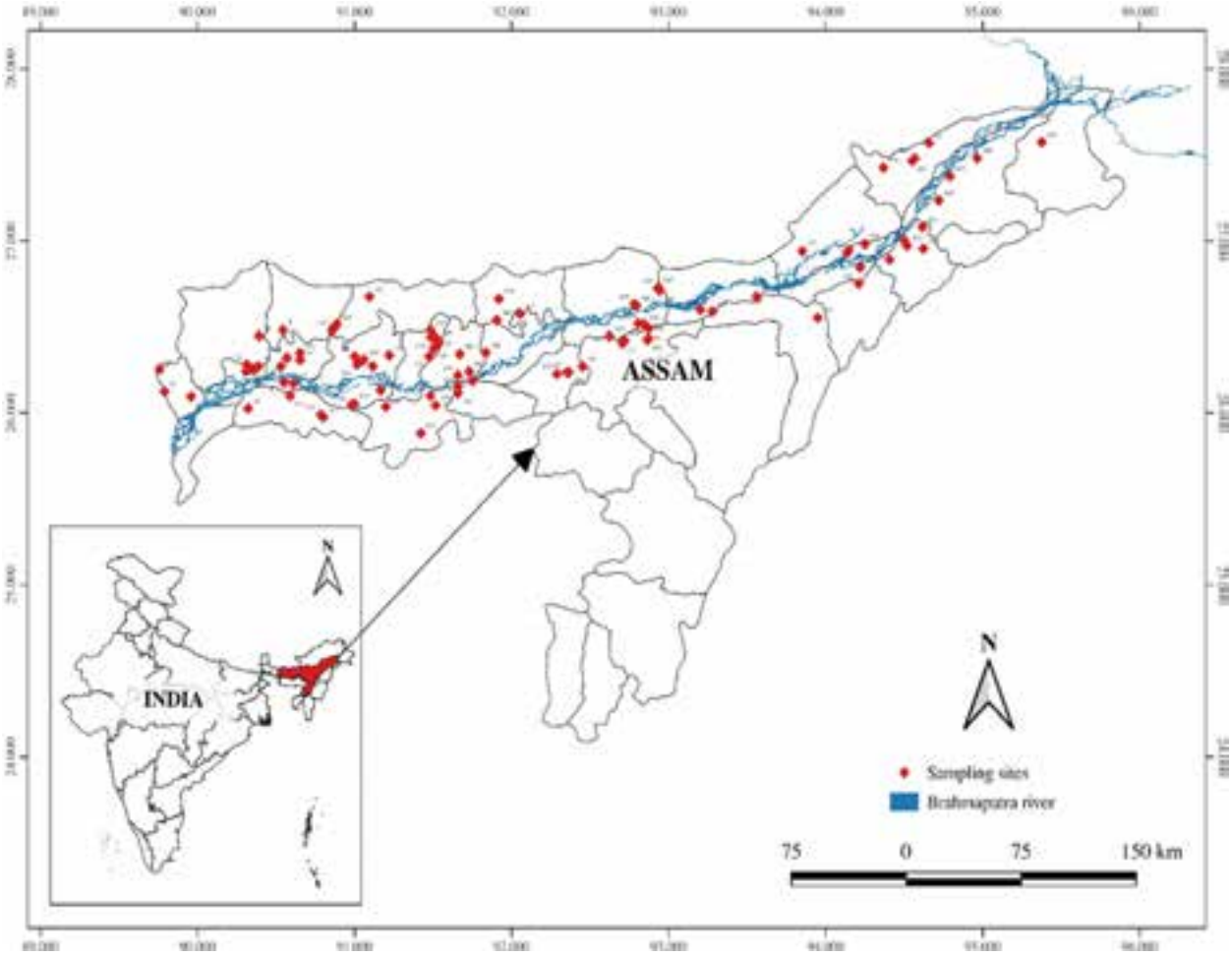


Figure 1. Location map showing desmid collection sites in Brahmaputra valley.

apex 8–9 µm broad.

Site of collection: Dhamar Beel, Goalpara; Sorbhog Pond, Barpeta.

Previous records and distribution in northeastern India: Manmecho Lake, Das & Keshri (2012).

Closterium acutum Brébisson 1848: 177, pl. XXX [30]: figs 5a, 5b, 5d, 5f; pl. XXXV: fig. 5

Cells elongate, 22–23.5 times longer than broad, semi-straight, slightly curved at extremities, cell wall smooth, dorsal margin convex and approximately straight, chloroplast with pyrenoids, 6–8 in number arranged in a series, cells 235–310 µm long and 10–14 µm broad, apex 2–3 µm broad.

Site of collection: Deepor Beel, Kamrup (M), Urpad Beel, Goalpara; Barsola Beel, Jorhat.

Previous records and distribution in northeastern India: Khanajan, Baruah & Baruah (2013); Dachi lake, Hajong & Ramanujam (2018); Deepor Beel, Baruah et al. (2020).

Closterium acutum var. *linea* (Perty) West & G. S. West 1900: 57

Basionym: *Closterium linea* Perty

Cells spindle-shaped, 31–36 times longer than broad, narrow, almost straight, gradually attenuated to acute and slightly curved poles, chloroplast with 8–10 pyrenoids, arranged in a row, cells 110–155 µm long and 3–5 µm broad, apex 1–1.5 µm broad.

Site of collection: Kusumfula Beel, Goalpara; Dheer Beel, Dhubri.

Previous records and distribution in northeastern India: Sivasagar, Phukan & Bora (2012).

Closterium acutum var. *variabile* (Lemmermann) Willi Krieger 1935: 262, pl. 13: figs 18–22

Basionym: *Closterium pseudospirotaenium* var. *variabile* Lemmermann

Cells sigmoid-shaped, 28–30 times longer than broad, narrow, gradually attenuated towards poles, strongly and irregularly curved, chloroplast with a series of pyrenoids, cells 90–140 µm long and 3–5 µm broad.

Site of collection: Shamaguri Beel, Nagaon.

Previous records and distribution in northeastern India: Northeastern India, Yasmin et al. (2011).

Closterium closterioides (Ralfs) A.Louis & Peeters 1967: 410, pl. 13: fig. 119

Basionym: *Penium closterioides* Ralfs

Cells are straight, elongated, 6–7 times longer than broad, both sides with a slight notch in the mid-region, gradually nar-

Table 1. Desmids collection sites of Brahmaputra valley.

Site no.	Latitude	Longitude	Name of collection site
S1	26.253°N	89.757°E	Goalnani Pond, Dhubri
S2	26.124°N	89.789°E	Konuri Beel, Dhubri
S3	26.094°N	89.958°E	Laokhoa Beel, Dhubri
S4	26.244°N	90.311°E	Gaurangtari Pond, Dhubri
S5	26.279°N	90.315°E	Diplai Beel, Kokrajhar
S6	26.026°N	90.322°E	Dhamar Beel, Goalpara
S7	26.256°N	90.353°E	Dakra Beel, Dhubri
S8	26.270°N	90.387°E	Dheer Beel, Dhubri
S9	26.448°N	90.390°E	Kursakati Pond, Kokrajhar
S10	26.272°N	90.531°E	Dolani Beel, Bongaigaon
S11	26.482°N	90.543°E	Dosomighat Pond, Bongaigaon
S12	26.177°N	90.550°E	Kumri Beel, Goalpara
S13	26.320°N	90.569°E	Tamranga Beel, Bongaigaon
S14	26.099°N	90.588°E	Urpad Beel, Goalpara
S15	26.170°N	90.609°E	Hasila Beel, Goalpara
S16	26.348°N	90.651°E	Deohati Pond, Bongaigaon
S17	26.309°N	90.652°E	Koya Kujia Beel, Bongaigaon
S18	25.988°N	90.785°E	Dudhnoi College Pond, Goalpara
S19	25.975°N	90.802°E	Kusumfula Beel, Goalpara
S20	26.477°N	90.857°E	Sorbhog Pond, Barpeta
S21	26.514°N	90.887°E	Sorbhog Beel, Barpeta
S22	26.045°N	90.980°E	Tiplai Pond, Goalpara
S23	26.053°N	90.997°E	Naitara Choutara Beel, Goalpara
S24	26.327°N	91.001°E	Madhab Choudhury College Pond, Barpeta
S25	26.282°N	91.014°E	Gandhi Beel, Barpeta
S26	26.308°N	91.058°E	Keotkuchi Pond, Barpeta
S27	26.675°N	91.093°E	Raja Beel, Baksa
S28	26.270°N	91.116°E	Akhara Beel, Barpeta
S29	26.132°N	91.165°E	Bejorsuti Pond, Kamrup
S30	26.036°N	91.198°E	Jiyeni Beel, Kamrup
S31	25.881°N	91.421°E	Chandubi Beel, Kamrup
S32	26.334°N	91.220°E	Kapla Beel, Barpeta
S33	26.328°N	91.475°E	Ulabari Pond, Nalbari
S34	26.439°N	91.485°E	Ghunkuchi Beel, Nalbari
S35	26.100°N	91.483°E	Rajapukhuri, Nahira Kamrup
S36	26.481°N	91.484°E	Katara Beel Paikarkuchi, Nalbari
S37	26.376°N	91.502°E	Bogol Road Beel, Nalbari
S38	26.443°N	91.508°E	Rajapukhuri Ghagrapar, Nalbari
S39	26.043°N	91.516°E	Majkuchi Pond, Kamrup
S40	26.424°N	91.530°E	Narpara Pond, Nalbari
S41	26.406°N	91.535°E	Borpukhri Ghagrapar, Nalbari
S42	26.153°N	91.657°E	Gauhati University Pond, Kamrup (M)
S43	26.114°N	91.657°E	Deepor Beel, Kamrup (M)
S44	26.218°N	91.658°E	Digholi Beel, Kamrup
S45	26.341°N	91.669°E	Borphukhuri, Kamalpur Kamrup
S46	26.240°N	91.730°E	Bornijora Pond, Jalah Kamrup
S47	26.186°N	91.751°E	Dighalipukhuri, Kamrup (M)
S48	26.349°N	91.835°E	Duminichowki Pond, Kamrup
S49	26.539°N	91.906°E	Lakhimpur pukhuri, Darrang
S50	26.662°N	91.919°E	Pond near Tangla College, Udalguri
S51	26.576°N	92.054°E	Rajapukhuri, Darrang
S52	26.226°N	92.288°E	Charan Beel, Morigaon
S53	26.237°N	92.352°E	Morakolong, Nagaon
S54	26.235°N	92.362°E	Dandua Beel, Morigaon
S55	26.269°N	92.452°E	Kachodhora Beel, Morigaon
S56	26.446°N	92.622°E	Dagaon Pond, Nagaon
S57	26.404°N	92.703°E	Barpeta Beel, Nagaon
S58	26.418°N	92.719°E	Rawmari Beel, Nagaon
S59	26.631°N	92.780°E	Hazarapar Pukhuri, Sonitpur
S60	26.623°N	92.792°E	Padumpukhuri, Sonitpur
S61	26.520°N	92.806°E	Haribhanga Beel, Nagaon
S62	26.514°N	92.841°E	Bhomoraguri Pond, Nagaon
S63	26.424°N	92.863°E	Shamaguri Beel, Nagaon
S64	26.432°N	92.871° E	Gatanga Beel, Nagaon
S65	26.492°N	92.872°E	Sibasthan-Potakollong, Nagaon
S66	26.723°N	92.931°E	Pachi Gaon Pond, Sonitpur
S67	26.728°N	92.934°E	Mohmara Pond, Sonitpur
S68	26.710°N	92.943°E	Panpoor Ghat, Sonitpur
S69	26.599°N	93.201°E	Daphlong Beel, Golaghat
S70	26.891°N	94.405°E	Dighali Beel, Nagaon
S71	26.675°N	93.558°E	Koladuwar Beel, Golaghat
S72	26.940°N	93.851°E	Radhapukhuri, Lakhimpur
S73	26.552°N	93.949°E	Jugi Beel, Golaghat
S74	26.931°N	94.139°E	Bheriki Beel, Jorhat
S75	26.945°N	94.145°E	Chakoli Beel, Majuli
S76	26.750°N	94.210°E	Tinkonia Pukhuri, Jorhat
S77	26.846°N	94.219°E	Barsola Beel, Jorhat
S78	26.981°N	94.250°E	Jor Beel, Jorhat
S79	27.425°N	94.367°E	Bhebeli Pond, Dhemaji
S80	26.891°N	94.405°E	Dighali Beel, Sivasagar
S81	27.000°N	94.502°E	Jogorahabi Beel, Sivasagar
S82	26.971°N	94.517°E	Buka Beel, Sivasagar
S83	27.465°N	94.551°E	Bharalichuk Pond, Dhemaji
S84	27.479°N	94.566°E	Himatichuk Pond, Dhemaji
S85	27.081°N	94.615°E	Moridesang, Sivasagar
S86	26.954°N	94.621°E	Jaysagar Pukhuri, Sivasagar
S87	27.569°N	94.658°E	Sripani Pond, Dhemaji
S88	27.235°N	94.720°E	Gohain Pukhuri, Sivasagar
S89	27.376°N	94.791°E	Bogibil Ghat, Dibrugarh
S90	27.481°N	94.964°E	Hiloidhari majgao Beel, Dibrugarh
S91	27.573°N	95.376°E	Maguri Motapung Beel, Tinsukia

rowing towards the poles, apices flatly obtuse, chloroplasts with 4–5 longitudinal ridges, each with 2–3 pyrenoids, cell wall smooth, cells 125–170 µm long 20–24 µm broad, apex 5–6 µm broad.
Site of collection: Chandubi Beel, Kamrup; Radhapukhuri, Lakhimpur, Sibasthan Potakollong, Nagaon; Kursakati Pond, Kokrajhar.

Previous records and distribution in northeastern India: Chandubi Beel, Nath & Baruah (2020).

Closterium closterioides var. *intermedium* (J.Roy & Bisset) Ruzicka 1973: 199, pl. 2: fig. 23

Basionym: *Penium libellula* var. *intermedium* Roy & Bisset 1894: 252

Cells straight, elongated, 5–6 times longer than broad, dorsal, and ventral sides similarly concave, gradually attenuated towards the truncated poles, cell wall smooth, axial chloroplast with 3–4 pyrenoids, cells 85–120 µm long and 17–20 µm broad, apex 6–7 µm broad.

Site of collection: Urpad Beel, Goalpara; Diplai Beel, Kokrajhar; Deohati Pond, Bongaigaon.

Previous records and distribution in northeastern India: Northeastern India, Yasmin et al. (2011); Urpad Beel, Deka et al. (2011); Kokrajhar, Das (2020).

Closterium cornu Ehrenberg ex Ralfs 1848: 176, pl. XXX [30]: figs 6f, 6g

Cells long, 19–21 times longer than broad, fusiform, straight, or slightly curved, outer margin with the arc of 33–40°, inner margin straight or very slightly concave, gradually attenuating towards narrowly rounded apices, chloroplast with three longitudinal ridges, with 2 pyrenoids, cell wall smooth and colourless, cells 192–237 µm long and 9–12 µm broad, apex 4–5 µm broad.

Site of collection: Jogorahabi Beel, Sivasagar; Dosomighat Pond, Bongaigaon.

Previous records and distribution in northeastern India: Dachi lake, Hajong & Ramanujam (2018).

Closterium cynthia De Notaris 1867: 65, fig. 71; pl. VII [7]

Cells medium-sized, lunate, 10–11 times longer than broad, moderately curved, lateral sides gradually attenuated to obtusely rounded poles, chloroplast axial with 5–6 pyrenoids, cell wall with longitudinal striae, girdle bands visible, cells 68–94 µm long and 6–9 µm broad, apex 1–2 µm broad.

Site of collection: Chandubi Beel, Kamrup; Maguri Motapung Beel, Tinsukia; Tiplai Pond, Goalpara.

Previous records and distribution in northeastern India: Sivasagar, Phukan & Bora (2012); Dachi lake, Hajong & Ramanujam (2018); Chandubi Beel, Nath & Baruah (2020).

Closterium decorum Brébisson 1856: 151, pl. 2: fig. 39

Cells medium-sized, 16–17 times longer than broad, solitary, middle region tubular and slightly curved, cell wall smooth, chloroplast with ridges, 10–13 pyrenoids arranged in an axile row, cells 130–187 µm long and 8–11 µm broad, apex 2–3 µm broad.

Site of collection: Deepor Beel, Kamrup (M); Gauhati University Pond, Kamrup (M).

Previous records and distribution in northeastern India: Khanajan, Baruah & Baruah (2013); Deepor Beel, Baruah et al. (2020).

Closterium dianae Ehrenberg ex Ralfs 1848: 168, figs 5a, 5c; pl. XXVIII [28]

Cells medium-sized, lunate, 11.6–13.8 times longer than broad, curved, concave ventral margin, apices smooth, cell wall yellowish to brownish, chloroplast ridged, pyrenoids 3–4, cells 152–175 µm long and 11–15 µm broad.

Site of collection: Deepor Beel, Kamrup (M); Chandubi Beel, Kamrup; Padumpukhuri, Sonitpur; Pachi Gaon Pond, Sonitpur.

Previous records and distribution in northeastern India: Loktak Lake, Jena & Adhikary (2011); Khanajan, Baruah & Baruah (2013); Dachi lake, Hajong & Ramanujam (2018); Deepor Beel, Baruah et al. (2020).

Closterium ehrenbergii Meneghini ex Ralfs 1848: 166, pl. XXVIII [28]: fig. 2

Cells large, elongated, about eight times longer than broad, dorsal side curved with an arc of 110–120°, swollen mid region of ventral side gradually attenuating towards broad and rounded apices, parietal chloroplast with a series of ridges, throughout the chloroplast numerous pyrenoids scattered, cell wall smooth, light brown to colourless, cells 430–560 µm long and 50–67 µm broad, apex 6–8 µm broad.

Site of collection: Chakoli Beel, Majuli; Hiloidhari Majgao Beel, Dibrugarh; Jaysagar Pukhuri, Sivasagar

Previous records and distribution in northeastern India: Northeastern India, Yasmin et al. (2011); Meghalaya, Das & Ramanujam (2010); Sivasagar, Phukan & Bora (2012).

Closterium elenkinii Kossinskaja 1936: 415, pl. I: fig. 3

Cells medium-sized, about 12.5–13.7 times longer than broad, slightly swollen in the central region, moderately curved with 70° of arc, tapering abruptly toward slightly produced apices, chloroplast with four longitudinal ridges, each chloroplast with four pyrenoids, cell wall smooth, vibrating granules present in the apices, cells 150–220 µm long and 12–16 µm broad, apex 2–3 µm broad.

Site of collection: Haribhanga Beel, Nagaon; Sorbhog Pond, Barpeta.

New to northeastern India (Image 1).

Closterium gracile Brébisson ex Ralfs 1848: 221, pl. XXI [21]: figs 8–12

Cells medium-sized, 24–35 times longer than broad, almost straight but slightly curved towards the apices, curvature with 37° of arc, lateral margins parallel, gradually tapering toward the apices, poles obtuse, cell wall smooth and colourless, 14 pyrenoids in the chloroplast, cells 140–172 µm long and 4–7 µm broad, apex 1.5–2 µm broad.

Site of collection: Kapla Beel, Barpeta; Sibasthan-Potakollong, Nagaon.

Previous records and distribution in northeastern India: Manmecho lake, Das & Keshri (2012), Arunachal Himalayas, Nath & Baruah (2021).

Closterium incurvum Brébisson 1856: 150, pl. 2: fig. 47

Cells small sized, 7.5–8.7 times longer than broad, strongly curved with 170° of arc, ventral side not inflated, strongly diminished toward apices, poles intensely rounded, axial plate-like chloroplast with a single pyrenoid; cell wall smooth and colourless, cells 70–91 µm long and 8–12 µm broad, apex 1–2 µm broad.

Site of collection: Bejorsuti Pond, Kamrup; Keotkuchi Pond, Barpeta.

Previous records and distribution in northeastern India: Loktak Lake, Jena & Adhikary (2011); northeastern India, Yasmin et al. (2011); Sivasagar, Phukan & Bora (2012); Arunachal Himalaya, Nath & Baruah (2021).

Closterium kuetzingii Brébisson 1856: 156, pl. 2: fig. 40

Cells long, about 27.5–28.5 times longer than broad, almost straight, apex slightly incurved with 42° of arc, the central region is spindle-shaped, dorsal and ventral sides almost equally convex, diminished abruptly toward the apices to form slightly swollen processes, rounded and slightly inflated poles with the thickened inner wall, cell wall striated and colourless, chloroplasts present only in the mid region, cells 220–314 µm long and 8–11 µm broad, apex 1.5–2 µm broad.

Site of collection: Deepor Beel, Kamrup (M); Urpad Beel, Goalpara; Chandubi Beel, Kamrup; Rawmari Beel, Nagaon; Dighalipukhuri, Kamrup (M).

Previous records and distribution in northeastern India: Loktak Lake, Jena & Adhikary (2011); North Eastern India, Yasmin et al. (2011); Urpad Beel Deka et al. (2011); Deepor Beel, Baruah et al. (2020); Arunachal Himalayas, Nath & Baruah (2021).

Closterium libellula var. *sikkimense* J. P. Keshri & D. Das 2016: 77, pl. XVI [16]: figs 314, 315

Cells long, almost straight, 8–9 times longer than broad, 34° of arc, a middle region slightly raised angularly, gradually attenuated towards broadly rounded apices, cell wall smooth and colourless, chloroplast with 6 longitudinal ridges exhibiting 6–9 pyrenoids, cells 176–190 µm long, 19–23 µm broad and apex 3–4.5 µm broad.

Site of collection: Goalnani Pond, Dhubri.

New to northeastern India (Image 2).

Closterium lineatum Ehrenberg ex Ralfs 1848: 173, fig. 1; pl. XXX [30]

Cell semi-straight, 34.5–37 times longer than broad, slightly curved in the apical region with 22–31° of arc, dorsal margin is nearly straight throughout the entire length, ventral margin almost straight, cell wall striated and yellowish to brownish in colour, truncated-rounded poles, axial chloroplast with several numbers of pyrenoids, cells 226–310 µm long and 6–9 µm broad, apex 2–3 µm broad.

Site of collection: Barpeta Beel, Nagaon**;** Morakolong, Nagaon

Previous records and distribution in northeastern India: Dachi Lake, Hajong & Ramanujam (2018).

Closterium lunula Ehrenberg & Hemprich ex Ralfs 1848: 163, pl. XXVII [27]: fig. 1

Cells large, 5–7 times longer than broad, almost straight, 44° of arc, broad abruptly but slightly attenuated near the truncately rounded poles, dorsal margin more curved than the ventral, ventral margin slightly concave in the mid-region, plate-like axial chloroplast with 4–5 ridges and containing six pyrenoids in a row in each semicell , cell wall smooth and colourless, cells 210–265 µm long, 30–51 µm broad and apex 4–6 µm broad.

Site of collection: Urpad Beel, Goalpara.

Previous records and distribution in northeastern India: Sivasagar, Phukan and Bora (2012); Urpad Beel, Deka et al. (2011); Arunachal Himalayas, Nath & Baruah (2021).

Closterium minutum var. *indicum* J.P.Keshri & D.Das

Cells small, 6.4–7.2 times longer than broad, moderately curved with 135° of arc, lunate, dorsal and ventral margins equally curved, slightly tapering to bluntly rounded poles, chloroplast axial plate having 3–4 pyrenoids, cell wall smooth and colourless, cells 58–80 µm long, 9–11 µm broad and apex 3–4 µm broad.

Site of collection: Katara Beel Paikarkuchi, Nalbari; Sorbhog Beel, Barpeta

New to northeastern India (Image 3).

Closterium navicula (Brébisson) Lütkemüller 1905: 337

Basionym: *Penium navicula* Brébisson

Cells small, straight, fusiform, 3.7–5.2 times longer than broad, moderately curved with 78° of arc, dorsal and ventral margins concave, gradually attenuated to widely rounded poles, chloroplast with 8 longitudinal ridges having a few pyrenoids, apical vacuole with granules, cells 30–52 µm long and 8–10 µm broad, apex 4–5 µm broad.

Site of collection: Urpad Beel, Goalpara; Laokhoa Beel, Dhubri; Deohati Pond, Bongaigaon.

Previous records and distribution in northeastern India: Urpad Beel, Deka et al. (2011); Arunachal Himalayas, Nath & Baruah (2021).

Closterium parvulum var. *maius* (Schmidle) Willi Krieger 1935: 277, pl. 16: fig. 18

Basionym: *Closterium parvulum* f. *maius* Schmidle

Cells medium-sized, lunate, 11–12 times longer than broad, moderately curved with 122–148° of arc, slightly convex dorsal side, concave ventral side, nearly straight throughout the entire length, without median swelling, pointed-rounded poles, cell wall smooth, hyaline to yellowish in colour, axial chloroplast with 2–3 pyrenoids, arranged in median series, cells 190–285 µm long and 17–23 µm broad, apex 3–4 µm broad.

Site of collection: Urpad Beel, Goalpara.

Previous records and distribution in northeastern India: Urpad Beel, Deka et al. (2011).

Closterium planum E. O. Hughes 1952: 284, fig. 35

Cells medium-sized, elongated, about 15–16 times longer than broad, slightly curved near the poles with 37–48° of arc, truncately rounded poles, cell wall smooth and brownish; outer margin slightly more curved than the inner margin; girdle band present, chloroplast having six longitudinal ridges and exhibiting six axial pyrenoids in each, cells 224–282 µm long and 14–18 µm broad, apex 6–7 µm broad.

Site of collection: Borphukhuri, Kamalpur Kamrup; Koladuwar Beel, Golaghat; Akhara Beel, Barpeta; Madhab Choudhury College Pond, Barpeta.

Previous records and distribution in northeastern India: Manmecho Lake, Das & Keshri (2012).

Closterium praelongum var. *brevius* (Nordstedt) Willi Krieger 1935: 324, pl. 25: fig. 29

Basionym: *Closterium praelongum* f. *brevius* Nordstedt

Cells medium-sized, 16–18.5 times longer than broad, dorsal and ventral margins parallel in the middle region, apices slightly recurved, curvature with 18° of arc, ridged chloroplast with 8–10 pyrenoids, cells 112–167 µm long and 7–9 µm broad, apex 4–5 µm broad.

Site of collection: Maguri Motapung Beel, Tinsukia.

New to northeastern India (Image 4).

Closterium pseudocynthia J. P. Keshri & D. Das 2016: 83, pl. XX [20]: figs 365, 366

Cells medium-sized, 13.5–15.2 times longer than broad, moderately curved with 118° of arc, both margins equally curved, gradually attenuated towards the sharply pointed poles, cell wall smooth and yellowish red, ridged chloroplast with 4–6 pyrenoids arranged in axial series, terminal vacuoles granulated, cells 216–320 µm long and 16–21 µm broad, apex 3–4 µm broad.

Site of collection: Chandubi Beel, Kamrup; Gandhi Beel, Barpeta, Morakolong, Nagaon

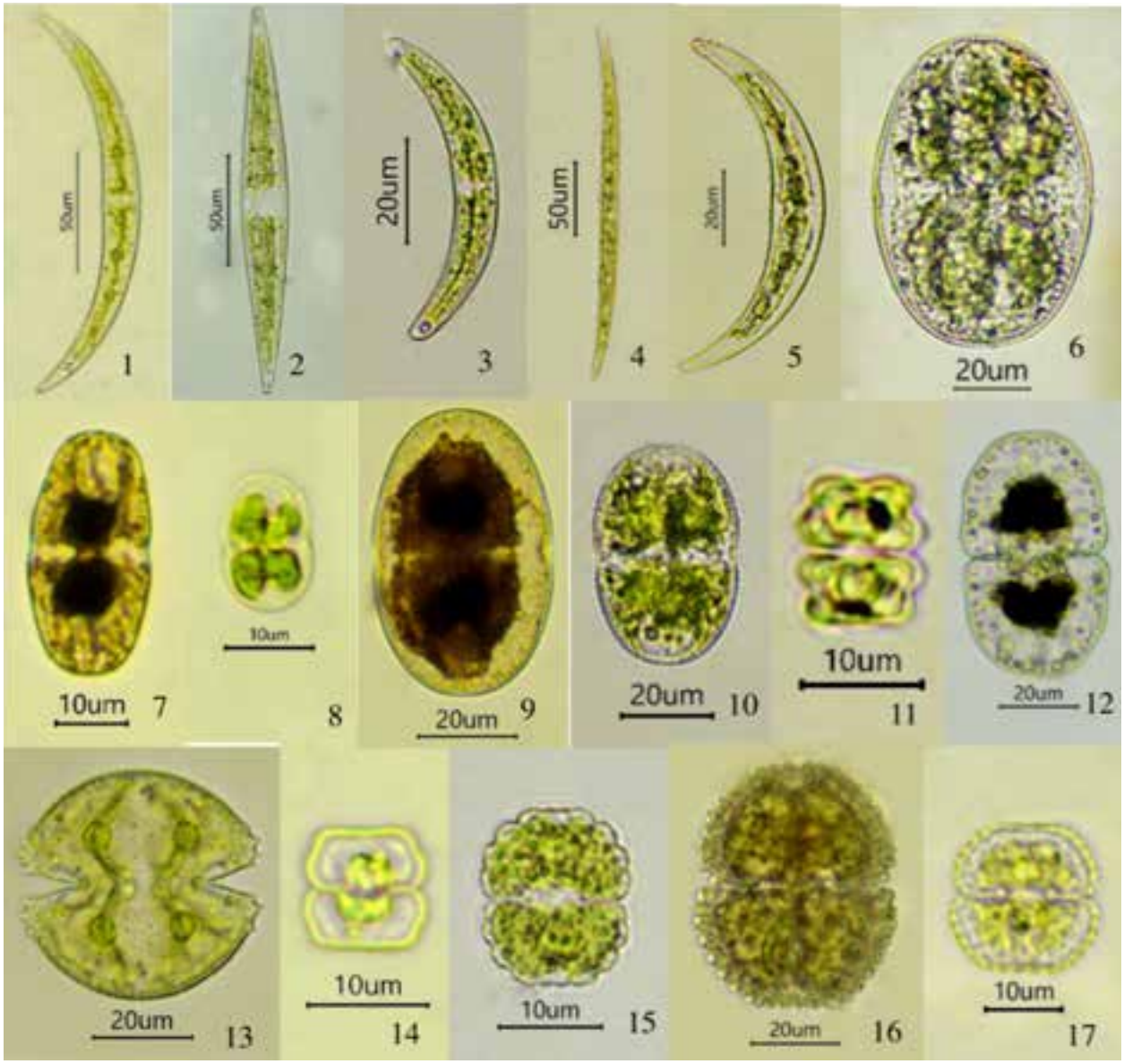


Image 1–17. 1—*Closterium elenkinii* | 2—*Closterium libellula* var. *sikkimense* | 3—*Closterium minutum* var. *indicum* | 4—*Closterium praelongum* var. *brevius* | 5—*Closterium tumidulum* f. *indicum* | 6—*Actinotaenium australe* | 7—*Actinotaenium cucurbitinum* var. *minutum* | 8—*Actinotaenium perminutum* | 9—*Actinotaenium pseudoglobossum* | 10—*Actinotaenium wollei* | 11—*Cosmarium abruptum* | 12—*Cosmarium angulatum* f. *majus* | 13—*Cosmarium auriculatum* | 14—*Cosmarium baffinense* | 15—*Cosmarium blyttii* | 16—*Cosmarium brebissonii* | 17—*Cosmarium calcareum*.

Previous records and distribution in northeastern India: Chandubi Beel, Nath & Baruah (2020); Arunachal Himalayas, Nath & Baruah (2021).

Closterium pseudolunula O.Borge 1909: 3, pl. 1: fig. 2

Cells medium-sized, about 8–9 times longer than broad; moderately curved with 48–72° of arc; dorsal margin convex, ventral margin straight for more than two-third of the entire length; apices broadly rounded; chloroplast axial with 4–6 pyrenoids; cell wall smooth and colourless, cells 220–302 µm long and 27–33 µm broad, apex 8–10 µm broad.

Site of collection: Urpad Beel, Goalpara; Hazarapar Pukhuri, Sonitpur.

Previous records and distribution in northeastern India: Urpad Beel, Deka et al. (2011).

Closterium rostratum Ehrenberg ex Ralfs 1848: 175, pl. XXX [30]: fig. 3

Cells large, semi-lunated, 12–13 times longer than broad, slightly curved with 35–50° of arc, both dorsal as well as ventral margins convex, ventral is more curved, fusiform mid-region, gradually narrowed towards the obliquely truncate poles, setaceous apical processes and slightly curved; striated cell wall, axial chloroplast with 3–7 lamellae exhibiting 3–6 pyrenoids, cells 362–490 µm long and 30–36 µm broad, apex 6–7 µm broad.

Site of collection: Chandubi Beel, Kamrup; Naitara Choutara

Beel, Goalpara; Keotkuchi Pond, Barpeta.

Previous records and distribution in northeastern India: Chandubi Beel, Nath & Baruah (2020); Arunachal Himalayas, Nath & Baruah (2021).

Closterium tumidulum f. *indicum* J.P.Keshri & D.Das 2016: 91, pl. XVI [16]: figs 316, 317

Cells medium-sized, 7–8 times longer than broad, strongly curved with 159° of arc, dorsal margin convex, ventral margin with slightly tumid mid–region, gradually narrowed towards the apices forming rounded poles, cell wall smooth and colourless, chloroplasts with 4 ridges, cells 114–130 µm long and 14–18 µm broad, apex 2–4 µm broad.

Site of collection: Gauhati University Pond, Kamrup (M).

New to northeastern India (Image 5).

Family: Desmidiaceae

Genus: *Actinotaenium*

Actinotaenium australe (Raciborski) Croasdale 1981: 4

Basionym: *Penium australe* Raciborski

Cells medium-sized, broadly elliptical in outline, about 1.5 times longer than broad, slightly constricted at the isthmus, very slight tapering towards the poles with broadly rounded apices, chloroplast with 6 longitudinal lamellae and a centrally placed large pyrenoid, cell wall punctate and colourless, cells 82–94 µm long, 57–64 µm broad and isthmus 54–56 µm broad.

Site of collection: Dhamar Beel, Goalpara.

New to northeastern India (Image 6).

Actinotaenium cucurbitinum var. *minutum* (Prescott) Tomaszewicz 1988: 44

Basionym:*Penium cucurbitinum* var. *minutum* Prescott

Cells small sized, about 2 times longer than broad, sinus a shallow notch, both lateral margins convex and slightly narrowing towards broadly rounded apices, punctate cell wall, axial chloroplast, cells 33–38 µm long, 16–18 µm broad and isthmus 14–15 µm broad.

Site of collection: Dheer Beel, Dhubri.

New to northeastern India (Image 7).

Actinotaenium cucurbita var. *rotundatum* (Willi Krieger) Teiling 1954: 407

Basionym: *Cosmarium cucurbita* f. *rotundatum* Krieger

Cells small sized, about 1.7–1.8 times longer than broad; sinus has a shallow notch; both lateral margins are convex, margins are slightly attenuated towards the poles, poles broadly rounded, cell wall with randomly organized fine punctate, axial chloroplast with longitudinal lamellae, cells 28–33 µm long, 15.7–18 µm broad and isthmus 14–16.5 µm broad.

Site of collection: Chandubi Beel, Kamrup; Koya Kujia Beel, Bongaigaon.

Previous records and distribution in northeastern India: Chandubi Beel, Nath & Baruah (2020).

*Actinotaenium g*lobosum (Bulnheim) Kurt Förster ex Compère 1976: 456

Basionym: *Cosmarium globosum* Bulnheim

Cells small sized, about 1.5 times longer than broad, slightly constricted at the middle region, semicells semicircular, lateral sides convex, apices broadly rounded, cell wall with fine punctae, axial chloroplast with a centrally placed pyrenoid, cells 28–33 µm long, 19–22 µm broad and isthmus 17–18 µm broad.

Site of collection: Chandubi Beel, Kamrup; Bheriki Beel, Jorhat

Previous records and distribution in northeastern India: Chandubi Beel, Nath & Baruah (2020).

Actinotaenium perminutum (G. S. West) Teiling 1954: 410, fig. 60

Basionym: *Cosmarium perminutum* G. S. West

Cells very small sized, about 1.4 times longer than broad, sinus a shallow notch, lateral margins slightly attenuated towards broadly rounded poles, cell wall punctate, axial chloroplast with a centrally placed pyrenoid, cells 13–16 µm long, 9–11 µm broad and isthmus 7–8 µm broad.

Site of collection: Maguri Motapung Beel, Tinsukia.

New to northeastern India (Image 8).

Actinotaenium pseudoglobossum Kurt Förster 1981: 237; pl. 2, fig. 20

Cells medium-sized, about 1.6–1.7 times longer than broad, sinus a slight notch, broadly elliptical semicells with rounded apex, cell wall with fine punctae, radiated chloroplast with pyrenoids, cells 58–84 µm long, 36–50 µm broad and isthmus 34–46 µm broad.

Site of collection: Haribhanga Beel, Nagaon.

New to northeastern India (Image 9).

Actinotaenium subglobosum (Nordstedt) Teiling 1954: 397

Basionym: *Cosmarium subglobosum* Nordstedt

Cells medium-sized, about 1.7 times longer than broad, sinus shallow notch, both apices and lateral margins broadly rounded, cell wall sparsely punctate, stellate axial chloroplast, having six longitudinal lamellae, cells long and broad, cells 65–87 µm long, 39–50 µm broad and isthmus 37–42 µm broad.

Site of collection: Chandubi Beel, Kamrup; Hasila Beel, Goalpara; Bhebeli Pond, Dhemaji.

Previous records and distribution in northeastern India: Chandubi Beel, Nath & Baruah (2020).

Actinotaenium wollei (West & G. S. West) Teiling ex Ruzika & Pouzar 1978: 61

Basionym: *Cosmarium globosum* var. *wollei* West & G. S. West

Cells medium-sized, about 1.7–1.8 times longer than broad; sinus notched, elliptical semicells with rounded apex, cell wall with punctae, stellate chloroplast, cells 55–76 µm long and 30–44 µm broad and isthmus 27–40 µm broad.

Site of collection: Kapla Beel, Barpeta; Ulabari Pond, Nalbari.

New to northeastern India (Image 10).

Genus: *Bambusina*

Bambusina borreri (Ralfs) Cleve 1864: 496

Basionym: *Desmidium borreri* Ralfs

Cells barrel-shaped, slightly constricted at midregion, sinus a notch of shallow depth, semicells circular in top view, occasionally with 2 opposite mammillae, small basal inflation on both sides of isthmus, lateral sides straight towards apices, apices broadly truncate, cell wall with very slight longitudinal striations at poles, cells 20–27 µm long, 14–17 µm broad and apex 8–10 µm broad.

Site of collection: Urpad Beel, Goalpara; Naitara Choutara Beel, Goalpara; Bhebeli Pond, Dhemaji.

Previous records and distribution in northeastern India: Urpad Beel, Deka et al. (2011).

Genus: *Cosmarium*

Cosmarium abruptum P. Lundell 1871: 43, pl. 2: fig. 22

Cells very small sized, almost as long as broad, median constriction deep, sinus open, pyramidal semicells with faintly un-

dulate apex, cell wall smooth, axial chloroplast with a centrally placed pyrenoid in each semicell, cells 11–15 µm long, 10–12 µm broad and isthmus 5–6 µm broad.

Site of collection: Dudhnoi College Pond, Goalpara.

New to northeastern India (Image 11).

Cosmarium angulatum f. *majus* (Grunow) W. B. Turner 1893: 56 (as 'major')

Basionym: *Euastrum angulatum* f. *major* Grunow

Cells medium-sized, about 1.5–1.6 times longer than broad, deeply constricted at midregion, isthmus thin with closed sinus, semicells 6-angled, basal angles rounded, lateral sides slightly convex above the basal angles and broadly rounded upper, lateral angles, then tapering and retuse to a narrow truncate apex, cell wall smooth, two chloroplasts in each semicells with two pyrenoids, cells 54–70 µm long, 35–43 µm broad and isthmus 11–15 µm broad.

Site of collection: Lakhimpur Pukhuri, Darrang.

New to northeastern India (Image 12).

Cosmarium angulosum Brébisson 1856: 127, pl. I [1]: fig. 17

Cells small sized, about 1.4–1.5 times longer than broad, median constriction deep, sinus open, subrectangular semicells, angular-elliptical in apical view, subcircular in lateral view, straight or very slightly convex lateral sides, apices truncately rounded, cell wall with punctae, single chloroplast with one pyrenoid, cells 12–18 µm long, 10–12 µm broad and isthmus 4–5 µm broad.

Site of collection: Jugi Beel, Golaghat.

Previous records and distribution in northeastern India: Dachi Lake, Hajong & Ramanujam (2018).

Cosmarium auriculatum Reinsch 1875: 83, Chlorophyllophyceae, pl. XIV [14]: fig. 5

Cells medium-sized, almost as long as broad, median constriction deep, sinus widely open, semicells transversely elliptic or slightly pyramidal with broadly rounded apices, apical notch absent, semicells circular in side view and elliptical in top view, basal angles of the semicells equipped with 3 stout processes, cell wall punctate, chloroplast with 2 pyrenoids in each semicell, cells 44–47 µm long, 45–49 µm broad and isthmus 22–24 µm broad.

Site of collection: Laokhoa Beel, Dhubri.

New to northeastern India (Image 13).

Cosmarium baffinense R. M. Whelden 1947: 73, pl. VI: fig. 2 (as 'baffinensis')

Cells very small sized, almost as long as broad, hexagonal semicells with nearly rounded angles, deeply constricted at mid-region, linear and closed sinus, lateral margins angularly concave, apex broad and flat, cell wall with fine punctae, cells 9–11 µm long, 10–11 µm broad and isthmus 3–4 µm broad.

Site of collection: Chakoli Beel, Majuli.

New to northeastern India (Image 14).

Cosmarium blyttii Wille 1880: 25, pl. 1: fig. 7

Cells very small sized, about 1.2–1.3 times longer than broad, median constriction deep, sinus closed, semi-cells subrectangular, chloroplasts with pyrenoids in each semicell, cell wall granular, cells 15–20 µm long, 12-15 µm broad and isthmus 4–6 µm broad.

Site of collection: Morakolong, Nagaon; Gandhi Beel, Barpeta.

New to northeastern India (Image 15).

Cosmarium botrytis Meneghini ex Ralfs 1848: 99, pl. XVI [16]: fig. 1

Cells medium-sized, about 1.2–1.4 times longer than broad, deeply constricted at mid-region, sinus narrowly linear, semicells ovate-pyramidal, lateral margins convex, apex truncate with rounded angles, cell wall equipped with concentric series of radiating granules, granules absent in the apices, cells 37–52 µm long, 29–36 µm broad and isthmus 12–16 µm broad.

Site of collection: Chandubi Beel, Kamrup; Sibasthan-Potakollong, Nagaon.

Previous records and distribution in northeastern India: Urpad Beel, Deka et al. (2011); Dachi Lake, Hajong. & Ramanujam (2018); Chandubi Beel, Nath & Baruah (2020).

Cosmarium brebissonii Meneghini ex Ralfs 1848: 100, pl. XVI [16]: fig. 3 a, b

Cells medium-sized, about 1.2–1.4 times longer than broad, deeply constricted at mid-region, sinus closed, semicells semicircular, lateral margins convex, apex broadly truncate with rounded angles, entire cell wall furnished with concentric series of stout granules including the apices, cells 32–46 µm long, 26–31 µm broad and isthmus 7–9 µm broad.

Site of collection: Dakra Beel, Dhubri.

New to northeastern India (Image 16).

Cosmarium calcareum Wittrock 1872: 58, pl. 4: fig. 13

Cells small sized, almost as long as broad, median constriction deep, sinus narrowly linear, semicells trapezoid, basal angles sub rectangular, lateral sides with 4–6 crenations, apex truncate with 5–6 faint and minute crenations, cell wall furnished with minute granules and a small granulate tumour in the centre, cells 19–21 µm long, 18–19 µm broad and isthmus 5–6 µm broad.

Site of collection: Rajapukhuri Ghagrapar, Nalbari.

New to northeastern India (Image 17).

Cosmarium coarctatum West 1892: 724, pl. IX [9]: fig. 11

Cells very small sized, about 1.3–1.4 times longer than broad, with shallow median constriction, sinus 'V' shaped notch and open outwardly, semicells rectangular, basal angles rounded, lateral sides almost parallel to a flat truncate apex, cell wall smooth, cells 12–14 µm long, 9–10 µm broad and isthmus 5–6 µm broad.

Site of collection: Bogibil Ghat, Dibrugarh.

New to northeastern India (Image 18).

Cosmarium connatum Brébisson ex Ralfs 1848: 108, pl. XVII [17]: fig. 10

Cells medium-sized, about 1.4 times longer than broad, shallow median constriction, sinus widely open, semicells transversely sub-elliptic, with a broad base, apex slightly flattened, cell wall with fine punctae, chloroplast with 2 large pyrenoids in each semicell, cells 59–66 µm long, 40–47 µm broad and isthmus 34–37 µm broad.

Site of collection: Diplai Beel, Kokrajhar; Akhara Beel, Barpeta; Bornijora Pond, Jalah Kamrup.

Previous records and distribution in northeastern India: Kokrajhar, Das (2020).

Cosmarium contractum var. *minutum* (Delponte) Coesel 1989: 183, pl. 2: fig. 4

Basionym: *Cosmarium minutum* Delponte

Cells small sized, about 1.4 times longer than broad, deeply constricted at midregion, sinus V-shaped and widely open, semicells almost circular, axial chloroplast with a centrally placed pyre-

noid, cell wall smooth, cells 27–32 µm long, 19–22 µm broad and isthmus 4–5 µm broad.

Site of collection: Chandubi Beel, Kamrup; Rawmari Beel, Nagaon; Borpukhri Ghagrapar, Nalbari.

Previous records and distribution in northeastern India: Chandubi Beel, Nath & Baruah (2020); Kokrajhar, Das (2020).

Cosmarium cycladatum W. B. Turner 1893: 54, pl. VIII [8]: fig. 12

Cells medium-sized, about 1.3–1.4 times longer than broad, deeply constricted at middle region with closed sinus, semicells semicircular, basal angles thin, lateral sides moderately convex then gradually tapering to form broadly rounded apices, lateral sides granulate-crenate, crenulations broad with two-minute projections at two angles each, the face of the semicells with a group of elongate thickenings extending below the apex, cell wall otherwise smooth, cells 40–55 µm long, 29–37 µm broad and isthmus 10–13 µm broad.

Site of collection: Dheer Beel, Dhubri; Ghunkuchi Beel, Nalbari.

Previous records and distribution in northeastern India: Kokrajhar, Das (2020).

Cosmarium cyclicum var. *arcticum* (Nordstedt) Gutwinski 1897: 147

Basionym: *Cosmarium cyclicum* subsp. *arcticum* Nordstedt

Cells medium-sized, almost as long as broad, subcircular or slightly hexagonal-circular, median constriction deep, sinus linear, semicells semicircular and margins with crenations, within the margin bigranulate, ornamental granules in a series of radial and concentric series, cells 38–43 µm long, 41–45 µm broad and isthmus 13–15 µm broad.

Site of collection: Lakhimpur pukhuri, Darrang.

New to northeastern India (Image 19).

Cosmarium cyclicum var. *crassum* R. M. Whelden 1947: 78, pl. V [5]: fig. 8

Cells moderately large, about 1.1 times longer than broad, circular-elliptic, median constriction deep, the sinus narrowly linear with dilated outwardly, semicells semi-circular with rounded basal angles, cell wall uniformly crenate with about 18 crenae and with one row of small furrows within the margin, axial chloroplast, two pyrenoids per semicells, cells 68–81 µm long, 60–68 µm broad and isthmus 20–23 µm broad.

Site of collection: Jogorahabi Beel, Sivasagar.

New to northeastern India (Image 20).

Cosmarium decoratum West & G. S. West 1895: 61, pl. VII [7]: fig. 21

Cells medium-sized, about 1.2–1.3 times longer than broad, median constriction very deep, sinus narrow and linear, semicells semi-elliptic, apices flat and truncate with broadly rounded angles, crenations at the margin, each semicell with two chloroplasts and two pyrenoids, cells 49–63 µm long, 40–47 µm broad and isthmus 13–16 µm broad.

Site of collection: Chandubi Beel, Kamrup; Chakoli Beel, Majuli; Kursakati Pond, Kokrajhar.

Previous records and distribution in northeastern India: Chandubi Beel, Nath & Baruah (2020); Kokrajhar, Das (2020).

Cosmarium densegranulatum Skuja 1928: 154, pl. III [3]: figs 17–20

Cells small sized, about 1.1 times broader than long, median constriction deep, sinus narrow and linear, semicells elliptic, both basal as well as apical angles rounded, lateral sides with denticulations, cell wall granulated, parietal chloroplast, single per semicell, cells 22–25 µm long, 19–22 µm broad and isthmus 6–7 µm broad.

Site of collection: Chandubi Beel, Kamrup; Dolani Beel, Bongaigaon.

Previous records and distribution in northeastern India: Chandubi Beel, Nath & Baruah (2020).

Cosmarium dorsitruncatum var. *pseudoscenedesmus* (West & G. S. West) Willi Krieger & Gerloff 1962: 26

Basionym: *Cosmarium pseudoscenedesmus* West & G. S. West

Cells small sized, about 1.2 times broader than long, median constriction very deep, sinus open outwardly, semicells trapeziform, apices flatly truncate and basal angles rounded, chloroplast axial, with one pyrenoid in each semicell, cells 18–23 µm long, 23–28 µm broad and isthmus 6–8 µm broad.

Site of collection: Chandubi Beel, Kamrup; Borphukhuri, Kamalpur Kamrup.

Previous records and distribution in northeastern India: Chandubi Beel, Nath & Baruah (2020).

Cosmarium forceps Brühl & Biswas 1926: 286, pl. 15: fig. 86

Cells medium-sized, about 1.2–1.3 times broader than long, almost circular, moderately constricted at midregion, broad isthmus, sinus open outwardly, semicells sub-semicircular, apices rounded, cell wall smooth, parietal chloroplast, pyrenoids 2 in number, cells 34–45 µm long, 42–59 µm broad and isthmus 20–24 µm broad.

Site of collection: Chandubi Beel, Kamrup; Bhomoraguri Pond, Nagaon; Dighali Beel, Sivasagar; Kumri Beel, Goalpara; Naitara Choutara Beel, Goalpara; Barpeta Beel, Nagaon; Tamranga Beel, Bongaigaon; Katara Beel Paikarkuchi, Nalbari; Deepor Beel, Kamrup (M); Kusumfula Beel, Goalpara; Jor Beel, Jorhat; Lakhimpur pukhuri, Darrang; Pond near Tangla College, Udalguri; Koladuwar Beel, Golaghat; Chakoli Beel, Majuli; Maguri Motapung Beel, Tinsukia; Sripani Pond, Dhemaji; Pachi Gaon Pond, Sonitpur; Majkuchi Pond, Kamrup; Kachodhora Beel, Morigaon; Diplai Beel, Kokrajhar; Dakra Beel, Dhubri; Koya Kujia Beel, Bongaigaon; Sorbhog Beel, Barpeta; Keotkuchi Pond, Barpeta; Raja Beel, Baksa; Jiyeni Beel, Kamrup; Goalnani Pond, Dhubri; Shamaguri Beel, Nagaon; Kapla Beel, Barpeta; Ulabari Pond, Nalbari.

Previous records and distribution in northeastern India: Loktak Lake, Jena & Adhikary (2011); Chandubi Beel, Nath & Baruah (2020); Arunachal Himalayas, Nath & Baruah (2021).

Cosmarium galeritum var. *subtumidum* O. Borge 1903: 95, pl. 3: fig. 14

Cells medium-sized, about 1.2 times longer than broad, median constriction deep, sinus closed, pyramidal semicells, both basal and apical angles approximately rounded, two parietal chloroplasts with several radiating ridges in each semicell, pyrenoids two in number, cells 49–60 µm long, 43–48 µm broad and isthmus 21–24 µm broad.

Site of collection: Chandubi Beel, Kamrup; Madhab Choudhury College Pond, Barpeta**;** Rajapukhuri, Nahira Kamrup.

Previous records and distribution in northeastern India: Chandubi Beel, Nath & Baruah (2020).

Cosmarium garrolense J. Roy & Bisset 1894: 101, pl. 2: fig. 4

Cells small sized, about 1.3 times longer than broad, median constriction deep, sinus linear and closed, semicells semi-circular, basal angle nearly rounded, lateral walls evenly convex with four undulations on each side of semicells, apex broad and flatly round-

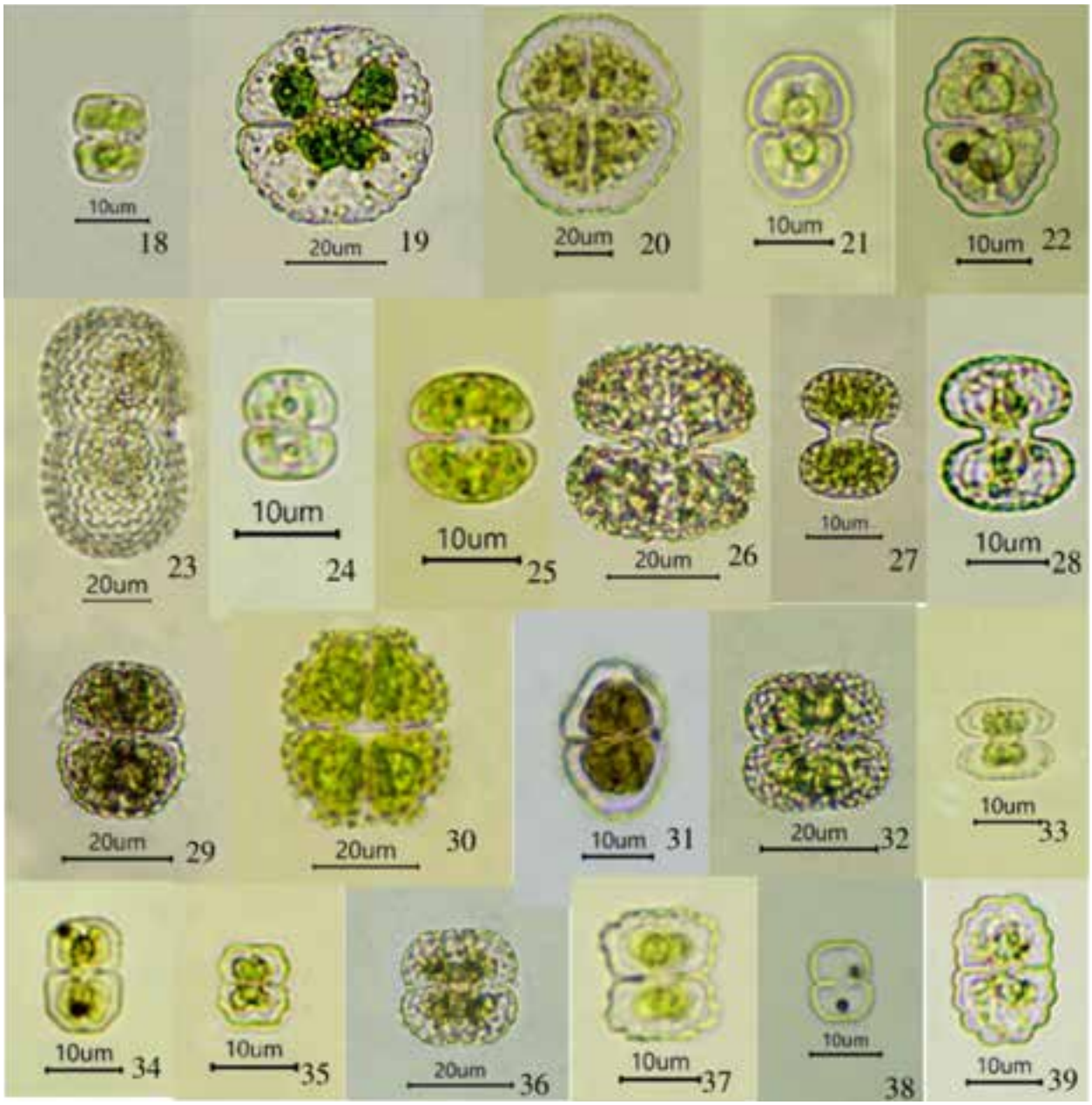


Image 18–39. 18—*Cosmarium coarctatum* | 19—*Cosmarium cyclicum* var. *arcticum* | 20—*Cosmarium cyclicum* var. *crassum* | 21—*Cosmarium granatum* var. *subangulare* | 22—*Cosmarium impressulum* var. *crenulatum* | 23—*Cosmarium mansangense* | 24—*Cosmarium minimum* var. *subrotundatum* | 25—*Cosmarium neodepressum* var. *reniforme* | 26—*Cosmarium ordinatum* | 27—*Cosmarium porteanum* | 28—*Cosmarium porteanum* var. *nephroideum* | 29—*Cosmarium praemorsum* | 30—*Cosmarium pseudoarmatum* | 31—*Cosmarium pseudogranatum* | 32—*Cosmarium punctulatum* var. *depressum* | 33—*Cosmarium pygmaeum* | 34—*Cosmarium rectangulare* var. *cambrense* | 35—*Cosmarium regnellii* var. *minimum* | 36—*Cosmarium reniforme* var. *minus* | 37—*Cosmarium seelyanum* | 38—*Cosmarium sexangulare* var. *minus* | 39—*Cosmarium undulatum* f. *reductum*

ed, cell wall smooth, cells 21–25 µm long, 16–18 µm broad and isthmus 5–6 µm broad.

Site of collection: Dighali Beel, Nagaon; Morakolong, Nagaon.

Previous records and distribution in northeastern India: Urpad Beel, Deka et al. (2011).

Cosmarium granatum Brébisson ex Ralfs 1848: 96, pl. XXXII [32]: fig. 6

Cells small sized, about 1.3–1.5 times longer than broad, elliptic, deeply constricted at midregion, sinus linear and opened outwardly, semicells truncate, pyramidate with rounded basal angles, lateral sides almost straight or slightly convex, chloroplast axile with only one pyrenoid, cells 22–29 µm long, 16–19 µm broad and isthmus 6–7 µm broad.

Site of collection: Urpad Beel, Goalpara**;** Deepor Beel, Kamrup (M); Digholi Beel, Kamrup; Dighalipukhuri, Kamrup (M).

Previous records and distribution in northeastern India: Urpad Beel, Deka et al. (2011); Khanajan, Baruah & Baruah (2013); Dachi Lake, Hajong & Ramanujam (2018); Deepor Beel, Baruah et al. (2020).

Cosmarium granatum var. *subangulare* West & G. S. West 1895: 54, pl. VIII: fig 4

Cells small sized, about 1.3–1.5 times longer than broad, median constriction deep, sinus closed, semicircular semicells, basal angles rounded, lateral margins convex and gradually slightly tapered towards retuse apex, cell wall smooth, chloroplast axial with a centrally placed pyrenoid in each semicell, cells 19–24 µm long, 14–16 µm broad and isthmus 5–6 µm broad.

Site of collection: Haribhanga Beel, Nagaon; Koya Kujia Beel, Bongaigaon; Dosomighat Pond, Bongaigaon.

New to northeastern India (Image 21).

Cosmarium hammeri Reinsch 1866: 115, pl. XXII [22] B 1: figs 1–10

Cells small sized, about 1.3–1.4 times longer than broad, median constriction deep, sinus linear and closed, semicells trapeziform, both basal as well as apical angles broadly rounded, lateral margins slightly concave and apex broad and truncate, axile chloroplasts with single pyrenoid in each semicell, cells 25–31 µm long, 18–22 µm broad and isthmus 7–8 broad.

Site of collection: Deepor Beel, Kamrup (M); Konuri Beel, Dhubri.

Previous records and distribution in northeastern India: Deepor Beel, Baruah et al. (2020).

Cosmarium impressulum Elfving 1881: 13, pl. I: fig. 9

Cells small sized, about 1.5–1.6 times longer than broad, median constriction deep, sinus narrowly linear and closed, semicells elongate semicircular, with rounded basal angles, lateral walls almost parallel and furnished with four undulations, retuse at apex, cell wall smooth; parietal chloroplast, cells 23–28 µm long, 15–17 µm broad, isthmus 4–5 µm broad.

Site of collection: Chandubi Beel, Kamrup; Bhomoraguri Pond, Nagaon.

Previous records and distribution in northeastern India: Chandubi Beel, Nath & Baruah (2020).

Cosmarium impressulum var. *crenulatum* (Nägeli) Willi Krieger & Gerloff 1965: 136, pl. 29: fig. 6

Basionym: *Cosmarium crenulatum* Nägeli

Cells small sized, about 1.2–1.3 times longer than broad, median constriction deep, sinus narrowly linear, outline oval with regularly undulated lateral walls, semicells transversely hexagonal, in apical view elliptical, in lateral view broadly oval, cell wall smooth, axial chloroplast with a centrally placed pyrenoid in each semicell, cells 24–30 µm long, 19–22 µm broad and isthmus 4–5 µm broad.

Site of collection: Rajapukhuri Ghagrapar, Nalbari.

New to northeastern India (Image 22).

Cosmarium impressulum var. *suborthogonum* (Raciborski) Taft 1945: 195, pl. 3: fig. 9 f

Basionym: *Cosmarium suborthogonum* Raciborski

Cells small sized, about 1.4–1.5 times longer than broad; median constriction deep, sinus narrowly linear and closed but slightly dilated at the apex, semicells subsemicircular, the basal angles broadly rounded, the lateral sides in the basal portion of the semicell parallel, the upper lateral sides with two undulations, retuse at the middle, cell wall smooth, cells 17–24 µm long, 12–16 µm broad and isthmus 5–6 µm broad.

Site of collection: Duminichowki Pond, Kamrup; Dighali Beel, Sivasagar**;** Gauhati University Pond, Kamrup (M).

Previous records and distribution in northeastern India: Manmecho Lake, Das & Keshri (2012).

Cosmarium javanicum Nordstedt 1880: 7, pl. 1: fig 10

Cells large sized, about 1.8 times longer than broad, median constriction a shallow notch, sinus linear and closed but slightly opened at the end; semicells rounded obovate, lateral walls evenly convex, apex broadly rounded; basal angles narrowly rounded; cell wall striated and with irregularly organized large punctae, cells 138–160 µm long, 72–87 µm broad and isthmus 50–55 µm broad.

Site of collection: Chandubi Beel, Kamrup; Jaysagar Pukhuri, Sivasagar.

Previous records and distribution in northeastern India: Chandubi Beel, Nath & Baruah (2020).

Cosmarium lundellii Delponte 1877: 13, pl. 7: figs 62–64

Cells medium-sized, about 1.2–1.3 times longer than broad, median constriction deep, sinus narrowly linear and slightly dilated at the end, semicells sub semi-circular with broadly rounded apices, cell wall punctate, punctate small, chloroplast parietal with large pyrenoids, cells 48–59 µm long, 40–45 µm broad and isthmus 16–19 µm broad.

Site of collection: Chandubi Beel, Kamrup; Bogibil Ghat, Dibrugarh**;** Narpara Pond, Nalbari; Charan Beel, Morigaon; Dosomighat Pond, Bongaigaon.

Previous records and distribution in northeastern India: Chandubi Beel, Nath & Baruah (2020); Arunachal Himalayas, Nath & Baruah (2021).

Cosmarium lundellii var. *corruptum* (W. B. Turner) West & G.S.West 1902: 162

Basionym: *Cosmarium corruptum* W. B. Turner

Cells medium-sized, almost as long as broad, median constriction deep, sinus widely open, semicells sub semi-circular with broadly rounded apices, cell wall with small punctae, chloroplast parietal with two pyrenoids in each semicell, cells 38–45 µm long, 36–40 µm broad and isthmus 16–18 µm broad.

Site of collection: Chandubi Beel, Kamrup; Digholi Beel, Kamrup.

Previous records and distribution in northeastern India: Chandubi Beel, Nath & Baruah (2020).

Cosmarium mansangense West & G. S. West 1908: 209, pl. XIV [14]: fig 15

Cell medium-sized, almost cylindrical, about 1.6 times longer than broad, median constriction shallow, sinus opened, semicells cylindrically-oblong, lateral margins almost straight, basal angles very slightly rotund, the apices broadly rounded, cell wall granulated, granules arranged in veitical series, chloroplast parietal, two pyrenoids per semicell, cells 67–72 µm long, 40–43 µm broad and isthmus 31–34 µm broad.

Site of collection: Shamaguri Beel, Nagaon.

New to northeastern India (Image 23).

Cosmarium minimum var. *subrotundatum* West & G. S. West 1895: 59, pl. VIII: fig 11

Cells very small sized, about 1.2–1.3 times longer than broad, median constriction moderately deep, sinus narrowly linear and nearly closed, elliptical semicells with broadly rounded basal angles, cell wall smooth, axial chloroplast with single pyrenoid in

each semicell, cells 10–12 µm long, 8–9 µm broad and isthmus 4–6 µm broad.

Site of collection: Dolani Beel, Bongaigaon.

New to northeastern India (Image 24).

Cosmarium miscellum Skuja 1964: 222, pl. XXXIX [39]: fig. 11

Cells medium-sized, about 1.2 times longer than broad, median constriction deep, sinus linear but open at extremities, semicells compressed semicircular with 22–26 marginal crenulations, cell wall granulate, granules arranged on periphery, in central tumour granules arranged in vertical series, cells 34–46 µm long, 30–37 µm broad and isthmus 14–16 µm broad.

Site of collection: Deepor Beel, Kamrup (M); Gaurangtari Pond, Dhubri; Koya Kujia Beel, Bongaigaon.

Previous records and distribution in northeastern India: Arunachal Pradesh, Das & Adhikary (2012); Khanajan, Baruah & Baruah (2013); Deepor Beel, Baruah et al. (2020).

Cosmarium neodepressum var. *minutum* (Heimerl) G. J. P. Ramos & C. W. N. Moura 2020: 2

Basionym: *Cosmarium depressum* f. *minutum* Heimerl

Cell small sized, nearly as broad as long, median constriction deep, sinus widely opened with V like notch at extremities, semicells elliptic with truncately rounded apex, chloroplast axial with single pyrenoid in each semicell, cell wall smooth, cells 15–20 µm long, 14–18 µm broad and isthmus 4–5 µm broad.

Site of collection: Chandubi Beel, Kamrup.

Previous records and distribution in northeastern India: Chandubi Beel, Nath & Baruah (2020).

Cosmarium neodepressum var. *reniforme* (West & G. S. West) G. J. P. Ramos & C. W. N. Moura 2020: 2

Basionym: *Cosmarium depressum* var. *reniforme* West & G. S. West.

Cells small sized, slightly longer than broad, median constriction deep, sinus linear and open, reniform semicells with broadly rounded apex, chloroplast axial with single pyrenoids in each semicell, cells 21–27 µm long, 19–23 µm broad and isthmus 4–5 µm broad.

Site of collection: Raja Beel, Baksa; Ulabari Pond, Nalbari.

New to northeastern India (Image 25).

Cosmarium nitidulum De Notaris 1867: 42, pl. III [3]: fig. 26

Cells small sized, about 1.3–1.4 times longer than broad, median constriction deep, sinus narrowly linear and slightly opened at the extremities, semicells truncate semicircular with broadly rounded basal as well as apical angles, lateral sides slightly convex, apex truncately rounded, cell wall minutely punctate, two axial chloroplasts in each semicell with single central pyrenoid, cells 28–37 µm long, 21–25 µm broad and isthmus 7–8 µm broad.

Site of collection: Dagaon Pond, Nagaon; Dudhnoi College Pond, Goalpara; Borphukhuri, Kamalpur Kamrup.

Previous records and distribution in northeastern India: Nagaland, Das & Adhikary (2012).

Cosmarium norimbergense Reinsch 1867: 117, pl. 22: figs A-IV: 1–11

Cells small sized, about 1.2–1.3 times longer than broad, median constriction deep, sinus narrow, linear, closed, semicells subrectangular with an undulation just above the rounded basal angles, apex with rounded angles and almost straight border, cell wall smooth, axial chloroplast with single pyrenoid in each semicells, cells 12–16 µm long, 10–12 µm broad and isthmus 4–5 µm broad.

Site of collection: Gandhi Beel, Barpeta; Bheriki Beel, Jorhat; Sripani Pond, Dhemaji; Shamaguri Beel, Nagaon.

Previous records and distribution in northeastern India: Loktak Lake, Jena & Adhikary (2011); Arunachal Himalayas, Nath & Baruah (2021).

Cosmarium norimbergense var. *depressum* (West & G. S. West) Willi Krieger & Gerloff 1969: 292, pl. 48: fig. 1

Basionym: *Cosmarium norimbergense* f. *depressum* West & G.S. West.

Cells very small sized, almost as long as broad, deeply constricted at middle, sinus narrowly linear and slightly opened at extremities, semicell subrectangular, lateral margins without undulations, apex with rounded angles and almost straight border, cell wall smooth, axial chloroplast with one pyrenoid in each cell, cells 7–10 µm long, 7–9 µm broad and isthmus 3–4 µm broad.

Site of collection: Dandua Beel, Morigaon; Hasila Beel, Goalpara; Ghunkuchi Beel, Nalbari.

Previous records and distribution in northeastern India: Loktak Lake, Jena & Adhikary (2011); Arunachal Himalayas, Nath & Baruah (2021).

Cosmarium obsoletum (Hantzsch) Reinsch 1867: 142, pl. 22:D:1: figs 1–4

Basionym: *Arthrodesmus obsoletus* Hantzsch

Cells medium-sized, transversely elliptic, almost as long as broad, median constriction deep, sinus narrow linear, closed except the extremities, semicells semicircular, apices broadly rounded, basal angles mammillately condensed, side angles slightly convex, 2 axial chloroplasts in each semicells with a centrally placed pyrenoid, cell wall punctate, cells 62–65 µm long, 61–63 µm broad and isthmus 32–34 µm broad.

Site of collection: Deepor Beel, Kamrup (M); Bharalichuk Pond, Dhemaji; Radhapukhuri, Lakhimpur; Sibasthan-Potakollong, Nagaon.

Previous records and distribution in northeastern India: Loktak Lake, Jena & Adhikary (2011); North Eastern India, Yasmin et al. (2011); Khanajan, Baruah & Baruah (2013); Deepor Beel, Baruah et al. (2020).

Cosmarium ordinatum (Børgesen) West & G. S. West 1896: 251, pl. 15: fig. 14

Basionym: *Cosmarium brasiliense* var. *ordinatum Børgesen*

Cells medium-sized, almost as long as broad, semicells slightly reniform, median constriction deep, sinus open and V shaped, cell wall verrucate, verrucae arranged in groups of 2-4 or 6–7 parallel rows in the middle of semicells, cells 35–39 µm long, 32–34 µm broad and isthmus 12–14 µm broad.

Site of collection: Naitara Choutara Beel, Goalpara.

New to northeastern India (Image 26).

Cosmarium pakistanicum A. K. Islam 1971: 926, pl. XIV [14]: fig. 2; pl XXIII [23]: figs 1–10

Cells large sized, about 1.6–1.8 times longer than broad, shallow constriction at the middle, sinus narrowly linear and closed, semicells broadly elliptic-pyramidate, basal angles narrowly rounded, lateral sides slightly retuse in the basal half then again slightly convex, apex broadly rounded, chloroplast with 10 longitudinal ridges, cell wall punctate, punctae irregularly arranged, cells 103–125 µm long, 62–69 µm broad and isthmus 47–50 µm broad.

Site of collection: Dheer Beel, Dhubri; Gaurangtari Pond, Dhubri; Borpukhri Ghagrapar, Nalbari; Gauhati University Pond, Kamrup (M).

Previous records and distribution in northeastern India: Kokrajhar, Das (2020).

Cosmarium porteanum W. Archer 1860: 49, pl. I [1]: fig. 8, 9 (as 'Portianum')

Cells small sized, about 1.4–1.5 times longer than broad, deeply constricted at the middle, sinus widely opened, semicells elliptic, cell wall granulate, rounded granules arranged in vertical series, axial chloroplast with single pyrenoid in each semicell, cells 17–23 µm long, 12–15 µm broad and isthmus 6–7 µm broad.

Site of collection: Sorbhog Beel, Barpeta; Tinkonia Pukhuri, Jorhat; Akhara Beel, Barpeta; Bornijora Pond, Jalah Kamrup.

New to northeastern India (Image 27).

Cosmarium porteanum f. *pseudoporteanum* J. P. Keshri & D. Das 2016: 116, pl. VI [6]: figs 187, 188

Cells small sized, about 1.4–1.5 times longer than broad, median constriction deep, sinus widely open with rounded margins, semicells circular, cell wall granulate, rounded granules arranged in seven vertical series, axial chloroplast with single pyrenoid in each semicell, cells 21–25 µm long, 14–17 µm broad and isthmus 7–8 µm broad.

Site of collection: Jiyeni Beel, Kamrup; Konuri Beel, Dhubri.

Previous records and distribution in northeastern India: Arunachal Himalayas, Nath & Baruah (2021).

Cosmarium porteanum var. *nephroideum* Wittrock 1872: 57 (as 'portianum var. nephroideum')

Cells small sized, about 1.1–1.3 times longer than broad, median constriction deep, sinus broadly open, semicells semicircular-elliptic, cell wall with granules arranged in 7 longitudinal series, cells 19–24 µm long, 16–18 µm broad and isthmus 6–8 µm broad.

Site of collection: Kapla Beel, Barpeta; Dolani Beel, Bongaigaon.

New to northeastern India (Image 28).

Cosmarium praemorsum Brébisson 1856: 128, pl. I: fig. 8

Cells medium-sized, about 1.2 times longer than broad, median constriction deep, sinus narrowly linear, Semicells subcircular with flattened apex, cell wall granulate, granules on the face of the semicells are small and disposed roughly in concentric series, but gradually diminishing towards the center, in top view semicell rhomboid-elliptic and slightly tumid at the middle on each margin, center of the semicell is devoid of granules, axile chloroplast with single pyrenoid in each semicell, cells 29–40 µm long, 24–31 µm broad, and isthmus 8–11 µm broad.

Site of collection: Barsola Beel, Jorhat.

New to northeastern India (Image 29).

Cosmarium pseudoamoenum Wille 1884: 18, pl. I [1]: fig. 37

Cells medium-sized, about 2 times longer than broad, median constriction a shallow notch, oblong semicells with slightly convex lateral sides, cell wall with concentric series of small granules, chloroplast with single pyrenoid in each semicell, cells 60–76 µm long, 30–36 µm broad and isthmus 19–22 µm broad.

Site of collection: Mohmara Pond, Sonitpur.

Previous records and distribution in northeastern India: Urpad Beel, Deka et al. (2011).

Cosmarium pseudoarmatum A. M. Scott & Prescott 1958: 49, fig. 14: 3

Cells medium-sized, about 1.3 times longer than broad, sinus narrowly linear and slightly dilated at extremities, semicells hemispherical with an undulation near the apex, apex almost flat, cell wall furnished with series of stout granules, cells 38–45 µm long, 29–33 µm broad and isthmus 11–13 µm broad.

Site of collection: Pond near Tangla College, Udalguri.

New to northeastern India (Image 30).

Cosmarium pseudoconnatum Nordstedt 1870: 214, pl. III [3]: fig. 17

Cells small sized, about 1.2–1.3 times longer than broad, median constriction deep, sinus closed, semicells pyramidal, lateral margins convex with truncate-rounded apex, cell wall with minute punctae, chloroplast with single pyrenoid in each semicell, cells 20–24 µm long, 16–18 µm broad and isthmus 4–5 µm broad.

Site of collection: Jogorahabi Beel, Sivasagar; Dagaon Pond, Nagaon.

Previous records and distribution in northeastern India: Urpad Beel, Deka et al. (2011).

Cosmarium pseudogranatum Nordstedt 1870: 211, pl. III [3]: fig. 27

Cells small sized, about 1.2–1.3 times longer than broad, median constriction deep, sinus closed, semicells pyramidal, lateral margins convex with truncate-rounded apex, cell wall with minute punctae, chloroplast with single pyrenoid in each semicell, cells 20–24 µm long, 16–18 µm broad and isthmus 4–5 µm broad.

Site of collection: Maguri Motapung Beel, Tinsukia.

New to northeastern India (Image 31).

Cosmarium punctulatum Brébisson 1856: 129, pl. I [1]: fig. 16

Cells small sized, about 1.1 times longer than broad, median constriction very deep, sinus closed but slightly dilated at extremities, semicells oblong-trapeziform with rounded basal angles, apex broadly truncate, in side view semicells circular, in top view cell elliptic, cell wall furnished with small granules, axial chloroplasts with single pyrenoid in each semicell, cells 20–26 µm long, 18–21 µm broad and isthmus 7–8 µm broad.

Site of collection: Jor Beel, Jorhat; Jugi Beel, Golaghat; Shamaguri Beel, Nagaon.

Previous records and distribution in northeastern India: Sivasagar, Phukan & Bora (2012); Urpad Beel Deka et al. (2011).

Cosmarium punctulatum var. *depressum* W. B. Turner

Cell small sized, almost as long as broad, median constriction deep, sinus narrowly linear but slightly dilated at extremities, semicells elliptical and slightly truncated, cell wall furnished with granules on horizontal series, axial chloroplasts with single pyrenoid in each semicell, cells 23–27 µm long 26–30 µm broad and isthmus 9–10 µm broad.

Site of collection: Gatanga Beel, Nagaon.

New to northeastern India (Image 32).

Cosmarium pygmaeum W. Archer 1864: 174, pl. 6: figs. 45–49 (as 'pygmœum')

Cells very small sized, slightly broader than long, median constriction deep, sinus narrowly linear but widely open at extremities, semicells oblong hexagonal, both basal as well as apical angles sharp, apex widely truncate with straight margins, a faint swelling at the center of each semicell, cell wall smooth, chloroplast with single pyrenoid in each semicell, cells 12–14 µm long, 14–16 µm broad and isthmus 4–5 µm broad.

Site of collection: Dheer Beel, Dhubri.

New to northeastern India (Image 33).

Cosmarium pyramidatum Brébisson ex Ralfs 1848: 94, pl. XV [15]: fig. 4

Cells large sized, about 1.5–1.8 times longer than broad, median constriction shallow, sinus narrow, pyramidal semicells, lateral sides somewhat convex, gradually attenuated towards truncate apex with rounded angles, basal angles acutely rounded, cell wall with two types of punctae, fine and slightly bigger punctae, intermixed with each other, cells 90–123 µm long, 59–68 µm broad and isthmus 48–52 µm broad.

Site of collection: Kumri Beel, Goalpara.

Previous records and distribution in northeastern India: Sivasagar, Phukan & Bora (2012); Urpad Beel Deka et al. (2011).

Cosmarium quadrum P. Lundell 1871: 25, pl. II [2]: fig. 11

Cells medium-sized, almost as long as broad, median constriction deep, sinus narrowly linear and slightly opened at margins, semicells quadrate, flatted, slightly depressed at the middle, lateral sides slightly convex, apex very slightly retuse, cell wall furnished with densely organised sloid granules, chloroplast axile with two pyrenoids per semicell, cells 48–53 µm long, 47–51 µm broad and isthmus 13–15 µm broad.

Site of collection: Narpara Pond, Nalbari; Deepor Beel, Kamrup (M); Digholi Beel, Kamrup; Dighalipukhuri, Kamrup (M).

Previous records and distribution in northeastern India: North Eastern India, Yasmin et al. (2011); Urpad Beel Deka et al. (2011); Sivasagar, Phukan & Bora (2012); Khanajan, Baruah & Baruah (2013); Deepor Beel, Baruah et al. (2020).

Cosmarium quadrum var. *minus* Nordstedt 1873: 11

Cells small sized, slightly broader than long, deeply constricted at the middle, narrowly linear sinus with a slightly opened extremity, semicells sub rectangular, rounded basal angles, broadly rounded apical angles, lateral walls slightly convex, apex slightly retuse, cell wall densely granulated with solid granules arranged in decussating sequence, at the margins of the semicells 23 granules are shown, in the middle of the apex the size of granules is slightly reduced, axile chloroplasts with two pyrenoids per semicell, cells 27–31 µm long, 30–34 µm broad and isthmus 9–11 µm broad.

Site of collection: Deepor Beel, Kamrup (M); Panpoor Ghat, Sonitpur; Dagaon Pond, Nagaon.

Previous records and distribution in northeastern India: Deepor Beel, Baruah et al. (2020); Urpad Beel Deka et al. (2011).

Cosmarium rectangulare var. *cambrense* (W. B. Turner) West & G. S. West 1896: 379

Basionym: *Cosmarium gotlandicum* var. *cambrense* W.B. Turner

Cells very small sized, about 1.5 times longer than broad, median constriction deep, sinus linear and slightly open towards the extremities, oblong semicells, lateral walls almost parallel with broadly rounded apical angles, cell wall punctate, punctae are densely scattered, axial chloroplasts with single or sometimes with two pyrenoids in each semicell, cells 15–18 µm long, 10–12 µm broad and isthmus 3–4 µm broad.

Site of collection: Lakhimpur pukhuri, Darrang.

New to northeastern India (Image 34)

Cosmarium regnellii var. *minimum* Eichler & Gutwinski 1894: 164, pl. IV [4]: fig. 6

Cells very small sized, about 1.1–1.2 longer than broad, median constriction deep, sinus narrowly linear and slightly dilated at the extremities, trapeziform to hexagonal semicells, lateral margins slightly convex, cell wall smooth, chloroplasts with single pyrenoid in each semicell, cells 9–12 µm long, 8–10 µm broad and isthmus 3–4 µm broad.

Site of collection: Jor Beel, Jorhat.

New to northeastern India (Image 35).

Cosmarium regnesi Reinsch 1866: 116, pl. XXII [22]: A; III [3]

Cells very small sized, almost as long as broad, median constriction deep, sinus widely open, semi-cells rectangular with broadly truncate, rounded apical angles and wide sunken vertex, wall of the semicell with 6 small granules, 2 apical and 2 lateral, another two granules on the face of the semicells, chloroplasts with single pyrenoid in each semicell, cells 12–15 µm long, 10–12 µm broad and isthmus 4–5 µm broad.

Site of collection: Naitara Choutara Beel, Goalpara; Dudhnoi College Pond, Goalpara; Shamaguri Beel, Nagaon; Dolani Beel, Bongaigaon.

Previous records and distribution in northeastern India: Arunachal Himalayas, Nath & Baruah (2021).

Cosmarium reniforme var. *minus* Irénée-Marie

Cell small sized, almost as long as broad, median constriction deep, the sinus narrowly linear and closed, semicells reniform, cell wall with solid round granules arranged in obliquely decussating series, about 15–16 granules at the margins of the semicells, cells 20–24 µm long, 19–22 µm broad and isthmus 5–6 µm broad.

Site of collection: Hiloidhari majgao Beel, Dibrugarh; Koya Kujia Beel, Bongaigaon.

New to northeastern India (Image 36).

Cosmarium rosae Ruzicka 1949: 84, figs 1–9; pl. XV [15]

Cells medium-sized, about 1.1 times longer than broad, median constriction deep, sinus linear and closed except at the extremities, semicells elliptic-reniform, lateral walls with minute undulations, 5 undulations in each lateral side; apex broadly rounded, cell wall punctate, axial chloroplast with single pyrenoid in each semicell, cells 28–33 µm long, 25–28 µm broad and isthmus 10–12 µm broad.

Site of collection: Gohain Pukhuri, Sivasagar; Padumpukhuri, Sonitpur; Ulabari Pond, Nalbari.

Previous records and distribution in northeastern India: Arunachal Himalayas, Nath & Baruah (2021).

Cosmarium seelyanum Wolle 1883: 16, pl. XXVII [27]: figs 14, 14 a

Cells small sized, about 1.1–1.2 times longer than broad, median constriction deep, sinus narrow, linear and closed, Semicell oblong, apex with 4 undulations; lateral walls with 2–3 undulations in each side, cell wall granulate, semicircular in side view and elliptic in top view, chloroplast with single pyrenoid in each semicell, cells 17–22 µm long, 15–17 µm broad and isthmus 5–7 µm broad.

Site of collection: Dakra Beel, Dhubri.

New to northeastern India (Image 37).

Cosmarium sexangulare var. *minus* Roy & Bisset 1886: 195

Cells very small sized, about 1.2–1.3 times longer than broad, median constriction deep, sinus narrowly linear and open at extremities, semicells elliptic-hexagonal, basal and apical angles rounded, apex slightly concave, cell wall smooth, cells 10–13 µm long, 8–10 µm broad and isthmus 3–4 µm broad.

Site of collection: Rajapukhuri Ghagrapar, Nalbari.

New to northeastern India (Image 38).

Cosmarium sexnotatum Gutwinski 1893: 123, pl. II [2]: fig. 7

Cells small sized, slightly longer than broad, deep median con-

striction, sinus narrowly linear with slightly dilated extremities, semicells subquadrangular with rounded angles, lateral walls with 3 broad undulations, apex truncate with straight margins, cell wall granulate, granules arranged in 2–3 horizontal series in the margin, elliptic in vertical view; chloroplast axile with a centrally placed pyrenoid in each semicell, cells 15–22 µm long, 13–17 µm broad and isthmus 4–5 µm broad.

Site of collection: Bejorsuti Pond, Kamrup; Himatichuk Pond, Dhemaji; Mohmara Pond, Sonitpur.

Previous records and distribution in northeastern India: Khanajan, Baruah & Baruah (2013); Deepor Beel, Baruah et al. (2020).

Cosmarium subcrenatum Hantzsch 1868: 164

Cells medium-sized, about 1.3–1.4 times longer than broad, median constriction deep, sinus narrow, linear and closed, pyramidal or trapezoid semicells with flattened apex, apical angle rounded, cell wall uniformly granulated, axial chloroplast with 2 pyrenoids in each semicell, cells 32–35 µm long, 23–25 µm broad and isthmus 8–10 µm broad.

Site of collection: Deepor Beel, Kamrup (M); Deohati Pond, Bongaigaon.

Previous records and distribution in northeastern India: Urpad Beel, Deka et al. (2011); Khanajan, Baruah & Baruah (2013); Meghalaya, Siangbood and Ramanujam (2014); Deepor Beel, Baruah et al. (2020).

Cosmarium subcostatum Nordstedt 1876: 37, pl. XII [12]: fig. 13

Cells medium-sized, about 1.3–1.4 times longer than broad, median constriction deep, sinus narrow, linear and closed, pyramidal or trapezoid semicells with flattened apex, apical angle rounded, cell wall uniformly granulated, axial chloroplast with 2 pyrenoids in each semicell, cells 32–35 µm long, 23–25 µm broad and isthmus 8–10 µm broad.

Site of collection: Urpad Beel, Goalpara.

Previous records and distribution in northeastern India: Urpad Beel, Deka et al. (2011).

Cosmarium tithophorum Nordstedt 1880: 6, fig. 6

Cells small sized, almost as long as broad, median constriction deep, sinus broadly open, semicells elliptic, semicells diagonally elliptic with basal angles narrowly rounded, apex rounded, cell wall smooth except a median mamilli at the face of each semicell, chloroplast axial with single pyrenoid in each semicell, cells 19-22 µm long, 18-20 µm broad and isthmus 4-5 µm broad.

Site of collection: Chandubi Beel, Kamrup.

Previous records and distribution in northeastern India: Chandubi Beel, Nath & Baruah (2020).

Cosmarium undulatum f. *reductum* Croasdale 1956: 59, pl. 3: fig. 9 (as 'var. *alaskanum* f. *reductum*')

Cells small sized, about 1.4 times longer than broad, deep constriction at the middle, sinus narrow, linear and closed, semicells pyramidal with convex lateral sides, entire margins with apex undulate regularly, 8 undulations in each semicell, cell wall smooth, chloroplasts with single pyrenoid in each semicell, cells 20-25 µm long, 14-17 µm broad and isthmus 4-5 µm broad.

Site of collection: Raja Beel, Baksa; Bornijora Pond, Jalah Kamrup.

New to northeastern India (Image 39).

Cosmarium undulatum var. *indicum* J. P. Keshri & D. Das 2016: 128, pl. VI [6]: figs 169, 170

Cells medium-sized, about 1.4-1.5 times longer than broad; median constriction deep, sinus narrow, linear and closed, semicells semi-circular, slightly elongate, lateral walls convex with broadly rounded apical angles, cell wall undulate with 16-17 smooth and equal undulations; basal angles acute, another 2 series of concentric undulations just below the margin, face of the semicells with 4 concentric granules arranged semicircularly, single axial chloroplast with a centrally placed pyrenoid in each semicell, cells 35-41 µm long, 24-27 µm broad and isthmus 10-12 µm broad.

Site of collection: Jiyeni Beel, Kamrup.

New to northeastern India (Image 40).

Cosmarium undulatum var. *minutum* Wittrock 1869: 11, pl. I [1]: fig. 3

Cells small sized, about 1.2 times longer than broad, median constriction deep, sinus linear and closed, semicells sub-semicircular with convex lateral walls, apex flat with rounded angles, entire margins including apex with faint undulations, 9 undulations in each semicells, cell wall smooth, single axial chloroplast with a central pyrenoid in each semicell, cells 18-25 µm long, 15-20 µm broad and isthmus 5-7 µm broad.

Site of collection: Deepor Beel, Kamrup (M); Rajapukhuri, Darrang; Dakra Beel, Dhubri.

Previous records and distribution in northeastern India: Deepor Beel, Baruah et al. (2020).

Genus: *Desmidium*

Desmidium aptogonum Brébisson ex Kützing 1849: 190

Cells medium-sized, triangular, attached one another to form a long filament, about 1.8 times broader than long, median constriction shallow, sinus widely open, semicells transversely oblong with a small basal swelling around the isthmus, then gradually narrowed towards the apex, apex is broad and concave in the midregion, apex produced at the angles to form connecting processes, cells 13-16 µm long, 24-29 µm broad and isthmus 18-20 µm broad.

Site of collection: Tiplai Pond, Goalpara; Urpad Beel, Goalpara; Akhara Beel, Barpeta.

Previous records and distribution in northeastern India: Urpad Beel, Deka et al. (2011); Sivasagar, Phukan & Bora (2012); Kokrajhar, Das (2020).

Desmidium baileyi f. *tetragonum* Nordstedt 1870: 220

Cells medium-sized, almost as long as broad, connected one another to form a long filament, shallow median constriction, semicells trapezoid, lateral walls parallel, apices with deep semi elliptic depression at the middle, tetra radiate axial chloroplast, cells 20-25 µm long and 19-22 µm broad.

Site of collection: Pond near Tangla College, Udalguri; Chandubi Beel, Kamrup; Shamaguri Beel, Nagaon.

Previous records and distribution in northeastern India: Chandubi Beel, Nath & Baruah (2020).

Desmidium bengalicum W. B. Turner 1893: 147, pl. XIX [19]: figs 1-3 (as 'Bengalicum')

Cells medium-sized, closely united to form a straight filament, about 1.5 times broader than long, enclosed in thick gelatinous sheath, median constriction shallow, sinus open, semicells narrowly elliptic with straight or slightly retuse apices, lateral walls more or less convex, cell wall smooth, cells 19-23 µm long and 30-36 µm broad.

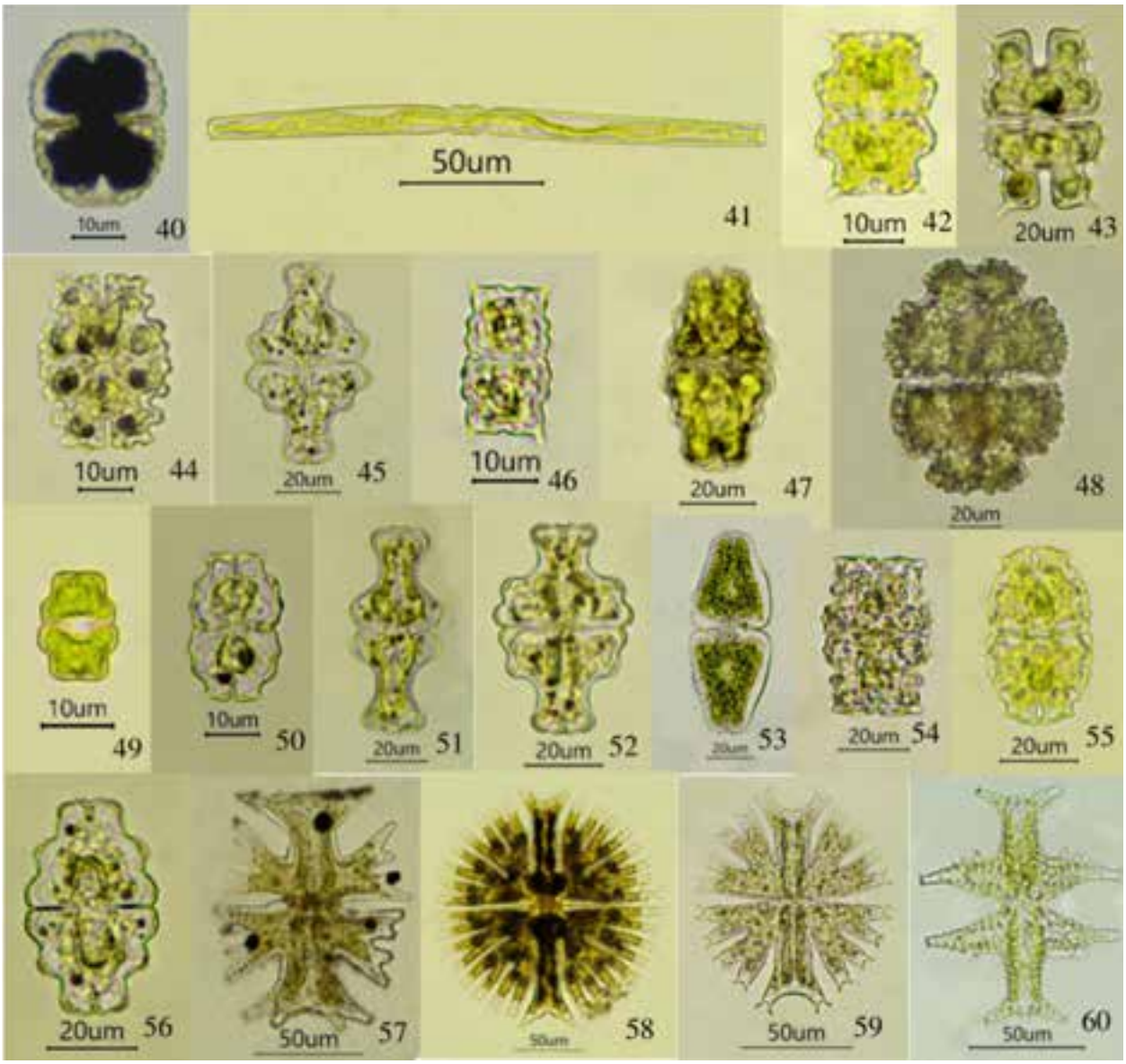


Image 40–60. 40—*Cosmarium undulatum* var. *indicum* | 41—*Docidium baculum* | 42—*Euastrum acanthophorum* | 43—*Euastrum ciastonii* | 44—*Euastrum coralloides* var. *trigibberum* | 45—*Euastrum didelta* var. *capitatum* | 46—*Euastrum exile* | 47—*Euastrum gnathophorum* var. *bulbosum* | 48—*Euastrum horikawae* | 49—*Euastrum insulare* | 50—*Euastrum lapponicum* | 51—*Euastrum longicolle* | 52— *Euastrum neosinuosum* var. *hakalukiense* | 53—*Euastrum obesum* | 54—*Euastrum paradoxum* | 55—*Euastrum serratum* | 56—*Euastrum sinuosum* var. *scrobiculatum* | 57—*Micrasterias americana* | 58—*Micrasterias lux* | 59—*Micrasterias radians* | 60—*Micrasterias tropica.*

Site of collection: Barpeta Beel, Nagaon; Deepor Beel, Kamrup (M); Dakra Beel, Dhubri; Gauhati University Pond, Kamrup (M).

Previous records and distribution in northeastern India: Loktak Lake, Jena & Adhikary (2011); Urpad Beel, Deka et al. (2011); Khanajan, Baruah & Baruah (2013); Deepor Beel, Baruah et al. (2020).

Desmidium coarctatum Nordstedt 1887: 155

Cells medium-sized, rectangular, about 1.3 times broader than long, median constriction shallow, sinus linear and slightly opened, rounded basal angles, apex flat and broad, cells 17-24 µm long and 22-33 µm broad.

Site of collection: Jogorahabi Beel, Sivasagar; Mohmara Pond, Sonitpur.

Previous records and distribution in northeastern India: Urpad Beel, Deka et al. (2011); Sivasagar, Phukan & Bora (2012); Kokrajhar, Das (2020).

Desmidium grevillei (Kützing ex Ralfs) De Bary 1858: 76, pl. 4: figs 30, 31

Basionym: *Didymoprium grevillei* Kützing ex Ralfs

Cells medium-sized, about 1.1-1.2 times broader than long, median constriction a shallow notch, sinus open, semicells oblong with rounded lateral walls, filament straight, cell wall smooth, axial

chloroplast, cells 18-22 µm long and 20-27 µm broad.

Site of collection: Dandua Beel, Morigaon.

Previous records and distribution in northeastern India: Dachi Lake, Hajong & Ramanujam (2018).

Desmidium swartzii C. Agardh ex Ralfs 1848: 61, pl. IV [4]: figs a-f

Cells medium-sized, narrowly rectangular, about 2.2-2.4 times broader than long, median constriction moderately deep, sinus linear but open at extremities, semicells narrowly oblong, lateral walls obliquely truncate with upper angle protruded toward the apex, apex somewhat straight without any depression, cell wall smooth, chloroplast axial, cells 13-17 µm long and 32-38 µm broad.

Site of collection: Katara Beel Paikarkuchi, Nalbari; Shamaguri Beel, Nagaon.

Previous records and distribution in northeastern India: Sivasagar, Phukan & Bora (2012); Kokrajhar, Das (2020).

Genus: *Docidium*

Docidium baculum Brébisson ex Ralfs 1848: 158, pl. XXXIII [33]: fig. 5a, b

Cells long, straight, cylindrical or very slightly narrowing towards extremities, median constriction shallow, sinus widely open, apex smooth, rounded-truncate, base of semicells with single inflation, cells 197-209 µm long, 11-13 µm broad, isthmus 7-7.5 µm broad and apex 6-7 µm broad.

Site of collection: Dheer Beel, Dhubri.

New to northeastern India (Image 41).

Genus: *Euastrum*

Euastrum acanthophorum W. B. Turner 1893: 82, pl. X [10]: fig. 53

Cells small sized, about 1.4 times longer than broad, pyramidal semicells with broad basal lobe and truncate apical lobe, apex inflated, furnished with acute granules at the lateral walls and apical lobes, three large warts and three scrobicles at the central protrusion, median constriction deep, sinus linear, narrow, almost closed inside but open towards extremities, terminal lobes contain projected long stout spines, cell wall punctate, chloroplast with single pyrenoid in each semicell, cells 26-32 µm long, 18-22 µm broad and isthmus 6-7 µm broad.

Site of collection: Naitara Choutara Beel, Goalpara; Rajapukhuri, Nahira Kamrup.

New to northeastern India (Image 42).

Euastrum ampullaceum var. *incavatum* W. B. Turner 1893: 78, pl. X [10]: fig. 59

Cells medium-sized, narrowly elliptic in outline, about 1.6 times longer than broad, shallow median constriction, sinus V shaped, semicells pyramidal, basal lobes broad and slightly bilobed, apex flately rounded, lateral walls concave, face of semicells with six protuberances, cell wall smooth, cells 61-66 µm long, 38-40 µm broad and isthmus 21-23 µm broad.

Site of collection: Chandubi Beel, Kamrup; Dakra Beel, Dhubri.

Previous records and distribution in northeastern India: Chandubi Beel, Nath & Baruah (2020).

Euastrum ansatum Ehrenberg ex Ralfs 1848: 85, pl. XIV [14]: fig. 2 a-f

Cells medium-sized, narrowly oval in outline, about 2 times longer than broad, semicells triangular-pyramidal, median constriction deep, sinus linear and closed at extrimities, basal angles broadly rounded, lateral margins forming low, rounded lateral lobes, then converging to flat apex with rounded angles, apical notch short, semicells with 3 short basal swellings and one mucilage pore on either side at the midregion, cell wall with fine punctae, cells 64-77 µm long, 32-38 µm broad and isthmus 12-14 µm broad.

Site of collection: Urpad Beel, Goalpara; Bharalichuk Pond, Dhemaji; Morakolong, Nagaon.

Previous records and distribution in northeastern India: Urpad Beel, Deka et al. (2011); Dachi Lake, Hajong & Ramanujam (2018); Chandubi Beel, Nath & Baruah (2020).

Euastrum bidentatum Nägeli 1849: 122, pl. VIID [7D]: fig. 1 a-f

Cells small sized, about 2 times longer than broad, median constriction deep, sinus almost closed but slightly dilated at the ends, tri-lobed semi-elliptical semicell, shallow interlobar incisions, lateral lobes ends with apex with slight indentations, polar lobe with deep V-shaped incision at the middle of apex, angular margins of the polar lobes with a wavy process, cell wall smooth, cells 55-68 µm long, 28-34 µm broad and isthmus 8-9 µm broad.

Site of collection: Buka Beel, Sivasagar; Ghunkuchi Beel, Nalbari.

Previous records and distribution in northeastern India: Urpad Beel, Deka et al. (2011).

Euastrum binale Ehrenberg ex Ralfs 1848: 90, pl. XIV [14]: fig. 8

Cells small sized, about 1.7-1.8 times longer than broad, median constriction deep, sinus narrow, linear and closed, both basal and apical angles broadly rounded and lateral walls rather deeply concave, apex with a shallow incision at the middle and furnished with a small submarginal granule on both sides, cells 17-22 µm long, 10-12 µm broad and isthmus 4-5 µm broad.

Site of collection: Charan Beel, Morigaon; Dolani Beel, Bongaigaon.

Previous records and distribution in northeastern India: Dachi Lake, Hajong & Ramanujam (2018).

Euastrum ceylanicum (West & G. S. West) Willi Krieger 1937: 627, pl. 90: figs 16, 17

Basionym: *Euastrum sinuosum* var. *ceylanicum* West & G. S. West

Cells medium-sized, about 1.2-1.3 times longer than broad, median constriction deep, sinus narrow, linear and closed except at extremities, tri-lobed semi cells, subcuneate apical lobe with a median shallow apical notch, lateral lobes prizontal, cell wall furnished with denticulations mostly distributed towards the distal regions of the lobes, axile chloroplasts with single pyrenoid per semicell, cells 40-51 pm long, 31-37 pm broad and isthmus 8-10 µm broad.

Site of collection: Dighali Beel, Nagaon; Dosomighat Pond, Bongaigaon.

Previous records and distribution in northeastern India: North Eastern India, Yasmin et al. (2011); Kokrajhar, Das (2020).

Euastrum ciastonii Raciborski 1892: 387, pl. VII [7]: fig. 28

Cells medium-sized, about 1.5-1.7 times longer than broad, median constriction deep, sinus angular and open widely towards extremities, basal lobes broadly rounded and furnished with several small teeth, lateral walls retuse to the slightly inflated polar lobes, apical sides slightly elevated to a narrow and very deep median cut, apical angles furnished with a short and sharp spine, face of the semicells with two circles of four granules, both the upper as well as lower lobes possess a patch of sub-marginal granules, rest of the cell wall smooth, cells 38-43 µm long, 22-27 µm broad

and isthmus 6-7 µm broad.

Site of collection: Maguri Motapung Beel, Tinsukia.

New to northeastern India (Image 43).

Euastrum clavatum W. B. Turner 1893: 85, pl. XI [11]: fig. 18

Cells medium-sized, about 1.5 times longer than broad, deep median constriction, sinus linear and open, semicells truncated-pyramidal, basal angles broadly rounded and furnished with 3-5 stout spines, apical angles with a shout spine and the apical margin of polar lobe with a U-shaped deep incision at the middle, slightly lower to the lateral side of spiral angles with small spines, apex of polar lobe mancate, cell wall smooth, cells 36-45 µm long, 24-29 µm broad and isthmus 6.5-8 µm broad.

Site of collection: Diplai Beel, Kokrajhar.

Previous records and distribution in northeastern India: Kaziranga National Park and Majuli River Island, Adhikary & Jena (2012).

Euastrum coralloides Joshua 1886: 639, pl. 23: fig. 10

Cells medium-sized, about 1.5 times longer than broad, median constriction deep, sinus narrow, linear and closed, semicells tri-lobed, polar lobe short and broad with deep and narrow median incision at the apex, lateral lobes bilobulate, cells 36-43 µm long, 23-28 µm broad and isthmus 6-8 µm broad.

Site of collection: Bogol Road Beel, Nalbari; Deepor Beel, Kamrup (M)

Previous records and distribution in northeastern India: Khanajan, Baruah & Baruah (2013); Deepor Beel, Baruah et al. (2020).

Euastrum coralloides var. *trigibberum* Lagerheim 1888: 3, pl. I [1]

Cells medium-sized, about 1.5 times longer than broad, nearly sub-rectangular in outline, median constriction deep, sinus narrowly linear and almost closed, semicells sub-pyramidate, 5-facial swellings, broader basal lobe with bilobed lateral walls, polar lobe bi-lobed, lower one short and upper one with single angular spine on each side, apical margin with undulations, somewhat lobed with a 'U' shaped long median open notch, on each sides of notch two prominent swellings, 3 swellings arranged in one row within basal lobe, cells 33-39 µm long, 21-25 pm broad and isthmus 6-7 µm broad.

Site of collection: Kapla Beel, Barpeta.

New to northeastern India (Image 44).

Euastrum denticulatum F. Gay 1884: 335

Cells small sized, about 1.3 times longer than broad, median constriction deep with narrowly linear and closed sinus, semicells 3-lobed and subtrapeziform in shape, each angle furnished with tiny spine, apical lobes appear wide with a deep V-shaped incision at the middle, cells 25-27 µm long, 18-20 µm broad and isthmus 5-6 µm broad.

Site of collection: Hazarapar Pukhuri, Sonitpur.

Previous records and distribution in northeastern India: Dachi Lake, Hajong & Ramanujam (2018).

Euastrum denticulatum var. *quadrifarium* Willi Krieger 1937: 585, pl. 80: figs 20, 21

Cells small sized, about 1.4 times longer than broad, median constriction deep, sinus narrow, linear and closed, semicells sub quadrate, apical lobes short and angles furnished with a short spine, apex flat and with a median notch, cell wall granulated, cells 27-31 µm long, 19-21 µm broad and isthmus 5-6 µm broad.

Site of collection: Chandubi Beel, Kamrup; Sorbhog Beel, Barpeta; Bogol Road Beel, Nalbari.

Previous records and distribution in northeastern India: Chandubi Beel, Nath & Baruah (2020); Kokrajhar, Das (2020); Arunachal Himalayas, Nath & Baruah (2021).

Euastrum didelta Ralfs 1848: 84, pl. XIV [14]: fig. 1

Cells large sized, about 1.7-1.8 times longer than broad, median constriction deep, sinus narrow, linear and closed except at extremities, pyramidal semicells with rounded lateral margin, polar lobe with truncated apex, forming a lip, cell wall punctate, cells 97-125 µm long, 55-68 µm broad and isthmus 18-22 µm broad.

Site of collection: Naitara Choutara Beel, Goalpara; Dagaon Pond, Nagaon.

Previous records and distribution in northeastern India: North Eastern India, Yasmin et al. (2011).

Euastrum didelta var. *capitatum* (A. M. Scott & Prescott) Anissimova & Guiry 2021: 1

Basionym: *Euastrum sinuosum* var. *capitatum* A. M. Scott & Prescott

Cells medium-sized, about 1.5-1.6 times longer than broad, deep median incision, sinus narrow, linear and closed outside, semicells truncate pyramidal, basal lobes broadly rounded, lateral margins retuse to polar lobe, apex slightly inflated, apical angles broadly rounded, apical margin flat and with a short median notch, a mucilage pore present at middle of each semicell, cells 62-74 um long, 38-47 um broad and isthmus 9-11 um broad.

Site of collection: Barsola Beel, Jorhat.

New to northeastern India (Image 45).

Euastrum dubium Nägeli 1849: 122, pl. VIID [7D]: fig. 2

Cells small sized, about 1.2-1.3 times longer than broad, median constriction deep, sinus narrow, linear and dilated at ends, pyramidal semicells with broad basal lobe and short apical lobe, apical lobes with a median incission and angles furnished with a stout spine, axile chloroplast with single pyrenoid in each semicell, cells 21-26 µm long, 17-20 µm broad and isthmus 5-6 µm broad.

Site of collection: Gatanga Beel, Nagaon.

Previous records and distribution in northeastern India: Meghalaya, Das & Ramanujam (2010).

Euastrum elegans Ralfs 1848: 89, pl. XIV [14]: figs 7b-d

Cells small sized, about 1.6-1.7 times longer than broad, median constriction deep, sinus linear and closed, semicells sub ovoid, 2 firm lateral projections at each side of semicell, semicells slightly narrowed towards the poles, apex with a narrow and deep incision at the middle, cells 27-33 µm long, 16-19 µm broad and isthmus 5-6 µm broad.

Site of collection: Chandubi Beel, Kamrup; Koladuwar Beel, Golaghat; Gaurangtari Pond, Dhubri.

Previous records and distribution in northeastern India: North Eastern India, Yasmin et al. (2011); Chandubi Beel, Nath & Baruah (2020); Arunachal Himalayas, Nath & Baruah (2021).

Euastrum exile var. *kaliganjense* A. K. Islam & Begum, 1991: 75

Cells small sized, almost rectangular in outline, about 2.2-2.4 times longer than broad, median constriction deep, sinus narrow, linear and slightly dilated inside and outside, lateral walls with 3 undulations, basal lobe slightly broader than the apical lobe, apical angles furnished with an stout and erect spine, apical margin undulate with a shallow median incision, semicells with a median swelling, cell wall ornamented with 4 large marginal and 4 small

internal crescentic processes, cells 27-31 µm long, 11-14 µm broad and isthmus 4-5 µm broad.

Site of collection: Kachodhora Beel, Morigaon.

New to northeastern India (Image 46).

Euastrum gnathophorum var. *bulbosum* A. M. Scott & Prescott 1961: 28, pl. 9: figs 9, 10

Cells medium-sized, about 1.6-1.7 times longer than broad, median constriction deep, sinus linear and closed, pyramidal semicells and tri-lobed, basal and apical angles broadly rounded, apex with a short median incision, chloroplast parietal, cells 48-61 long 30-35 broad and isthmus 10-12 µm broad.

Site of collection: Gandhi Beel, Barpeta.

New to northeastern India (Image 47).

Euastrum horikawae T. Hinode 1960: 113, photo 1: fig. 3: 16-18 (as 'Horikawae')

Cells large sized, about 1.3-1.4 times longer than broad, median constriction deep, sinus narrow, linear and slightly opened at extremities, semicells semicircular and bilobed, basal lobes very large, angles broadly rounded, bearing on each lateral margin 6-10 bifid to quadrifid verrucae, separated from apical lobe by a small semicircular cleft, apical lobe wide, angles broadly rounded with 4-6 trifid verrucae at the margin, apex truncate with a broad shallow median incision, just below center of face a large elliptical ornament bounded by 12-18 emarginated verrucae, lateral lobes each bearing about 24 or more bifid to multifid verrucae, 7-12 alike verrucae on each of apical lobules, cells oblong in side view, broadly elliptical in vertical view, in center of apical lobe an elliptical group of large pores present, cells 91-114 µm long, 67-78 µm broad and isthmus 17-20 µm broad.

Site of collection: Shamaguri Beel, Nagaon.

New to northeastern India (Image 48).

Euastrum insulare (Wittrock) J. Roy 1877: 70

Basionym: *Euastrum binale* var. *insulare* Wittrock

Cells very small sized, about 1.6-1.7 times longer than broad, median constriction deep, sinus narrowly linear and closed, semicell trapeziform, lateral walls undulate, apex with a shallow median notch, oval in side view, cell wall smooth, chloroplast with one pyrenoid in each semicell, cells 14-18 µm long, 8-11 µm broad and isthmus 2.5-3.5 µm broad.

Site of collection: Katara Beel Paikarkuchi, Nalbari; Rajapukhuri, Nahira Kamrup.

New to northeastern India (Image 49).

Euastrum lapponicum Schmidle 1898: 47, pl. I [1]: fig. 29 (as 'Lapponicum')

Cells small sized, about 1.6-1.7 times longer than broad, median constriction deep, sinus narrow, linear and closed, broad basal lobes with undulate lateral walls, polar lobes short, broad with parallel margins, apical margin flat, angles furnished with a short spine, apex with a short median notch, face of semicell with a prominent protuberance bearing a pair of large granules, cell wall granulate, oval in vertical view, poles knob like with a subapical swelling on either side, oval or broadly elliptical in side view, cells 27-31 µm long, 16-18 µm broad and isthmus 6-7 µm broad.

Site of collection: Mohmara Pond, Sonitpur; Tinkonia Pukhuri, Jorhat.

New to northeastern India (Image 50).

Euastrum longicolle Nordstedt 1887: 156 (as 'ß longicolle')

Cells medium-sized, elongate, about 2.2 times longer than broad, median constriction deep, sinus narrow linear and closed except at extremities, semicells vase-shaped, tri-lobed, basal lobes high, somewhat angular on margins, sharply retuse to a long, columnar polar lobe with slightly diverging sides, apex inflated with rounded angles, apical margin flat but with a short and narrow median notch, face of semicell with 2-transverse rows of protuberances, cell wall punctate, subrectangular in side view with truncately rounded at apex, margins sloping outwardly to basal swelling, cells 69-78 µm long, 31-35 µm broad and isthmus 9-11 µm broad.

Site of collection: Koya Kujia Beel, Bongaigaon.

New to northeastern India (Image 51).

Euastrum luetkemuelleri F. Ducellier 1918: 134, fig. 123 a (as 'lütkemüllerii')

Cells small sized, truncate oval, about 1.3-1.4 times longer than broad, median constriction deep, sinus linear and closed, semicells truncate-pyramidal, basal lobes with narrowly rounded angles, lateral margins retuse and converging to the apex, polar lobe nearly rectangular with bluntly pointed angles, the apical margin flat but with a shallow median notch, face of the semicells with a broad swelling, cell wall smooth, cells 22-27 µm long, 16-19 µm broad and isthmus 4-5 µm broad.

Site of collection: Tiplai Pond, Goalpara; Narpara Pond, Nalbari; Shamaguri Beel, Nagaon.

Previous records and distribution in northeastern India: Arunachal Himalayas, Nath & Baruah (2021).

Euastrum neosinuosum var. *hakalukiense* (A. K. Islam & Haroon) Anissimova & Guiry 2021: 2

Basionym: *Euastrum sinuosum* var. *hakalukiense* A. K. Islam & Haroon

Cells medium-sized, about 1.6-1.7 times longer than broad, median constriction deep, sinus closed, basal lobes with two swellings on each side near margins, apical lobe is extended with almost parallel margins, apex flat, truncate with a short median notch, two swellings one on each side of the apical notch near corners, two mucilage pores present at middle of apical lobes, cells 55-66 µm long, 33-37 µm broad and isthmus 8-10 µm broad.

Site of collection: Deohati Pond, Bongaigaon.

New to northeastern India (Image 52).

Euastrum obesum Joshua 1886: 638, pl. 23: figs 19, 20

Cells moderately large sized, about 2.4-2.6 times longer than broad, median constriction deep, sinus narrow and open at ends, semicells pyramidal with truncate apex, basal lobes with narrowly rounded angles, apical angles rounded, apes flat with a short and narrow median notch, lateral margins retuse slightly, cell wall smooth, cells 86-92 µm long, 32-38 µm broad and isthmus 11-12 µm broad.

Site of collection: Duminichowki Pond, Kamrup; Jugi Beel, Golaghat.

New to northeastern India (Image 53).

Euastrum obesum var. *subangulare* West & G. S. West 1895: 50, pl. 6: fig. 15

Cells moderately large sized, narrowly elliptic in outline, about 2.4-2.6 times longer than broad, median constriction deep, sinus linear and closed, semicells pyramidal with truncate apex, basal lobes narrowly rounded, apical angles rounded, apex with a short median notch, lateral margins retuse slightly then converging towards the apex, cell wall smooth, cells 90-97 µm long, 34-40 µm broad and isthmus 14-16 µm broad.

Site of collection: Moridesang, Sivasagar; Borpukhri Ghagrapar, Nalbari; Gauhati University Pond, Kamrup (M).

Previous records and distribution in northeastern India: Chandubi Beel, Nath & Baruah (2020).

Euastrum paradoxum W. B. Turner 1893: 83, pl. XI [11]: fig. 4

Cells medium-sized, quadrangular in outline, about 1.4-1.5 times longer than broad, median constriction deep, sinus linear and closed but slightly open at the ends, semicells tri-crenulate on lateral walls, truncate at the apex with a apical notch, apical angles furnished with a short teeth, cell wall granulated, slightly constricted in side view, ovate-lanceolate, cells 41-49 µm long, 28-32 µm broad and isthmus 9-10 µm broad.

Site of collection: Dighali Beel, Sivasagar.

New to northeastern India (Image 54).

Euastrum serratum Joshua 1886: 639, pl. 23: figs 1, 2

Cells medium-sized, ellipsoid in out line, about 1.7 times longer than broad, median constriction deep, sinus linear and closed, semicell semipyramidate, lateral margins serrated, basal lobes divided into 2 short lobules, each lobule with a shallow notch at the tip, incision between apical lobe and upper basal lobe fairly deep, above this incision a single subapical lobule of polar lobe with depressed tip present, upper lobule of polar lobe broadly truncated, apex undulate with a deep and open median notch, apical angles furnished with a small horizontal spine, at base of each basal, lateral, and polar lobes in all 6 small processes present, cells 42-49 µm long, 24-28 µm broad and isthmus 7.5-9 µm broad.

Site of collection: Dheer Beel, Dhubri; Gohain Pukhuri, Sivasagar; Majkuchi Pond, Kamrup**.**

New to northeastern India (Image 55).

Euastrum sinuosum var. *scrobiculatum* (Nordstedt) Willi Krieger 1937: 503, pl. 63: figs 2, 3

Basionym: *Euastrum sinuosum* f. *scrobiculatu* Nordstedt

Cells medium-sized, about 1.8-1.9 times longer than broad, median constriction deep, sinus narrowly linear and closed, semicell pyramidate, lateral margins undulate, basal lobes broad and large with rounded angles, apical lobe short with rounded angles, apex nearly flat with a short median incision, cells 45-58 µm long, 25-30 µm broad and isthmus 10-11 µm broad.

Site of collection: Sorbhog Beel, Barpeta.

New to northeastern India (Image 56).

Euastrum subhypochondrum F. E. Fritsch & M. F. Rich 1937: 176, fig. 10 A-E

Cells medium-sized, almost as long as broad, median constriction deep, sinus 'V' shaped and open outwardly, semicells with very broad basal and narrow apical lobes, apex with undulation, apical angles furnished with two stout spines, angles of basal lobes also furnished with small spines but more in numbers, cell wall granulated, cells 49-58 µm long, 45-50 µm broad and isthmus 12-14 µm broad.

Site of collection: Chandubi Beel, Kamrup; Gandhi Beel, Barpeta; Bornijora Pond, Jalah Kamrup.

Previous records and distribution in northeastern India: Chandubi Beel, Nath & Baruah (2020).

Euastrum spinulosum var. *burmense* (West & G. S. West) Willi Krieger 1937: 636

Basionym: *Euastrum inermius* var. *burmense* West & G. S. West

Cells medium-sized, about 1.2-1.3 times longer than broad, quadrangular in outline, deeply constricted at middle, sinus linear and closed, semicells 5-lobed, lobes furnished with small spines, cell wall granulated, granules organized in circular pattern, median region of each semicell furnished with larger granules, cells 47-60 µm long, 39-45 µm broad and isthmus 10-12 µm broad.

Site of collection: Chandubi Beel, Kamrup; Barpeta Beel, Nagaon.

Previous records and distribution in northeastern India: Chandubi Beel, Nath & Baruah (2020).

Euastrum spinulosum var. *lindiae* Grönblad & A. M. Scott 1958: 17: pl. VII [7]: figs 84-88, photo 347

Cells medium-sized, quadrate in outline, about 1.1-1.2 times longer than broad, median constriction deep, sinus linear and closed, basal angles narrowly rounded and produced, lateral walls retuse forming 'V'-shaped incision and forming narrowly rounded lateral lobes, apical lobes more produced than the typical, apex slightly retuse near the midregion, lobes furnished with short blunt spines, face of the lobes with scattered spines, face of the semicells with granules arranged in circle at the middle, cell wall otherwise smooth, cells 44-55 µm long, 37-43 µm broad and isthmus 10-12 µm broad.

Site of collection: Kapla Beel, Barpeta; Daphlong Beel, Golaghat; Majkuchi Pond, Kamrup.

Previous records and distribution in northeastern India: Kokrajhar, Das (2020); Arunachal Himalayas, Nath & Baruah (2021).

Euastrum turgidum var. *grunovii* W. B. Turner 1893: 75, pl. X [10]: fig. 29 (as 'ß *grunovii*')

Cells large sized, almost rectangular in outline, about 1.2-1.3 times longer than broad, median constriction deep, sinus narrow but open outwardly at extremities, semicells bilobed, polar lobe with truncate apex, only one ornate central swelling or tumour, each semicell with broad basal lobe, lateral margins slightly depressed at the middle by shallow sinus, apical lobe with the truncate apical wall, cell wall punctate, cells 105–121 µm long, 81-91 µm broad and isthmus 32–35 µm broad.

Site of collection: Chakoli Beel, Majuli.

Previous records and distribution in northeastern India: Kaziranga National Park and Majuli River Island, Adhikary & Jena (2012).

Genus: *Haplotaenium*

Haplotaenium minutum (Ralfs) Bando 1988:176

Basionym: *Docidium minutum* Ralfs

Cells long, cylindrical, about 13-15 times longer than broad, median constriction a shallow notch, sinus open, lateral walls retuse and parallel, apical margins rounded, cell walls smooth, chloroplast axial with 2–8 pyrenoids in each semicell, cells 120-143 µm long, 8–10.5 µm broad and apex 3-4 µm broad.

Site of collection: Chandubi Beel, Kamrup; Shamaguri Beel, Nagaon.

Previous records and distribution in northeastern India: Urpad Beel, Deka et al. (2011).

Haplotaenium minutum var. *gracile* (Wille) Bando 1988: 176

Basionym: *Penium minutum* var. *gracile* Wille

Cells long, cylindrical, about 16–20 times longer than broad, median constriction a minute notch, lateral walls parallel but very slightly tapering at the apices, apex truncate with rounded angles, cell wall punctate and punctae arranged in oblique series, chloroplast axial, cells 146-188 µm long, 6–9 µm broad and apex 3-4 µm broad.

Site of collection: Chandubi Beel, Kamrup; Diplai Beel, Kokrajhar.

Previous records and distribution in northeastern India: Chandubi Beel, Nath & Baruah (2020).

Genus: *Hyalotheca*

Hyalotheca dissiliens Brébisson ex Ralfs 1848: 51, pl. I [1]: fig. 1 a–i

Cells small sized, about 1.2 times broader than long, united one another to form long filaments, sinus a very slight median depression in the lateral walls, semicells cylindrical-discoidal, the lateral walls slightly convex, the apices broadly truncate, cylindrical in vertical view, one axial chloroplast in each semicell with a centrally placed pyrenoid, and several radiating ridges flattened at extremities, cells 12–15 µm long 15-19 µm broad and isthmus 14–16 µm broad.

Site of collection: Urpad Beel, Goalpara; Hasila Beel, Goalpara.

Previous records and distribution in northeastern India: Urpad Beel, Deka et al. (2011); Dachi Lake, Hajong & Ramanujam (2018).

Hyalotheca mucosa Ralfs 1848: 53, pl. I [1]: fig. 2

Basionym: *Conferva mucosa* Mertens

Cells small sized, almost as long as broad, attached end to end to form a short filament, no median depression, very slightly constricted at the joints; semicells transversely sub-rectangular, lateral walls almost parallel, convex with broadly rounded apical angles, apex broad and truncate, cell wall smooth except two series of tiny granules just beneath the apices, cells 12–16 µm long and 13-15 µm broad.

Site of collection: Haribhanga Beel, Nagaon.

Previous records and distribution in northeastern India: South Sikkim, Das & Keshri (2013).

Genus: *Micrasterias*

Micrasterias alata Wallich 1860: 279, pl. XIII [12]: fig. 11

Cells large sized, almost as long as broad, median constriction deep, sinus widely open towards extremities, the upper margin of the upper member extends vertically, parallel to the polar lobe, and is divided from it by a deep and narrow incision, lateral lobes were once divided, the lower member was simple, and all divisions were deep, lobules were swollen at the base before abruptly and narrowly tapering to tridentate extremities, polar lobe slender with parallel sides, abruptly branching at apex into 2 slender diverging processes, cell wall smooth, cells 125–157 µm long, 121-134 µm broad and isthmus 18–21 µm broad.

Site of collection: Chandubi Beel, Kamrup; Moridesang, Sivasagar.

Previous records and distribution in northeastern India: Loktak Lake, Jena & Adhikary (2011); South Sikkim, Das & Keshri (2013); Chandubi Beel, Nath & Baruah (2020); Kokrajhar, Das (2020).

Micrasterias americana Ehrenberg ex Ralfs 1848: xix [Errata and Addenda]

Cells large sized, about 1.1–1.2 times longer than broad, median constriction deep, sinus open, acute towards apex, semicells semielliptical 5–lobed with conspicuously protruding polar lobe, retuse apex and angles produced into stout, diverging narrow incision processes with ends truncate and denticulate, from the base of each process arise 2 similar accessory processes, one on each side, lateral lobes divided into 2 lobules single spine or with comparatively shallow incisions dissecting them, cell wall granulate, granules scattered, cells 110–132 µm long, 92–108 µm broad and isthmus 23–26 µm broad.

Site of collection: Dhamar Beel, Goalpara.

New to northeastern India (Image 57).

Micrasterias ceratofera Joshua 1885: 34, pl. 254: fig. 4

Cells large sized, about 1.4–1.5 times longer than broad, median constriction deep, sinus widely open, acute-angled, semicells pyramidal-hexagonal, basal lobes broad, once divided, furnished with single long and blunt spine on each angle, spines oppositely directed, upper lobe elongate, lateral walls very slight attenuate, apex retuse with two long and diverging blunt spines, cell wall smooth, cells 182–215 µm long with spines, 126–140 µm broad with spines and isthmus 22–25 µm broad.

Site of collection: Chandubi Beel, Kamrup; Dagaon Pond, Nagaon.

Previous records and distribution in northeastern India: Chandubi Beel, Nath & Baruah (2020).

Micrasterias foliacea Bailey ex Ralfs 1848: 210, pl. XXXV [35]: fig. 3

Cells medium-sized, sometimes occur singly or united with one another to form filaments, cells rectangular, about 1.4 times broader than long, median constriction deep, sinus linear, lateral lobes divided to the second and third order, different, the lower lobules horizontal, the upper lobules diverging, its upper part reduced to a conical projection, polar lobe very distinctive, basal part narrow with erect parallel margins, the middle of the apex features a very broad, deep subrectangular excavation, with the upper three-quarters of the lobe significantly extended, angles stout, ending in 2 widely divergent teeth, a depressed portion of the apex bearing two unequal stout spines on each side, cells 50–56 µm long, 71–80 µm broad and isthmus 13–15 µm broad.

Site of collection: Chandubi Beel, Kamrup; Katara Beel Paikarkuchi, Nalbari; Kapla Beel, Barpeta**;** Urpad Beel, Goalpara**;** Pond near Tangla College, Udalguri; Bogibil Ghat, Dibrugarh; Panpoor Ghat, Sonitpur; Naitara Choutara Beel, Goalpara; Dheer Beel, Dhubri; Gauhati University Pond, Kamrup (M); Dhamar Beel, Goalpara; Kumri Beel, Goalpara; Dudhnoi College Pond, Goalpara; Kusumfula Beel, Goalpara; Jor Beel, Jorhat; Bheriki Beel, Jorhat; Dighali Beel, Nagaon; Jaysagar Pukhuri, Sivasagar; Jogorahabi Beel, Sivasagar; Lakhimpur pukhuri, Darrang; Hazarapar Pukhuri, Sonitpur; Daphlong Beel, Golaghat; Chakoli Beel, Majuli; Maguri Motapung Beel, Tinsukia; Himatichuk Pond, Dhemaji; Radhapukhuri, Lakhimpur; Duminichowki Pond, Kamrup; Shamaguri Beel, Nagaon; Morakolong, Nagaon**;** Rawmari Beel, Nagaon**;** Kachodhora Beel, Morigaon; Diplai Beel, Kokrajhar; Konuri Beel, Dhubri; Laokhoa Beel, Dhubri; Dolani Beel, Bongaigaon; Tamranga Beel, Bongaigaon**;** Akhara Beel, Barpeta; Sorbhog Beel, Barpeta; Borpukhri Ghagrapar, Nalbari**;** Jiyeni Beel, Kamrup; Deepor Beel, Kamrup (M)

Previous records and distribution in northeastern India: Loktak Lake, Jena & Adhikary (2011); Urpad Beel, Deka et al. (2011); Sivasagar, Phukan & Bora (2012); Khanajan, Baruah & Baruah (2013); South Sikkim, Das & Keshri (2013); Chandubi Beel, Nath & Baruah (2020); Kokrajhar, Das (2020); Arunachal Himalayas, Nath & Baruah (2021).

Micrasterias lux Joshua 1886: 636, pl. XXII [22]: fig. 12

Cells large sized, spherical or subspherical shaped, almost as long as broad, median constriction very deep, sinus closed inside and open towards extremities, semicell 3-lobed, each of 2 main lateral lobes further divided into 4 lateral lobelets, each lobelet into 2-lobules having emarginated apices or spines (total 8 lobules in each side of semicell), lobules long and stout, apical lobe with a shallow and broad median notch, 2 lobules having spiny tips, cell wall punctate, cells 173–191 µm long, 159–170 µm broad and isthmus 23–26 µm broad.

Site of collection: Maguri Motapung Beel, Tinsukia.

New to northeastern India (Image 58).

Micrasterias mahabuleshwarensis J. Hobson 1863: 169, first fig. (as 'Mahabuleshwarensis')

Cells large sized, about 1.2 times longer than broad, median constriction very deep, sinus widely open, polar lobe in lower half quadrate, above widely expanding into narrow diverging processes at the angles, with more nearly erect accessory processes at their base, arising asymmetrically, one at the front and one at the back of the apex, apex nearly straight, lateral lobes once divided into narrow and tapering processes, processes with serrated walls, ends tri-denticulate, semicells with a row of acute intra-marginal granules along the inner part of the major incisions, with a small granulate central protuberance above the isthmus, cells 140–165 µm long, 118–133 µm broad and isthmus 26–28 µm broad.

Site of collection: Ghunkuchi Beel, Nalbari.

Previous records and distribution in northeastern India: Loktak Lake, Jena & Adhikary (2011).

Micrasterias pinnatifida Ralfs 1848: 77, pl. X [10]: fig. 3

Cells medium-sized, slightly broader than long, very deeply constricted at middle, sinus closed inside but widely open towards extremities, broad basal lobes, undivided, conical, horizontally extended, somewhat constrict just before the bifid extremity, apical lobes horizontally spreading, apex very slightly convex, polar extension smaller than the basal lobes, bifid at the extremities, cell wall smooth, chloroplast with few pyrenoids, cells 53–59 µm long, 62–67 µm broad and isthmus 10–11 µm broad.

Site of collection: Chandubi Beel, Kamrup; Urpad Beel, Goalpara; Naitara Choutara Beel, Goalpara; Dheer Beel, Dhubri; Maguri Motapung Beel, Tinsukia; Kapla Beel, Barpeta**;** Jiyeni Beel, Kamrup; Radhapukhuri, Lakhimpur; Kusumfula Beel, Goalpara; Kumri Beel, Goalpara; Tiplai Pond, Goalpara; Barsola Beel, Jorhat**;** Buka Beel, Sivasagar**;** Jaysagar Pukhuri, Sivasagar**;** Gohain Pukhuri, Sivasagar**;** Rajapukhuri, Darrang; Padumpukhuri, Sonitpur; Koladuwar Beel, Golaghat; Chakoli Beel, Majuli; Hiloidhari majgao Beel, Dibrugarh; Bhebeli Pond, Dhemaji; Mohmara Pond, Sonitpur; Dagaon Pond, Nagaon; Haribhanga Beel, Nagaon; Shamaguri Beel, Nagaon; Rawmari Beel, Nagaon; Charan Beel, Morigaon; Diplai Beel, Kokrajhar; Goalnani Pond, Dhubri; Deohati Pond, Bongaigaon; Tamranga Beel, Bongaigaon ; Laokhoa Beel, Dhubri; Sorbhog Beel, Barpeta; Bogol Road Beel, Nalbari**;** Digholi Beel, Kamrup; Deepor Beel, Kamrup (M)

Previous records and distribution in northeastern India: Loktak Lake, Jena & Adhikary (2011); North Eastern India, Yasmin et al. (2011); Urpad Beel, Deka et al. (2011); Sivasagar, Phukan & Bora (2012); Chandubi Beel, Nath & Baruah (2020); Kokrajhar, Das (2020); Arunachal Himalayas, Nath & Baruah (2021).

Micrasterias radians W. B. Turner 1893: 91, pl. V [5]: fig. 6 a

Cells large sized, about 1.2 times longer than broad, median constriction very deep, sinus open throughout, lateral lobes evenly twice divided, lobules slightly swollen at the base, terminating in a pair of divergent teeth, polar lobe slightly exerted, the lower walls parallel, the upper part diverging and apex deeply concave between the 2 short bi-dentate processes, all incision widely open, cell wall smooth, cells 103–122 µm long, 83–94 µm broad and isthmus 16–18 µm broad.

Site of collection: Dolani Beel, Bongaigaon.

New to northeastern India (Image 59).

Micrasterias thomasiana W. Archer 1862: 239, pl. XII [12]: figs 1–10 (as 'Thomasiana')

Cells large sized, slightly longer than broad, outline sub-circular, median constriction deep, sinus narrow and linear, semicells 5-lobed with closed liner incisions between lobes, polar lobe narrow, wedge-shaped with concave lateral margins and with a moderately deep median notch, on each side is an apiculate, emarginate swelling, outer angles with 1 or 2 small spines, lateral lobes almost equal with a deep and closed incision dividing each into 2 equal lobules, each lobule with a less deep and V-shaped secondary incision and usually with 2 further divisions, the extremities furnished with tooth-like outgrowth, cells 157–184 µm long, 140–157 µm broad and isthmus 24–26 µm broad.

Site of collection: Dighali Beel, Nagaon.

Previous records and distribution in northeastern India: North Eastern India, Yasmin et al. (2011).

Micrasterias tropica Nordstedt 1870: 219, pl. 2: fig 15

Cells large sized, about 1.3 times longer than broad, median constriction very deep, sinus widely open, polar lobe with erect, parallel-sided lower part and a diverging upper part, the apex flat between the long and spreading processes, lateral lobe undivided, horizontally extended, strongly tapered; with small stout marginal spines toward the ends of the lateral lobes and polar processes, and similar spines within the margins of all but the extremities, spines paired at the depressed apex, in top view semicells fusiform, marginal and inter-marginal spines present, cells 101–122 µm long, 85–93 µm broad and isthmus 17–19 µm broad.

Site of collection: Tamranga Beel, Bongaigaon; Rawmari Beel, Nagaon; Rajapukhuri, Darrang.

New to northeastern India (Image 60).

Micrasterias zeylanica F. E. Fritsch 1907: 246, fig. 4 C

Cells medium-sized, almost as long as broad, median constriction deep, sinus open at extremities, semicells 3-lobed, lobes separated by incisions, ends of terminal lobe bluntly pointed, lateral lobes with two blunt processes, separated by a narrow and shallow depression, the processes next to the sinus being horizontal, the other bent down toward the sinus, polar lobe widely spreading, slightly drawn out at each extremity into a horizontal or deflected process, apex flatly convex, cell wall smooth, cells 49–55 µm long, 50–57 µm broad and isthmus 8–9.5 µm broad.

Site of collection: Dighali Beel, Nagaon; Deepor Beel, Kamrup (M).

Previous records and distribution in northeastern India: North Eastern India, Yasmin et al. (2011); Khanajan, Baruah & Baruah (2013); Deepor Beel, Baruah et al. (2020); Kokrajhar, Das (2020).

Genus: *Onychonema*

Onychonema uncinatum Wallich 1860: 195, pl. VIII [8]: figs 7–11

Cells small sized, rectangular in outline, about 1.5 times broader than long, deeply constricted, sinus linear inside, and open towards extremities, cells attached by a cellular extension called cornua and form a long filament, a row of minute teeth present between cornua, cells 12–16 µm long, 18–24 µm broad and isthmus 4–5 µm broad.

Site of collection: Chandubi Beel, Kamrup; Deepor Beel, Kamrup (M); Dakra Beel, Dhubri.

Previous records and distribution in northeastern India: Loktak Lake, Jena & Adhikary (2011); Chandubi Beel, Nath & Baruah (2020); Deepor Beel, Baruah et al. (2020).

Genus: *Pleurotaenium*

Pleurotaenium ehrenbergii (Ralfs) De Bary 1858: index, 75

Basionym: *Docidium ehrenbergii* Ralfs

Cells straight, long with truncate apices, about 11 times longer than broad, median constriction a shallow notch, semicell's lateral walls slightly tapering to a rounded truncate apex, cell wall smooth, chloroplast parietal, cells 221–278 µm long, 20–24 µm broad and apex 14–16 µm broad.

Site of collection: Chandubi Beel, Kamrup; Dandua Beel, Morigaon; Bharalichuk Pond, Dhemaji.

Previous records and distribution in northeastern India: North Eastern India, Yasmin et al. (2011); Sivasagar, Phukan & Bora (2012); South Sikkim, Das & Keshri (2013); Chandubi Beel, Nath & Baruah (2020).

Pleurotaenium ehrenbergii var. *elongatum* (West) West 1892: 119

Basionym: *Docidium ehrenbergii* var. *elongatum* West

Cells straight, very long, about 20 times longer than broad, shallow constriction at the middle, semicells with prominent basal inflation with 1 or 2 smaller swelling beyond, walls slightly tapering to a rounded truncate apex, in face view six tubercles visible, cell wall finely punctate, band like parietal chloroplast with several pyrenoids in each semicell, cells 397–465 µm long, 20–24 µm broad and apex 13–15 µm broad.

Site of collection: Chandubi Beel, Kamrup; Katara Beel Paikarkuchi, Nalbari.

Previous records and distribution in northeastern India: Chandubi Beel, Nath & Baruah (2020).

Pleurotaenium kayei (W. Archer) Rabenhorst 1868: 439

Basionym: *Docidium kayei* W. Archer

Cells cylindrical, about 4.6 times longer than broad, median constriction prominent, sinus widely open, each semicell broader at the base and gradually tapering towards the apex, lateral walls undulate up to the base of the apex and furnished with 5-ring-like whorls of spiny outgrowths from the base of semicell up to below the apex, apex flatly truncate with a ring of 10–12 short spines, cells 277–318 µm long, 59–68 µm broad, isthmus 30–32 µm broad and apex 40–44 µm broad with spines.

Site of collection: Dakra Beel, Dhubri.

New to northeastern India (Image 61).

Pleurotaenium nodosum (Bailey ex Ralfs) P.Lundell 1871: 90

Basionym: *Docidium nodosum* Bailey ex Ralfs

Cells straight, long, crenate in face view, about 4.7–5 times longer than broad, semicells with nodulose margins caused by 4 evenly spaced rings of bulbous nodules, semicells tapering very slightly towards the slightly dilated apex, apex furnished with a crown of 6 conical teeth like projections, cell wall smooth, chloroplast with parietal bands, cells 128–164 µm long, 27–33 µm broad and apex 14–16 µm broad.

Site of collection: Naitara Choutara Beel, Goalpara.

New to northeastern India (Image 62).

Pleurotaenium trabecula Nägeli 1849: 104

Cells cylindrical, straight and long, about 10–12 times longer than broad, with slight but definite basal inflation, lateral walls straight, parallel and slightly narrowing towards the truncate poles with rounded angles, cell wall with fine punctae, chloroplasts with 3–4 lateral bands and with several scattered pyrenoids, cells 461–555 µm long, 31–35 µm broad and apex 19–22 µm broad.

Site of collection: Chandubi Beel, Kamrup.

Previous records and distribution in northeastern India: North Eastern India, Yasmin et al. (2011); Sivasagar, Phukan & Bora (2012); Chandubi Beel, Nath & Baruah (2020).

Pleurotaenium trochiscum West & G. S. West 1896: 235, pl. 13: figs 4, 5

Cells cylindrical, straight and long, about 7–9.8 times longer than broad, lateral walls undulate and slightly attenuated towards the apex, the base of semicells flattened, margin incised, cells 220–354 µm long, 31–36 µm broad and apex 16–18 µm broad.

Site of collection: Raja Beel, Baksa; Borpukhri Ghagrapar, Nalbari.

New to northeastern India (Image 63).

Genus: *Sphaerozosma*

Sphaerozosma laeve var. *latum* (West & G. S. West) Kurt Förster 1973: 580

Basionym: *Onychonema laeve* var. *latum* West & G. S. West

Cells medium-sized, compressed, subrectangular, about 1.5–1.6 times broader than long, median constriction very deep and narrow, sinus open at extremities, the lateral angles furnished with a long stout converging spine, apical processes about as long as the spines, the apex slightly raised and undulate, cells joined end to end forming long pseudofilament, cells 14–17 µm long, 22–28 µm broad and isthmus 5–6 µm broad.

Site of collection: Dheer Beel, Dhubri.

New to northeastern India (Image 64).

Sphaerozosma laeve var. *micracanthum* (Nordstedt) Thomasson (as 'micracantha')

Basionym: *Onychonema laeve* var. *micracanthum* Nordstedt

Cells small sized, about 1.2–1.3 times broader than long, with median constriction very deep and narrow, sinus linear, semicells oblong-reniform, the lateral angles furnished with a very short spine, apices flat, cells joined end to end forming long pseudofilament, cells 12–14 µm long, 15–19 µm broad and isthmus 3–5 µm broad.

Site of collection: Jor Beel, Jorhat.

New to northeastern India (Image 65).

Sphaerozosma vertebratum Brébisson ex Ralfs 1848: 65, pl. VI [6]: fig. 1; pl. XXXII [32]: fig. 2

Cells small sized, compressed, about 1.5 times broader than long, median constriction deep, sinus narrowly linear and open outwardly, the apical process of the semicells very short, often tuberculate and does not overlap the adjoining cells, chloroplast with single pyrenoid in each semicells, cells 10–12 µm long, 13–18 µm broad and isthmus 5–6 µm broad.

Site of collection: Shamaguri Beel, Nagaon.

Previous records and distribution in northeastern India: Loktak Lake, Jena & Adhikary (2011).

Genus: *Spondylosium*

Spondylosium planum (Wolle) West & G. S. West 1912: 430, pl. 19: figs 5–8

Basionym: *Sphaerozosma pulchrum* var. *planum* Wolle

Cells small sized, almost as long as broad, sub-cylindrical in outline with rounded angles, median constriction deep, sinus widely open, apex flat with rounded angles, cells united to form a long filament, cell wall smooth, chloroplast parietal with single pyrenoid per semicell, cells 10–12 µm long, 11–15 µm broad and isthmus 6–7 µm broad.

Site of collection: Chandubi Beel, Kamrup; Himatichuk Pond, Dhemaji; Gandhi Beel, Barpeta.

Previous records and distribution in northeastern India: Urpad

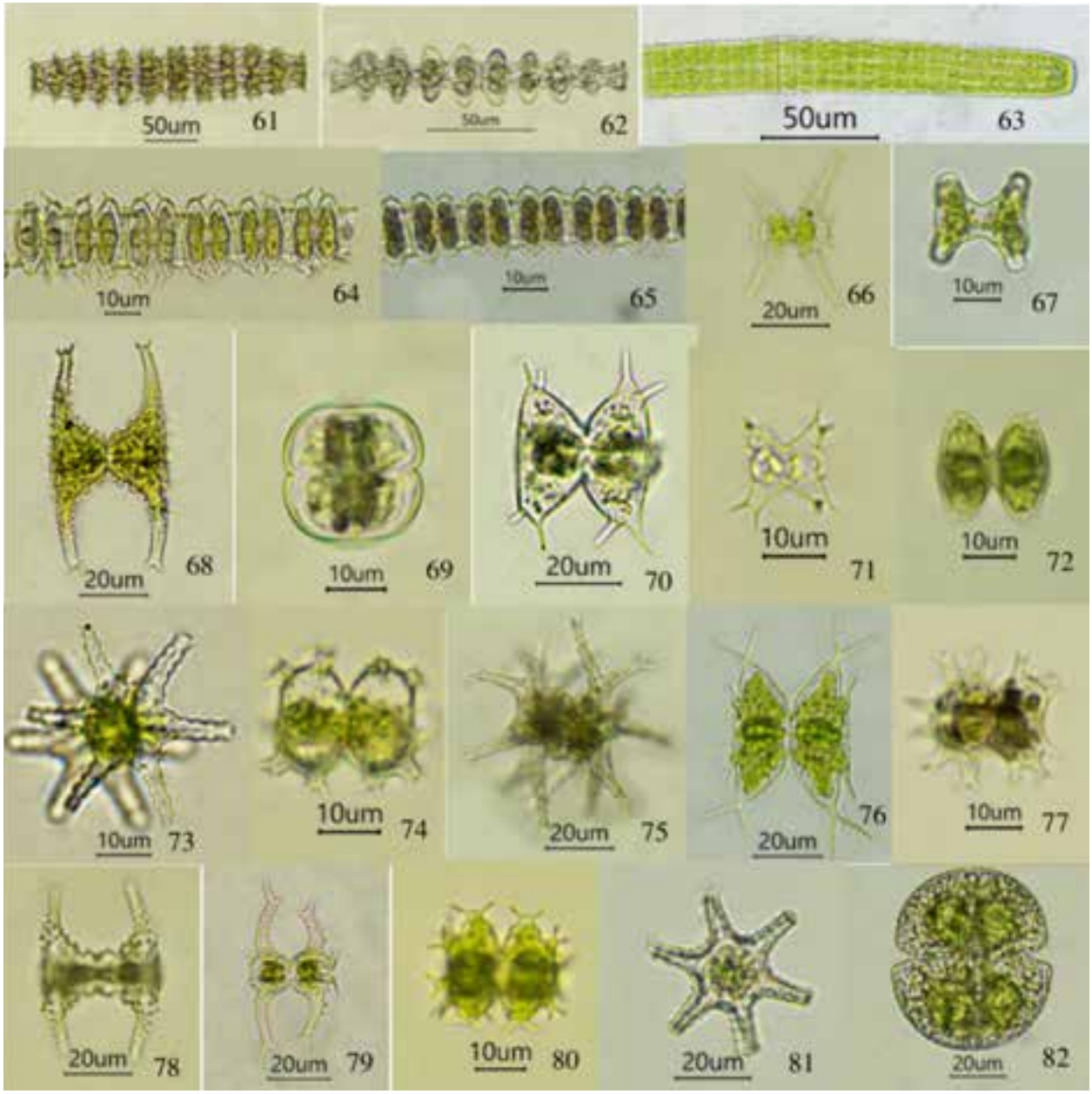


Image 61–82. 61—*Pleurotaenium kayei* | 62—*Pleurotaenium nodosum* | 63—*Pleurotaenium trochiscum* | 64—*Sphaerozosma laeve* var. *latum* | 65—*Sphaerozosma laeve* var. *micracanthum* | 66—*Staurastrum acanthocephalum* | 67—*Staurastrum alternans* | 68—*Staurastrum bengalense* | 69—*Staurastrum bieneanum* | 70—*Staurastrum bifidum* | 71—*Staurastrum botanense* | 72—*Staurastrum brevispina* | 73—*Staurastrum coroniferum* | 74—*Staurastrum duplex* | 75—*Staurastrum elegans* var. *bidentatum* | 76—*Staurastrum freemanii* | 77—*Staurastrum furcatum* | 78—*Staurastrum johnsonii* | 79—*Staurastrum saltans* | 80—*Staurastrum simonyi* | 81—*Staurastrum willsii* | 82—*Staurastrum zahlbruckneri.*

Beel, Deka et al. (2011); Sivasagar, Phukan & Bora (2012); Chandubi Beel, Nath & Baruah (2020).

Spondylosium nitens var. *triangulare* W. B. Turner 1893: 44, pl. XVII [17]: fig. 17 a, c

Cells small sized, almost as long as broad, with deep median constriction, sinus widely open and U-shaped, cells united to form a long unbranched filament, semicells flatly triangular to oblong, apical and lateral angles rounded; cell wall smooth; chloroplast axial with single pyrenoid per semicell, cells 22–25 µm long and 25–28 µm broad, isthmus 7–8 µm broad.

Site of collection: Chandubi Beel, Kamrup.

Previous records and distribution in northeastern India: Chandubi Beel, Nath & Baruah (2020).

Genus: *Staurastrum*

Staurastrum acanthocephalum Skuja 1949: 151, pl. XXXIV [34]: fig. 25

Cells medium-sized, about 1.9–2 times broader than long,

median constriction deep, sinus widely open, semicells bi-lobed, broad basal lobe and small apical lobe, two arms in each pole with distinct spines in arm tip, one longer spine present in the base of each arm, cells 18–21 µm long, 35–42 µm broad and isthmus 7–9 µm broad.

Site of collection: Dosomighat Pond, Bongaigaon.

New to northeastern India (Image 66).

Staurastrum alternans Brébisson 1848: 132, pl. XXI [21]: fig. 7

Cells small sized, almost as long as broad, median constriction deep, sinus widely open, torsion of the cell in the region of the isthmus, 3-angled in apical view, concave angles, cell wall furnished with irregularly arranged granules, cells 20–22 µm long, 20–23 µm broad and isthmus 8–9 µm broad.

Site of collection: Pachi Gaon Pond, Sonitpur.

New to northeastern India (Image 67).

Staurastrum bengalense W. B. Turner 1893: 124, no fig. (as 'Bengalense')

Cells medium-sized, compressed, about 2 times broader than long, median constriction deep, sinus widely open, semicells wedged with converging processes, with a serrate-toothed margin at the apex of the trifid, base and the apex of the semicells with 3 series of transversely arranged verrucae, basal part of each side emarginate with 4 or 8 short projections placed vertically (2, 2) decorated, fusiform in top view, cells 32–36 µm long, 64–75 µm broad and isthmus 9–10 µm broad.

Site of collection: Sorbhog Beel, Barpeta.

New to northeastern India (Image 68).

Staurastrum bieneanum Rabenhorst 1862: no. 1410

Cells small sized, almost as broad as long, median constriction deep, sinus slightly open at ends, semicells transversely elliptic, lateral margins convex and slightly tapering towards the apex, apical angles are sharply rounded, the apical margin convex, cell wall punctate, cells 24–27 µm long, 23–25 µm broad and isthmus 7–8 µm broad.

Site of collection: Gatanga Beel, Nagaon.

New to northeastern India (Image 69).

Staurastrum bifidum Brébisson ex Ralfs 1848: 215

Cells medium-sized, about 1.5–1.6 times broader than long, median constriction moderately deep, the sinus widely open, semicells semielliptical, the basal margins symmetrically convex to acutely rounded apical angles which bear two long sharp and superimposed spines, the apical margin broadly convex, cell wall smooth, cells triangular in top view, the margins concave, the poles bifurcate and furnished with 2 long and stout spines, cells 30–35 µm long, 48–55 µm broad and isthmus 10–12 µm broad.

Site of collection: Katara Beel Paikarkuchi, Nalbari; Shamaguri Beel, Nagaon; Dakra Beel, Dhubri.

New to northeastern India (Image 70).

Staurastrum botanense Playfair 1907: 191, pl. IV [4]: fig. 19

Cells small sized, about 1.2 times broader than long, median constriction deep, the sinus widely open, semicells triangular, apical lobes produced and bearing two superimposed spines, the lower bifid, the basal margin convex and diverging, the apical margin truncate and straight, cells triangular in top view, the margins slightly concave, the poles rounded and bearing 2 superimposed spines, cells 15–18 µm long, 18–22 µm broad and isthmus 6–7 µm broad.

Site of collection: Konuri Beel, Dhubri.

New to northeastern India (Image 71).

Staurastrum brevispina Brébisson 1848: 124, pl. XXXIV [34]: fig. 7

Cells small sized, almost as long as broad, median constriction deep, sinus 'V' shaped and widely open, semicells broadly elliptic with a short spine at each rounded corner, cells in top view triangular with rounded angles and concave sides, cell wall punctate, cells 21–25 µm long, 23–28 µm broad and isthmus 6–7 µm broad.

Site of collection: Tamranga Beel, Bongaigaon; Gauhati University Pond, Kamrup (M).

New to northeastern India (Image 72).

Staurastrum coroniferum W. B. Turner 1893: 114, pl. XIII [13]: fig. 21

Cells medium-sized, almost as long as broad, sinus open, semicells spindle shaped, regularly and greatly inflated from the base, with small quadrangular warts at the truncated apex, a 6-star view from the top, corners in thick straight processes 6 transversely granulate-striated produced, the central part of a hexagon, with rounded corners, tips of the processes are granuliferous, cells 42–46 µm long, 45–50 µm broad and isthmus 10–12 µm.

Site of collection: Jiyeni Beel, Kamrup.

New to northeastern India (Image 73).

Staurastrum crenulatum (Nägeli) Delponte 1877: 68 [reprint p. 164], pl. 12: figs 1–11

Basionym: *Phycastrum crenulatum* Nägeli

Cells medium-sized, slightly longer than broad, sinus open, processes with short spine at the extremities, apex flat with spines at the angles, cells 25–31 µm long, 27–36 µm broad, and isthmus 6–7 µm broad.

Site of collection: Urpad Beel, Goalpara; Diplai Beel, Kokrajhar.

Previous records and distribution in northeastern India: Urpad Beel, Deka et al. (2011); Sivasagar, Phukan & Bora (2012); Khanajan, Baruah & Baruah (2013); Deepor Beel, Baruah et al. (2020); Kokrajhar, Das (2020).

Staurastrum duplex Wolle 1883: 29, pl. XXVII: fig. 10, 10a

Cells small sized, about 1.2 times longer than broad, median constriction moderately deep, sinus open, semicells transversely rectangular, the vertical margin convex and then concave into lower, bi-spinate basal processes, lateral walls parallel to the upper angles which are similarly extended into short, truncate, bi-spinate processes, the apical margin broadly convex, cell wall smooth, cells triangular in top view, the margins broadly concave, the angles protracted into bifurcate and bi-spinate processes, cells 24–28 µm long, 20–23 µm broad and isthmus 9–10 µm broad.

Site of collection: Dakra Beel, Dhubri.

New to northeastern India (Image 74).

Staurastrum elegans var. *bidentatum* (R. Gutwinski) Thomasson 1986: 347

Basionym: *Staurastrum sexangulare* var. *bidentatum* Gutwinski

Cells medium-sized, almost as broad as long, median constriction moderately deep, sinus open, semicells depressed and globose shaped, furnished with long paired processes arranged in 2 whorls, divergent upper whorl and lower horizontal, not overlapping each other, walls of processes with 3–4 denticulations, end of processes with 3–4 spines, cells 53–59 µm along with processes, 58–66 µm broad with processes and isthmus 11–13 µm broad.

Site of collection: Bhebeli Pond, Dhemaji.

New to northeastern India (Image 75).

Staurastrum freemanii West & G. S. West

Cells medium-sized, subfusiform, about 1.6–1.7 times broader than long, median constriction deep, sinus acute and widely open, lateral angles produced to form moderately long, stout and tapering divergent processes furnished with 2 stout spines at the end, apex slightly convex, rarely flat, cell wall granulated, a pair of additional spines alternately located on each semicell, cells 38–45 µm long, 65–76 µm broad and isthmus 12–13 µm broad.

Site of collection: Akhara Beel, Barpeta.

New to northeastern India (Image 76).

Staurastrum furcatum Brébisson 1856: 136

Cells medium-sized, almost as broad as long, median constriction deep, sinus widely open, semicells transversally oval to subglobose, apical margin broadly convex and angles furnished with a pair of stout, bi-spinate processes, dorsal as well as ventral walls almost equally convex, basal margins convex towards lateral angles and each with a stout bi-spinate process , cell wall smooth, cells 25–29 µm long, 27–33 µm broad and isthmus 6–7 µm broad.

Site of collection: Barpeta Beel, Nagaon.

New to northeastern India (Image 77).

Staurastrum gracile Ralfs ex Ralfs 1848: 136, pl. XXII [22]: fig. 12 a-d

Cells medium-sized, about 1.3 times broader than long, sinus open, semicells slightly broadening towards the faintly convex apex, angles produced to form long processes, processes furnished with several concentric series of denticulations and three small spines at the tip, triangular in top view, chloroplast axial, one pyrenoid per semicell, cells 28-34 µm long, 39-45 µm broad and isthmus 7-8 µm broad.

Site of collection: Chandubi Beel, Kamrup; Dheer Beel, Dhubri; Shamaguri Beel, Nagaon.

Previous records and distribution in northeastern India: Arunachal Pradesh, Das & Adhikary (2012); Khanajan, Baruah & Baruah (2013); Chandubi Beel, Nath & Baruah (2020).

Staurastrum gracile var. *coronulatum* Boldt 1885: 116, pl. V [5]: fig. 28

Cells medium-sized, about 1.2–1.3 times broader than long, median constriction shallow, sinus with an acute notch, semicells gradually broadened towards the apices, apical margin convex and undulate, having emarginate processes, triangular in top view, processes furnished with 2–3 minute spines at the tip and showing dentations within lateral walls, cells 60–65 µm long and 74–85 µm broad, and isthmus 11–12 µm broad.

Site of collection: Chandubi Beel, Kamrup; Dandua Beel, Morigaon; Konuri Beel, Dhubri.

Previous records and distribution in northeastern India: Chandubi Beel, Nath & Baruah (2020)

Staurastrum johnsonii West & G. S. West 1896: 266, pl. 17: fig. 16

Cells medium-sized, about 1.5 times broader than long, median constriction shallow, sinus a notch and open, semicells gradually broadened towards the apices, apical margins slightly convex and undulate, each undulation with 2 very small spines at the tip, triangular in top view, lateral margins undulate too, lateral processes furnished with 3-minute spines at the tip, cells 33–38 µm long and 51–57 µm broad and isthmus 10–11 µm broad.

Site of collection: Raja Beel, Baksa.

New to northeastern India (Image 78).

Staurastrum longibrachiatum (Borge) Gutwinski 1902

Basionym: *Staurastrum bicorne* var. *longebrachiatum* O. Borge

Cells medium-sized, about 1.7 times broader than long, median constriction shallow, sinus a notch and open widely, semicells bowl shaped, margins gradually diverging into apical processes, processes with two bi-spinate protrusions at the base, also furnished with a series of denticulations on ventral margin and series of incisions and verrucae at the margins of semicell, apical angles protracted into horizontally directed long and slender processes with 2 small spines at the tip, apical margins truncate and furnished with a series of verrucae, cells 35–40 µm long and 61–69 µm broad and isthmus 7–9 µm broad.

Site of collection: Kumri Beel, Goalpara; Chandubi Beel, Kamrup.

Previous records and distribution in northeastern India: Chandubi Beel, Nath & Baruah (2020).

Staurastrum margaritaceum Meneghini ex Ralfs 1848: 134, pl. XXI [21]: fig. 9 a–e

Cells medium-sized, almost as long as broad, shallow median constriction, sinus widely open, semicells cup-shaped, convex apical and basal margins with horizontally directed truncate lateral projections, projections furnished with vertical series of granules, appear five rayed in vertical view, margins strongly concave, transverse series of granules distributed all over the body excluding the mid-region, cells 38–42 µm long, 40–46 µm broad and isthmus 10–12 µm broad.

Site of collection: Chandubi Beel, Kamrup; Urpad Beel, Goalpara; Maguri Motapung Beel, Tinsukia; Sripani Pond, Dhemaji.

Previous records and distribution in northeastern India: Dachi Lake, Hajong & Ramanujam (2018); Chandubi Beel, Nath & Baruah (2020); Arunachal Himalayas, Nath & Baruah (2021).

Staurastrum polytrichum (Perty) Rabenhorst 1868: 214

Basionym: *Phycastrum polytrichum* Perty

Cells medium-sized, slightly longer than broad, median constriction deep, sinus acute and open, semicells elliptical, margins broadly oval and furnished with moderately long, acute spines arranged in concentric circles around the angles and gradually becoming shorter towards the apex, cells triangular in vertical view with slightly concave lateral sides, cell wall punctate, cells 33–40 µm long, 26–32 µm broad and isthmus 8–9 µm broad.

Site of collection: Tiplai Pond, Goalpara; Rajapukhuri Ghagrapar, Nalbari; Gauhati University Pond, Kamrup (M).

Previous records and distribution in northeastern India: North Eastern India, Yasmin et al. (2011).

Staurastrum punctulatum Brébisson 1848: 133, pl. XXII [22]: fig. 1

Cells small sized, almost as long as broad, median constriction deep, sinus acute and broadly open, semicells angularly elliptic with dorsal as well as ventral walls equally convex, angles acutely rounded, triangular in top view, cell wall granulate, granules flattened and arranged in uniform series encircling the angles, cells 25–29 µm long, 26–31 µm broad and isthmus 8–9 µm broad.

Site of collection: Urpad Beel, Goalpara; Barsola Beel, Jorhat.

Previous records and distribution in northeastern India: Urpad Beel, Deka et al. (2011); Meghalaya, Siangbood & Ramanujam (2014).

Staurastrum pseudotetracerum (Nordstedt) West & G.S.West 1895: 79, pl. 8: fig 39

Basionym: *Staurastrum contortum* var. *pseudotetrace-*

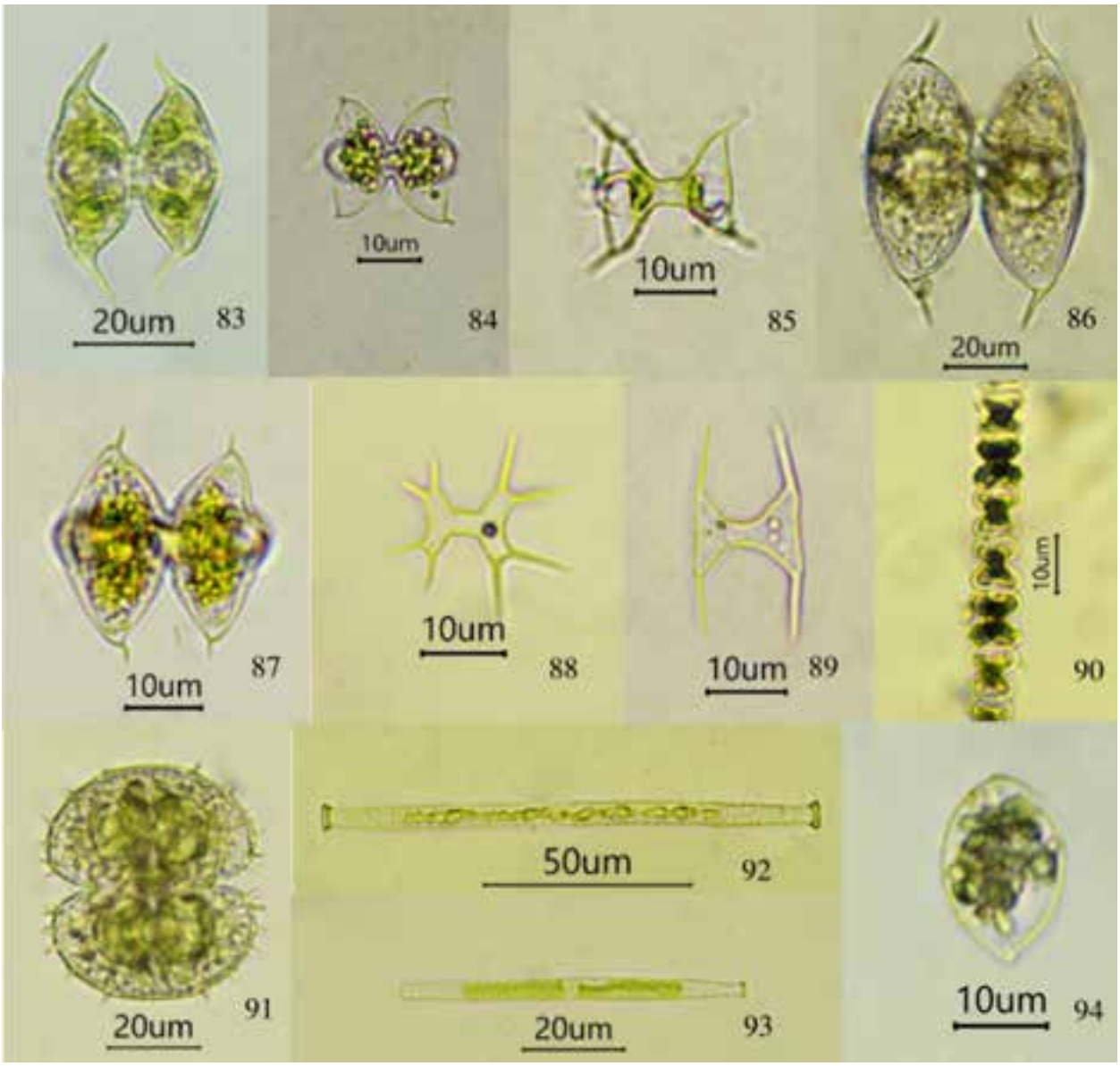


Image 83–94. 83—*Staurodesmus cuspidicurvatus* | 84—*Staurodesmus dejectus* | 85—*Staurodesmus dejectus* var. *apiculatus* | 86—*Staurodesmus dickiei* | 87—*Staurodesmus megacanthus* | 88—*Staurodesmus octocornis* | 89—*Staurodesmus unicornis* | 90—*Teilingia excavata* | 91—*Xanthidium pulchrum* | 92—*Gonatozygon brebissonii* | 93—*Gonatozygon brebissonii* var. *minutum* | 94—*Mesotaenium chlamydosporum*.

rum Nordstedt

Cells small sized, slightly broader than long, with deep median constriction, sinus triangular in outline and widely open towards extremities, semicells cuneate, apex slightly convex, lateral angles emarginated to form strongly deviating processes with three very small spines at the tip, triangular in vertical view with slightly concave margins, cells 23–26 µm long, 25–29 µm broad and isthmus 6–7 µm broad.

Site of collection: Chandubi Beel, Kamrup.

Previous records and distribution in northeastern India: Chandubi Beel, Nath & Baruah (2020).

Staurastrum recurvatum W. B. Turner 1893: 128, pl. XVI [16]: fig. 16

Cells small sized, about 1.2 times broader than long, median constriction deep, sinus broadly open towards extremities, semicells fusiform shaped, angles produced into short and strong processes ornamented with 5–6 concentric series of denticulations, chloroplast axial, one pyrenoid per semicell, cells 23–26 µm long, 28–32 µm broad and isthmus 5–6 µm broad.

Site of collection: Chandubi Beel, Kamrup; Goalnani Pond, Dhubri; Daphlong Beel, Golaghat.

Previous records and distribution in northeastern India: Chandubi Beel, Nath & Baruah (2020).

Staurastrum saltans W. Joshua 1882: 641, pl. XXIII [23]: fig. 21

Cells medium-sized, about 1.7–1.8 times broader than long, median constriction shallow, sinus widely open, semicells nearly

circular with angles produced into long processes, the entire margin of processes with continuous small undulations and tips with 2 stout, unequal, divergent spines, apex flat and with another 2 pairs of oppositely directed spines in each semicell, cells 25–31 µm long, 46–54 µm broad and isthmus 7–8 µm broad.

Site of collection: Kachodhora Beel, Morigaon; Bogol Road Beel, Nalbari.

New to northeastern India (Image 79).

Staurastrum simonyi Heimerl 1891: 67, pl. V [5]: fig. 23

Cells small sized, almost as long as broad, median constriction deep, sinus acute and widely open, semicells sub-fusiform or sub semi-circular, dorsal and ventral margins equally convex, lateral angles truncate and provided with 2–4 small spines, apical margin with a series of 4 spines between each pair of consecutive angles, the two median ones being the largest and projecting conspicuously from the apex, further with an occasional series of 4 smaller spines beneath the first series, triangular in top view, lateral walls straight or slightly concave or convex, angles obtusely rounded and furnished with 2–4 small spines, angles occasionally with traces of about 2 or 3 concentric series of minute distant denticulations, cells 24–28 µm long, 23–26 µm broad and isthmus 8–9 µm broad.

Site of collection: Rajapukhuri, Nahira Kamrup.

New to northeastern India (Image 80).

Staurastrum striolatum f. *brasiliense* W. B. Turner 1893: 109, pl. XIII [13]: fig. 15 (as 'brasiliensis')

Cells small sized, almost identical in length and breadth, median constriction shallow, sinus widely opened towards extremities, semicells sub elliptic, 4radiated in top view, margins greatly convex, processes parallel, with blunt ends and rounded angles, lateral margins of processes equipped with series of granules, apex truncate, cell wall smooth, cells 21–24 µm long, 22–25 µm broad and isthmus 11–12 µm broad.

Site of collection: Chandubi Beel, Kamrup; Dheer Beel, Dhubri.

Previous records and distribution in northeastern India: Chandubi Beel, Nath & Baruah (2020).

Staurastrum talisheekense A. M. Scott & Grönblad 1957: 47, pl. 28: figs 16–18

Cells medium-sized, nearly as long as broad, median constriction shallow, sinus a notch and open widely towards extremities, semicells bowl shaped, with six short radiating processes, processes slightly tapering towards the apex, apices with 4-5 small spines, margins concave between processes, lateral processes furnished with three rows of granules, apical margins slightly convex, cell wall smooth, cells 35–41 µm long 37–44 µm broad and isthmus 12–13 µm broad.

Site of collection: Chandubi Beel, Kamrup.

Previous records and distribution in northeastern India: Chandubi Beel, Nath & Baruah (2020).

Staurastrum teliferum var. *gladiosum* (W. B. Turner) Coesel & Meesters 2013: 157, pl. 44: figs 1–9

Basionym: *Staurastrum gladiosum* W. B. Turner

Cells medium-sized, almost as long as broad, median constriction deep, sinus acute and open widely, semicells broadly elliptic, entire cell wall irregularly furnished with short and stout spines, chloroplast axial, single pyrenoid in each semicell, cells 46–53 µm long, 45–51 µm broad and isthmus 18–20 µm broad.

Site of collection: Chandubi Beel, Kamrup; Naitara Choutara Beel, Goalpara.

Previous records and distribution in northeastern India: Chandubi Beel, Nath & Baruah (2020); Kokrajhar, Das (2020).

Staurastrum tetracerum Ralfs ex Ralfs 1848: 137, pl. XXIII [23]: fig. 7 a–f

Cells small sized, almost as long as broad, median constriction shallow, sinus a small notch and open outwardly, semicells triangular, angles produced into processes, processes tapering towards the tip, margins of processes furnished with granules, cells 18–21 µm long, 20–22 µm broad and isthmus 5–6 µm broad.

Site of collection: Deepor Beel, Kamrup (M).

Previous records and distribution in northeastern India: Khanajan, Baruah & Baruah (2013); Deepor Beel, Baruah et al. (2020).

Staurastrum tohopekaligense Wolle 1885: 128, pl. LI [51]: figs 4, 5

Cells medium-sized, about 1.4–1.6 times broader than long, median constriction deep, sinus widely open towards extremities, semicells oval, lateral angles produced into long slender processes, 9 in each semicell, a pair of short and divergent spines at the tip of processes, cells 39–47 µm long, 63–70 µm broad and isthmus 17–19 µm broad.

Site of collection: Chandubi Beel, Kamrup; Urpad Beel, Goalpara; Kapla Beel, Barpeta.

Previous records and distribution in northeastern India: Loktak Lake, Jena & Adhikary (2011); Urpad Beel, Deka et al. (2011); Chandubi Beel, Nath & Baruah (2020).

Staurastrum willsii W. B. Turner

Cells medium-sized, almost as long as broad, median constriction shallow, sinus a small notch and open widely, semicells broadly wedge-shaped, angular straight bases, lateral angles produce into moderately long processes, 6 seen in top view, margins between processes slightly concave, process substriated-granulated, apex truncate, furnished with warts in pairs at the base, cell wall in the lower part of the semicells smooth, from the top center of a hexagon, with bi-emarginate-rounded corners, furnished with 3 small warts arranged hexagonally, cells 43–49 µm long, 46–53 µm broad and isthmus 15–17 µm broad.

Site of collection: Ulabari Pond, Nalbari.

New to northeastern India (Image 81).

Staurastrum zahlbruckneri Lütkemüller 1900: 125, pl. 6: figs 41–43

Cells medium-sized, about 1.1–1.2 times longer than broad, elliptical in outline, median constriction moderately deep, sinus narrowly linear inside and widely open at ends, semicells semicircular, angles subtended, lateral margins subparallel and converging to a broadly rounded apex, triangular in top view with gently convex margins with rounded angles, bilobed from the base or obliquely viewed at the corners, cell wall thick and punctate, parietal chloroplast, cells 65–75 µm long, 56–62 µm broad and isthmus 24–26 µm broad.

Site of collection: Digholi Beel, Kamrup.

New to northeastern India (Image 82).

Genus: *Staurodesmus*

Staurodesmus convergens (Ehrenberg ex Ralfs) S.Lillieroth 1950: 264

Basionym: *Arthrodesmus convergens* Ehrenberg ex Ralfs

Cells medium-sized, slightly broader than long, median constriction very deep, sinus open widely at extremities, semicells transversely elliptic, apical as well as basal margins convex, lateral

angles furnished with the downwardly directed stout spine, cell wall smooth, chloroplast axial with single pyrenoid per semicell, cells 47–54 µm long, 50–58 µm broad and isthmus 16–18 µm broad.

Site of collection: Urpad Beel, Goalpara; Pachi Gaon Pond, Sonitpur; Majkuchi Pond, Kamrup.

Previous records and distribution in northeastern India: Urpad Beel, Deka et al. (2011); Sivasagar, Phukan & Bora (2012); Dachi Lake, Hajong & Ramanujam (2018); Chandubi Beel, Nath & Baruah (2020).

Staurodesmus cuspidatus (Brébisson) Teiling 1967: 534, pl. 9: figs 10, 11, 13–15, 19

Basionym: *Staurastrum cuspidatum* Brébisson

Cells small sized, slightly broader than long, median constriction deep, isthmus elongated, sinus widely open outwardly, semicells elliptic and projected into one long spine in each angle, glabrous, apical margins slightly convex, median portion of cell wall granulated, cells 20–23 µm long, 22–26 µm broad and isthmus 4–5 µm broad.

Site of collection: Kusumfula Beel, Goalpara; Keotkuchi Pond, Barpeta.

Previous records and distribution in northeastern India: Loktak Lake, Jena & Adhikary (2011).

Staurodesmus cuspidicurvatus Coesel & Meesters 2013: 22, pl. 12: figs 1–7

Cell medium-sized, about 1.4 times broader than long, median constriction deep, sinus open widely, lateral angles produced into processes with a long, stout, and inwardly bent spine at tips, apical margins convex, chloroplast axial with pyrenoids, cell wall smooth, cells 30–34 µm long, 43–50 µm broad and isthmus 9–10 µm broad.

Site of collection: Moridesang, Sivasagar.

New to northeastern India (Image 83).

Staurodesmus dejectus (Brébisson) Teiling 1954: 128

Basionym: *Staurastrum dejectum* Brébisson

Cells small sized, triradiate in top view, almost as broad as long, median constriction deep, sinus widely open and V-shaped, isthmus slightly elongated, semicells cup-shaped, lateral angles furnished with a very short and divergent spine, cell wall smooth, cells 20-23 µm long, 22–25 µm broad and isthmus 5–6 µm broad.

Site of collection: Hasila Beel, Goalpara.

New to northeastern India (Image 84).

Staurodesmus dejectus var. *apiculatus* (Brébisson) Croasdale 1957: 128

Basionym: *Staurastrum apiculatum* Brébisson

Cells small sized, triradiate in top view, slightly broader than long, median constriction deep, sinus widely open, isthmus prominently elongated, semicells cup-shaped, apical margins flat, lateral angles furnished with a moderately long and vertically directed spine, cell wall smooth, cells 16–19 µm long, 19–23 µm broad and isthmus 3–4 µm broad.

Site of collection: Kusumfula Beel, Goalpara.

New to northeastern India (Image 85).

Staurodesmus dickiei Hinode 1971: 123, fig. XI [11]: 1; pl. V [5]: fig. 9

Cells medium-sized, about 1.4 times broader than long, triradiate in top view, median constriction deep, sinus V-shaped and widely open outwardly, semicells elliptical, both upper and lower margins equally convex, lateral angles with short, convergent and incurved spines, cell wall smooth, cells 50–58 µm long, 70–81 µm broad and isthmus 11–12 µm broad.

Site of collection: Koya Kujia Beel, Bongaigaon.

New to northeastern India (Image 86).

Staurodesmus megacanthus (P.Lundell) Thunmark 1948: 686

Basionym: *Staurastrum megacanthum* P.Lundell

Cells small sized, tri-radiate in top view, slightly broader than long, median constriction deep, sinus widely open, semicells transverse spindle shaped, apical and basal margins convex, lateral angles furnished with a short, parallel or divergent spine, chloroplast axial, cells 25–29 µm long, 28–33 µm broad and isthmus 4–5 µm broad.

Site of collection: Goalnani Pond, Dhubri.

New to northeastern India (Image 87).

Staurodesmus octocornis (Ehrenberg ex Ralfs) Stastny, Skaloud & Neustupa 2013: 414

Basionym: *Xanthidium octocorne* Ehrenberg ex Ralfs

Cells small sized, slightly broader than long, median constriction deep, sinus widely open, isthmus elongated, lateral walls and apices of semicells concave with rounded upper and lower angles furnished with a long spine, cell wall smooth, cells 17–20 µm long, 21–23 µm broad and isthmus 3–4 µm broad.

Site of collection: Rajapukhuri Ghagrapar, Nalbari; Hasila Beel, Goalpara.

New to northeastern India (Image 88).

Staurodesmus unicornis var. *gracilis* (M. O. P. Iyengar & Vimala) Teiling 1967: 540, pl. 11: figs 3, 5, 9, 10

Basionym: *Staurastrum unicorne* var. *gracile* M. O. P. Iyengar & Vimala Bai

Cells small sized, about 1.4 times broader than long, median constriction very deep, isthmus elongated, sinus widely open, semicells triangular, apical margins slightly curved, each apical angle furnished with a long, stout, and incurved spine, cells 18–20 µm long, 26–29 µm broad and isthmus 4–5 µm broad.

Site of collection: Chandubi Beel, Kamrup; Panpoor Ghat, Sonitpur.

Previous records and distribution in northeastern India: Chandubi Beel, Nath & Baruah (2020).

Staurodesmus unicornis (W. B. Turner) Coesel & Van Geest 2016: 104, figs 1 H, 3 C

Basionym: *Staurastrum unicorne* W. B. Turner.

Cells small sized, almost twice as long as broad, median constriction very deep, sinus widely open, isthmus elongated, semicells triangular, apical margins slightly concave, each apical angle furnished with a long, stout, and slightly incurved spine, cells 14–17 µm long, 25–29 µm broad with spines and isthmus 2–3 µm broad.

Site of collection: Jaysagar Pukhuri, Sivasagar; Dudhnoi College Pond, Goalpara.

New to northeastern India (Image 89).

Genus: *Streptonema*

Streptonema trilobatum Wallich 1860: 196, pl. VIII [8]: figs 1–6

Cells medium-sized, about 1.7 times broader than long, united one another to form a long filament, median constriction deep, angles rounded, semicells with 3 inflamed lobes in vertical view, cells 23–27 µm long, 41–47 µm broad and isthmus 8–10 µm broad.

Site of collection: Chandubi Beel, Kamrup.

Previous records and distribution in northeastern India: Lok-

tak Lake, Jena & Adhikary (2011); Chandubi Beel, Nath & Baruah (2020).

Genus: *Teilingia*

Teilingia excavata (Ralfs ex Ralfs) Bourrelly 1964: 190, fig. 10

Basionym: *Sphaerozosma excavatum* Ralfs ex Ralfs

Cells very small sized, almost as broad as long, cells joined end to end loosely by connecting processes forming a short pseudofilament, shallow median constriction, sinus openly wide with obtuse-angle, semicells oval-elliptic, oval in face view, apex flattened with 4 very small granule like connecting processes, cell wall smooth, cells 9–11 µm long, 8–10 µm broad and isthmus 5–6 µm broad.

Site of collection: Pond near Tangla College, Udalguri.

New to northeastern India (Image 90).

Teilingia granulata (J. Roy & Bisset) Bourrelly 1964: 190, fig. 9

Basionym: *Sphaerozosma granulatum* J. Roy & Bisset

Cells very small sized, almost as broad as long, cells attached one another to form a long filament, sub-cylindrical with rounded angles, median constriction deep, sinus widely open, apex flatly rounded and furnished with four granules, semicells oblong, lateral walls rounded, furnished with three marginal granules, cell wall smooth otherwise, cells 8–11 µm long, 10–13 µm broad and isthmus 3–4 µm broad.

Site of collection: Chandubi Beel, Kamrup; Naitara Choutara Beel, Goalpara; Maguri Motapung Beel, Tinsukia.

Previous records and distribution in northeastern India: Chandubi Beel, Nath & Baruah (2020).

Genus: *Triploceras*

Triploceras gracile Bailey 1851: 38, pl. 1: fig. 10

Cells elongate, about 11 times longer than broad, semicells gradually tapering towards apices, with 9 whorls of 13 short, mammilate spine, spines in upper few whorls upwardly directed, in lower whorls outward or straight, apex divided into 3 short protuberances each furnished with paired short spines at the tip, usually a pair of blunt spines between the primary splits, cells 304-332 µm long and 26–29 µm broad and apex 13–14 µm broad.

Site of collection: Chandubi Beel, Kamrup; Diplai Beel, Kokrajhar; Konuri Beel, Dhubri; Ulabari Pond, Nalbari.

Previous records and distribution in northeastern India: Chandubi Beel, Nath & Baruah (2020); Kokrajhar, Das (2020).

Genus: *Xanthidium*

Xanthidium acanthophorum Nordstedt 1880: 11, pl. I [1]: fig. 20

Cells medium-sized, slightly longer than broad, semicells oval, deep median constriction, sinus open and acute-angled, lateral walls convex and somewhat attenuated at the apex, equipped with two pairs of long, blunt, slightly curved spines on each side, apical margin flat and furnished with four straight long blunt spines, cell wall with scattered punctae, two chloroplasts per semicell, cells 49–55 µm long, 45–49 µm broad and isthmus 9–10 µm broad.

Site of collection: Chandubi Beel, Kamrup; Dheer Beel, Dhubri; Urpad Beel, Goalpara; Tinkonia Pukhuri, Jorhat.

Previous records and distribution in northeastern India: Chandubi Beel, Nath & Baruah (2020).

Xanthidium antilopaeum Kützing 1849: 177

Cells medium-sized, almost as long as broad, median constriction deep, sinus linear and slightly dilated outwardly, semicells subelliptic-hexagonal with slightly rounded angles, each angle furnished with two straight and long spines, cell wall smooth, cells 55–62 µm long, 62–67 µm broad and isthmus 20–22 µm broad.

Site of collection: Chandubi Beel, Kamrup; Ghunkuchi Beel, Nalbari.

Previous records and distribution in northeastern India: Sivasagar, Phukan & Bora (2012); Chandubi Beel, Nath & Baruah (2020).

Xanthidium antilopaeum f. *javanicum* (Nordstedt) Coesel 2007: 12, fig. 28 (as 'var. hebridarum f. javanicum')

Basionym: *Xanthidium antilopaeum* var. *javanicum* Nordstedt

Cells medium-sized, about 1.2 times longer than broad, median constriction deep, sinus V-shaped and widely open, semicells subelliptic-hexagonal, apical margin straight or slightly convex, lateral margins concave, a pair of long and stout spines of equal size located at apical angles, basal margins concave, angles furnished with two identical, long and strong spines, arranged horizontally, cell wall hyaline and punctate, chloroplasts axial, cells 42–47 µm long, 54–60 µm broad and isthmus 11–13 µm.

Site of collection: Diplai Beel, Kokrajhar.

Previous records and distribution in northeastern India: Kokrajhar, Das (2020).

Xanthidium pulchrum W. B. Turner 1993: 102, pl. XIII [13]: fig. 10

Cells medium-sized, cosmariform, almost as long as broad, median constriction moderately deep, sinus open, semi-cells oval, apical as well as lateral margins furnished with 3 short and thick spines, towards the base equipped with similar 10 spines irregularly arranged, the central region near the isthmus glabrous, and above isthmus furnished with 12–14 transversely arranged small scribbles, ovate ellipsoidal in top view, cells 50–54 µm long, 51–55 µm broad and isthmus 30–32 µm.

Site of collection: Goalnani Pond, Dhubri.

New to northeastern India (Image 91).

Xanthidium superbum var. *centricorne* Prowse ex Levanets & Guiry, nom. inval. 2021: 2

Cells large sized, about 1.2–1.3 times longer than broad, median constriction deep, sinus slender and open at extremities, semicells oval, cell wall furnished with numerous firm spines, single chloroplast in each semicell with many pyrenoids, cells 90–103 µm long, 71–77 µm broad and isthmus 32–35 µm.

Site of collection: Chandubi Beel, Kamrup; Borpukhri Ghagrapar, Nalbari.

Previous records and distribution in northeastern India: Chandubi Beel, Nath & Baruah (2020).

Family: Gonatozygaceae

Genus: *Gonatozygon*

Gonatozygon aculeatum W. N. Hastings 1892: 29

Cells elongated, cylindrical, about 15 times longer than broad, lateral sides straight and parallel but very slightly diverging towards the poles, apices truncate with slightly rounded apical angles, cell wall ornamented with small, straight spines but poles smooth, chloroplast axial with seven pyrenoids, cells 163–195 µm long, 11–13 µm broad and apex 12–15 µm broad.

Site of collection: Chandubi Beel, Kamrup; Koya Kujia Beel, Bongaigaon; Bheriki Beel, Jorhat; Majkuchi Pond, Kamrup.

Previous records and distribution in northeastern India: Chandubi Beel, Nath & Baruah (2020).

Table 2. Region-wise accounts of desmid flora in water bodies of different river basins of the Indian subcontinent.

Region of Indian subcontinent	Algologists	Total number of desmid species	Most speciose genus	Number of species of the most speciose genus
Eastern India	Jena et al. (2006)	45	*Cosmarium*	19
	Suseela & Toppo (2007)	40	*Cosmarium*	31
	Mallick & Keshri (2011)	7	*Cylindrocystis*	07
	Das & Keshri (2016)	272	*Cosmarium*	81
	Nandi et al. (2019)	34	*Cosmarium*	34
Western India	Patil & Jawale (2014)	36	*Cosmarium*	21
	Shahare (2016)	21	*Cosmarium*	09
	Reddy & Chaturvedi (2017)	45	*Cosmarium*	26
	Mhaske & Talwankar (2018)	12	*Cosmarium*	12
	Valvi & Gautam (2020)	18	*Cosmarium*	10
Northern India	Pandey & Pandey (1980)	10	*Cosmarium*	07
	Prakash et al. (2005)	10	*Cosmarium* *Euastrum* *Micrasterias* *Pleurotaenium*	02 02 02 02
	Shukla et al. (2008)	48	*Cosmarium*	29
	Dwivedi et al. (2009)	39	*Cosmarium*	28
	Verma et al. (2021)	338	*Cosmarium*	163
	Komal et al. (2021)	21	*Cosmarium*	11
	Sarma et al. (2022)	51	*Cosmarium*	29
Southern India	Kiran (2016)	46	*Cosmarium*	25
	Babu & Vasanthakumar (2020)	35	*Cosmarium*	35
Central India	Singh et al. (2011)	49	*Cosmarium*	29
	Agarker & Agarkar (1977)	68	*Cosmarium*	30
	Agrawal (2016)	36	*Cosmarium*	18
Northeastern India	Dickie (1882)	13	*Cosmarium*	06
	Rao (1963)	01	*Cosmarium*	01
	Prasad & Misra (1987)	18	*Cosmarium*	10
	Gupta (2002)	16	*Closterium*	04
	Kumar & Rai (2005)	07	*Closterium*	04
	Das et al. (2009)	13	*Cosmarium*	09
	Bhakta et al. (2010)	05	*Cosmarium*	04
	Deka et al. (2011)	91	*Cosmarium*	41
	Yasmin et al. (2011)	38	*Cosmarium*	10
	Phukan & Bora (2012)	73	*Closterium* *Cosmarium*	16 16
	Das & Keshri (2012)	15	*Closterium*	06
	Das & Keshri (2012)	12	*Closterium*	05
	Das & Keshri (2013)	12	*Micrasterias* *Pleurotaenium* *Staurastrum*	03 03 03
	Das & Keshri (2013)	16	*Cosmarium*	6
	Baruah & Baruah (2013)	22	*Cosmarium*	09
	Das (2020)	71	*Cosmarium*	16
	Kuotsu & Chaturvedi (2020)	20	*Cosmarium*	07
Brahmaputra River Basin	Present Study	231	*Cosmarium*	69

Gonatozygon brebissonii De Bary 1858: 28, 77, pl. IV [4]: figs 26, 27

Cells elongate, narrow, spindle shaped, about 19–22 times longer than broad, margins tapering to slightly swollen capitate apices, margins densely granulate, apex dilated, truncate, apical angles slightly rounded, chloroplast axial and ribbonlike with series of 8–12 pyrenoids, cells 110–132 µm long, 5–7 µm broad and apex 6–8 µm broad.

Site of collection: Charan Beel, Morigaon; Ulabari Pond, Nalbari.

New to northeastern India (Image 92).

Gonatozygon brebissonii var. *minutum* (West) West & G.S.West 1900: 39, pl. I: figs 15, 16

Basionym: *Gonatozygon minutum* West

Cells elongate, very narrow, spindle-shaped, about 15.6–16.2 times longer than broad, margins tapering towards slightly swollen capitate apices, cell wall densely granulate, apex dilated, truncate, apical angles slightly rounded, chloroplast axial and ribbon-like with series pyrenoids, cells 65–78 µm long, 4–5 µm broad and apex 2–3 µm broad.

Site of collection: Haribhanga Beel, Nagaon.

New to northeastern India (Image 93).

Gonatozygon monotaenium De Bary 1856: 106

Cell elongated, cylindrical, about 16.3–18.7 times longer than broad, lateral sides parallel to slightly concave, apices slightly dilated with truncate ends, ribbonlike chloroplast with series of evenly arranged 6–16 pyrenoids, cell wall granulate, granules closely arranged, cells 98–150 µm long, 6–8 µm broad and apex 7–8 µm broad.

Site of collection: Narpara Pond, Nalbari.

Previous records and distribution in northeastern India: Dachi Lake, Hajong & Ramanujam (2018).

Order: Zygnematales

Family: Mesotaeniaceae

Genus: *Netrium*

Netrium digitus (Brébisson ex Ralfs) Itzigsohn & Rothe 1856: no. 508

Basionym: *Penium digitus* Brébisson ex Ralfs

Cells are large, solitary, broadly fusiform, about 2.7–3 times longer than broad, lateral walls convex, gradually tapering from the middle to broadly rounded-truncated poles, cell wall smooth, single chloroplast in each semicell with many pyrenoids, cells 96–130 µm long, 35–41 µm broad and apex 15–16 µm broad.

Site of collection: Chandubi Beel, Kamrup; Urpad Beel, Goalpara; Dheer Beel, Dhubri; Dighali Beel, Nagaon; Bheriki Beel, Jorhat; Daphlong Beel, Golaghat.

Previous records and distribution in northeastern India: Loktak Lake, Jena & Adhikary (2011); North Eastern India, Yasmin et al. (2011); Urpad Beel, Deka et al. (2011); Dachi Lake, Hajong & Ramanujam (2018); Kokrajhar, Das (2020).

Netrium oblongum var. *acuminatum* Irénée-Marie 1954: 111

Cells medium-sized, solitary, elongated, fusiform, about 4.6–5 times longer than broad, lateral margins convex, gradually tapering from the middle towards the rounded poles, slightly retuse near the apex, single chloroplast in each semicell with numerous pyrenoids, cell wall smooth, cells 172–205 µm long, 37–41 µm broad and apex 16–18 µm broad.

Site of collection: Chandubi Beel, Kamrup; Jogorahabi Beel, Sivasagar; Rajapukhuri, Nahira Kamrup.

Previous records and distribution in northeastern India: Chandubi Beel, Nath & Baruah (2020).

Genus: *Spirotaenia*

Spirotaenia condensata Brébisson 1848: 179, pl. XXXIV [34]: fig. 1

Cells cylindrical, solitary, elongated with broadly rounded poles, about 8.7–9.2 times longer than broad, lateral sides slightly convex but almost parallel, cell wall smooth, chloroplast parietal, ribbon-like having 7 close turns, cells 123–158 µm long, 14–17 µm broad and apex 8–9 µm broad.

Site of collection: Raja Beel, Baksa; Digholi Beel, Kamrup.

Previous records and distribution in northeastern India: Kokrajhar, Das (2020).

Family: Zygnemataceae

Genus: *Cylindrocystis*

Cylindrocystis brebissonii (Ralfs) De Bary 1858: 35, 74

Basionym: *Penium brebissonii* Ralfs

Cells small sized, cylindrical, straight, cells about 2.2 times longer than broad, lateral margins parallel with rounded apex, devoid of median constriction, cell wall smooth or sometimes granulated, chloroplasts ridged, cells 27–32 µm long and 12–14 µm broad.

Site of collection: Dhamar Beel, Goalpara.

Previous records and distribution in northeastern India: Loktak Lake, Jena & Adhikary (2011).

Genus: *Mesotaenium*

Mesotaenium chlamydosporum De Bary 1858: 75, pl. VII D: figs 1–29

Cells small sized, oblong, about 1.5–1.6 times longer than broad, poles broadly rounded, with small apical nodules, chloroplast parietal and plate-like, cell wall smooth, cells 20–24 µm long and 13–15 µm broad.

Site of collection: Kusumfula Beel, Goalpara.

New to northeastern India (Image 94).

DISCUSSION

The outcome of the present endeavour is the comprehensive account of desmid flora from the Brahmaputra valley of the northeastern region of India. Altogether 231 desmids under two orders, five families, and 25 genera were recorded during the study period which is slightly higher than the number of desmids reported by Islam & Haroon (1980); Islam & Akter (2005); Islam & Irfanullah (2006); Ekhator et al. (2013); Ramos et al. (2021); Coesel & Geest (2008); Stamenkovic & Cvijan (2008) in different parts of the world excluding Das & Keshri (2016); Verma et al. (2021).

Results also revealed that the Desmidiaceae was the dominant family with the highest representation of 19 genera and 195 species followed by Closteriaceae (1 genus and 27 species), Gonatozygaceae (1 genus and 4 species), Mesotaeniaceae (2 genera and 3 species), and Zygnemataceae (2 genera and 2 species). Amongst the genera, *Cosmarium* was the dominant one with 69 spe-

cies followed by *Euastrum* (33 species), *Staurastrum* (31 species), and *Closterium* (27 species) respectively. An inclusive account of desmid flora from various parts of the Indian subcontinent reported dominancy of *Cosmarium* in other river basins of the Indian subcontinent (Table 2). It was noted that the *Cosmarium* showed overall dominance in the majority of waterbodies in Bangladesh also (Islam & Haroon 1980; Islam & Irfanullah 2006).

The results further showed that the number of desmids (231) recorded during the present exploration suppresses the earlier records of desmids from northeastern India (Bordoloi 1983; Deka et al. 2011; Yasmin et al. 2011; Phukan & Bora 2012; Baruah & Baruah 2013; Das 2020) and it was found that out of the 231 reported species, a total of 94 species were reported for the first time from the northeastern region of India.

As the Brahmaputra River basin harbours a higher number of desmids (231), the region could be considered a suitable habitat for the desmids diversity and could be explored for bio-prospection in a phased manner. Another interesting fact that emerged in the present study is that *Cosmarium forceps, Micrasterias foliacea,* and *Micrasterias pinnatifida* were universally present in a majority of the water bodies located in the entire stretch of Brahmaputra River which invites an in-depth ecological study.

REFERENCES

Adhikary, S.P. & M. Jena (2012). Algal diversity of Kaziranga Natonal Park and Majuli river island hotspots in Assam. *Nelumbo* 54: 218–238. https://doi.org/10.20324/nelumbo/v54/2012/57436

Agarkar, M.S. & D.S. Agarkar (1977). Desmids from Panchmarhi, Madhya Pradesh, India. *Hydrobiologia* 54(1): 23–32.

Agrawal, B. (2016). Seasonal variations of physico-chemical factors and diversity of desmids (Algae) in Shahpura lake of Bhopal, India. *Environment Conservation Journal* 17(1&2): 67–72. https://doi.org/10.36953/ECJ.2016.171208

Ahmed, Z.U., Z.N.T. Begum, M.A. Hasan, M. Khondker, S.M.H. Kabir, M. Ahmed, A.T.A. Ahmed, A.K.A. Rahman & E.U. Haque (eds.) (2007). *Encyclopedia of Flora and Fauna of Bangladesh,* Vol.3. *Algae, Chlorophyta (Aphanochaetaceae-Zygnemataceae).* Asiatic Society of Bangladesh, Dhaka, 812 pp.

Aquino, C.A.N., N.C. Bueno, L.C. Servat & J.C. Bortolini (2017). The genus *Euastrum* Ehrenberg ex Ralfs (Desmidiaceae) in a subtropical stream adjacent to the Parque Nacional do Iguaçu, Paraná State, Brazil. *Honea* 44(1): 1–9. https://doi.org/10.1590/2236-8906-55/2016

Babu, B. & S. Vasanthakumar (2020). Diversity and new records of *Cosmarium* Corda ex Ralfs (Desmidiales, Zygnematophyceae) from Kanniyakumari District, Tamil Nadu, India. *Indian Hydrobiology* 19(1&2): 263–284.

Baruah, P.P., B. Boruah, S. Nath, H. Kalita & S. Bhattacharjee (2020). Algal Diversity in Deepor Beel of Assam: A Ramsar site of North East India. *Nelumbo* 62(2): 221–252. https://doi.org/10.20324/nelumbo/v62/2020/153155

Baruah, P.P., R. Boruah & J. Thakuria (2013). Chlorophycean diversity of Deepor Beel Wildlife Sanctuary. *Phykos* 43(2): 33–42.

Baruah, P.P. & R. Boruah (2013). Desmid diversity in Khanajan - a manmade channel linking Deepor Beel Ramsar site to Brahmaputra River (India). *Plant Science Research* 35(1&2): 56–60.

Baruah, P.P., B. Kakati & I. Ahmed (2009). Some Fresh Water Algae of Oil Refinery Effluent Drains of Assam, India. *Our Nature* 7: 139–145. https://doi.org/10.3126/on.v7i1.2561

Bhakta, S., S.K. Das & S.P. Adhikary (2010). Freshwater algae of Sikkim. *The Journal of Indian Botanical Society* 89(1 & 2): 169–184.

Bordoloi, D. & P.P. Baruah (2015). Composition and Seasonality of Phytoplankton in a Crude Oil Effluent holding Pond of Digboi Oil Field, Assam (India). *Bulletin of Environment, Pharmacology and Life Sciences* 4(80): 76–82.

Bordoloi, R.P.M. (1983). On some abnormal and asymmetric desmids of Assam. *Phykos* 22(1–2): 120–124.

Borics, G., J. Padisák, I. Grigorszky, I. Oldal, L.I. Péterfi & L. Momeu (1998). Green algal flora of the acidic bog-lake, Balátató SW Hungary. *Biologia* 53: 457–465.

Brook, A.J. (1981): *The Biology of Desmids*. University of California Press, Berkeley and Los Angeles, 276 pp.

Coesel, P.F.M. (1996). Biography of desmids. *Hydrobiologia* 336: 41–53. https://doi.org/10.1007/BF00010818

Coesel, P.F.M. (1998). *Sieralgen en natuurwaarden. Wetenschappelijke Mededeling KNNV 224*. Uitgeverij Koninklijke Nederlandse Natuurhistorische Vereniging, Utrecht, 56 pp.

Coesel, P.F.M. & A.Van Geest (2008). Taxonomic and biogeographical notes on Okavango desmids (Zygnematophyceae, Streptophyta). *Systematics and Geography of Plants* 78(1): 27–46.

Croasdale, H.T., C.E.deM. Bicudo & G.W. Prescott (1983). *A synopsis of North American desmids. Part II. Desmidiaceae: Placodermae. Section 5. The filamentous genera*. The University of Nebrasca Press, USA, 117 pp.

Dadhwal, V.K., A. Mahendran, J.R. Sharma, W.M. Tembhurney, V.V. Rao, R.K. Jain, P. Satyanarayana, R.R. Dutta, M. Gorsi & S.V. Pravalika (2014). *Brahmaputra Basin*. Government of India, Ministry of Water Resources, 119 pp.

Das, S.K. & S.P. Adhikary (2012). Diversity of freshwater algae in Arunachal Pradesh and their distribution in different altitudes. *The Journal of Indian Botanical Society* 91(1–3): 160–182.

Das, S.K. & S.P. Adhikary (2012). Freshwater Algae of Nagaland. *The Journal of Indian botanical Society* 91(1–3): 99–123.

Das, D. & J.P. Keshri (2012). Desmids from Manmecho (Mamencho) Lake, Eastern Himalaya. I. *NeBIO* 3(2): 37–44.

Das, D. & J.P. Keshri (2012). Desmids from Manmecho (Mamencho) Lake, Eastern Himalaya. II. *NeBIO* 3(5): 11–19.

Das, D. & J.P. Keshri (2013). Desmids from South Sikkim, India. *Nelumbo* 55: 172–180. https://doi.org/10.20324/nelumbo%2Fv55%2F2013%2F73295

Das, D. & J.P. Keshri (2013). Desmids of Khechiperi Lake, Sikkim Eastern Himalaya. *Algological Studies* 143: 27–42.

Das, D. & J.P. Keshri (2016). *Desmids of Eastern Himalaya*. *Bibliotheca Phycologica Vol. 119*. J. Cramer. Germany, 260pp.

Das, S.K., L.K., Samad, P. Ramanujam & S.P. Adhikary (2009). Freshwater algae of Meghalaya. *The Journal of Indian Botanical Society* 88(1&2): 102–118.

Das, R. (2020). Preliminary checklist of desmids from Kokrajhar District, Assam, India. *Journal of Biodiversity and Environmental Sciences* 17(4): 10–20.

Das, M & P. Ramanujam (2010). A comparative study on diversity of algae in coal mine impacted and unimpacted streams of Jaintia Hills, Meghalaya. *Journal of Indian Botanical Society* 89: 204–209.

Deka, S.J. & G.C. Sarma (2011). Preliminary Checklist of Oscillatoriaceae (Cyanophyta), Goalpara District, Assam, India. *International Journal of Applied Biology and Pharmaceutical Technology* 2(4): 430–433.

Deka, S.J., G.C. Sarma & S.P. Deka (2011). Preliminary Checklist of desmids of Urpad Beel (Wetland), Goalpara district, Assam, India. *Asian Journal of Experimental Biological Sciences* 2(3): 391–398.

Dickie, G. (1882). Notes on algae from Himalayas. *Journal of the Linnean Society. Botany* 19: 230–232.

Dwivedi, R.K., C.P. Shukla, P.K. Misra, S.K. Shukla & M.K. Seth (2009). On Desmids of Southern Himachal Pradesh of Indo-Western Himalaya. *Feddes Repertorium* 120(3–4): 236–249. https://doi.org/10.1002/fedr.200911106

Ekhator, O., J.O. Ihenyen & G.O. Okooboh (2013). Desmids of Osse River, Edo State Nigeria. *International Journal of Modern Botany* 3(2):25–31.

Fehér, G. (2003). The desmid flora of some alkaline lakes and wetlands in Southern Hungary. *Biologia* 58(4): 671– 683.

Guiry, M.D. & G.M. Guiry (2022). AlgaeBase. World-wide electronic publication, National University of Ireland, Galway. http://www.algaebase.org.Searched on 17 December 2022.

Gupta, R.K. (2002). A checklist of algal flora of Shillong, Meghalaya. *Journal of Economic and Taxonomic Botany* 26(2): 464–468.

Hajong, P. & P. Ramanujam (2018). Seasonal variation in algal diversity and productivity in Dachi lake, Meghalaya. *Journal of Algal Biomass Utilization* 9(2): 9–24.

Islam, A.K.M.N. & N. Akter (2005). Desmids of some selected areas of Bangladesh. 3. Docidium, Pleurotaenium, Triplastrum and Triploceras. *Bangladesh Journal of Plant Taxonomy* 12(1): 11–23. https://doi.org/10.3329/bjpt.v12i1.608

Islam, A.K.M.N. & A.K.Y. Haroon (1980). Desmids of Bangladesh. *International Review of Hydrobiology* 65(4): 551–604.

Islam, A.K.M.N. & H.M.D. Irfanullah (2006). Hydrobiological studies within the tea gardens at srimangal, Bangladesh. vi. Desmids (*Xanthidium, Arthrodesmus, Staurodesmus* and *Staurastrum*). *Bangladesh Journal of Plant Taxonomy* 13(2): 111–129.

Jena, M., S.K. Ratha & S.P. Adhikary (2006). Desmids (Zygnematales, Chlorophyceae) of Orissa state and neighboring regions, India. *Algological Studies* 122(1): 17–34.

Jena, M. & S.P. Adhikary (2011). Algal Diversity of Loktak Lake, Manipur. *Nelumbo* 53: 21 – 48. https://doi.org/10.20324/nelumbo%2Fv53%2F2011%2F57502

John, D.M., B.A. Whitton & A.J. Brook (2005). *The Freshwater Algal Flora of the British Isles*. An Identification Guide to Freshwater and Terrestrial Algae. Cambridge University Press and Natural History Museum, Cambridge, 702 pp.

Kuotsu, K. & S.K. Chaturvedi (2020). Diversity of desmids from freshwater bodies of Kohima district Nagaland India. *The Journal of Indian Botanical Society* 100(3&4): 177–184.

Kiran, B.R. (2016). Distribution and Occurrence of Desmids in Bhadra Reservoir, Karnataka. *International Journal of Research in Environmental Science* 2(3):16–23. https://doi.org/10.20431/2454-9444.0203002

Komal, J.I.S. Khattar, D.P. Singh & Y. Singh (2021). New records of Desmids from Ropar wetland (a Ramsar site) of Punjab, India. *Plant Science Today* 8(4): 137–148. https://doi.org/10.14719/pst.2021.8.4.1229

Krieger, W. (1933). Die Desmidiaceen der Deutschen. Limnologischen Sunda-Expedition. In Archiv fur Hydrobiologie, Supplement 9. Tropische Binnengew 3: 129–225.

Krieger, W. (1937). Die Desmidiaceen Europas mit Beriicksichtigung der aussereuropiiischen Arten. *Rabenhomt's Kryptogamenflora* 13: 1–712.

Kumar, S. & S.K. Rai (2005). Contribution to the algal flora (Chlorophyceae) of Namchi, Sikkim Himalayas. *Our Nature* 3: 50–55.

Lenzenweger, R. (1996). *Desmidiaceenflora von Österreich, Teil 1*. Bibliotheca Phycologica Band 101, J. Cramer, Berlin, Stuttgart, 162 pp.

Lenzenweger, R. (1997). *Desmidiaceanflora von Österreich, Teil 2.* Bibliotheca Phycologica Band 102, J. Cramer, Berlin, Stuttgart, 218 pp.

Lenzenweger, R. (1999). *Desmidiaceenflora von Österreich. Teil 3.* Bibliotheca Phycologica Band 104, J. Cramer, Berlin, Stuttgart, 216 pp.

Lenzenweger, R. (2003). *Desmidiaceenflora von Österreich. Teil 4.* Bibliotheca Phycologica Band 111, J. Cramer, Berlin, Stuttgart, 87 pp.

Lewis, L.A. & R.M. Mccourt (2004). Green algae and the origin of land plants. *American Journal of Botany* 91: 1535–1556.

Mallick, P. & J.P. Keshri (2011). Contribution to the desmid flora of India II. Genus *Cylindrocystis* Meneghini from West Bengal. *Bionature* 31(2): 55–59.

Mhaske, T.K. & D.S. Talwankar (2018). Occurrence of Cosmarium species in Khadakpurna reservoir, Buldana district – Maharashtra, India. *GSC Biological and Pharmaceutical Sciences*5(3): 20–24. https://doi.org/10.30574/gscbps.2018.5.3.0136

Nandi, C., S. Bhowmick, P.C. Gorain & R. Pal (2019). New and rare records of *Cosmarium* (Desmidiaceae, Zygnematales) from India. *Phytomorphology* 69(1–2): 41–49.

Nath, S. & P.P. Baruah (2020). Algal Diversity in Chandubi Beel, a Tectonic Water Body of North East India. N*elumbo* 62(1): 68–89. https://doi.org/10.20324/nelumbo%2Fv62%2F2020%2F152221

Nath, S. & P.P. Baruah (2021). Checklist of phytoplankton of the foot hill belt of Arunachal Himalayas. *Asian Journal of Conservation Biology* 10(1): 56–67.https://doi.org/10.53562/ajcb.YGSE3373

Pandey, U.C. & D.C. Pandey (1980). Desmids of Allahabad. *The Journal of Indian Botanical Society* 59: 246–250.

Patil, S.A. & A.K. Jawale (2014). Desmids from Mangrul Dam, Dist. Jalgaon, Maharashtra. *International Journal of Geology, Earth and Environmental Sciences* 4(1): 137–146.

Paul, G., J. Stastny & A. Doege (2017). *Rote Liste und Artenliste Sachsens–Zieralgen. – Landesamt für Landwirtschaft*, Umwelt und Geologie, Dresden, 120 pp.

Phukan, S. & S.P. Bora (2012). Preliminary reports of desmids (algae, Chlorophyceae) From Sivasagar district of Assam. *Journal of Frontline Research in Arts and Sciences* 2: 134–141.

Prakash, J., S. Kishore, D.K. Asthana, P.K. Misra & S.K. Singh (2005). Morphotaxonomy of Fresh Water Chlorophycean Algae Oesmids) From Siddharth Nagar, U.P. India. *Ecoprint* 12: 21–25. https://doi.org/10.3126/eco.v12i0.3193

Prasad, B.N. & P.K. Misra (1992). *Fresh Water Algal Flora of Andaman & Nicobar Islands*. *Vol. II*. Bishen Singh Mahendra Pal Singh, Dehra Dun, 238 pp.

Ramos, G.J.P., M.A.D. Santos & C.W.D.N. Moura (2021). How hidden is the diversity of the genus *Cosmarium* (Desmidiaceae) in the Brazilian Caatinga? *Acta Botanica Brasilica* 35(2): 188–214. https://doi.org/10.1590/0102-33062020abb0370

Rao, R.S. (1963). A botanical tour in Sikkim State, Eastern Himalayas. *Bulletin of the Botanical Survey of India* 5: 165–205.

Reddy, M. & A. Chaturvedi (2017). Desmids from the rivers of Chandrapur district, Maharashtra. *NeBIO* 8(1): 25–34.

Ruggiero, M.A., D.P. Gordon, T.M. Orrell, N. Bailly, T. Bourgoin, R.C. Brusca, T.C. Smith, M.D. Guiry & P.M. Kirk (2015). A higher-level classification of all living organisms. *PLoSONE* 10(4): e0119248. https://doi.org/10.1371/journal.pone.0119248

Sharma, A., K. Toppo & R.K. Gupta (2022). Season variation and desmids diversity (Zygnematales, Zygnemataceae) from Jim Corbett National Park (JCNP), India. *The Journal of Indian Botanical Society* 102(1): 6–29.

Siangbood, H. & P. Ramanujam (2014). Effect of anthropogenic activities on algal assemblages in Umiew river, Meghalaya. *Phykos* 44(1): 41–51.

Shahare, P.C. (2016). Desmid flora of Chulband Dam, Gondia district, Maharashtra, (India). *International Journal of Researches in Biosciences, Agriculture and Technology* IV(3): 41–44.

Shukla, S.K., C.P. Shukla & P.K. Misra (2008). Desmids (Chlorophyceae, Conjugales, Desmidiaceae) from Foothills of Western Himalaya, India. *Algae* 23(1): 1–14. https://doi.org/10.4490/algae.2008.23.1.001

Singh, P., K. Toppo & M.R. Suseela (2011). Desmids of Janjgir Champa of Chattisgarh. *The Journal of Indian Botanical Society* 90(3&4):

297–301.

Stamenkovic, M. & M. Cvijan (2008). Desmid flora (Chlorophyta, Zygnematophyceae) of the Danube in the Province of Vojvodina (Northern Serbia). *Archives of Biological Sciences* 60(2): 181–199. https://doi.org/10.2298/ABS0802181S

Suseela, M.R. & K. Toppo (2007). Contribution to the Desmid Flora of Sikkim Himalayas, India. *Bulletin of the National Museum of Nature and Science, Series B* 33(3–4): 105–114.

Verma, S., K. Toppo & S. Nayaka (2021). Comprehensive checklist of algal class Chlorophyceae (Sensu Fritsch 1935) for Uttar Pradesh India with updated taxonomic status. *Journal of Threatened Taxa* 13(14): 20218–20248. https://doi.org/10.11609/jott.6508.13.14.20218-20248

Valvi, A.B. & P.K. Gautam (2020). Studies on Some Desmids of Toranmal Reserve Forest of Satpura Ranges, Nandurbar District, Maharashtra, India. *Aegaeum Journal* 8(4): 355–361.

Yasmin, F., B.B. Buragohain & K.K. Medhi (2011). Planktonic Desmid Flora of south of the eastern Himalayas: A systematic approach on Algae-I. *International Journal of Botany* 7(2): 154–161. https://doi.org/10.3923/ijb.2011.154.161

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 February 2024 | 16(2): 24694–24706

ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

https://doi.org/10.11609/jott.8766.16.2.24694-24706

#8766 | Received 05 October 2023 | Final received 16 January 2024 | Finally accepted 26 January 2024

OPEN ACCESS

COMMUNICATION

Distribution status and roost characteristics of Indian Flying Fox *Pteropus medius* Temminck, 1825 (Mammalia: Chiroptera: Pteropodidae) in Kurukshetra district, Haryana, India

Ritu Devi [1] & **Parmesh Kumar** [2]

[1,2] Department of Zoology, Institute of Integrated and Honors Studies, Kurukshetra University, Kurukshetra, Haryana 136119, India.
[1] ritudevi8508@gmail.com (corresponding author), [2] parmesh@kuk.ac.in

Abstract: The Indian Flying Fox *Pteropus medius* plays a major role in the maintenance of a healthy ecosystem and is very specific in selecting roosting sites. The present study was conducted from January 2021 to March 2022 to document the occurrence of roosting colonies, the roosting sites and the population characteristics of *P. medius* in Kurukshetra district, Haryana. Of the 10 roosting sites identified in four tehsils of Kurukshetra district, 60% were located close to water sources, 20% were near agricultural fields, and the remaining sites were in roadside plantations. Eight roosting sites were observed to be permanent and two were temporary. A total of 233 trees belonging to seven families, eight genera, and nine species were identified as roost trees for this species. Our survey results show that *P. medius* preferred (77.42%) roosting majorly on trees of the Myrtaceae family (*Eucalyptus*), while very few individuals (0.5%) were recorded on *Phoenix dactylifera*. A positive Pearson correlation between the population of the roosting bats and the roost tree characteristics such as height ($r = 0.320$, $p < 0.001$), dbh ($r = 0.226$, $p < 0.001$), and circumference ($r = 0.293$, $p < 0.001$) was also observed. The findings of the current study revealed that *P. medius* prefers to roost on tall trees with large diameters at breast height, located near water bodies and agricultural fields. Protecting such large and tall trees would benefit the conservation of roosting sites of this species and its populations.

Keywords: Bats, circumference, colony, correlation, diameter at breast height, habitat, height, population, trees, water bodies.

Editor: Bhargavi Srinivasulu, Osmania University, Hyderabad, India.

Date of publication: 26 February 2024 (online & print)

Citation: Devi, R. & P. Kumar (2024). Distribution status and roost characteristics of Indian Flying Fox *Pteropus medius* Temminck, 1825 (Mammalia: Chiroptera: Pteropodidae) in Kurukshetra district, Haryana, India. *Journal of Threatened Taxa* 16(2): 24694–24706. https://doi.org/10.11609/jott.8766.16.2.24694-24706

Funding: The research is funded by CSIR in the form of SRF to one of the authors i.e., Ritu Devi.

Competing interests: The authors declare no competing interests.

Author details: Dr. Parmesh Kumar is professor of Zoology, Department of Zoology, Institute of Integrated & Honors Studies, Kurukshetra University Kurukshetra. He has published dozens of papers in the journals of national and international repute, and a few book chapters on biodiversity. His field of research includes wildlife ecology and animal behaviour. Ritu Devi is a research scholar and pursuing her PhD from Department of Zoology, Kurukshetra University, Kurukshetra.

Author contributions: PK conceived and designed the study as well as wrote the final draft of the manuscript. RD performed the field surveys, analysed the data and prepared the rough draft of the manuscript. Both authors read and approved the final manuscript.

Acknowledgements: We are highly thankful to the Department of Zoology, Kurukshetra University, Kurukshetra for providing the requisite facilities. One of the authors, Ritu Devi is thankful to the Council of Scientific & Industrial Research (CSIR), New Delhi, India for providing financial support in the form of JRF to conduct this research work.

INTRODUCTION

Bats belong to the order Chiroptera, which is the main contributor to mammalian diversity with over 1,455 species distributed all over the World (Simmons & Cirranello 2023) except for the Arctic, Antarctic, extreme desert areas, and a few isolated oceanic islands. Chiropterans are unique in being the only mammals capable of powered flight like Aves (Anderson & Ruxton 2020; Mishra et al. 2020). The order Chiroptera is divided into two suborders – Yinpterochiroptera (Pteropodidae and Rhinolophoidae) and Yangochiroptera (Microchiroptera excluding Rhinolophoidae) (Simmons & Cirranello 2023). Pteropodidae is the only one of them that lacks laryngeal echolocation capacity (Nojiri et al. 2021) and instead relies on eyesight and smell detection abilities to locate food (Teeling et al. 2002). The latest checklist enumerated 136 species of bats in India (Srinivasulu et al. 2023) accounting for more than 90% of the overall diversity of bats in South Asian countries (Mishra et al. 2020). Among the 12 species of fruit bats occurring in India, three species occur commonly and are distributed throughout the country: *Pteropus medius*, *Rousettus leschenaultii* and *Cynopterus sphinx* (Srinivasulu et al. 2023).

The Indian Flying Fox *Pteropus medius* is one of the largest fruit bats in the world and belongs to the family Pteropodidae (Mishra et al. 2020). This species is largely found in southern Asia and widely distributed in India. *P. medius* is a social species that typically roosts in large colonies of hundreds to thousands of individuals on large and tall trees (Roy et al. 2020). Fruit bats display insightful selection of roosting site exhibiting a preference for particular biotic, abiotic, and geographical factors, their roosting choices are intricately linked to both flora and various environmental variables exhibiting a strong association with specific ecological conditions (Gulraiz et al. 2015). Bat roosting sites in both rural and urban areas are found in a variety of habitats, viz., close to agricultural fields, ponds, temples, and human habitats such as public parks, home gardens, industrial areas, and by the sides of roads (Raza & Ilyas 2018; Madala et al. 2022). The roosting locations range from dense foliage to open areas with large trees which may help in ease of flight, providing shelter from strong winds and support in thermoregulation (Pandian & Suresh 2021). They are animals of considerable economic importance and are crucial for the survival of more than 114 plant species in the world (Aziz et al. 2021). Indian Flying Foxes are integral to ecosystem functioning, performing crucial role such as pollination, seed distribution, and nutrient cycling (Fujita & Tuttle 1991; Goveas et al. 2006; Kumar & Elangovan 2019; Madala et al. 2022). Globally, *P. medius* has been listed as 'Least Concern' in the IUCN Red list of Threatened Species (Tsang 2020) and is included in Schedule II under the Wildlife (Protection) Amendment Act, 2021 of India. However, the numbers of individuals are decreasing constantly (Dey et al. 2013; Raza & Ilyas 2018) due to the loss of habitat, felling of trees, electrocution, scarcity of food sources, expansion of highways, construction of buildings, public disturbances, and hunting (Chakravarthy & Yeshwanth 2008; Ali 2010), and its role as seed disperser, pollinator and forest regenerator is ignored (Gulraiz et al. 2015).

To survive successfully, all animals require food and shelter, which means the bats need to find an appropriate place to roost. Diurnal roost site selection is a part of habitat selection that affects an animal's ability to survive and reproduce. The daytime roost site is where *P. medius* spends about half of its life for activities like copulation, rest, maternal care, social interactions, and to escape from adverse weather and predators (Kumar & Elangovan 2019). Hence, a study on the bat's ecology, their habitats, and diurnal roosting requirements is the first step toward their effective conservation. No detailed research studies have been carried out on the roosting habits and habitats of *P. medius* in Haryana; hence, to fill up this research gap, the current study was conducted to identify *P. medius* roosting colonies and to document the roost tree characteristics in the Kurukshetra district of Haryana.

MATERIALS AND METHODS

Study area

The study was conducted in all the four tehsils/ blocks (Pehowa, Thanesar, Ladwa, and Shahbad) of Kurukshetra district in Haryana state, northern India. Kurukshetra is situated at 29.969° N and 76.878° E at an elevation of 260 m and has an area of 1,530 km² (Figure 1). Kurukshetra is one of the agriculturally advanced districts of the state of Haryana, India. Agricultural activities of the district are dependent on tube wells and canals. Rice-wheat cropping system dominates with the consequent marginalization of pulses and oilseed. Sugarcane is also being grown in the study area as a cash crop. The district is devoid of any perennial river. The river Markanda flows in the northwestern part of the district which originates in Nahan hills. The Yamuna River flows along the eastern and northern boundaries, respectively. The popular Sutlej-Yamuna-Link canal

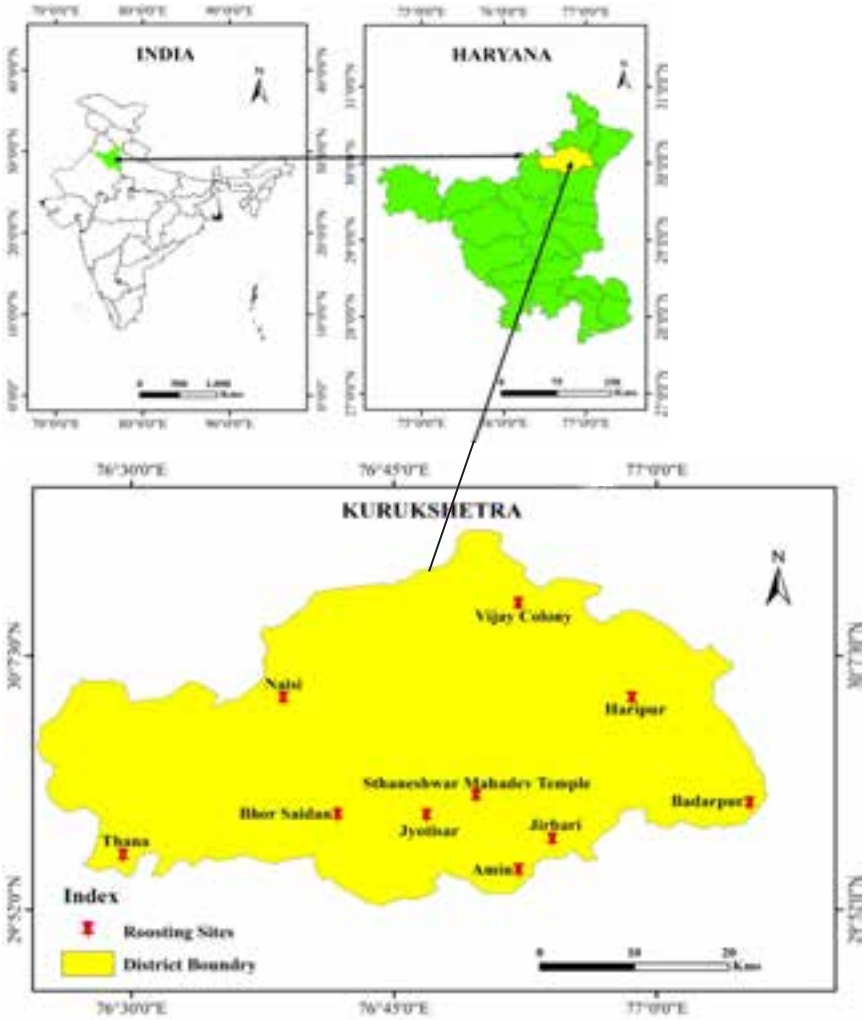


Figure 1. Map of Kurukshetra district, Haryana, with locations of roosting sites.

joining the Sutlej and Yamuna flows across Kurukshetra. Narwana canal which is a branch canal of Bhakra passes through Kurukshetra and is considered as the lifeline of the Haryana state. The soil is generally alluvial loam and clay does not constitute the average texture of the soil. The district has rich potential for the development of horticulture. Major fruit varieties grown in the district are mango, guava, citrus, ber, sapota, and pear/plums. The study area experiences a sub-tropical climate and has three distinct seasons: Rainy (July–September), cool and dry (October–February), and hot dry (March–June). The normal annual rainfall of the district is 582 mm which is unevenly distributed over the area and temperature ranges 3–45 °C.

Data collection

Initially, field surveys were conducted in the study area from January 2021 to March 2021 in Kurukshetra district to identify the roosting sites of *P. medius*. Initial information regarding the roosting sites was collected through direct interaction/oral inquiry with villagers, and people from the surrounding areas of the study area were also consulted. The identified roosting sites were surveyed every month from April 2021 to March 2022 to collect data on roost characteristics and colony size of *P. medius*. The number of bats at each roosting site was counted by direct roost count method (Kunz et al. 2009) with the help of field binoculars (Nikon 8 x 40) and photographed with a Canon SX-70 camera. The geo-coordinate of each roosting site was recorded using Garmin Etrex 30x GPS (hand-held device). Arc GIS 10.8 was used to prepare the roost distribution map of *P. medius* in the study area. Various parameters of the roosting tree such as species of the tree, origin (exotic or native), circumference, diameter at breast height (dbh) and tree height were recorded early in the morning/

before the arrival of Indian Flying Fox at the roost. The trees used for roosting were identified to species level. The circumference of the roost tree was measured using a measuring tape. To measure the dbh of the trees, the girth (g) of the tree at breast height was measured with a measuring tape, and then the diameter at breast height (dbh) was calculated by the formula dbh = g/π. The height of the roost tree was measured by using a clinometer (Hahn et al. 2014). Data on the number of the trees used by bats at a roost, type of the roost (permanent/ temporary), habitat of each roosting site (i.e., near water bodies, agricultural fields or roads), and the status of the roost were also recorded.

Statistical Analysis

The information regarding the number of bats, number of trees, height of roost tree, dbh, and circumference of trees were compiled in MS-Excel followed by data analysis and interpretation. Roost tree characteristics (height, circumference, and dbh) were considered as independent units for statistical analysis and thus Pearson correlation analysis was carried out to check the relationship between (SPSS 2007):

1. The bat abundance (colony size per tree) and height of the roost tree
2. The bat abundance and dbh of the roost tree
3. The bat abundance and circumference of the roost tree

All the analyses were performed in the statistical package for social science (SPSS software version 26.0).

RESULTS

A total of 10 roosting sites of *P. medius* were identified during the study period in Kurukshetra district, Haryana. The location, geo-coordinates, elevation, distance from nearest water bodies, number of roost trees, colony size, type of the roost, habitat and status of the roosting site are given in Table 1. Six roosting sites (Thana, Bhor Saidan, Jyotisar, Amin, Sthaneshwar Mahadev temple, and Badarpur) were located near to the water bodies (pond n = 1; water channel n = 3; and canal n = 2) (Image 1), two roosting sites (Naisi and Vijay Colony) were close to agricultural fields (Image 2) and the remaining two (Jirbari and Haripur) were located in road-side plantations (Image 3). Among the recorded roosting sites, two roosting sites (Amin and Sthaneshwar Mahadev temple) were used by bats as temporary roosts because the bats were found to use these roosts only during certain months of the year (April–July, November–March at Amin; August–November, February and March at Sthaneshwar Mahadev temple) and the remaining eight roosting sites were used as permanent roost during the study period. Bats undertook local migration during peak mating season at Amin roosting site, and in peak summer and winter months at Sthaneshwar Mahdev temple to more favorable roosts where large aggregation of individuals occurred. Migration during peak summer and winter season may be due to unfavorable temperature and weather conditions in this region. In the study area *P. medius* was found to use both single (aggregation of individuals on a single tree) and dispersed/scattered roosts (aggregation of individuals on different trees at a roosting site). Of the total identified roosts, the Amin was a single roost on the tall *Ficus religiosa* whose well-spread crown accommodated a modest number (minimum colony size) of Indian Flying Foxes, whereas nine roosts (Thana, Bhor Saidan, Naisi, Jyotisar, Sthaneshwar Mahadev temple, Jirbari, Haripur, Vijay Colony, and Badarpur) were dispersed roosts (Table 1).

A total of 233 trees belonging to seven families, eight genera and nine species were used as roost trees by *P. medius* in the study area. The roost tree species in the study area included Neem *Azadirachta indica,* Peepal *Ficus religiosa,* Banyan *Ficus benghalensis,* Jamun *Syzygium cumini*, Red Silk Cotton *Bombax ceiba,* Flame Tree *Delonix regia*, Date Palm *Phoenix dactylifera*, Indian Elm *Holoptelea integrifolia*, and Forest Red Gum *Eucalyptus tereticornis* (Image 4). The roost sites of Indian Flying Fox in the study area comprised a minimum of one tree species (Amin) to a maximum of eight tree species (Bhor Saidan). As far as the number of trees in a diurnal roost is concerned, a minimum of one tree was observed at Amin roost whereas a maximum of 45 trees were recorded in the roost at Vijay Colony, Shahabad. Thus, *P. medius* did not maintain any consistency in roost tree selection in the Kurukshetra district. Among the nine tree species identified as roost trees of *P. medius*, seven are of native origin and two of exotic origin (Table 2). Of the 233 roost trees, *Eucalyptus tereticornis* of Myrtaceae family was used as roost predominantly (n = 163), followed by *Holoptelea integrifolia* (n = 32), *Syzygium cumini* (n = 14), *Azadirachta indica* (n = 6), *Ficus religiosa* (n = 6), *Phoenix dactylifera* (n = 5), *Bombax ceiba* (n = 3), *Delonix regia* (n = 2), and *Ficus benghalensis* (n = 2) (Figure 2).

The height of the roost trees varied from 5.4 m (*Azadirachta indica*) to 34.6 m (Eucalyptus) with a mean height of 25.72 m. The mean dbh of the roost tree was found to be 53.58 cm ranging from 40.0 cm

Image 1. Study area map showing various roosting sites which are located near water bodies in Kurukshetra district (R indicates the roosting site and W indicates water body).

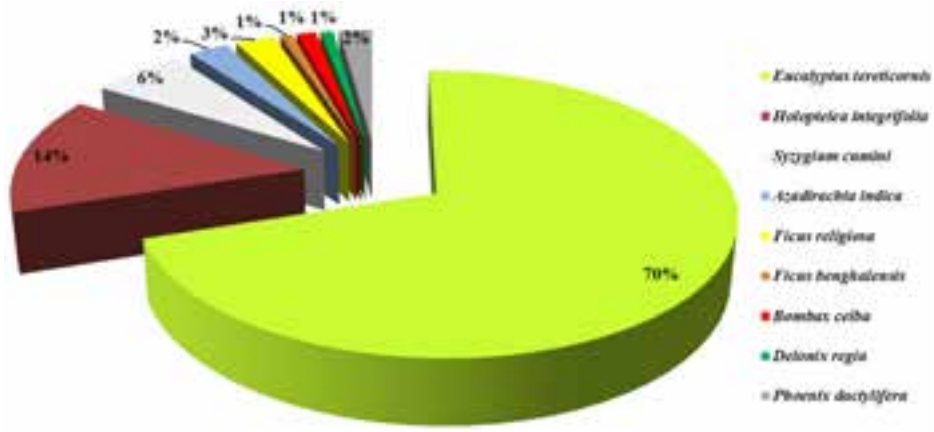


Figure 2. Roost tree diversity used by *Pteropus medius* in Kurukshetra district.

Table 1. Distribution of roosting sites and average population size of Indian Flying Fox *Pteropus medius* in Kurukshetra district, Haryana.

	Tehsil	Location of the roosting site	Coordinates	Elevation (m)	Distance from nearest water body	Colony size (M ± SE)	No. of roost trees	Type of roost	Habitat of roost	Status
1.	Pehowa	Bhor Saidan	N 29.920284 E 76.492825	248	5.01 m	529±20.15 (410–642)	44	Permanent & dispersed	At the edge of crocodile breeding center pond in village Bhor Saidan	Relatively safe, rarely disturbed by visitors
2.	Pehowa	Thana	N 29.920121 E 76.495768	258	6.36 m	232.0 ±20.5 (138–369)	22	Permanent & dispersed	At the edge of pond in village Thana	Highly disturbed by human activities
3.	Pehowa	Naisi	N 30.079287 E 76.644301	258	730.9 m	356.5±24.9 (198–450)	28	Permanent & dispersed	Near agricultural fields in village Naisi	Relatively disturbed
4.	Thanesar	Jyotisar	N 29.962274 E 76.780665	253	4.10 m	174.1±19.9 (78–297)	17	Permanent & dispersed	Between Sutlej Yamuna link canal and Narwana branch	Disturbed by moving traffic
5.	Thanesar	Amin	N 29.907035 E 76.870809	258	43.61 m	19.5±4.07 (12–39)	1	Temporary & single	At the edge of surajkund in village Amin	Disturbed by villagers
6.	Thanesar	Jirbari	N 29.936747 E 76.900876	258	695.21 m	308.6±22 (176–430)	21	Permanent & dispersed	At road-side plantation on national highway-44	Disturbed by moving traffic
7.	Thanesar	Sthaneshwar Mahadev temple	N 29.981198 E 76.827961	258	9.1 m	25.5±7.07 (29–61)	3	Temporary & dispersed	In the premises of temple	Religious site, disturbed by visitors
8.	Shahbad	Haripur	N 30.086299 E 76.968970	336	663.02 m	297.0±15.9 (192–391)	19	Permanent & dispersed	At road-side plantation on Shahbad-Ladwa road	Highly disturbed by moving vehicles
9.	Shahbad	Vijay colony	N 30.176264 E 76.868887	267	471.23 m	882.5±46.6 (660–1238)	45	Permanent & dispersed	Near agricultural fields in Vijay Colony	Undisturbed, relatively safe
10.	Ladwa	Badarpur	N 29.957700 E 77.097949	257	89.23 m	748.9±31.4 (562–893)	33	Permanent & dispersed	At the edge of West Yamuna canal in village Badarpur	Undisturbed, safer

(*Delonix regia*) to 201.13 cm (*Ficus benghalensis*). The Pearson correlation analysis showed significant positive correlation between bat abundance (colony size per tree) and the characteristics of the roost tree such as height (r = 0.320, N = 233, P <0.001) (Figure 3), dbh (r = 0.226, N = 233, P <0.001) (Figure 4) and circumference of the roost tree (r = 0.293, N = 233, P <0.001) (Figure 5). Thus, the height, dbh and circumference of the roost trees influence the roosting habits of *P. medius*.

All the identified permanent roosts of *P. medius* in the study area were comprised of only one tree species except at Bhor Saidan roosting site. Hence, data on seasonal variations in preference of roosting tree species were collected only at Bhor Saidan roosting site (Figure 6). In summer, *P. medius* was observed roosting underneath the canopy of the thick foliage of *Syzygium cumini* roosting trees, flapping their wings, while in the winter *P. medius* was observed roosting with closed wings at the edge of the branches of *Azadirachta indica* roosting trees.

A total of 42,892 individuals of *P. medius* were observed across 10 roosting sites in the Kurukshetra district during the study period. The maximum colony size comprising 10,591 individuals was recorded at Vijay Colony, Shahbad, and the minimum colony size (234 individuals) was observed at Amin roosting site (Figure 7). The colony size of *P. medius* fluctuated between seasons and was recorded to be higher in winter than summer at all roosting sites (Figure 8).

DISCUSSION

In the present study, 10 roosting sites of *P. medius* were recorded from Kurukshetra district, Haryana. The observed colonies of bats are comparable to the earlier studies in different regions of India. For instance, Gaikwad et al. (2012) recorded 16 colonies of the Indian Flying Fox in Maharashtra, Talmale (2014) recorded 27 roosting sites in Madhya Pradesh, and Madala et al. (2022) recorded 11 roosting sites in the midland laterite hillocks of northern Kerala. Flying foxes usually have either a permanent diurnal roost (bats are always present although in variable numbers) or a temporary roost (sites that are used only occasionally) (Jenkins et al. 2007). Likewise in the present study, two sites out of the 10 were temporary roosts and eight were permanent roosts. In India and Nepal, the colonies of *P. medius* mostly preferred to choose trees for roosting near human settlements (Chakravarthy et al. 2009; Krystufek 2009; Katuwal et al. 2019) but in the present study, the

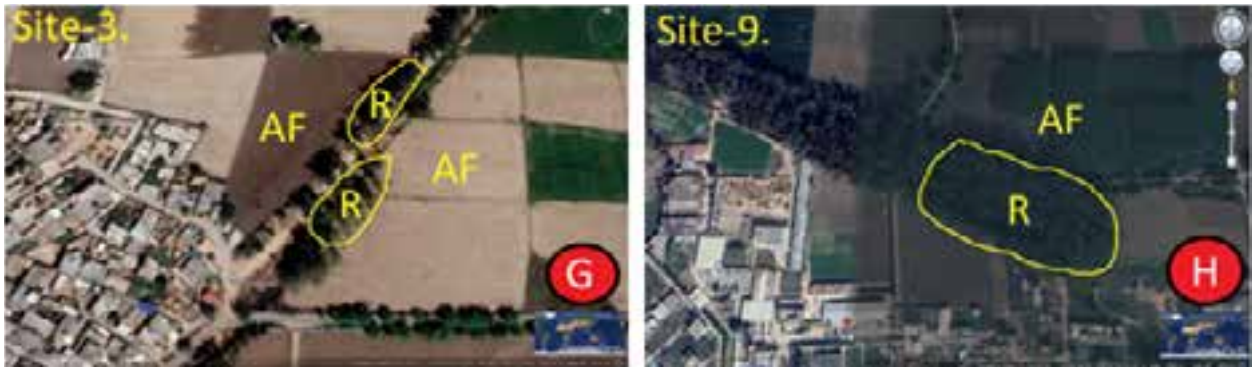


Image 2. Study area map showing roosting sites which are located near agricultural fields in Kurukshetra district (AF indicates agricultural fields).

Image 3. Study area map showing roosting sites which are located on road-side plantations in Kurukshetra district (Yellow arrow in image I indicates national highway 44 and in image J indicates Shahbad-Ladwa road).

majority of roosting sites (60%) were observed near water bodies. Rest of the roosting sites were observed near agricultural fields (20%) and on the roadside plantations (20%). These results are in confirmation with previous studies that in Uttar Pradesh (Kumar et al. 2017), 49% of the colonies of *P. medius* were observed near human habitation and 41% of the colonies near water bodies in Tamil Nadu (Dhivahar & Isaac 2018), 90% of the roosting sites were observed near water bodies and the rest 10% were located near agricultural land and residential area, and in the urban areas of Lahore, Pakistan (Gulraiz et al. 2015), the roosting sites were observed near water bodies. The presence of roosting sites near water bodies facilitates the water requirement and thermal balance of bats during hot seasons (Welbergen et al. 2008; Russo & Ancillotto 2015). In our study we observed the bats hovering above the water's surface, dipping their bodies in water to drink, cool themselves, and lick their body hairs for water (Image 5). It has also been reported that certain species, like *P. livingstonii* and *P. alecto* favor roosts next to waterbodies because they provide a humid atmosphere (Granek 2002).

In the present study the Indian Flying Fox roosted on nine species of trees which reflect their flexibility to occupy diverse habitat conditions. These results are consistent with previous records that *P. medius* roost on different species of trees in India (Chakravarthy & Yeshwanth 2008; Bhatnagar & Salvi 2011; Timalsina & Ghimire 2011; Dey et al. 2013; Ali 2014; Manandhar et al. 2018; Mishra et al. 2020; Madala et al. 2022). *P. medius* has been known to use 22 species of trees as their roost in 20 districts of Uttar Pradesh (Kumar & Elangovan 2019), nine species of avenue trees in Delhi (Mishra et al. 2020) and seven species of trees in Baghnadi village of district Rajnandgaon, Chhattisgarh.

Pteropus species often choose larger trees for roosting (Gulraiz et al. 2015; Kumar & Elangovan 2019) which provide better protection against unfavorable environmental conditions and updrafts for easier flight (Pierson & Rainey 1992; Granek 2002; Dey et al. 2013). In India, *P. medius* has been reported to prefer *Ficus* spp. for roosting (Srinivasulu & Srinivasulu 2004; Goveas et al. 2006; Chakravarthy et al. 2009; Maruthupandian & Marimuthu 2013; Raza & Ilyas 2018; Mishra et al.

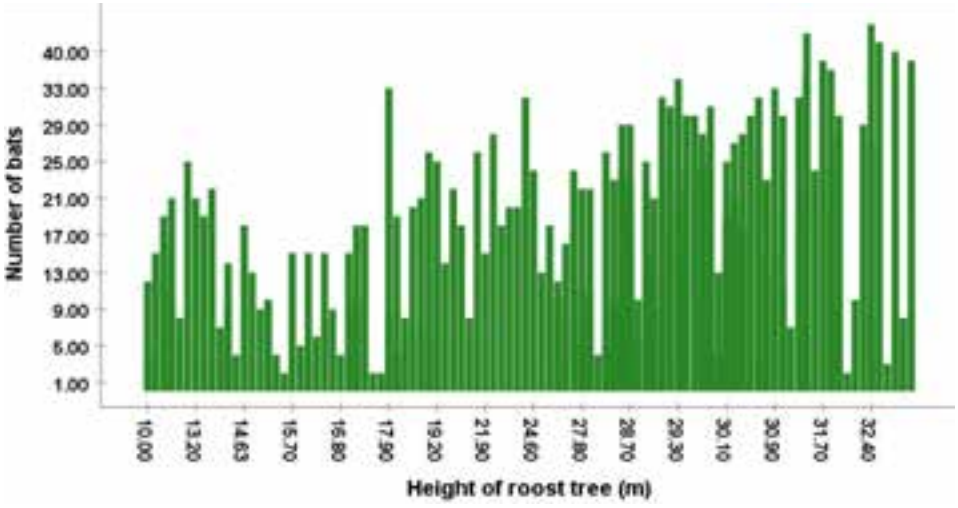


Figure 3. Variation in number of bats roosting with change in height of roost tree.

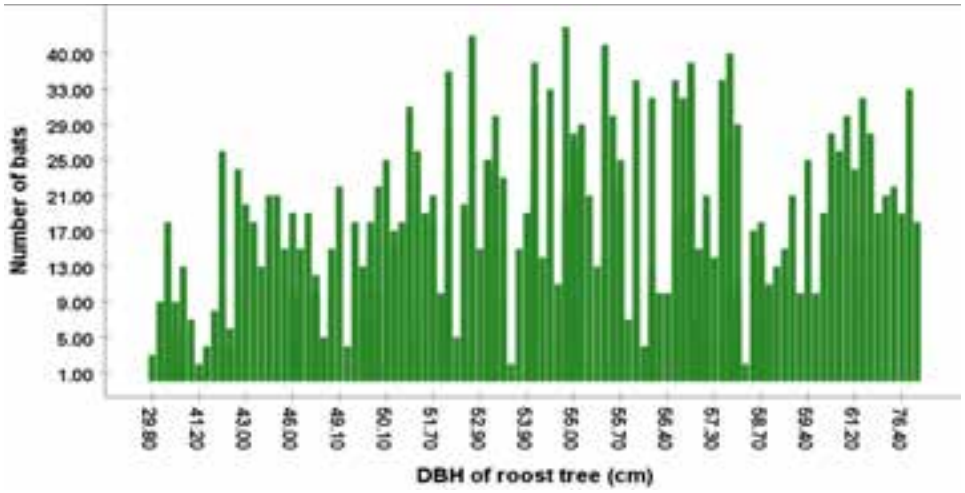


Figure 4. Variation in number of bats roosting with change in DBH of roost tree.

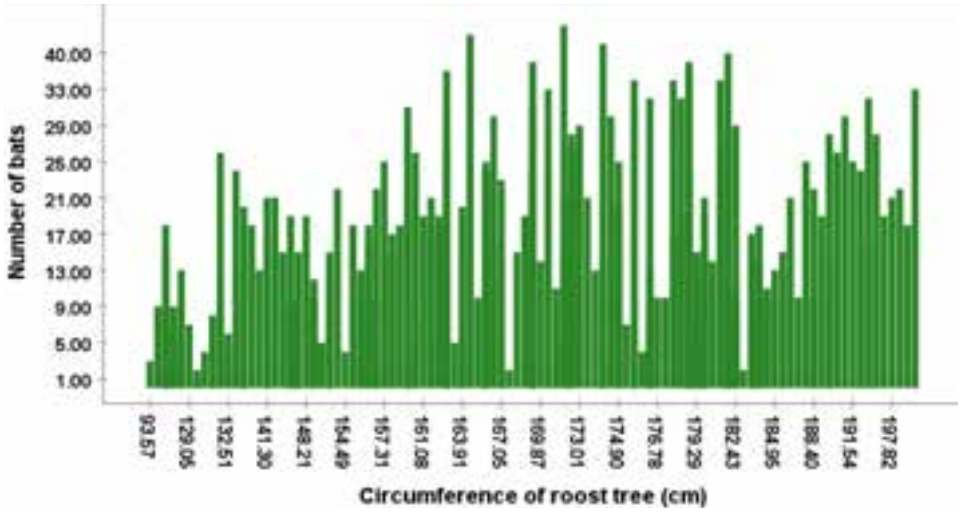


Figure 5. Variation in number of bats roosting with change in circumference of roost tree.

Table 2. Roost tree and roost characteristics of Indian Flying Fox *Pteropus medius* in Kurukshetra district, Haryana.

	Roosting site	Roost tree species			Origin	Circumference (cm)	DBH (cm)	Height (m)	No. of bats
		Family	Scientific name	Common name					
1.	Bhor Saidan	Meliaceae	*Azadirachta indica*	Neem	Native	190.39±5.10	60.63±1.62	21.06±0.84	137.5±16.5 (52–215)
		Moraceae	*Ficus religiosa*	Peepal	Native	188.05±12.25	59.89±4.09	17.90±0.37	57.75±3.82 (35–76)
		Moraceae	*Ficus benghalensis*	Banyan	Native	414.02	131.85	17.20	32.91±4.22 (13–60)
		Myrtaceae	*Syzygium cumini*	Jamun	Native	136.85±3.69	43.58±0.85	16.70±1.10	141.3±10.6 (86–210)
		Bombaceae	*Bombax ceiba*	Red Silk Cotton	Native	132±0.80	42.06±0.94	24.60±2.90	55.25±7.08 (21–90)
		Fabaceae	*Delonix regia*	Flame Tree	Exotic	130.31±4.71	41.50±1.50	19.10±0.30	34.41±6.31 (12–79)
		Arecaceae	*Phoenix dactylifera*	Date Palm	Native	131.37±2.88	41.84±0.91	18.90±0.60	19.83±5.22 (5–64)
		Ulmaceae	*Holoptelea integrifolia*	Indian Elm	Native	160.3±18.2	42.58±1.02	15.70±0.70	51.33±6.72 (12–80)
2.	Thana	Ulmaceae	*Holoptelea integrifolia*	Indian Elm	Native	185.90±1.36	59.20±0.43	8.17±1.45	232.0±20.5 (138–369)
3.	Naisi	Myrtaceae	*Eucalyptus tereticornis*	Forest Red Gum	Exotic	180.57±1.23	57.29±0.34	30.05±2.46	356.5±24.9 (198–450)
4.	Jyotisar	Myrtaceae	*Eucalyptus tereticornis*	Forest Red Gum	Exotic	161.91±3.21	51.56±1.02	29.37±3.35	174.1±19.9 (78–297)
5.	Amin	Moraceae	*Ficus religiosa*	Peepal	Native	240.79	76.50	13.24	19.5±4.07 (12–39)
6.	Jirbari	Myrtaceae	*Eucalyptus tereticornis*	Forest Red Gum	Exotic	176.55±1.49	56.22±0.47	29.10±1.93	308.6±22.0 (176–430)
7.	Sthaneshwar Mahadev temple	Meliaceae	*Azadirachta indica*	Neem	Native	212.8	67.51	5.40	1.25±0.42 (1–4)
		Moraceae	*Ficus religiosa*	Peepal	Native	214.4	68.15	6.40	9.25±2.49 (12–21)
		Moraceae	*Ficus benghalensis*	Banyan	Native	216.2	68.71	14.63	18±4.75 (16-41)
8.	Haripur	Myrtaceae	*Eucalyptus tereticornis*	Forest Red Gum	Exotic	157.54±3.12	50.17±1.00	28.30±1.72	297±15.95 (192–391)
9.	Vijay Colony	Myrtaceae	*Eucalyptus tereticornis*	Forest Red Gum	Exotic	163.53±1.82	52.08±0.58	29.07±3.47	882.5±46.6 (660–1238)
10.	Badarpur	Myrtaceae	*Eucalyptus tereticornis*	Forest Red Gum	Exotic	164.65±1.63	52.17±0.52	25.90±3.31	748.9±31.4 (562–893)

2020). However, in the present study area, *Eucalyptus* was found to be the preferred roosting tree species for *P. medius*. It might be due to the reason that the *Eucalyptus* tree is branched and taller than other tree species in the area which provided more exposure to sunlight for warming the body. The preference of flying foxes in taller trees may be due to the aerodynamic advantages offered by larger trees, facilitating smoother take-off and landing. Additionally, towering trees may serve as a protective refuge, shielding the flying foxes from human-induced threats (Granek 2002; Gulraiz et al. 2015). The results of the present study support previous observations made elsewhere that *P. medius* prefers to roost in trees with increased dbh (Hahn et al. 2014; Kumar & Elangovan 2019; Madala et al. 2022) and increased height (Kumar & Elangovan 2019; Madala et al. 2022). Trees with increased height normally develop increased dbh (Metzger 1893). Trees with increased dbh and circumference are long-lasting, and have more ability to resist heavy rain, wind, and drought conditions (Madala et al. 2022).

Among the nine tree species used as roosts, seven species were native and two species were exotic, clearly depicting the preference toward native trees for roosting by *P. medius*. Earlier studies also reported that *Pteropus* spp. prefer native trees for roosting and feeding (Granek 2002; Gulraiz et al. 2015; Madala et al. 2022).

The number of individuals of *P. medius* per colony was found to vary in different areas. In Jambughoda Wildlife Sanctuary, Gujarat a colony of 11,000 individuals was observed (Vyas & Upadhyay 2014), in Odisha the colony size of Indian Flying Fox ranged 43–6,141 individuals (Rao & Poyyamoli 2017), in Delhi the peak colony size of 1,660 individuals were recorded (Mishra et al. 2020) and

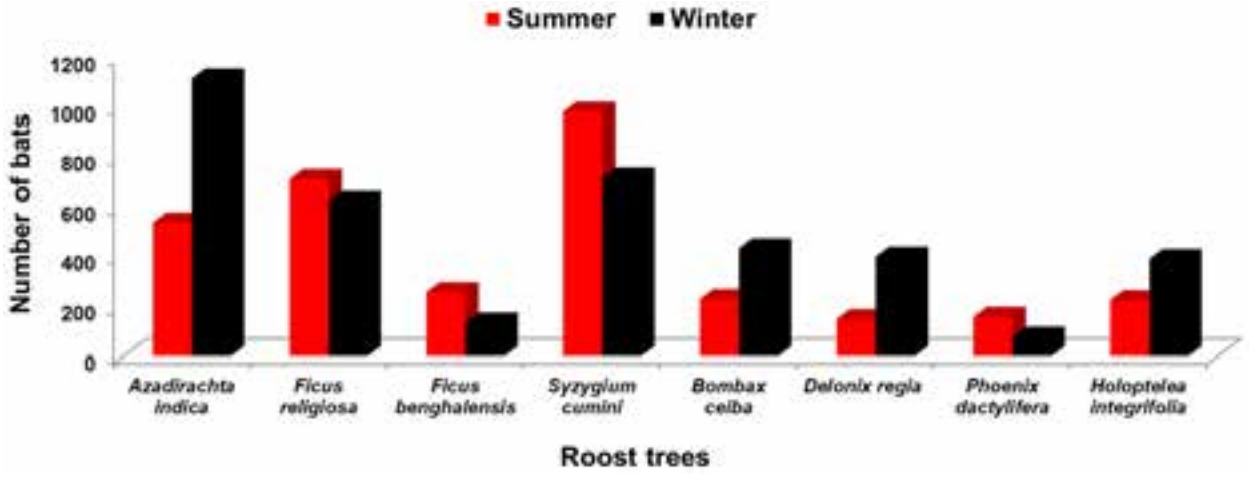


Figure 6. Roosting variation of *Pteropus medius* in different seasons in Kurukshetra district.

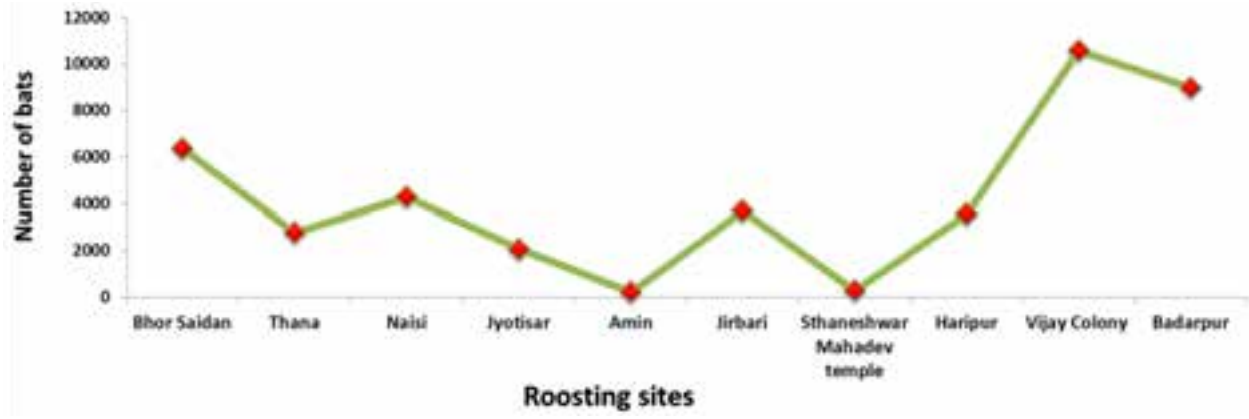


Figure 7. Colony size of *Pteropus medius* at different roosting sites in Kurukshetra district.

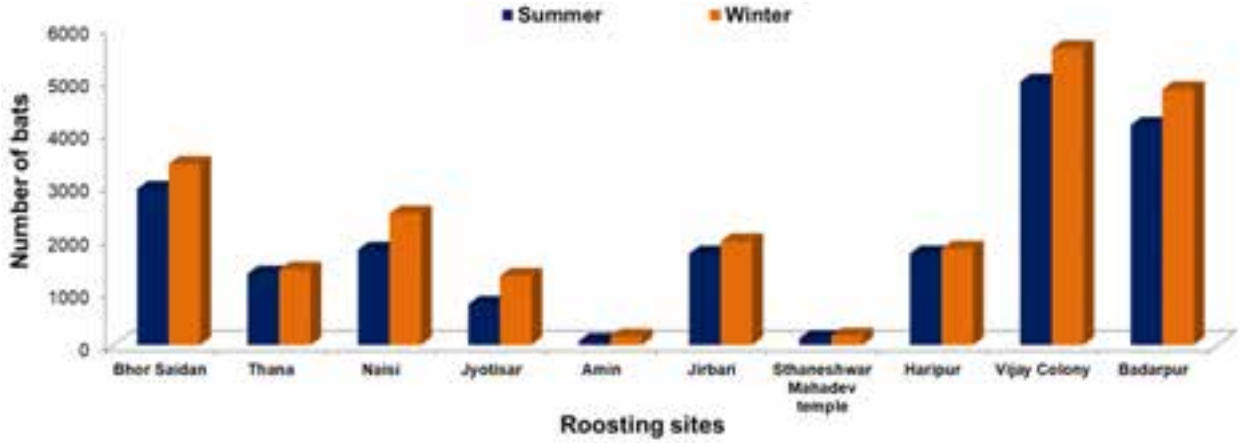


Figure 8. Roosting variation of *Pteropus medius* in different seasons in Kurukshetra district.

Image 4. Details about the roost trees preferred by *Pteropus medius* in Kurukshetra district: A—Neem *Azadirachta indica* | B—Peepal *Ficus religiosa* | C—Banyan *Ficus benghalensis* | D—Jamun *Syzygium cumini* | E—Red Silk Cotton *Bombax ceiba* | F—Flame tree *Delonix regia* | G—Date Palm *Phoenix dactylifera* | H—Indian Elm *Holoptelea integrifolia* | I—Forest Red Gum *Eucalyptus tereticornis*. © Ritu Devi.

Image 5. *Pteropus medius* hovering above the water's surface to cool themselves during warm hours of the day. © Ritu Devi.

in the present study area the colony size of Indian Flying Fox ranged 234–10,591 individuals.

CONCLUSION

The current study revealed the occurrence of various roosting sites, roost characteristics, and populations of *P. medius* in Kurukshetra district. A total of 10 roosting sites were observed in four tehsils of Kurukshetra district. The majority of roosting sites (60%) were located near water bodies. The wide distribution of *P. medius* showed that Kurukshetra district has suitable habitats for its continued survival. The result of the present study showed that *P. medius* roost on open tree branches of different types of roosting trees which reflects their flexibility to occupy diverse habitat conditions that provide many advantages to the bats like protection from human interference, thermoregulation, and enable them to take-off and land more easily. The highest colony size of bats was observed in Vijay colony, Shahbad which showed the presence of maximum number of roost trees compared to other roosting sites. Thus, the population of *P. medius* was also linked with the number of roost trees which provides better protection for their survival and reproduction. It can be concluded from the present study that *P. medius* prefers to roost near water bodies, on tall trees with relatively larger diameters and these are the key factors affecting their distribution. For long-term protection of *P. medius*, further research needs to be undertaken in the study area along with creating awareness among the public on the ecological and economic significance of bats. Future studies on the distribution and conservation of *P. medius* in Kurukshetra area may benefit from the findings of the current study.

REFERENCES

Ali, A. (2010). Population trend and conservation status of Indian Flying Fox, *Pteropus giganteus* (Brunnich, 1872) (Chiroptera: Pteropodidae) in western Assam. *The Ecoscan* 4(4): 311–312.

Ali, A. (2014). Interaction of Indian Flying Foxes *Pteropus giganteus* (Brunnich, 1782) with the plant species in the Lower Brahmaputra Valley of Assam. *Small Mammal Mail* 6: 12–14.

Anderson, S.C. & G.D. Ruxton (2020). The evolution of flight in bats: a novel hypothesis. *Mammal Review* 50(4): 426–439. https://doi.org/10.1111/mam.12211

Aziz, S.A., K.R. McConkey, K. Tanalgo, T. Sritongchuay, M.R. Low, J.Y. Yong, T.L. Mildenstein, C.E. Nuevo-Diego, V.C. Lim & P.A. Racey (2021). The critical importance of Old World fruit bats for healthy ecosystems and economies. *Frontiers in Ecology and Evolution* 9: 1–29. https://doi.org/10.3389/fevo.2021.641411

Bhatnagar, C. & R. Salvi (2011). Sites and roosting ecology of bats of Udaipur district, Rajasthan. *Small Mammal Mail* 3: 31–35.

Chakravarthy, A.K. & H.M. Yeshwanth (2008). Status of roost of Indian fruit bat (*Pteropus giganteus*) in Karnataka, South India. *Bat Net CCISNA Newsletter* 9: 16–18.

Chakravarthy, A.K., H.M. Yeshwanth, L.V. Kumar & N.P. Kumar (2009). Giant Indian fruit bat (*Pteropus giganteus* Brunnich) roost in Karnataka, South India: a case for preservation as a heritage site. *Tigerpaper* 36(3): 25–31.

Dey, S., U. Roy & S. Chattopadhyay (2013). Distribution and abundance of three populations of Indian Flying Fox (*Pteropus giganteus*) from Purulia district of West Bengal, India. *Taprobanica* 5(1): 60–66. https://doi.org/10.4038/tapro.v5i1.5664

Dhivahar, J. & S.S. Isaac (2018). Survey on distribution and conservation status of the Indian flying fox *Pteropus giganteus*: A bioindicator of wetland ecosystem. *Journal of Chemical and Environmental Sciences* 6(1): 75–80.

Fujita, M.S. & M.D. Tuttle (1991). Flying foxes (Chiroptera: Pteropodidae): threatened animals of key ecological and economic importance. *Conservation Biology* 5(4): 455–463. https://doi.org/10.1111/j.1523-1739.1991.tb00352.x

Gaikwad, M., S. Narwade, K. Fartade & V. Korad (2012). A review of the distribution of bats in southwestern region of Deccan, Maharashtra-India and conservation recommendations. *Taprobanica* 4(1): 27–36. https://doi.org/10.47605/tapro.v4i1.62

Goveas, S.W, E.C. Miranda, S. Seena & K.R. Sridhar (2006). Observations on guano and bolus of Indian Flying Fox, *Pteropus giganteus*. *Current Science* 90(2): 160–162.

Granek, E. (2002). Conservation of *Pteropus livingstonii* based on roost site habitat characteristics on Anjouan and Moheli, Comoros islands. *Biological Conservation* 108(1): 93–100. https://doi.org/10.1016/

S0006-3207(02)00093-9

Gulraiz, T.L., A. Javid, M. Mahmood-Ul-Hassan, A. Maqbool, S. Ashraf, M. Hussain & S. Daud (2015). Roost characteristics and habitat preferences of Indian Flying Fox (*Pteropus giganteus*) in urban areas of Lahore, Pakistan. *Turkish Journal of Zoology* 39(3): 388–394. https://doi.org/10.3906/zoo-1401-71

Hahn, M.B., J.H. Epstein, E.S. Gurley, M.S. Islam, S.P. Luby, P. Daszak & J.A. Patz (2014). Roosting behaviour and habitat selection of *Pteropus giganteus* reveal potential links to Nipah virus epidemiology. *Journal of Applied Ecology* 51(2): 376–387. https://doi.org/10.1111/1365-2664.12212

Jenkins, R.K., P.A. Racey, D. Andriafidison, N. Razafindrakoto, E. Razafimahatratra, A. Rabearivelo, Z. Ratsimandresy, R.H. Andrianandrasana & H.J. Razafimanahaka (2007). Not rare, but threatened: the endemic Madagascar flying fox *Pteropus rufus* in a fragmented landscape. *Oryx* 41(2): 263–271. https://doi.org/10.1017/S0030605307001883

Katuwal, H.B., S. Kushwaha & R.C. Quan (2019). Indian Flying Fox *Pteropus giganteus* is declining in lowland Nepal: need of conservation actions. *Journal of Bat Research & Conservation* 12(1): 60–63. https://doi.org/10.14709/BarbJ.12.1.2019.08

Krystufek, B. (2009). Indian Flying Fox *Pteropus giganteus* colony in Peradeniya Botanical Gardens, Sri Lanka. *Hystrix* 20(1): 29–35. https://doi.org/10.4404/hystrix-20.1-4430

Kumar, R. & V. Elangovan (2019). Effect of tree characteristics on roost selection of the Indian Flying Fox, *Pteropus giganteus*. *Journal of Bat Research & Conservation* 12(1): 100–106. https://doi.org/10.14709/BarbJ.12.1.2019.13

Kumar, R., D.N. Prasad & V. Elangovan (2017). An update on distribution of the Indian Flying Fox, *Pteropus giganteus* in Uttar Pradesh, India. *Trends in Biosciences* 10(37): 7794–7801.

Kunz, T.H., M. Betke, N.I. Hristov & M.J. Vonhof (2009). Methods for assessing colony size, population size and relative abundance of bats, pp. 133–157. In: Kunz, T.H. & S. Parsons (eds.). *Ecological and Behavioral Methods for the Study of Bats*. Johns Hopkins University Press, Baltimore, Maryland, 901 pp.

Madala, M.F., C. Guna, A. Pradeepan & A.K. Chalil (2022). Roost tree characteristics of *Pteropus medius* (Chiroptera: Pteropodidae) in the midland laterite hillocks of northern Kerala, India. *Journal of Asia-Pacific Biodiversity* 15(4): 465–472. https://doi.org/10.1016/j.japb.2022.04.011

Manandhar, S., S. Thapa, T. K. Shrestha, R. Jyakhwo, W. Wright & A. Aryal (2018). Population status and diurnal behaviour of the Indian Flying Fox *Pteropus giganteus* (Brünnich, 1782) in Kathmandu Valley, Nepal. *Proceedings of the Zoological Society* 71(4): 363–375. https://doi.org/10.1007/s12595-017-0219-x

Maruthupandian, J. & G. Marimuthu (2013). Cunnilingus apparently increases duration of copulation in the Indian Flying Fox, *Pteropus giganteus*. *PLOS One* 8(3): 1–3. https://doi.org/10.1371/journal.pone.0059743

Metzger, K. (1893). The wind as a decisive factor for the growth of the trees. *Mundener Forstliche Hefte* 5: 35–86.

Mishra, R., S. Dookia & P. Bhattacharya (2020). Avenue plantations as biodiversity havens: a case study of population status of the Indian Flying Fox, *Pteropus giganteus* Brunnich, 1782 and implications for its conservation in the urban megacity, Delhi, India. *Proceedings of the Zoological Society* 73(2): 127–136. https://doi.org/10.1007/s12595-019-00308-3

Nojiri, T., L.A. Wilson, C. Lopez-Aguirre, V.T. Tu, S. Kuratani, K. Ito, H. Higashiyama, N.T. Son, D. Fukui, A. Sadier, K.E. Saers, H. Endo, S. Kamihori & D. Koyabu (2021). Embryonic evidence uncovers convergent origins of laryngeal echolocation in bats. *Current Biology* 31(7): 1353–1365. https://doi.org/10.1016/j.cub.2020.12.043

O'Brien, J. (2011). Bats of the western Indian ocean islands. *Animals* 1(3): 259–290. https://doi.org/10.3390/ani1030259

Pandian, M. & S. Suresh (2021). Roosting habits and habitats of the Indian Flying Fox *Pteropus medius* Temminck, 1825 in the northern districts of Tamil Nadu, India. *Journal of Threatened Taxa* 13(12): 19675–19688. https://doi.org/10.11609/jott.7468.13.12.19675-19688

Pierson, E.D. & W.E. Rainey (1992). The biology of flying foxes of the genus *Pteropus*: a review, pp. 1–17. In: Wilson, D.E. & G.L. Graham (ed.). Pacific Island Flying Foxes. Proceedings of an International Conservation Conference, Washington, D.C.. U. S. Fish and Wildlife Services Biological Report 90.

Rao, S. & G. Poyyamoli (2017). Roosting, foraging and mating behaviours of Indian Flying Fox (*Pteropus giganteus*) in Rourkela, Odisha, 18 pp. https://doi.org/10.2139/ssrn.3007088

Raza, M. & O. Ilyas (2018). Preliminary study on status and ecology of *Pteropus giganteus* in Aligarh city, Uttar Pradesh. *Indian Forester* 144(10): 986–991.

Roy, K., G.K. Saha & S. Mazumdar (2020). Seasonal influence on the diurnal roosting behaviour of free-ranging Indian Flying Fox *Pteropus giganteus* in an urban landscape, India. *Biologia* 75: 1955–1961. https://doi.org/10.2478/s11756-020-00472-4

Russo, D. & L. Ancillotto (2015). Sensitivity of bats to urbanization: a review. *Mammalian Biology* 80(3): 205–212. https://doi.org/10.1016/j.mambio.2014.10.003

Simmons, N.B. & A.L. Cirranello (2023). *Bat species of the world: a taxonomic and geographic database*. Version 1.4. Accessed on 10 November 2023. https://batnames.org/home.html

SPSS (2007). Statistical Package for Social Sciences. 2007. SPSS for windows, version 26.0. Chicago: SPSS Inc.

Srinivasulu, C., A. Srinivasulu & B. Srinivasulu (2023). Checklist of the bats of India (v1.7). Accessed on 16 July 2023. https://threatenedtaxa.org/index.php/JoTT/checklists/bats/india

Srinivasulu, C. & B. Srinivasulu (2004). Highway development affects the population of the Indian Flying Fox *Pteropus giganteus* (Brunnich, 1782). *Zoos' Print Journal* 19(1): 1329. https://doi.org/10.11609/JoTT.ZPJ.19.1.1329

Talmale, S.S. (2014). Records of roosting sites of Indian Flying Fox (*Pteropus giganteus* (Brunnich, 1782) from Madhya Pradesh, India. *Small Mammal Mail* 6(1): 9–11.

Teeling, E.C., O. Madsen, R.A. Van Den Bussche, W.W. de Jong, M.J. Stanhope & M.S. Springer (2002). Microbat paraphyly and the convergent evolution of a key innovation in Old World Rhinolophoid microbats. *Proceedings of the National Academy of Sciences* 99(3): 1431–1436. https://doi.org/10.1073/pnas.022477199

Timalsina, N. & R. Ghimire (2011). Monitoring of ptero-camp at Lainchaur-Kathmandu. *Small Mammal Mail* 2(2): 24.

Tsang, S.M. (2020). *Pteropus giganteus*. *The IUCN Red List of Threatened Species* 2020: e.T18725A194134899. Accessed on 03 October 2023. https://doi.org/10.2305/IUCN.UK.2020-3.RLTS.T18725A194134899.en

Vyas, R. & K. Upadhaya (2014). Study of the Indian Flying Fox (*Pteropus giganteus*) colonies of Jambughoda Wildlife Sanctuary, Gujarat, India: record of largest roosting congregation at Targol. *Small Mammal Mail* 6(1): 1–8.

Welbergen, J.A., S.M. Klose, N. Markus & P. Eby (2008). Climate change and the effects of temperature extremes on Australian flying-foxes. *Proceedings of the Royal Society B: Biological Sciences* 275(1633): 419–425. https://doi.org/10.1098/rspb.2007.1385

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 February 2024 | 16(2): 24707–24729
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.7699.16.2.24707-24729
#7699 | Received 12 October 2021 | Final received 27 January 2024 | Finally accepted 03 February 2024
OPEN ACCESS

COMMUNICATION

Avifauna of four protected areas of Terai-Arc Landscape, India: significant records and a checklist of species

Shariq Safi [1†], Tanveer Ahmed [2†], Junid Nazeer Shah [3], Meraj Anwar [4] & Kamlesh K. Maurya [5]

[1] Department of Wildlife Sciences, Aligarh Muslim University, Aligarh, Uttar Pradesh 202002, India.
[2] Department of Landscape Planning and Management, Wildlife Institute of India, Dehradun, Uttarakhand 248001, India.
[3] Ajaz Environment Consultants, Sharjah, P.O. Box 48521, UAE.
[4, 5] WWF-India, 172-B, Lodi Estate, New Delhi 110003, India.
[1] shariq4920.ss@gmail.com, [2] tanveerwildlife@gmail.com, [3] jnshah@aj-env.com, [4] anwar.meraj@gmail.com,
[5] kamlesh.wii@gmail.com (corresponding author)
† These authors contributed equally to this work.

Abstract: Protected areas (PAs) in Terai-Arc landscape are relatively poorly explored as far as bird communities are concerned. Here we report a checklist and significant records of birds recorded during opportunistic observations and systematic bird surveys in four PAs: Katerniaghat Wildlife Sanctuary (2001–2004, 2006, 2008, and 2015); Pilibhit Tiger Reserve (2014–15); Valmiki Tiger Reserve (2014–17), and Udaipur Wildlife Sanctuary (2018). We have compiled a checklist of 424 species that includes 358 species in the Katerniaghat Wildlife Sanctuary, 306 species in the Valmiki Tiger Reserve, 236 species in the Pilibhit Tiger Reserve, and 128 species in Udaipur Wildlife Sanctuary. Most species belong to the Insectivore guild (190 species, 44.8%), while the nectivorous guild was the least represented (10 species, 2.35%). A total of 9% of species in the region were either globally threatened (6 Critically Endangered, 5 Endangered, and 8 Vulnerable) or Near Threatened (19 species). Sightings of species of conservation importance have been discussed.

Keywords: Bird diversity, Critically Endangered, globally threatened, Katerniaghat Wildlife Sanctuary, Pilibhit Tiger Reserve, species richness, Udaipur Wildlife Sanctuary, Valmiki Tiger Reserve.

Editor: H. Byju, Coimbatore, Tamil Nadu, India. **Date of publication:** 26 February 2024 (online & print)

Citation: Safi, S., T. Ahmed, J.N. Shah, M. Anwar & K.K. Maurya (2024). Avifauna of four protected areas of Terai-Arc Landscape, India: significant records and a checklist of species. *Journal of Threatened Taxa* 16(2): 24707–24729. https://doi.org/10.11609/jott.7699.16.2.24707-24729

Funding: The study was funded by WWF-India.

Competing interests: The authors declare no competing interests.

Author details: See end of this article.

Author contributions: SS—Data collection, data analysis & visualization, methodology, writing the original draft. TA—Data collection, writing the original draft. JNS—Data collection, review & editing. MA—Supervision, review & editing. KKM—Data collection, conceptualization, supervision, coordination, manuscript review & comments.

Acknowledgements: The authors are thankful to the Environment, Forest and Climate Change Department, Govt. of Uttar Pradesh and Bihar, and protected area managers for permission and their constant support. We are grateful to Mr. Ravi Singh, Dr. Sejal Worah, Dr. Dipankar Ghose, Mr. Yash Magan Sehtia, Dr. Joydeep Bose, Dr. A.K. Singh, Mr. Joy Dasgupta, Dr. Mudit Gupta and Dr. Pranav Chanchani of WWF-India. SS and KKM are greatly acknowledge the support of Mr. Arif Ahmad, Mr. Ahmed Shane Rehman, Ms. Umme Kulsum, Ms. Maryam Nasir and Mr. Rohit Ravi, whose support was instrumental in data collection. Authors are grateful to Mr. Dabeer Hasan, Mr. Fazlur Rahman and Mr. Naresh Kumar for their valuable information.

INTRODUCTION

The Terai-Arc landscape is a part of the Terai-Duar Savanna Eco-region, between River Bagmati (Nepal) to the Yamuna (India) spreading over an area of 30,000 km^2. In India, the region runs parallel to the foothills of the Himalayas encompassing the Shivalik hills, the Bhabar tract, and the Terai plains (Rodgers & Panwar 1988). Once covered with a continuous mosaic of dense forest and tall grassland, the natural vegetation of the region today exists amid human habitation and agricultural land (Johnsingh et al. 2004). The natural vegetation is being conserved and managed under four national parks (NP): Rajaji NP, Corbett NP, Dudhwa NP, and Valmiki NP, along with five wildlife sanctuaries (WS): Sonanadi WS, Kishanpur WS, Katerniaghat WS, Suhelwa WS, and Sohagibarwa WS, which sustain birds and mammals representing Himalayan and Gangetic plain affinities along with many species of national and international importance (Rahmani et al. 1989; Pandey et al. 1994; Chanchani et al. 2014).

Protected areas (PAs) of the Terai-Arc landscape have been explored relatively less as far as bird communities are concerned. Previous research on avifauna was either to assess community structure and status of particular groups or species and has been restricted to limited PAs of this landscape. Pandey et al. (1994) assessed the bird community structure of Rajaji NP. Dhakate et al. (2008) and Kidwai et al. (2013) highlighted the status of water birds and terrestrial birds of Corbett NP respectively. Rahmani et al. (1989) and Javed et al. (1999) determine the status of Bengal Florican *Houbaropsis bengalensis* and Swamp Francolin *Francolinus gularis*, respectively, in Dudhwa NP. Maheswaran & Rahmani (2005) studied the breeding biology of Black-necked Stork *Ephippiorhynchus asiaticus* in Dudhwa NP. Kalam (2005) and Sethy & Chauhan (2011) conducted studies to look at avian diversity in Katerniaghat WS. Very few ornithological studies have been carried out in the Valmiki Tiger Reserve (TR) (Sinha 2012; Choudhury 2016). Hence avifaunal composition of many PAs of the Terai-Arc landscape is not known hitherto and it is therefore desirable to understand the avifaunal composition to bridge the knowledge gap.

STUDY AREA

Avifaunal surveys were carried out in Pilibhit TR and Valmiki TR, and Katerniaghat WS, and Udaipur WS. These PAs are situated on the Indo-Nepal border in Uttar Pradesh and Bihar (Figure 1).

Katerniaghat WS (KWS) (27.916–28.416 °N, 81.000–81.416 °E) covers an area of 400.09 km^2 and is located in the Upper Gangetic plain in the Terai of Bahraich district, Uttar Pradesh, India (Figure 1). KWS was declared as a wildlife sanctuary in 1976. It is connected with Bardia NP in Nepal via the Khata corridor. The Girwa (Karnali) river and a major canal flow through this sanctuary, which is a part of the Dudhwa TR. Other areas of the sanctuary are disturbed because the narrow forest is bisected by a railway line and several roads. The major forest types found here are northern moist deciduous sal forest, northern dry plain sal forest, northern tropical dry deciduous sal forest, tropical seasonal swamp forest, low alluvial savannah, and moist sal savannah forests (WWF-India 2007).

Pilibhit Tiger Reserve (PTR) (28.866–28.767 °N, 79.916–82.250 °E) is spread over an area of 730.24 km^2 and is located in Pilibhit District of Uttar Pradesh, India. It is connected with the Terai-Bhabar forests of the Surai range of Terai East forest division in Uttarakhand in the north-west, Kishanpur WS in the south-east and Shuklaphanta NP in Nepal in the north. PTR supports a mosaic of dry and moist deciduous, scrub savannah and alluvial grasslands (Anwar et al. 2010).

Valmiki Tiger Reserve (VTR) (area 901.2 km^2, 27.167–27.50 °N, 83.833–84.167 °E) is located in the West Champaran district of Bihar in the eastern part of Terai-Arc landscape and the west by the Gandak River. It is contiguous with Nepal's Chitwan NP in the north, sharing a boundary of ~100 km along which is forested habitat. VTR's elevation ranges between 140 m and 874 m. Vegetation is represented by the bhabar dun sal forest, dry Shivalik sal forest, western Gangetic moist mixed deciduous forest, Khair-sissoo forest, cane brakes, eastern wet alluvial grassland, and Barringtonia swamp forest (Champion & Seth 1968; Maurya & Borah 2013) which makes it one of the 16 important bird area (IBA) in Bihar (Rahmani et al. 2016).

Udaipur Wildlife Sanctuary (UWS) (26.778–26.820 °N, 84.406–84.454 °E) encompassing an area of 887.35 ha of forest land is situated in the West Champaran district of Bihar, 50–60 km south to VTR. The unique feature of UWS is its being a forested wetland. The sanctuary has 'Saraiyaman Lake', an IBA (Rahmani et al. 2016). The vegetation is represented by mixed deciduous forest, riverine forest dominated by *Syzygium cumini*, plantation, grasslands, and aquatic vegetation.

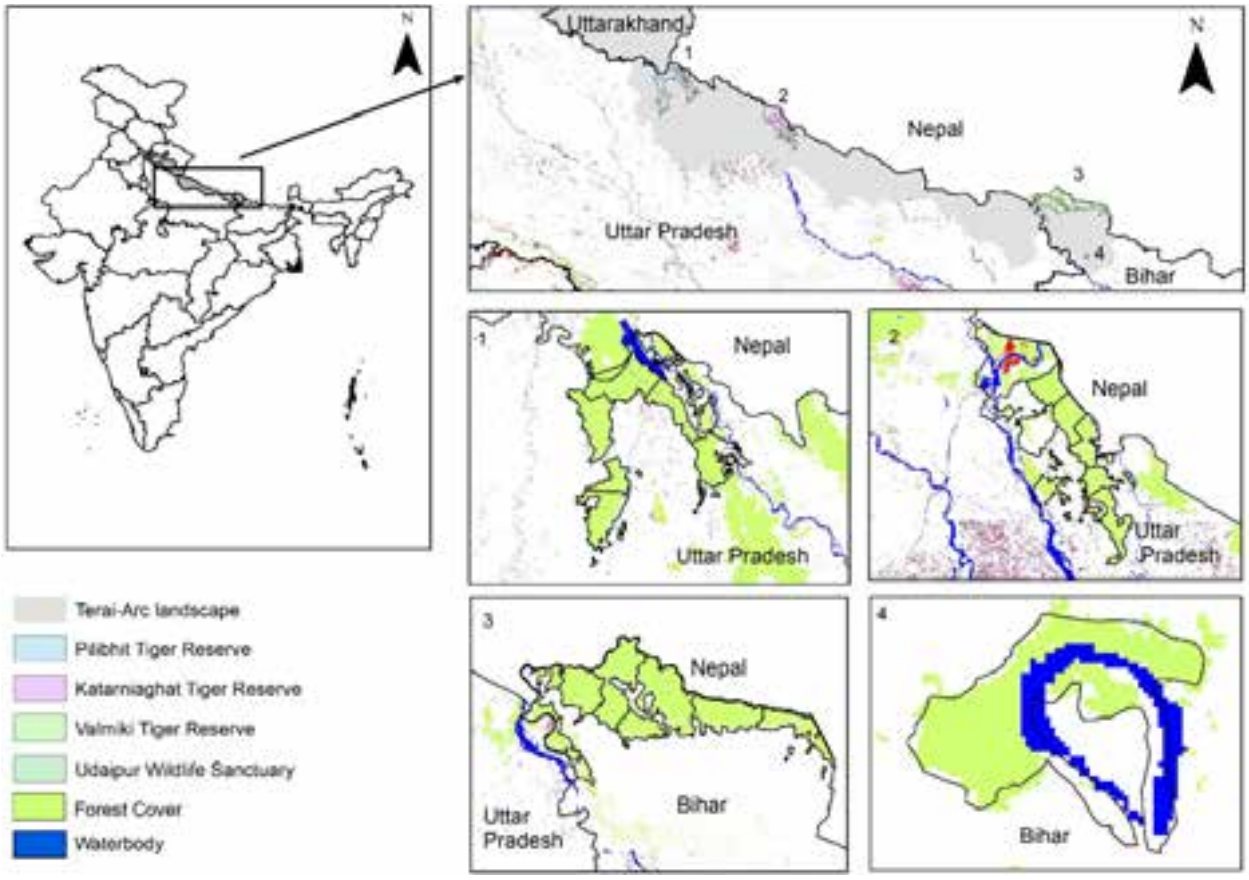


Figure 1. Map of study areas in Terai Arc landscape, India.

METHODS

Birds were recorded traversing trail and road transects in PTR (between March and May 2014, February and May 2015); and KWS (during 2001–2004, 2006, 2008, and 2015) (MacKinnon & Phillips 1993). In VTR, birds were recorded randomly during camera traps exercises and while travelling within the forests between 2014 and 2017. Birds of UWS were surveyed between 17 and 19 February 2018 for terrestrial birds (MacKinnon & Phillips 1993) and the total count method for water birds. Species photo-captured in camera traps (used for tiger census) were also included to compile the species list of each protected area.

MacKinnon's species richness was used for terrestrial species enumeration. One km long linear transects were laid in/along various habitats viz. woodland (sal, sal-mixed, moist riverine, dry riverine, teak plantation), water body (river and streams), grassland, barren land, and scrubland. On each transect, a list of 20 different species in KWS, PTR, and VTR, while a list of 15 species in UWS was generated traversing slowly at a speed of 0.5 km/hr. Once a list was completed, another list was prepared. No species was recorded more than once in each list. A total of 266 lists in KWS, 108 lists in PTR, 58 lists in VTR, and 18 lists in UWS were prepared. Birds were surveyed between 0700 h and 1000 h in the morning and 1600 h to 1900 h in the evening. All the bird species identified by sight or calls were recorded along with their number. Only confirmed identified bird species were included in the study.

The total count method was used to determine the richness of water birds. Species were recorded along with their number from morning hours till noon (0700–1200 h). Since it was not possible to cover the entire 'Saraiyaman Lake' from a single point, birds were counted by selecting more than one point. The survey was not conducted during adverse climatic conditions like rain and cloudy days. Bird species recorded were classified into various feeding guilds and migratory status based on the diet descriptions available (Ali & Ripley 1987; Grimmett et al. 2011). Sorenson's similarity index was used to calculate the similarity between bird species in different study sites using the following formula:

S = 2C/A+B, where,

C—common species between the sites | A—total number of species in site A | B—total number of species in site B.

RESULTS AND DISCUSSION

A checklist of 424 species; 298 terrestrial, 82 water birds, and 44 water-associated ones representing 20 orders and 78 families was compiled from four PAs of the Terai-Arc landscape (Table 1). The diversity of birds might be underestimated because some may have been missed due to their cryptic nature and observer inattention. The total bird species compiled from PAs of Terai-Arc Landscape represents around 30% of the Indian Subcontinent (Praveen et al. 2019) and 47% of the Indian Himalaya (Mandal et al. 2018) indicating that Terai-Arc landscape as among the most avifaunal diverse regions of India. The Terai-Arc landscape is located at the confluence of the Himalaya and Gangetic plains (Rodger & Panwar 1988) and hence supports species of both biogeographic zones.

The richness of species was observed maximum in KWS (n=358), followed by VTR (n = 306), PTR (n = 236), and UWS (n = 128, Table 2). The high richness of birds in KWS may be attributed to the structural complexity and diverse habitat that offer foraging and nesting opportunities to birds (Tews et al. 2004; Ahmed et al. 2019). Moreover, the Terai-Arc landscape is a mosaic of diverse habitat types; sal-forest, sal-mixed forest, dry riverine forest, moist riverine forest, grassland, scrubland, open lands, and wetlands and rivers (Chanchani et al. 2014). Benton et al. (2003) highlighted a heterogeneous landscape is likely to support more species owing to the (a) specialization of various resources and, (b) reduced competition between species (Fahrig et al. 2011) and landscape complementation (Dunning et al. 1992).

The earlier comprehensive study in KWS, conducted by Kalam (2005), reported 154 species, while Sethy & Chauhan (2011) documented 200 species. We report 358 species in KWS, of which 148 species were common with those of Kalam (2005), and 173 species with Sethy & Chauhan (2011). The present study didn't record six species such as Drongo Cuckoo *Surniculus lugubris*, Wallcreeper *Tichodroma muraria,* and Eurasian Blackbird *Turdus merula* reported earlier by Kalam (2005) and 21 species by Sethy & Chauhan (2011). These include Lesser Cuckoo *Cuculus poliocephalus*, Common Flameback *Dinopium javanense*, Red-headed Trogon *Harpactes erythrocephalus*, Rosy Minivet *Pericrocotus roseus*, Red-headed Finch *Amadina erythrocephala* and Caspian Tern *Hydroprogne caspia*.

In VTR, an earlier study conducted by Choudhary (2016) has reported 246 species. Of these, 205 were found common with the present study (n = 306). There are 40 bird species such as Amur Falcon *Falco amurensis*, Vernal Hanging-Parrot *Loriculus vernalis,* Red-breasted Parakeet *Psittacula alexandri,* and Plumbeous Redstart *Rhyacornis fuliginosa* reported by Choudhary (2016) that we didn't report. We recorded 101 different species which were not observed in the earlier study by Choudhary (2016).

In PTR and UWS, no scientific studies have been carried out so far. However, records in the management plan of UWS report 91 species, of which, 89 were common with the present study (n = 128).

Significant records: Threatened Species

Among the species recorded (n = 424), 19 (CR: 6, EN: 5, VU: 8) species were globally threatened and 19 species were near threatened (Table 2, IUCN 2018). The critically endangered (CR) species recorded during the survey were White-rumped Vulture *Gyps bengalensis*, Indian Vulture *Gyps indicus*, Slender-billed Vulture *Gyps tenuirostris*, Red-headed Vulture *Sarcogyps calvus*, Bengal Florican *Houbaropsis bengalensis* and Yellow-breasted Bunting *Emberiza aureola* (IUCN 2018). The sightings of threatened birds are enumerated below:

Vultures

Seven species of vultures: White-rumped Vulture (WRV), Indian Vulture (IV), Slender-billed Vulture (SBV), Red-headed Vulture (RHV), Egyptian Vulture *Neophron percnopterus* (EV), Himalayan Vulture *Gyps himalayensis* (HV) and Griffon Vulture *Gyps fulvus* (GV) were recorded from the PAs of Terai-Arc Landscape. In KWS, a flock of 155 individuals consisting of WRV (n = 152) and IV (n = 3) was sighted feeding on a cattle carcass near Bichia village in 2001. Besides, 32 active nests of WRV were found along the Girwa River. During March 2016, a mixed flock of HV, WRV, and SBV was sighted feeding on carcasses between Dhakerwa town and Bichia market near Katerniaghat WS. In VTR, a mixed flock of WRV and IV were sighted feeding on carcasses in the Harnatand range (36 individuals), perching on a *Bombax ceiba* tree in Valmiki Nagar Range (RHV: 1, HV: 2), and flying over Ganauli range (EV: 1).

Pallas's Fish Eagle *Haliaeetus leucoryphus*

Endangered. In KWS, an active nest of Pallas's Fish Eagle was recorded near Girija Barrage during 2001–

Table 1. Systematic checklist and status of birds in four protected areas of Terai-Arc landscape, India.

Family	Species name	Habitat	Feeding guild	IUCN Red List status	KWS	PTR	VTR	UWS	Status in PAs
Phasianidae	Black Francolin *Francolinus francolinus*	GL	O	LC	2015	2014, 2015	2016	2018	R
Phasianidae	Grey Francolin *Francolinus pondicerianus*	GL/AGR	O	LC	2001, 2002, 2004, 2015	2014, 2015	2014, 2015, 2017	2018	R
Phasianidae	Swamp Francolin *Ortygornis gularis*	ML/GL	O	VU	2001	-	2016	-	R
Phasianidae	Common Quail *Coturnix coturnix*	GL	O	LC	2001, 2002, 2004, 2008, 2015	-	2014, 2016, 2017	-	R
Phasianidae	Small Buttonquail *Turnix sylvaticus*	GL/AGR	O	LC	-	-	2017	-	R
Phasianidae	Jungle Bush Quail *Perdicula asiatica*	GL	O	LC	2002, 2006, 2015	-	-	2018	R
Phasianidae	Rain Quail *Coturnix coromandelica*	GL	O	LC	2002, 2003, 2008	-	-	-	WV
Phasianidae	Blue-breasted Quail *Synoicus chinensis*	GL	O	LC	-	-	2014	-	R
Phasianidae	Red Spurfowl *Galloperdix spadicea*	SF/MF	O	LC	-	2015	-	-	R
Phasianidae	Red Junglefowl *Gallus gallus*	SF/MF	O	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	2018	R
Phasianidae	Kalij Pheasant *Lophura leucomelanos*	SF/MF	O	LC	-	-	2016, 2017	-	R
Phasianidae	Indian Peafowl *Pavo cristatus*	MF	O	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	2018	R
Anatidae	Lesser Whistling Duck *Dendrocygna javanica*	WL	O	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	2018	R
Anatidae	Fulvous Whistling Duck *Dendrocygna bicolor*	WL	H	LC	2001, 2002, 2003, 2006	-	-	-	WV
Anatidae	Greylag Goose *Anser anser*	WL	H	LC	2001, 2002, 2006, 2008	-	-	-	WV
Anatidae	Bar-headed Goose *Anser indicus*	WL	H	LC	2001, 2002, 2006	2014	2016	-	WV
Anatidae	Comb Duck *Sarkidiornis melanotos*	WL	O	LC	2001, 2002, 2003, 2006, 2008, 2015	-	-	-	R
Anatidae	Ruddy Shelduck *Tadorna ferruginea*	WL	O	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2015, 2016, 2017	2018	WV
Anatidae	Cotton Teal *Nettapus coromandelianus*	WL	H	LC	2001, 2003, 2006, 2015	2015	-	2018	R
Anatidae	Gadwall *Mareca strepera*	WL	H	LC	2001, 2003, 2006	-	-	2018	WV
Anatidae	Eurasian Wigeon *Mareca penelope*	WL	H	LC	2002, 2003, 2006, 2015	2014	-	2018	WV
Anatidae	Mallard *Anas platyrhynchos*	WL	H	LC	2002, 2003, 2006	2015	-	2018	WV
Anatidae	Indian Spot-billed Duck *Anas poecilorhyncha*	WL	H	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2015	2015, 2016, 2017	2018	WV
Anatidae	Northern Shoveler *Spatula clypeata*	WL	O	LC	2002, 2006, 2015	2015	-	-	WV
Anatidae	Northern Pintail *Anas acuta*	WL	H	LC	2001, 2002, 2004, 2008, 2015	-	2016, 2017	2018	WV
Anatidae	Garganey *Spatula querquedula*	WL	H	LC	2001, 2002, 2006, 2008, 2015	-	-	-	WV
Anatidae	Green-winged Teal *Anas crecca*	WL	H	LC	2001, 2002, 2006, 2008	-	-	2018	WV
Anatidae	Red-crested Pochard *Netta rufina*	WL	O	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2015, 2016, 2017	2018	WV
Anatidae	Common Pochard *Aythya ferina*	WL	O	LC	2001, 2002, 2006, 2008, 2015	-	-	2018	WV
Anatidae	Ferruginous Duck *Aythya nyroca*	WL	O	NT	2001, 2002, 2006	2016	-	2018	WV
Anatidae	Tufted Duck *Aythya fuligula*	WL	O	LC	2001, 2002, 2008	2014	-	-	WV
Anatidae	Common Merganser *Mergus merganser*	WL	P	LC	2015	-	2017	-	WV
Podicipedidae	Little Grebe *Tachybaptus ruficollis*	WL	O	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2015	2015, 2017	2018	R

Family	Species name	Habitat	Feeding guild	IUCN Red List status	KWS	PTR	VTR	UWS	Status in PAs
Podicipedidae	Great Crested Grebe *Podiceps cristatus*	WL	O	LC	2001, 2004, 2006, 2008, 2015	2015	2015, 2016	2018	WV
Ciconiidae	Painted Stork *Mycteria leucocephala*	WL	P	NT	2015	2014, 2016	2017	-	LM
Ciconiidae	Asian Openbill *Anastomus oscitans*	WL	C	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2015	2015, 2016	2018	R
Ciconiidae	Black Stork *Ciconia nigra*	WL	C	LC	-	-	2016, 2017	-	WV
Ciconiidae	Woolly-necked Stork *Ciconia episcopus*	WL	C	VU	2008, 2015	2014, 2016	2017	-	R
Ciconiidae	White Stork *Ciconia ciconia*	WL	C	LC	2001	2014	-	-	WV
Ciconiidae	Black-necked Stork *Ephippiorhynchus asiaticus*	WL	C	NT	2003	2016	2018	-	R
Ciconiidae	Lesser Adjutant *Leptoptilos javanicus*	WL	C	VU	2006, 2015	2014	2017	-	R
Threskiornithidae	Black-headed Ibis *Threskiornis melanocephalus*	WL	C	NT	2008, 2015	2015	-	-	LM
Threskiornithidae	Red-naped Ibis *Pseudibis papillosa*	WL/ML	C	LC	2003, 2006, 2015	-	2015, 2016	-	LM
Threskiornithidae	Eurasian Spoonbill *Platalea leucorodia*	WL	O	LC	2001, 2002, 2003, 2006, 2008, 2015	-	-	-	LM
Ardeidae	Little Bittern *Ixobrychus minutus*	WL/ML	C	LC	2001, 2002, 2006, 2015	2014	-	-	WV
Ardeidae	Yellow Bittern *Ixobrychus sinensis*	WL/ML	C	LC	2001, 2002, 2003, 2006, 2008, 2015	-	-	-	R
Ardeidae	Cinnamon Bittern *Ixobrychus cinnamomeus*	WL/ML	C	LC	2002, 2004, 2008	-	2015	-	R
Ardeidae	Black Bittern *Ixobrychus flavicollis*	WL/ML	C	LC	2015	-	-	2018	R
Ardeidae	Striated Heron *Butorides striata*	WL/ML	C	LC	2002, 2003, 2008	2015	-	-	R
Ardeidae	Black-crowned Night Heron *Nycticorax nycticorax*	WL	C	LC	2003, 2004	2015	2015	-	R
Ardeidae	Indian Pond Heron *Ardeola grayii*	WL/ML	C	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	2018	R
Ardeidae	Grey Heron *Ardea cinerea*	WL	P	LC	2001, 2002, 2004, 2006, 2008, 2015	2014	2015, 2017	2018	WV
Ardeidae	Purple Heron *Ardea purpurea*	WL	C	LC	2001, 2002, 2004, 2006, 2015	2014, 2015	-	-	R
Ardeidae	White-eared Night Heron *Gorsachius magnificus*	WL/RF	C	EN	-	-	2016	-	R
Ardeidae	Cattle Egret *Bubulcus ibis*	WL/ML	I	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	2018	R
Ardeidae	Great Egret *Ardea alba*	WL	C	LC	2002, 2003, 2008	2014	2016, 2017	-	R
Ardeidae	Intermediate Egret *Ardea intermedia*	WL	C	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2015, 2016, 2017	2018	R
Ardeidae	Little Egret *Egretta garzetta*	WL	C	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014	2014, 2015, 2016, 2017	2018	R
Pelecanidae	Great White Pelican *Pelecanus onocrotalus*	WL	P	LC	2001	-	-	-	WV
Pelecanidae	Spot-billed Pelican *Pelecanus philippensis*	WL	P	NT	2001	-	-	-	WV
Anhingidae	Oriental Darter *Anhinga melanogaster*	WL	P	NT	2002, 2004, 2015, 2016	2016	2016, 2017	-	R
Phalacrocoracidae	Little Cormorant *Microcarbo niger*	WL	P	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2015, 2016, 2017	2018	R
Phalacrocoracidae	Indian Cormorant *Phalacrocorax fuscicollis*	WL	P	LC	2002, 2003, 2006, 2008, 2015	2014, 2015	2016, 2017	-	R
Phalacrocoracidae	Great Cormorant *Phalacrocorax carbo*	WL	P	LC	2001, 2002, 2003, 2006, 2008	2014	2015, 2017	2018	R
Falconidae	Collared Falconet *Microhierax caerulescens*	SF	C	LC	-	-	2017	-	R

Family	Species name	Habitat	Feeding guild	IUCN Red List status	KWS	PTR	VTR	UWS	Status in PAs
Falconidae	Common Kestrel *Falco tinnunculus*	GL	C	LC	2003, 2006	-	2014, 2017	-	WV
Falconidae	Red-necked Falcon *Falco chicquera*	GL	C	LC	-	-	2014	-	R
Falconidae	Eurasian Hobby *Falco subbuteo*	MF/WGL/ AGR	C	LC	-	-	2015	-	PM
Falconidae	Laggar Falcon *Falco jugger*	GL	C	NT	2004	-	2017	-	R
Falconidae	Peregrine Falcon *Falco peregrinus*	ML	C	LC	2002, 2006, 2008	2014	2017	-	WV
Pandionidae	Osprey *Pandion haliaetus*	WL	C	LC	2001, 2002, 2003, 2004, 2008, 2015	2015	2015, 2016	2018	WV
Accipitridae	Black-winged Kite *Elanus caeruleus*	MF/WGL	O	LC	2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	-	R
Accipitridae	Black Kite *Milvus migrans*	MF/WGL	O	LC	2001, 2002, 2003, 2004, 2006, 2008	2014	2015, 2017	2018	R
Accipitridae	Brahminy Kite *Haliastur indus*	WL	C	LC	2008	2015	2014, 2015, 2016	-	WV
Accipitridae	White-tailed Sea Eagle *Haliaeetus albicilla*	WL	C	LC	2003	-	-	-	WV
Accipitridae	Pallas's Fish Eagle *Haliaeetus leucoryphus*	WL	C	EN	2001, 2002, 2016	-	2017	-	WV
Accipitridae	Grey-headed Fish Eagle *Haliaeetus ichthyaetus*	WL/MF	C	NT	2008, 2015	2015	2016	-	R
Accipitridae	Black Eagle *Ictinaetus malaiensis*	MF	C	LC	-	-	2015, 2016	-	R
Accipitridae	Short-toed Snake Eagle *Circaetus gallicus*	WGL/MF	C	LC	2004, 2006	2015	2015	-	R
Accipitridae	Crested Serpent Eagle *Spilornis cheela*	MF/WGL	C	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	2018	R
Accipitridae	Oriental Honey-buzzard *Pernis ptilorhynchus*	MF	I	LC	2001, 2002, 2003, 2004, 2006, 2015	2015	2015, 2016, 2017	2018	R
Accipitridae	Himalayan Buzzard *Buteo refectus*	MF/SF	C	LC	-	-	2015	-	WV
Accipitridae	Egyptian Vulture *Neophron percnopterus*	GL/MF/ RB/AGL	C	EN	2016	2015	2016	2018	R
Accipitridae	White-rumped Vulture *Gyps bengalensis*	GL/RB/ AGL	C	CR	2001, 2002, 2004, 2015, 2016	-	2016	2018	R
Accipitridae	Indian Vulture *Gyps indicus*	RB/AGL/ GL	C	CR	2001	2014	2016	-	LM
Accipitridae	Slender-billed Vulture *Gyps tenuirostris*	AGL	C	CR	2001-2004, 2008, 2016	-	-	-	R
Accipitridae	Himalayan Vulture *Gyps himalayensis*	AGL/RB	C	NT	2016	-	2016	-	WV
Accipitridae	Griffon Vulture *Gyps fulvus*	RB/MF	C	LC	2016	-	-	2018	WV
Accipitridae	Red-headed Vulture *Sarcogyps calvus*	GL/AGR/ MF	C	CR	2015	-	2016	2018	R
Accipitridae	Eurasian Marsh Harrier *Circus aeruginosus*	WL/WGL	C	LC	2001, 2004, 2015	-	2015	2018	WV
Accipitridae	Hen Harrier *Circus cyaneus*	GL	C	LC	2001, 2004	-	2014	-	WV
Accipitridae	Pallid Harrier *Circus macrourus*	GL/WGL/ AGR	C	NT	2004	-	2016	-	WV
Accipitridae	Crested Goshawk *Accipiter trivirgatus*	MF	C	LC	-	-	2016	-	R
Accipitridae	Shikra *Accipiter badius*	MF	C	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	2018	R
Accipitridae	Besra *Accipiter virgatus*	MF	C	LC	-	-	2015	-	R
Accipitridae	Eurasian Sparrowhawk *Accipiter nisus*	MF	C	LC	2006	2015	2015	-	R
Accipitridae	White-eyed Buzzard *Butastur teesa*	MF/GL	C	LC	2001, 2003, 2006	2015	2015	-	R
Accipitridae	Long-legged Buzzard *Buteo rufinus*	MF/GL	C	LC	2001, 2002, 2008	-	-	-	WV
Accipitridae	Greater Spotted Eagle *Clanga clanga*	WL	C	VU	2002	-	2016	-	WV
Accipitridae	Tawny Eagle *Aquila rapax*	MF/WGL	C	LC	2006, 2008	2015	2015	-	R
Accipitridae	Steppe Eagle *Aquila nipalensis*	MF/WGL	C	EN	2001, 2002	-	2014, 2015, 2017	-	WV

Family	Species name	Habitat	Feeding guild	IUCN Red List status	KWS	PTR	VTR	UWS	Status in PAs
Accipitridae	Eastern Imperial Eagle *Aquila heliaca*	WGL/AGR	C	VU	-	-	2016	-	WV
Accipitridae	Bonelli's Eagle *Aquila fasciata*	MF	C	LC	2006, 2015	2015	-	-	R
Accipitridae	Booted Eagle *Hieraaetus pennatus*	MF	C	LC	-	-	2014	-	WV
Accipitridae	Changeable Hawk Eagle *Nisaetus limnaeetus*	MF	C	LC	2002, 2003, 2008	2015	2015, 2017	-	R
Otididae	Bengal Florican *Houbaropsis bengalensis*	GL	O	CR	-	2014	-	-	R
Rallidae	Ruddy-breasted Crake *Zapornia fusca*	ML	O	LC	2004	-	-	-	R
Rallidae	White-breasted Waterhen *Amaurornis phoenicurus*	ML	O	LC	2001, 2002, 2003, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	-	R
Rallidae	Brown Crake *Zapornia akool*	ML	O	LC	2004, 2008	2014	-	-	R
Rallidae	Watercock *Gallicrex cinerea*	ML	O	LC	2002, 2003	-	-	-	SV
Rallidae	Purple Swamphen *Porphyrio porphyrio*	WL	O	LC	2001, 2003, 2008, 2015	2014	2015, 2016	-	R
Rallidae	Common Moorhen *Gallinula chloropus*	ML	O	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	2018	R
Rallidae	Eurasian Coot *Fulica atra*	WL	O	LC	2001, 2002, 2003, 2006, 2015	2015	-	2018	WV
Gruidae	Sarus Crane *Antigone antigone*	ML/WL	O	VU	2001, 2004	2014	2017	-	R
Burhinidae	Eurasian Thick-knee *Burhinus oedicnemus*	GL	I	LC	2001, 2002, 2006, 2008, 2015	-	-	-	R
Burhinidae	Great Thick-knee *Esacus recurvirostris*	GL	I	NT	2006	-	2017	-	R
Jacanidae	Pheasant-tailed Jacana *Hydrophasianus chirurgus*	WL	H	LC	2001, 2002, 2004, 2006, 2008, 2015	-	2015, 2016	2018	R
Jacanidae	Bronze-winged Jacana *Metopidius indicus*	WL	H	LC	2001, 2002, 2003, 2004, 2006, 2015	2015	2015, 2016, 2017	2018	R
Recurvirostridae	Black-winged Stilt *Himantopus himantopus*	WL	O	LC	2004, 2006, 2008	2014	2015, 2016, 2017	-	WV
Charadriidae	River Lapwing *Vanellus duvaucelii*	WL/ML	I	NT	2001, 2002, 2004, 2015	2016	2016	-	R
Charadriidae	Yellow-wattled Lapwing *Vanellus malabaricus*	WL/GL	I	LC	2001, 2006, 2008	-	2015, 2017	2018	R
Charadriidae	Grey-headed Lapwing *Vanellus cinereus*	WL/ML	I	LC	2004	2015	2014	2018	WV
Charadriidae	Red-wattled Lapwing *Vanellus indicus*	WL/GL	I	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	2018	R
Charadriidae	White-tailed Lapwing *Vanellus leucurus*	WL	I	LC	2001	-	-	-	WV
Charadriidae	Pacific Golden Plover *Pluvialis fulva*	ML/GL	I	LC	2002	-	-	-	WV
Charadriidae	Little Ringed Plover *Charadrius dubius*	WL	I	LC	2001, 2002, 2004, 2006, 2015	-	2014, 2015, 2017	-	WV
Rostratulidae	Greater Painted-snipe *Rostratula benghalensis*	WL	O	LC	2001, 2002, 2008, 2015	-	-	-	R
Scolopacidae	Ruff *Calidris pugnax*	WL	I	LC	2001, 2002	-	-	-	WV
Scolopacidae	Jack Snipe *Lymnocryptes minimus*	ML	I	LC	2002, 2003	-	-	-	WV
Scolopacidae	Common Snipe *Gallinago gallinago*	M	O	LC	2006	2014	-	2018	WV
Scolopacidae	Black-tailed Godwit *Limosa limosa*	ML	O	NT	2006	-	-	-	WV
Scolopacidae	Eurasian Curlew *Numenius arquata*	WL	C	NT	2002	-	2016	-	WV
Scolopacidae	Spotted Redshank *Tringa erythropus*	WL	I	LC	2002, 2003, 2006, 2015	-	-	-	WV
Scolopacidae	Common Redshank *Tringa totanus*	WL	I	LC	2006	2015	2015	-	WV
Scolopacidae	Marsh Sandpiper *Tringa stagnatilis*	WL	I	LC	2002, 2003, 2006	-	2014	-	WV
Scolopacidae	Common Greenshank *Tringa nebularia*	WL	C	LC	2008, 2015	-	-	-	WV
Scolopacidae	Green Sandpiper *Tringa ochropus*	WL	I	LC	2001, 2002, 2006, 2008, 2015	-	-	-	WV
Scolopacidae	Wood Sandpiper *Tringa glareola*	WL	P	LC	2008	2014	2015	-	WV

Family	Species name	Habitat	Feeding guild	IUCN Red List status	KWS	PTR	VTR	UWS	Status in PAs
Scolopacidae	Common Sandpiper *Actitis hypoleucos*	WL	I	LC	2001, 2002, 2003, 2006, 2008, 2015	2015	2014, 2016	2018	WV
Scolopacidae	Little Stint *Calidris minuta*	WL	O	LC	2006, 2008	2015	-	-	WV
Scolopacidae	Temminck's Stint *Calidris temminckii*	WL	O	LC	2001, 2002, 2008	-	-	-	WV
Glareolidae	Small Pratincole *Glareola lactea*	GL/WL	I	LC	2001, 2003, 2008	-	2014	-	R
Laridae	Pallas's Gull *Ichthyaetus ichthyaetus*	WL	C	LC	-	2014	2016, 2017	-	WV
Laridae	Brown-headed Gull *Chroicocephalus brunnicephalus*	WL	C	LC	2004, 2006	2015	-	-	PM
Laridae	Black-headed Gull *Chroicocephalus ridibundus*	WL	C	LC	2001, 2002, 2003, 2008, 2015	-	-	-	PM
Laridae	River Tern *Sterna aurantia*	WL	C	NT	2003, 2008	2016	-	-	R
Laridae	Little Tern *Sternula albifrons*	WL	C	LC	2002, 2004, 2006	-	-	-	R
Laridae	Black-bellied Tern *Sterna acuticauda*	WL	C	NT	2004, 2005, 2006, 2008, 2015	-	-	-	R
Laridae	Whiskered Tern *Chlidonias hybrida*	WL	C	LC	2002	2014	-	-	WV
Laridae	Indian Skimmer *Rynchops albicollis*	WL	C	EN	2015	-	-	-	PM
Columbidae	Rock Pigeon *Columba livia*	SF/MF	G	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	2018	R
Columbidae	Oriental Turtle Dove *Streptopelia orientalis*	SF	G	LC	2006, 2008, 2015	-	2015, 2017	-	WV
Columbidae	Eurasian Collared Dove *Streptopelia decaocto*	MF/SF/GL	G	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	2018	R
Columbidae	Red Collared Dove *Streptopelia tranquebarica*	GL	G	LC	2003, 2006, 2015	2015	2015, 2016	-	R
Columbidae	Spotted Dove *Stigmatopelia chinensis*	SF/MF	G	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	2018	R
Columbidae	Laughing Dove *Stigmatopelia senegalensis*	MF/GL	G	LC	2003, 2004, 2006, 2008, 2015	2015	2014, 2016	-	R
Columbidae	Orange-breasted Green Pigeon *Treron bicinctus*	SF/MF	F	LC	2001, 2002, 2006	2014, 2015	2014, 2015	-	R
Columbidae	Yellow-footed Green Pigeon *Treron phoenicopterus*	SF/MF	F	LC	2001, 2002, 2003, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	-	R
Columbidae	Pin-tailed Green Pigeon *Treron apicauda*	SF/MF	F	LC	2003, 2004, 2006, 2008	-	-	-	R
Columbidae	Ashy-headed Green Pigeon *Treron phayrei*	SF/MF	F	NT	-	-	2017	-	R
Columbidae	Emerald Dove *Chalcophaps indica*	SF	F	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	2018	R
Psittacidae	Alexandrine Parakeet *Psittacula eupatria*	MF/WGL	F	NT	2015	2015	2017	2018	R
Psittacidae	Rose-ringed Parakeet *Psittacula krameri*	MF/WGL	F	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	2018	R
Psittacidae	Plum-headed Parakeet *Psittacula cyanocephala*	MF/WGL	F	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	2018	R
Psittacidae	Slaty-headed Parakeet *Psittacula himalayana*	MF/WGL	F	LC	2002, 2003, 2015	-	-	-	R
Cuculidae	Pied Cuckoo *Clamator jacobinus*	MF/WGL	I	LC	2002, 2004, 2008	-	2015, 2017	-	SV
Cuculidae	Chestnut-winged Cuckoo *Clamator coromandus*	MF	I	LC	-	-	2015, 2016	-	SV
Cuculidae	Common Hawk Cuckoo *Hierococcyx varius*	MF/WGL	I	LC	2001, 2002, 2003, 2006, 2008, 2015	2015	2015, 2016, 2017	2018	R
Cuculidae	Indian Cuckoo *Cuculus micropterus*	MF/SF	I	LC	2002, 2003	2014	2015, 2016	-	SV
Cuculidae	Eurasian Cuckoo *Cuculus canorus*	MF/SF/GL	I	LC	2001, 2002	2015	2015, 2016	-	SV
Cuculidae	Banded Bay Cuckoo *Cacomantis sonneratii*	MF	I	LC	2002, 2003	-	-	-	R

Family	Species name	Habitat	Feeding guild	IUCN Red List status	KWS	PTR	VTR	UWS	Status in PAs
Cuculidae	Grey-bellied Cuckoo *Cacomantis passerinus*	GL/WGL	I	LC	2001	-	-	-	SV
Cuculidae	Asian Emerald Cuckoo *Chrysococcyx maculatus*	MF/SF	I	LC	2002, 2006, 2015	-	-	-	SV
Cuculidae	Drongo Cuckoo *Surniculus lugubris*	MF	I	LC	-	-	2015	-	SV
Cuculidae	Asian Koel *Eudynamys scolopaceus*	MF/SF	F	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2015	2014, 2015, 2016, 2017	2018	R
Cuculidae	Green-billed Malkoha *Phaenicophaeus tristis*	MF	I	LC	2008, 2015	2015	2014, 2016	-	R
Cuculidae	Sirkeer Malkoha *Taccocua leschenaultii*	MF/GL/ WGL	F	LC	2015	-	2015, 2017	-	R
Cuculidae	Greater Coucal *Centropus sinensis*	MF/WGL	O	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	2018	R
Cuculidae	Lesser Coucal *Centropus bengalensis*	GL	O	LC	2006	2014	2015	-	R
Tytonidae	Barn Owl *Tyto alba*	GL/MF	C	LC	2001, 2008	2015	2014, 2016	-	R
Tytonidae	Eastern Grass Owl *Tyto longimembris*	GL	C	LC	2001, 2006, 2015	-	-	-	R
Strigidae	Collared Scops Owl *Otus lettia*	MF/WGL	C	LC	2001, 2003	2015	-	-	R
Strigidae	Oriental Scops Owl *Otus sunia*	MF/AGR	C	LC	2015	-	2014, 2017	-	R
Strigidae	Indian Scops Owl *Otus bakkamoena*	MF/SF	C	LC	-	-	2015, 2016, 2017	-	R
Strigidae	Asian Barred Owlet *Glaucidium cuculoides*	SF/MF/GL	C	LC	2002, 2006, 2008, 2015	2014, 2015	2015, 2017	-	R
Strigidae	Jungle Owlet *Glaucidium radiatum*	SF/MF/GL	C	LC	2004, 2006	2014	2015, 2016, 2017	-	R
Strigidae	Spotted Owlet *Athene brama*	WGL/MF	C	LC	2001, 2002, 2004, 2006, 2008, 2015	2015	2014, 2016, 2017	2018	R
Strigidae	Eurasian Eagle Owl *Bubo bubo*	SF/MF/GL	C	LC	2001, 2006, 2015	-	-	-	R
Strigidae	Dusky Eagle Owl *Bubo coromandus*	SF	C	LC	2001, 2002, 2006	-	-	-	R
Strigidae	Brown Fish Owl *Ketupa zeylonensis*	WL/MF	C	LC	2001, 2003, 2004, 2015	-	2015, 2016, 2017	2018	R
Strigidae	Brown Wood Owl *Strix leptogrammica*	SF/MF	C	LC	2001, 2006	-	-	-	R
Strigidae	Brown Hawk Owl *Ninox scutulata*	MF	C	LC	2015	2014, 2015	2014, 2015, 2017	-	R
Caprimulgidae	Large-tailed Nightjar *Caprimulgus macrurus*	SF/WGL	I	LC	2002, 2006, 2008	-	2014, 2015, 2017	-	R
Caprimulgidae	Grey Nightjar *Caprimulgus indicus*	MF/SF	I	LC	-	-	2015	-	R
Caprimulgidae	Indian Nightjar *Caprimulgus asiaticus*	MF	I	LC	2002, 2003, 2015	2015	2014	-	R
Caprimulgidae	Savanna Nightjar *Caprimulgus affinis*	MF/WGL	I	LC	2002, 2003	-	-	-	R
Hemiprocnidae	Crested Treeswift *Hemiprocne coronata*	MF/WGL	I	LC	2002, 2003, 2006	-	-	-	R
Apodidae	Asian Palm Swift *Cypsiurus balasiensis*	AGR/WGL	I	LC	2015	2015	2014, 2015	-	R
Apodidae	Little Swift *Apus affinis*	AGR/GL	I	LC	2006, 2008	-	2014, 2016	-	R
Apodidae	White-rumped Needletail *Zoonavena sylvatica*	MF	I	LC	-	-	2016	-	LM
Upupidae	Common Hoopoe *Upupa epops*	GL/WGL/ AGR	I	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	2018	R
Coraciidae	Indian Roller *Coracias benghalensis*	MF/GL	I	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	2018	R
Coraciidae	Dollarbird *Eurystomus orientalis*	SF/MF	I	LC	-	-	2016, 2017	-	R
Alcedinidae	Stork-billed Kingfisher *Pelargopsis capensis*	WL/RF	P	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	2018	R

Family	Species name	Habitat	Feeding guild	IUCN Red List status	KWS	PTR	VTR	UWS	Status in PAs
Alcedinidae	White-throated Kingfisher *Halcyon smyrnensis*	WL/RF/GL	P	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	2018	R
Alcedinidae	Black-capped Kingfisher *Halcyon pileata*	WL	P	LC	-	-	2014	-	PM
Alcedinidae	Common Kingfisher *Alcedo atthis*	WL	P	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	2018	R
Alcedinidae	Crested Kingfisher *Megaceryle lugubris*	WL	P	LC	2001, 2002, 2004, 2006	-	-	-	R
Alcedinidae	Pied Kingfisher *Ceryle rudis*	WL	P	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	2018	R
Meropidae	Blue-bearded Bee-eater *Nyctyornis athertoni*	MF/GL	I	LC	2002, 2003, 2004, 2008, 2015	2014, 2015	2015. 2016, 2017	-	R
Meropidae	Green Bee-eater *Merops orientalis*	MF/GL/WGL	I	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	2018	R
Meropidae	Blue-tailed Bee-eater *Merops philippinus*	MF/GL/WGL	I	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2015, 2016, 2017	2018	SV
Meropidae	Chestnut-headed Bee-eater *Merops leschenaulti*	MF/GL/WGL	I	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014	2014, 2015, 2016, 2017	2018	SV
Bucerotidae	Indian Grey Hornbill *Ocyceros birostris*	SF/MF/GL	F	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	2018	R
Bucerotidae	Oriental Pied Hornbill *Anthracoceros albirostris*	SF/MF/WGL	F	LC	2002, 2003, 2006, 2015	2014, 2015	2014, 2015, 2016, 2017	-	R
Bucerotidae	Great Hornbill *Buceros bicornis*	SF/MF	F	NT	2015	2016	2017	-	R
Megalaimidae	Brown-headed Barbet *Psilopogon zeylanicus*	SF/WGL	F	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	2018	R
Megalaimidae	Lineated Barbet *Psilopogon lineatus*	MF/AGR/SF	F	LC	-	2014	2014	-	R
Megalaimidae	Blue-throated Barbet *Psilopogon asiaticus*	SF/WGL	F	LC	2002, 2006, 2008, 2015	-	2017	-	R
Megalaimidae	Coppersmith Barbet *Psilopogon haemacephalus*	SF/MF/WGL	F	LC	2001, 2002, 2015	2014	2015, 2016, 2017	-	R
Picidae	Eurasian Wryneck *Jynx torquilla*	SF/RF/MF	I	LC	2008	-	2015	-	WV
Picidae	Speckled Piculet *Picumnus innominatus*	SF/MF	I	LC	-	-	2015	-	R
Picidae	Rufous Woodpecker *Micropternus brachyurus*	SF/WGL	I	LC	2002, 2006	2015	2014, 2015	-	R
Picidae	Great Slaty Woodpecker *Mulleripicus pulverulentus*	SF	I	VU	2004	2014	2017	-	R
Picidae	Brown-capped Pygmy Woodpecker *Yungipicus nanus*	RF/MF/SF/WGL	I	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2015	2014, 2015, 2016, 2017	2018	R
Picidae	Grey-capped Pygmy Woodpecker *Yungipicus canicapillus*	RF/MF/SF/WGL	I	LC	2001, 2002, 2003, 2004, 2008, 2015	2014	2014, 2015, 2016	2018	R
Picidae	Fulvous-breasted Woodpecker *Dendrocopos macei*	SF	I	LC	-	-	2014, 2016	2018	R
Picidae	Yellow-crowned Woodpecker *Leiopicus mahrattensis*	MF/WGL	I	LC	2015	2015	2015, 2016	-	R
Picidae	Lesser Yellownape *Picus chlorolophus*	SF	I	LC	2001, 2002, 2003, 2008, 2015	-	-	-	R
Picidae	Greater Yellownape *Chrysophlegma flavinucha*	SF	I	LC	2001, 2006	-	2015, 2016	-	R
Picidae	Streak-throated Woodpecker *Picus xanthopygaeus*	SF/WGL	I	LC	2003, 2006, 2015	2014, 2015	-	-	R
Picidae	Scaly-bellied Woodpecker *Picus squamatus*	SF/WGL	I	LC	2002, 2006, 2008	2015	-	-	R
Picidae	Grey-headed Woodpecker *Picus canus*	SF	I	LC	2001, 2003, 2008, 2015	2014, 2015	2014, 2015, 2016	-	R

Family	Species name	Habitat	Feeding guild	IUCN Red List status	KWS	PTR	VTR	UWS	Status in PAs
Picidae	Himalayan Golden-backed Woodpecker *Dinopium shorii*	SF/MF/ RF/WGL	I	LC	2008, 2015	2014	-	2018	R
Picidae	Lesser Golden-backed Woodpecker *Dinopium benghalense*	SF/MF/ RF/WGL	I	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	2018	R
Picidae	Greater Golden-backed Woodpecker *Chrysocolaptes lucidus*	SF/WGL	I	LC	2006, 2015	2015	2016, 2017	-	R
Picidae	White-naped Woodpecker *Chrysocolaptes festivus*	SF/WGL	I	LC	-	2015	-	-	R
Pittidae	Indian Pitta *Pitta brachyura*	SF	I	LC	2001, 2002	2015	2016, 2017	-	SV
Tephrodornithidae	Large Woodshrike *Tephrodornis virgatus*	SF/MF/ WGL	I	LC	2015	2015	2014, 2015, 2016	-	R
Tephrodornithidae	Common Woodshrike *Tephrodornis pondicerianus*	GL/SF/ WGL	I	LC	2001	2015	2014, 2015, 2016	-	R
Artamidae	Ashy Woodswallow *Artamus fuscus*	SF	I	LC	2003, 2004, 2006	-	-	-	R
Campephagidae	Large Cuckooshrike *Coracina macei*	SF/WGL	I	LC	2001, 2003, 2008	2015	2014, 2017	2018	SV
Campephagidae	Black-winged Cuckooshrike *Lalage melaschistos*	SF/MF	I	LC	-	-	2015	2018	R
Campephagidae	Black-headed Cuckooshrike *Lalage melanoptera*	SF/MF	I	LC	-	-	2015, 2016	-	R
Campephagidae	Bar-winged Flycatcher-shrike *Hemipus picatus*	SF/RF/ MF/WGL	I	LC	-	-	2014, 2015, 2017	-	R
Aegithinidae	Common Iora *Aegithina tiphia*	SF/RF/ MF/WGL	I	LC	2002, 2008, 2015	2014	2014, 2015, 2016	-	R
Campephagidae	Small Minivet *Pericrocotus cinnamomeus*	SF/MF/ WGL	I	LC	2002, 2004, 2006, 2008, 2015	2015	2014, 2015, 2016	2018	R
Campephagidae	Long-tailed Minivet *Pericrocotus ethologus*	SF/RF	I	LC	2002, 2003, 2008, 2015	2014	2014, 2015, 2016	-	R
Campephagidae	Short-billed Minivet *Pericrocotus brevirostris*	SF	I	LC	2002, 2004	-	2014	-	R
Campephagidae	Scarlet Minivet *Pericrocotus speciosus*	SF/MF	I	LC	2002, 2003, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	-	R
Laniidae	Brown Shrike *Lanius cristatus*	MF/AGR	I	LC	2015	-	2014, 2015	-	WV
Laniidae	Bay-backed Shrike *Lanius vittatus*	WGL	I	LC	2002	2015	2015, 2016	-	R
Laniidae	Long-tailed Shrike *Lanius schach*	WGL	C	LC	2003, 2008	2014	2014, 2015	-	R
Laniidae	Great Grey Shrike *Lanius excubitor*	MF/AGR	C	LC	-	-	2015	-	VA
Laniidae	Grey-backed Shrike *Lanius tephronotus*	AGR/MF	C	LC	2003	2015	-	-	WV
Laniidae	Isabelline Shrike *Lanius isabellinus*	WGL	C	LC	2015	2015	-	-	WV
Dicruridae	Lesser Racket-tailed Drongo *Dicrurus remifer*	SF/MF	I	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	2018	R
Dicruridae	Greater Racket-tailed Drongo *Dicrurus paradiseus*	SF/MF	I	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	2018	R
Dicruridae	Spangled Drongo *Dicrurus bracteatus*	SF/MF	I	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014	2014, 2015, 2016, 2017	2018	R
Dicruridae	Black Drongo *Dicrurus macrocercus*	SF/MF/ WGL	I	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	2018	R
Dicruridae	Ashy Drongo *Dicrurus leucophaeus*	SF	I	LC	2001, 2002, 2003, 2004, 2008, 2015	2014, 2015	2015, 2016, 2017	2018	WV
Dicruridae	White-bellied Drongo *Dicrurus caerulescens*	SF/MF/ WGL/RF	I	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	2018	R
Dicruridae	Crow-billed Drongo *Dicrurus annectans*	SF/MF/GL	I	LC	2003, 2015	2014	2015, 2016	-	SV
Oriolidae	Indian Golden Oriole *Oriolus kundoo*	MF/WGL	I	LC	2002, 2008, 2015	2014	2015, 2016	-	R
Oriolidae	Black-hooded Oriole *Oriolus xanthornus*	SF/MF/ WGL/RF	I	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	2018	R

Family	Species name	Habitat	Feeding guild	IUCN Red List status	KWS	PTR	VTR	UWS	Status in PAs
Stenostiridae	Yellow-bellied Fantail *Chelidorhynx hypoxanthus*	SF/MF/ WGL	I	LC	2001, 2002, 2008, 2015	-	-	-	WV
Rhipiduridae	White-throated Fantail *Rhipidura albicollis*	WGL/GL	I	LC	2001, 2004, 2006, 2008, 2015	2015	2014, 2016	2018	WV
Rhipiduridae	White-browed Fantail *Rhipidura aureola*	SF/MF/ WGL	I	LC	2001, 2002, 2008	2015	2015	-	R
Monarchidae	Indian Paradise-flycatcher *Terpsiphone paradisi*	SF/RF	I	LC	2001, 2002, 2004, 2006, 2008, 2015	2015	2014, 2015, 2016, 2017	-	SV
Monarchidae	Black-naped Monarch *Hypothymis azurea*	SF/RF	I	LC	2006	-	2017	-	WV
Corvidae	Red-billed Blue Magpie *Urocissa erythrorhyncha*	SF/MF/RF	O	LC	-	-	2014, 2015, 2016, 2017	-	R
Corvidae	Common Green Magpie *Cissa chinensis*	SF/RF	C	LC	-	-	2016, 2017	-	R
Corvidae	Rufous Treepie *Dendrocitta vagabunda*	SF/MF/ WGL	O	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	2018	R
Corvidae	Large-billed Crow *Corvus macrorhynchos*	SF/MF/ WGL	C	LC	2001, 2002, 2003, 2004, 2006, 2015	-	2014, 2015, 2016	2018	R
Corvidae	House Crow *Corvus splendens*	MF/AGR	C	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	2018	R
Paridae	Cinereous Tit *Parus cinereus*	SF/MF/ WGL/RF	I	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	2018	R
Paridae	Green-backed Tit *Parus monticolus*	SF/MF	I	LC	-	-	2014	-	R
Paridae	Black-lored Tit *Machlolophus xanthogenys*	SF/MF	I	LC	-	-	2015	-	R
Paridae	Fire-capped Tit *Cephalopyrus flammiceps*	MF/RF	I	LC	2002, 2003	-	-	-	WV
Hirundinidae	Plain Martin *Riparia paludicola*	WL/ML	I	LC	2002, 2004, 2008, 2015	-	2014, 2015, 2016	2018	R
Hirundinidae	Sand Martin *Riparia riparia*	WL/ML/ WGL	I	LC	2003, 2008	2015	-	-	WV
Hirundinidae	Eurasian Crag Martin *Ptyonoprogne rupestris*	ML/WL	I	LC	2001	2014	2015	-	WV
Hirundinidae	Dusky Crag Martin *Ptyonoprogne concolor*	ML/WL	I	LC	2001, 2004, 2006	-	2015	-	R
Hirundinidae	Streak-throated Swallow *Petrochelidon fluvicola*	GL/ML	I	LC	2002, 2003	2015	-	-	R
Hirundinidae	Wire-tailed Swallow *Hirundo smithii*	GL/WGL/ AGR	I	LC	2001, 2002, 2003, 2008, 2015	2014, 2015	-	-	R
Hirundinidae	Barn Swallow *Hirundo rustica*	GL/ML	I	LC	2002, 2006, 2008, 2015	2014, 2015	-	2018	WV
Hirundinidae	Red-rumped Swallow *Cecropis daurica*	GL/ML	I	LC	2001, 2004, 2008	2015	-	-	R
Alaudidae	Singing Bushlark *Mirafra cantillans*	GL	G, I	LC	2006	-	2015	-	R
Alaudidae	Bengal Bushlark *Mirafra assamica*	GL	G, I	LC	2015	2014	2016	-	R
Alaudidae	Indian Bushlark *Mirafra erythroptera*	GL/AGR	G, I	LC	2001, 2006, 2008	2015	2014, 2015, 2016	-	R
Alaudidae	Rufous-tailed Lark *Ammomanes phoenicura*	GL	G, I	LC	-	-	2015	-	R
Alaudidae	Sand Lark *Alaudala raytal*	ML/GL	G, I	LC	-	-	2014, 2015	-	R
Alaudidae	Ashy-crowned Sparrow Lark *Eremopterix griseus*	AGR/GL	G, I	LC	-	-	2015	-	R
Alaudidae	Crested Lark *Galerida cristata*	GL/AGR	G, I	LC	2015	2014	-	-	R
Alaudidae	Oriental Skylark *Alauda gulgula*	GL/AGR	G, I	LC	2004, 2006	-	2015	-	R
Pycnonotidae	Himalayan Bulbul *Pycnonotus leucogenys*	MF/RF	I	LC	2001, 2002, 2004, 2006, 2015	-	2014, 2015, 2016, 2017	-	R
Pycnonotidae	Black-crested Bulbul *Rubigula flaviventris*	SF/MF	I	LC	-	-	2014, 2015, 2017	-	R
Pycnonotidae	Red-whiskered Bulbul *Pycnonotus jocosus*	SF/MF/RF	I	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	2018	R

Family	Species name	Habitat	Feeding guild	IUCN Red List status	KWS	PTR	VTR	UWS	Status in PAs
Pycnonotidae	Red-vented Bulbul *Pycnonotus cafer*	SF/MF/ WGL	I	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	2018	R
Pycnonotidae	Black Bulbul *Hypsipetes leucocephalus*	SF/MF	I	LC	-	-	2014, 2017	-	R
Cisticolidae	Grey-breasted Prinia *Prinia hodgsonii*	GL/WGL	N	LC	2006, 2008, 2015	2015	2015, 2016	-	R
Cisticolidae	Jungle Prinia *Prinia sylvatica*	GL	I	LC	2004, 2008, 2015	2015	2015, 2016	-	R
Cisticolidae	Yellow-bellied Prinia *Prinia flaviventris*	GL	I	LC	2001, 2002, 2004, 2015	-	2015, 2016	-	R
Cisticolidae	Ashy Prinia *Prinia socialis*	GL/WGL	N	LC	2001, 2008	2015	2014, 2017	-	R
Cisticolidae	Plain Prinia *Prinia inornata*	GL/WGL	N	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2015	2014, 2015, 2016, 2017	2018	R
Cisticolidae	Zitting Cisticola *Cisticola juncidis*	GL	I	LC	2001, 2002, 2003, 2004, 2015	2015	2014, 2015, 2017	2018	R
Cisticolidae	Golden-headed Cisticola *Cisticola exilis*	GL	I	LC	2001, 2002, 2003	-	-	-	R
Cisticolidae	Common Tailorbird *Orthotomus sutorius*	SF/MF/ WGL	I	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	2018	R
Locustellidae	Striated Grassbird *Megalurus palustris*	ML	I	LC	2003	2014	2015	-	R
Scotocercidae	Grey-sided Bush Warbler *Cettia brunnifrons*	GL	I	LC	2001, 2003	-	-	-	WV
Locustellidae	West Himalayan Bush Warbler *Locustella kashmirensis*	GL	I	LC	2003, 2004	-	-	-	WV
Locustellidae	Grasshopper Warbler *Locustella naevia*	ML	I	LC	2004, 2006	-	-	-	WV
Pellorneidae	Rufous-rumped Grassbird *Graminicola bengalensis*	GL	I	LC	2001	2014	2015	-	R
Acrocephalidae	Clamorous Reed Warbler *Acrocephalus stentoreus*	ML	I	LC	2001, 2002, 2008, 2015	-	2015	2018	WV
Acrocephalidae	Paddyfield Warbler *Acrocephalus agricola*	ML	I	LC	2002, 2003, 2006	-	2014, 2016	-	WV
Acrocephalidae	Blyth's Reed Warbler *Acrocephalus dumetorum*	ML	I	LC	2002, 2003, 2004, 2006	-	2014, 2015, 2016	-	WV
Scotocercidae	Grey-bellied Tesia *Tesia cyaniventer*	SF	I	LC	2002, 2003	-	-	-	WV
Phylloscopidae	Common Chiffchaff *Phylloscopus collybita*	MF/WGL	I	LC	2004, 2006	2015	2014, 2017	2018	WV
Phylloscopidae	Dusky Warbler *Phylloscopus fuscatus*	GL	I	LC	-	-	2014	-	WV
Phylloscopidae	Smoky Warbler *Phylloscopus fuligiventer*	WL	I	LC	2003, 2006	2015	-	-	WV
Phylloscopidae	Tickell's Leaf Warbler *Phylloscopus affinis*	MF/AGR	I	LC	2015	-	2014	-	WV
Phylloscopidae	Yellow-browed Warbler *Phylloscopus inornatus*	SF/MF/ RF/WGL	I	LC	2001, 2002, 2003, 2008	-	-	-	WV
Phylloscopidae	Hume's Leaf Warbler *Phylloscopus humei*	MF/SF/ RF/WGL	I	LC	2001, 2004, 2006	2015	2014, 2016	2018	WV
Phylloscopidae	Greenish Warbler *Phylloscopus trochiloides*	SF/MF/RF	I	LC	2001, 2003, 2015	2015	2014, 2015, 2016	-	WV
Phylloscopidae	Blyth's Leaf Warbler *Phylloscopus reguloides*	SF/MF/ WGL	I	LC	2002, 2006	2014	2015	-	WV
Phylloscopidae	Western Crowned Warbler *Phylloscopus occipitalis*	SF/MF/ RF/WGL	I	LC	2001, 2002, 2003, 2006, 2008	-	-	-	WV
Leiothrichidae	Nepal Fulvetta *Alcippe nipalensis*	SF/MF	I	LC	-	-	2014, 2017	-	R
Sylviidae	Lesser Whitethroat *Curruca curruca*	MF/SF	I	LC	2015	-	2014, 2015, 2016	-	WV
Sylviidae	Eastern Orphean Warbler *Curruca crassirostris*	MF/ SCRUB	I	LC	-	-	2014	-	WV
Pellorneidae	Puff-throated Babbler *Pellorneum ruficeps*	SF/MF	I	LC	-	-	2014, 2015, 2017	-	R
Timaliidae	Pin-striped Tit Babbler *Mixornis gularis*	MF/WGL	I	LC	2003	2015	2015	-	R

Family	Species name	Habitat	Feeding guild	IUCN Red List status	KWS	PTR	VTR	UWS	Status in PAs
Timaliidae	Chestnut-capped Babbler *Timalia pileata*	GL	I	LC	2006, 2008, 2015	2015	-	-	R
Timaliidae	Tawny-bellied Babbler *Dumetia hyperythra*	MF/WGL	I	LC	2004, 2006	-	2014	-	R
Leiothrichidae	Common Babbler *Argya caudata*	MF	O	LC	2001, 2002, 2003, 2008, 2015	-	2014, 2015, 2016, 2017	-	R
Leiothrichidae	Striated Babbler *Argya earlei*	ML	O	LC	2001, 2002, 2006	2015	-	-	R
Leiothrichidae	Large Grey Babbler *Argya malcolmi*	MF/WGL	O	LC	2002, 2006	2014, 2015	2016, 2017	-	R
Leiothrichidae	Jungle Babbler *Argya striata*	MF/WGL	O	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	2018	R
Sylviidae	Yellow-eyed Babbler *Chrysomma sinense*	GL/WGL	O	LC	2001, 2003, 2008	2014, 2015	2015	-	R
Leiothrichidae	White-throated Laughingthrush *Garrulax albogularis*	SF/MF	I	LC	-	-	2014, 2016	-	R
Leiothrichidae	Lesser Necklaced Laughingthrush *Garrulax monileger*	SF/MF	I	LC	-	-	2016, 2017	-	R
Leiothrichidae	Greater Necklaced Laughingthrush *Garrulax pectoralis*	SF/MF	I	LC	-	-	2016, 2017	-	R
Zosteropidae	Oriental White-Eye *Zosterops palpebrosus*	SF/MF	I	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2015	2014, 2015, 2016, 2017	2018	R
Sittidae	Indian Nuthatch *Sitta castanea*	SF/MF	I	LC	2003, 2004, 2008	-	2014, 2016	-	R
Sittidae	Chestnut-bellied Nuthatch *Sitta cinnamoventris*	SF/MF	I	LC	2001, 2003, 2008	2015	2014, 2015, 2016	-	R
Sittidae	Velvet-fronted Nuthatch *Sitta frontalis*	SF/MF	I	LC	2001, 2002, 2003, 2006, 2015	-	2014, 2015, 2016	-	R
Certhiidae	Bar-tailed Treecreeper *Certhia himalayana*	SF	I	LC	2001, 2002, 2003, 2006, 2008, 2015	-	-	-	WV
Sturnidae	Jungle Myna *Acridotheres fuscus*	MF/WGL	O	LC	2001, 2003, 2006, 2008, 2015	2015	2014, 2015, 2016	-	R
Sturnidae	Bank Myna *Acridotheres ginginianus*	GL/WGL	O	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	2018	R
Sturnidae	Common Myna *Acridotheres tristis*	GL/WGL	O	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	2018	R
Sturnidae	Hill Myna *Gracula religiosa*	MF	O	LC	-	-	2015, 2016, 2017	-	R
Sturnidae	Asian Pied Starling *Gracupica contra*	WGL	O	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	2018	R
Sturnidae	Chestnut-tailed Starling *Sturnia malabarica*	WGL	O	LC	2001, 2002, 2008	2015	2015, 2016	-	R
Sturnidae	Brahminy Starling *Sturnia pagodarum*	MF/WGL	O	LC	2002, 2003, 2008, 2015	-	2016, 2017	2018	R
Sturnidae	European Starling *Sturnus vulgaris*	GL/AGR	O	LC	2002, 2003, 2006, 2015	2014, 2015	-	2018	WV
Sturnidae	Rosy Starling *Pastor roseus*	GL/AGR	F	LC	-	-	2015, 2017	-	PM
Sturnidae	Spot-winged Starling *Saroglossa spilopterus*	SF/MF	I	LC	-	-	2015	-	SV
Muscicapidae	Blue Whistling Thrush *Myophonus caeruleus*	SF	I	LC	2001, 2003, 2006, 2015	2015	2014, 2017	-	WV
Turdidae	Orange-headed Thrush *Geokichla citrina*	SF/MF	I	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2015, 2016, 2017	2018	R
Turdidae	Scaly Thrush *Zoothera dauma*	SF/MF	O	LC	-	-	2016	-	WV
Turdidae	Grey-winged Blackbird *Turdus boulboul*	SF	I	LC	2003, 2006	-	-	-	WV
Turdidae	Tibetan Blackbird *Turdus maximus*	SF	I	LC	-	-	2014, 2016, 2017	-	WV
Turdidae	Tickell's Thrush *Turdus unicolor*	MF	O	LC	-	-	-	2018	WV
Turdidae	Black-throated Thrush *Turdus atrogularis*	WGL	I	LC	2008, 2015	2015	2016	-	WV

Family	Species name	Habitat	Feeding guild	IUCN Red List status	KWS	PTR	VTR	UWS	Status in PAs
Muscicapidae	Bluethroat *Luscinia svecica*	GL/WL	I	LC	2006, 2008, 2015	2015	-	-	WV
Muscicapidae	Siberian Rubythroat *Calliope calliope*	GL/WL	I	LC	2001, 2002, 2008, 2015	-	2015, 2016	-	WV
Muscicapidae	Himalayan Rubythroat *Calliope pectoralis*	GL	I	LC	2002, 2003, 2006	-	-	-	WV
Muscicapidae	Oriental Magpie Robin *Copsychus saularis*	SF/MF/ RF/WGL	I	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	2018	R
Muscicapidae	White-rumped Shama *Copsychus malabaricus*	SF/MF	I	LC	2001, 2002, 2003, 2008, 2015	2015	2014, 2015, 2016, 2017	-	R
Muscicapidae	Indian Robin *Copsychus fulicatus*	GL/WGL	I	LC	2001, 2002, 2003, 2004, 2006, 2015	-	2014, 2015, 2016, 2017	-	R
Muscicapidae	White-capped Redstart *Phoenicurus leucocephalus*	WL/ML	I	LC	2015	2015	2014, 2016, 2017	-	WV
Muscicapidae	Black Redstart *Phoenicurus ochruros*	RF/WGL	I	LC	2002, 2003, 2008, 2015	2015	2014, 2015 2016, 2017	-	WV
Muscicapidae	Little Forktail *Enicurus scouleri*	SF/MF	I	LC	-	-	2014, 2017	-	UC
Muscicapidae	Black-backed Forktail *Enicurus immaculatus*	SF/MF	I	LC	-	-	2014, 2015, 2016	-	R
Muscicapidae	White-throated Bushchat *Saxicola insignis*	GL	I	VU	-	-	2016	-	WV
Muscicapidae	Siberian Stonechat *Saxicola maurus*	GL	I	LC	2001, 2002, 2004, 2006, 2015	2015	2014, 2017	2018	WV
Muscicapidae	White-tailed Stonechat *Saxicola leucurus*	GL	I	LC	2002, 2006, 2008	2015	-	-	R
Muscicapidae	Pied Bushchat *Saxicola caprata*	GL	I	LC	2002, 2006, 2008, 2015	2014, 2015	2014, 2015 2016, 2017	-	R
Muscicapidae	Jerdon's Bushchat *Saxicola jerdoni*	WGL	I	LC	-	2015	-	-	R
Muscicapidae	Grey Bushchat *Saxicola ferreus*	WGL	I	LC	2001, 2006, 2008	2015	-	-	WV
Muscicapidae	Brown Rock Chat *Oenanthe fusca*	GL	I	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	-	2014, 2015, 2016, 2017	-	R
Muscicapidae	Blue Rock Thrush *Monticola solitarius*	WGL	I	LC	2008, 2015	2015	-	-	WV
Muscicapidae	Asian Brown Flycatcher *Muscicapa dauurica*	MF/SF	I	LC	-	-	2014, 2015, 2016, 2017	-	R
Muscicapidae	Rufous-gorgeted Flycatcher *Ficedula strophiata*	RF	I	LC	2006, 2008, 2015	-	-	-	WV
Muscicapidae	Red-breasted Flycatcher *Ficedula parva*	SF/MF/ RF/WGL	I	LC	2003, 2004, 2008	2015	2014, 2017	2018	WV
Muscicapidae	Taiga Flycatcher *Ficedula albicilla*	MF/ SCRUB	I	LC	-	-	-	2018	WV
Muscicapidae	Little Pied Flycatcher *Ficedula westermanni*	SF/WGL	I	LC	2001, 2006, 2008	-	2014	-	WV
Muscicapidae	Ultramarine Flycatcher *Ficedula superciliaris*	SF/MF/ DG	I	LC	2004, 2006, 2008, 2015	-	-	-	WV
Muscicapidae	Verditer Flycatcher *Eumyias thalassinus*	SF/MF/ WGL	I	LC	2002, 2006, 2008	2015	2015, 2017	-	WV
Muscicapidae	Tickell's Blue Flycatcher *Cyornis tickelliae*	SF/MF/ WGL	I	LC	2015	2015	-	-	WV
Muscicapidae	Pale-chinned Blue Flycatcher *Cyornis poliogenys*	MF/SF	I	LC	-	-	2015	-	UC
Stenostiridae	Grey-headed Canary-flycatcher *Culicicapa ceylonensis*	SF/MF/ WGL	I	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	2018	WV
Chloropseidae	Golden-fronted Leafbird *Chloropsis aurifrons*	SF/MF	N	LC	2003, 2008, 2015	2014	2014, 2017	-	R
Chloropseidae	Orange-bellied Leafbird *Chloropsis hardwickii*	SF/MF	N	LC	2002, 2003, 2006, 2015	-	-	-	R
Dicaeidae	Thick-billed Flowerpecker *Dicaeum agile*	MF/SF	N	LC	-	-	2015, 2016	2018	R
Dicaeidae	Pale-billed Flowerpecker *Dicaeum erythrorhynchos*	SF/MF/RF	N	LC	2001, 2003, 2008	2015	2016	2018	R

Family	Species name	Habitat	Feeding guild	IUCN Red List status	KWS	PTR	VTR	UWS	Status in PAs
Nectariniidae	Purple Sunbird *Cinnyris asiaticus*	MF/WGL	N	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	2018	R
Nectariniidae	Crimson Sunbird *Aethopyga siparaja*	SF/MF	N	LC	2001, 2008, 2015	-	2014	-	R
Nectariniidae	Little Spiderhunter *Arachnothera longirostra*	MF/AGR	N	LC	-	-	2015	-	UC
Passeridae	House Sparrow *Passer domesticus*	MF/WGL	G	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016, 2017	2018	R
Passeridae	Yellow-throated Sparrow *Gymnoris xanthocollis*	SF/MF/ WGL	G	LC	2001, 2002, 2003, 2006, 2008, 2015	2015	2015, 2016, 2017	2018	R
Ploceidae	Black-breasted Weaver *Ploceus benghalensis*	GL/WGL	O	LC	2002, 2003, 2008	-	-	-	R
Ploceidae	Streaked Weaver *Ploceus manyar*	GL/WGL	O	LC	2002, 2004	-	2015, 2017	-	R
Ploceidae	Baya Weaver *Ploceus philippinus*	GL	O	LC	2001, 2002, 2003, 2004, 2006, 2015	2015	2015, 2016, 2017	2018	R
Estrildidae	Indian Silverbill *Euodice malabarica*	GL/WGL	G	LC	2001, 2002, 2003, 2004, 2008, 2015	2014, 2015	2015, 2017	2018	R
Estrildidae	Red Avadavat *Amandava amandava*	GL	G	LC	2002, 2003, 2008,	2015	2014, 2015, 2016	-	R
Estrildidae	White-rumped Munia *Lonchura striata*	GL	G	LC	2001, 2003, 2006, 2008, 2015	-	-	2018	R
Estrildidae	Scaly-breasted Munia *Lonchura punctulata*	GL	G	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2015, 2016 2017	2018	R
Estrildidae	Black-headed Munia *Lonchura malacca*	GL	G	LC	2002, 2003, 2006, 2015	2015	2014, 2015, 2016	-	R
Motacillidae	Yellow Wagtail *Motacilla flava*	SF/MF/ WGL	I	LC	2008, 2015	2014	2014, 2017	-	WV
Motacillidae	Citrine Wagtail *Motacilla citreola*	WL/WGL	I	LC	2001, 2002, 2003, 2008, 2015	2015	2014, 2015, 2016 2017	2018	WV
Motacillidae	Grey Wagtail *Motacilla cinerea*	WL	I	LC	2001, 2002, 2003, 2004, 2006, 2015	-	2014, 2016, 2017	2018	WV
Motacillidae	White Wagtail *Motacilla alba*	WL	I	LC	2001, 2002, 2003, 2004, 2006, 2008, 2015	2014, 2015	2014, 2015, 2016 2017	2018	WV
Motacillidae	White-browed Wagtail *Motacilla maderaspatensis*	WL/GL	I	LC	2002, 2003, 2008,	2014	2014, 2015, 2017	-	WV
Motacillidae	Richard's Pipit *Anthus richardi*	GL	I	LC	2001, 2003, 2006	-	2015	-	WV
Motacillidae	Paddyfield Pipit *Anthus rufulus*	GL	I	LC	2002, 2003, 2008, 2015	2014	2014, 2015, 2016, 2017	-	R
Motacillidae	Tawny Pipit *Anthus campestris*	GL	I	LC	2001, 2002, 2003, 2006	-	2015	-	WV
Motacillidae	Blyth's Pipit *Anthus godlewskii*	GL	I	LC	-	-	2015	-	WV
Motacillidae	Tree Pipit *Anthus trivialis*	GL	I	LC	2006	2015	2014, 2017	-	WV
Motacillidae	Olive-backed Pipit *Anthus hodgsoni*	GL	I	LC	2001, 2003, 2008	-	2015, 2017	2018	WV
Fringillidae	Common Rosefinch *Carpodacus erythrinus*	MF/WGL	G	LC	2004, 2006, 2015	2015	-	-	WV
Emberizidae	Crested Bunting *Emberiza lathami*	GL	G	LC	2006, 2008	2015	-	-	WV
Emberizidae	White-capped Bunting *Emberiza stewarti*	GL	G	LC	2001, 2003	-	-	-	WV
Emberizidae	Chestnut-eared Bunting *Emberiza fucata*	GL	G	LC	2001, 2004	-	-	-	WV
Emberizidae	Yellow-breasted Bunting *Emberiza aureola*	GL/WGL	G	CR	2001	-	-	-	WV

Habitat type: GL—Grassland | AGR—Agricultural grassland | WGL—Wooded grassland | ML—Marshland | SF—Sal forest | MF—Mixed forest | RF—Riverine forest | WL—Wetland | RB—Riverbank | DG—Degraded.
Numeral represents year of sightings in study areas.
IUCN Red List status: CR—Critically Endangered | EN—Endangered | NT—Near Threatened | LC—Least Concern | VU—Vulnerable.
Status in PAs: R—Resident | WV—Winter visitor | SV—Summer visitor | LM—Local migrant | PM—Passage migrant | UC—Uncertain | VA—Vagrant.

2002. An individual was also sighted in February 2016 between Naughat and the watch tower in Katerniaghat range of KWS. And another individual near Koleshwar mandir on the bank of Gandak river in VTR during March 2017.

Steppe Eagle *Aquila nipalensis*

Endangered. Steppe eagle was seen regularly during winters in the woodland of Valmiki Nagar and Ganauli ranges of VTR between 2014 and 2017 (Image 1). The species was also sighted twice near the Bhikna thori area in the Manguraha range of VTR during the later part of December 2017.

Greater Spotted Eagle *Clanga clanga*

Vulnerable. A single bird was observed twice in the winter on the banks of Gandak River in Valmikinagar range of VTR in the last week of December 2016.

Bengal Florican *Houbaropsis bengalensis*

Critically Endangered. In PTR, a male Bengal Florican was sighted in Chaugebi grassland, Mahof range during April 2014. This species is considered as one of the most endangered bustards of the world. In Uttar Pradesh, the recorded estimated population of this species was 22 individuals (Sivakumar et al. 2014). Javed & Rahmani (1998) expected the possible occurrence of this species in KWS, however, no sighting of this species occurred during the survey. The patches of short grasses and mosaic of agriculture field throughout the terai is considered potential habitats for Bengal Florican.

Swamp Francolin *Ortygornis gularis*

Vulnerable and endemic to the Indian subcontinent, a small population is distributed along the foothills of the Himalayas in tall and swampy grasslands of Terai as well as the floodplains in northern India and Nepal. During the 2001 survey, the bird was sighted frequently on Bund road in Katerniaghat range. A maximum of 12 individuals were sighted in marshy habitats around 4–5 km before Kailaspuri gate in KWS. However, no individual was sighted during 2015. Two individuals of Swamp Francolin were seen on 23 Dec 2016 in the swamp habitat of Madanpur range in VTR.

Image 1. Steppe Eagle. © Shariq Safi

Indian Skimmer *Rynchops albicollis*

Endangered. Seven individuals of Indian Skimmer were observed flying over the Girwa River on 24 April 2015 in Katerniaghat (Image 2). Earlier studies in the KWS have not highlighted the occurrence of this species (Kalam 2005; Sethy & Chauhan 2011; Rahmani et al. 2016). No sightings were reported from PTR, Dudhwa NP, and VTR.

White-eared Night Heron *Gorsachius magnificus*

Endangered. An immature female of White-eared Night Heron was photo-captured on 24 November 2016 in a camera trap deployed near a slow-flowing perennial rivulet surrounded by moist deciduous forest type in Raghia range of VTR (Image 3). The species was recorded for the first time in Indian subcontinent (Shafi et al. 2018). The species is very rare with only 250–999 mature individuals distributed over southern and eastern China and northeastern Vietnam (BirdLife International 2017).

Woolly-necked Stork *Ciconia episcopus*

Vulnerable. Except for Udaipur WS, Woolly-necked Stork was commonly sighted in groups of one to four individuals in and around the PAs (Image 4). In PTR, a single individual was sighted on 16 February 2014 in the Mala range and on Madhotanda road on 29 March 2016. In Katerniaghat, two individuals were sighted on the bank of Girwa river near watch tower in Katerniaghat range during March 2008 and four individuals in bhainsalot phanta (grassland) in Nishangada range during April 2008. In VTR, an individual of Woolly-necked Stork was sighted in Bhasahwa and Madrahwa ghat in the Madanpur range on 17 and 22 January 2017.

Lesser Adjutant *Leptoptilos javanicus*

Vulnerable. A group of 24 individuals was sighted in a crop field around 2 km from Madanpur forest rest house towards Bagaha road in VTR in February 2017. In KWS, three individuals of Lesser Adjutant were sighted on Banda road near Mantri Mod on 28 March 2006. Two individuals were recorded in Sujauli range while

Image 2. Indian Skimmer in Katerniaghat Wildlife Sanctuary. © Rohit Ravi.

Image 3. White-eared Night Heron *Gorsachius magnificus* in VTR. © WWF-India/VTR.

Image 4. Woolly-necked Stork. © Shariq Safi.

deploying camera on 20 April 2015 and five individuals were seen perching on a tree in Mala range of PTR on 16 Feb 2014.

Spot-billed Pelican *Pelecanus philippensis*

Near Threatened. Six individuals of Spot-billed Pelican were sighted during the winters of 2001 in Girjapuri barrage in KWS. However, no individual was sighted during 2015–16 surveys in Katerniaghat.

Sarus Crane *Antigone antigone*

Vulnerable. A flock of six and four individuals was sighted in Garha corridor and near Richola chowki, Mala range respectively during 2014 in PTR. In VTR, a group of seven individuals was seen foraging in a crop field near Rampur check post in Madanpur range on 21 February 2017. Once common in Uttar Pradesh, Bihar, West Bengal, Assam, Rajasthan, Madhya Pradesh, and Gujarat, the population of this species is declining across its distribution range (BirdLife International 2016).

Great Slaty Woodpecker *Mulleripicus pulverulentus*

Vulnerable. An individual of Great Slaty Woodpecker was sighted in January 2004 near Gharial centre of Katerniaghat WS. In VTR, the species was sighted on two occasions; a group of three individuals in Gobardhana range during December 2017 and two individuals in Ganauli ranges during March 2017.

White-throated Bushchat *Saxicola insignis*

Vulnerable. Rare; two male individuals were observed on the railway track in Madanpur range of VTR in first week of February 2016.

Yellow-breasted bunting *Emberiza aureola*

Critically Endangered. This species was sighted in woody grassland patch of Katerniaghat range of KWS in December 2001. The presence of this species has also been highlighted from Dudhwa NP with uncertain status (Javed & Rahmani 1998), the migratory status of the species was doubtful in KWS too. However, it appears to be winter migrant in southeastern Asia including India

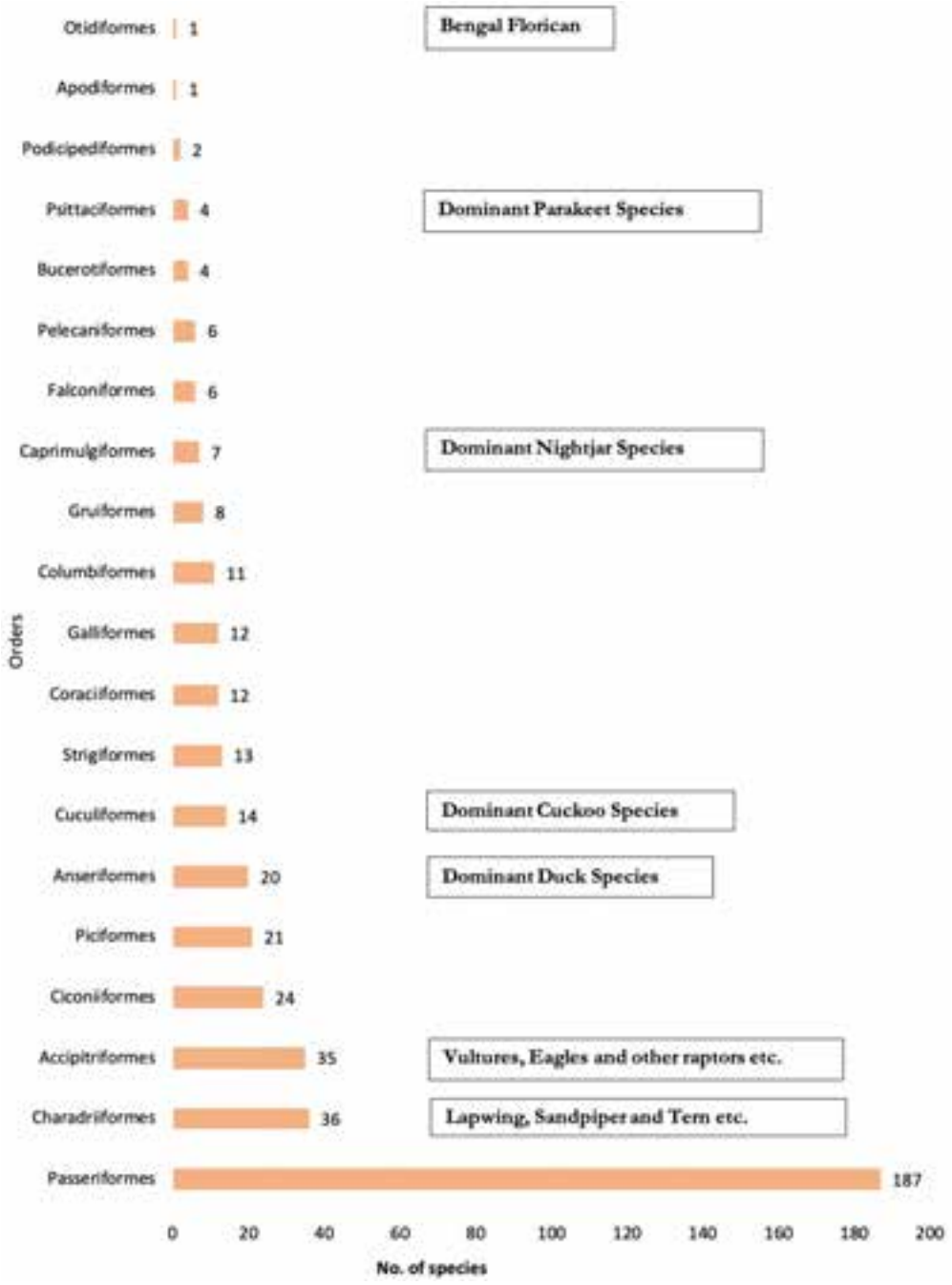


Figure 2. Order-wise richness of avian species observed in protected areas of Terai-Arc landscape, India.

(Grimmett et al. 2011).

An analysis of avian species composition between the PAs indicated KWS had a high similarity index value with PTR (S = 0.77) and VTR (S = 0.74, Table 3). PTR shared a high proportion of similar species with VTR (S = 0.69, Table 3). Avian community composition of UWS differ from rest of PAs; PTR (S = 0.58), KWS (S = 0.50), and VTR (S = 0.50). This might be related to the prevalence of similar habitat, i.e., woodland in Valmiki, Pilibhit and Katerniaghat (Chanchani et al. 2014). Since majority of area of UWS is under wetland, hence different bird community structure could be expected.

Majority of the species in the region (187 species; 44.1%) belong to the order Passeriformes (Figure 2). The higher prevalence of Passeriformes in the Terai-Arc landscape is consistent with many other studies conducted in the other part of Terai-Arc landscape and elsewhere in India (Singh et al. 2013; Ahmed et al. 2015,

Table 2. IUCN Red List status of avian species recorded in four different protected areas of Terai-Arc landscape, India.

Protected area	Critically Endangered	Endangered	Vulnerable	Near Threatened	Least Concern	Total
Katerniaghat WS	5	4	6	18	325	358
Pilibhit TR	4	1	4	11	216	236
Valmiki TR	3	4	7	13	279	306
Udaipur WS	2	1	0	2	123	128
Overall	**6**	**5**	**8**	**19**	**386**	**424**

Table 3. Similarity in avian species between four protected areas of Terai-Arc landscape, India.

Protected area	Pilibhit TR	Valmiki TR	Udaipur WS
Katerniaghat WS	0.77	0.74	0.50
Pilibhit TR		0.69	0.58
Valmiki TR			0.50

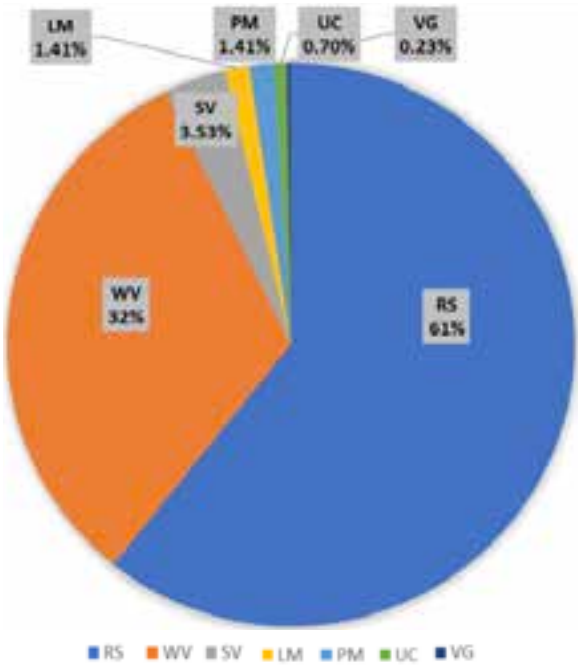


Figure 3. Residential status of avian species recorded from protected areas of Terai-Arc landscape, India. (RS—Resident | WV-Winter Visitor | SV—Summer Visitor | LM—Local Migrant | PM—Passage Migrant | UC—Uncertain | VG—Vagrant).

2019). Family Accipitridae (34 species) dominated the region and it was followed by Muscicapidae (28 species) and Anatidae (20 species). Majority of the species such as Black Francolin, Red Spurfowl *Galloperdix spadicea*, Oriental Darter *Anhinga melanogaster*, Crested Serpent Eagle *Spilornis cheela*, Shikra *Accipiter badius*, and Common Hawk Cuckoo *Hierococcyx varius* were residents (n = 258, 60.8%) followed by winter visitors such as Bar-headed Goose *Anser indicus*, Ruddy Shelduck *Tadorna ferruginea*, Red-crested Pochard *Netta rufina*, and Osprey *Pandion haliaetus* (n = 135, 31.8%), summer visitors such as Pied Cuckoo *Clamator jacobinus*, Indian Cuckoo *Cuculus micropterus*, Large Cuckooshrike *Coracina macei*, and Indian Paradise-flycatcher *Terpsiphone paradisi* (n = 15, 3.53%) and local migrant such as Painted Stork *Mycteria leucocephala* and Black-headed Ibis *Threskiornis melanocephalus* (n = 6, 1.41%) and passage migrant like Indian Skimmer *Rynchops albicollis* and Rosy Starling *Pastor roseus* (n = 6, 1.41%). Three species with uncertain status, viz., Pale-chinned Blue Flycatcher *Cyornis poliogenys,* Little Spiderhunter *Arachnothera longirostra*, and Little Forktail *Enicurus scouleri* was recorded. One vagrant species viz. Great Grey Shrike *Lanius excubitor* was also recorded in the area (Figure 3).

Based on their food preferences, a majority of bird species (190 species, 44.8%) belonged to the insectivorous guild, followed by carnivores (88 species, 20.7%) and omnivores (70 species, 16.5%) (Figure 4). Nectivorous guild was the least represented guild in the region (10 species, 2.35%). The dominancy of insectivores has been observed in various regions of India (Sultana & Khan 2000; Sultana et al. 2007; Aggarwal et al. 2008; Acharya et al. 2010; Joshi & Bhatt 2011; Ahmed et al. 2015). High tree density along with moist conditions favour richness and abundance of insects (Erwin 1982; Chettri et al. 2005). Since the study was carried out in PAs with high tree density (FSI 2019), hence dominancy of insectivorous species in Terai-Arc landscape could be expected.

Terai-Arc landscape is a biologically diverse eco-region and has been listed among the conservation landscapes of global importance for its unique Terai-Duar Savanna and Grassland habitats, which support more than 600 species of birds (Chanchani et al. 2014). Many Critically Endangered species were observed here during the study, showing the potential of the landscape as a good habitat for avifauna. The study will serve as

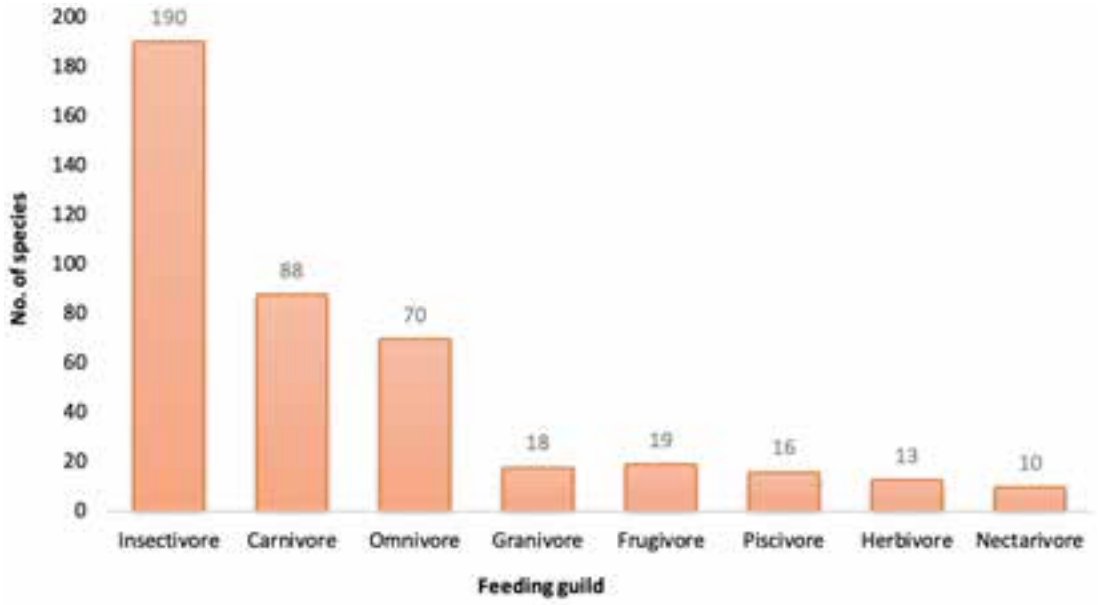


Figure 4. Avifaunal species in different feeding guilds recorded in protected areas of the Terai-Arc landscape, India.

baseline data for better management and conservation of the existing species. Further long-term studies in the landscape in different seasons are required to prepare a holistic checklist of birds found here as our study had limitations of being not continuous in all the mentioned PAs. Since the forest area in the landscape is surrounded by the rapidly increasing human population, which traditionally depends upon forest resources such as fuelwood, fodder, non-timber forest products and grazing, posing a serious threat to the habitats of the PAs (Wikramanayake et al. 2010). The presence of an all-weather road and railway track inside the KWS and VTR is leading to a high level of disturbance (Maurya & Borah 2013; Chanchani et al. 2014). Water bodies in KWS and UWLS are very important for water birds including waders, many winter visitors and local migrant species recorded here. Illegal fishing is one of the threats to water birds observed here (Chanchani et al. 2014). The infestation of grassland by *Lantana* spp. due to over-grazing and other human-induced disturbances, including fire as management practice, are among the major threats to the grassland ecosystems (Javed & Rahmani 1998). The present study reports nearly 19% species (n = 80) are dependent on grassland and grassland-associated habitats, therefore conservation of grassland with adequate scientific knowledge with proper monitoring plan is needed.

REFERENCES

Acharya, B.K., L. Vijayan & B. Chettri (2010). The bird community of Shingba Rhododendron Wildlife Sanctuary, Sikkim, Eastern Himalaya, India. *Tropical Ecology* 51(2): 149–159.

Aggarwal, S., D.N. Sahi & A.A. Wani (2008). Feeding guilds of avifauna of Nandini Wildlife Sanctuary, Jammu (Jammu and Kashmir). *Ecoscan* 2(2): 157–160.

Ahmed, T., A. Khan & P. Chandan (2015). A pilot survey of the avifauna of Rangdum Valley, Kargil, Ladakh (Indian Trans-Himalaya). *Journal of Threatened Taxa* 7(6): 7274–7281; http://doi.org/10.11609/JoTT.o3965.7274-81

Ahmed, T., H.S. Bargali & A. Khan (2019). Status and distribution of avifauna in Ramnagar Forest Division, western Terai-Arc Landscape, Uttarakhand. *Indian Forester* 145(10): 935–945.

Ali, S. & S.D. Ripley (1987). *Compact Handbook of the Birds of India and Pakistan*. Oxford University Press, New Delhi, 278pp.

Anwar, M., H. Kumar & J. Vattakaven (2010). Status of Tigers in Pilibhit Forest Division, Terai Arc Landscape, Uttar Pradesh, India, WWF-India, 44 pp; https://www.wwfindia.org/news_facts/wwf_publications/?8480/Status-of-Tigers-in-Pilibhit-Forest-Division.

Benton, T., J.A. Vickery & J.D. Wilson (2003). Farmland bio-diversity: is habitat heterogeneity the key? *Trends in Ecology & Evolution* 18: 182– 188.

BirdLife International (2016). *Antigone antigone*. The IUCN Red List of Threatened Species 2016: e.T22692064A93335364. Downloaded on 20 April 2021. https://doi.org/10.2305/IUCN.UK.2016-3.RLTS.T22692064A93335364.en

BirdLife International (2017). *Gorsachius magnificus*. The IUCN Red List of Threatened Species 2017: e.T22697232A117359084. Downloaded on 13 April 2018. https://doi.org/10.2305/IUCN.UK.2017-3.RLTS.T22697232A117359084.en

Champion, H.G. & S.K. Seth (1968). *A Revised Survey of the Forest Types of India.* Government of India, New Delhi, 453 pp.

Chanchani, P., B.R. Lamichhane, S. Malla, K. Maurya, A. Bista, R. Warrier, S. Nair, M. Almeida, R. Ravi, R. Sharma, M. Dhakal, S.P. Yadav, M. Thapa, S.R. Jnawali, N.M.B. Pradhan, N. Subedi, G.J. Thapa, H. Yadav, Y.V. Jhala, Q. Qureshi, J. Vattakaven & J. Borah (2014). Tigers of the Transboundary Terai Arc Landscape: Status, Distribution and Movement in the Terai of India and Nepal. National

Tiger Conservation Authority, Government of India & Department of National Park and Wildlife Conservation, Government of Nepal, 98 pp.

Chettri, N., D.C. Deb, E. Sharma & R. Jackson (2005). The relationship between bird communities and habitat. *Mountain Research and Development* 25(3): 235–243.

Choudhury, A.U. (2016). Bird observations from Valmiki Tiger Reserve, Bihar. *Indian BIRDS* 11(3): 57– 63.

Dhakate, P.M., T.A. Patil & R. Bhartari (2008). Wetland birds of Corbett Tiger Reserve Landscape, pp. 1974–1982. In: Sengupata, M. & R. Dalwani (eds.). Proceeding of Taal 2007: The 12th world lake conference.

Dunning, J.B., B.J. Danielson & H.R. Pulliam (1992). Ecological processes that affect populations in complex landscapes. *Oikos* 65(1): 169–175.

Erwin, T.L. (1982). Tropical forests: Their richness in Coleoptera and other arthropod species. *Coleopterists Bulletin* 36(1): 74–75.

Fahrig, L., J. Baudry, L. Brotons, F.G. Burel, T.O. Crist, R.J. Fuller, C. Sirami, G.M. Siriwardena & J.L. Martin (2011). Functional landscape heterogeneity and animal biodiversity in agricultural landscapes. *Ecology Letters* 14: 101– 112.

Forest Survey of India (2019). India State of Forest Report 2019. *16th edition*, *Vol. 2*. 382 pp.

Grimmett, R., C. Inskipp & T. Inskipp (2011). *Birds of the Indian Subcontinent.* Oxford University Press, New Delhi, 888 pp.

IUCN (2018). IUCN Red List of Threatened Species. Available at: www.iucnredlist.org. Date accessed: 20 April 2021.

Javed, S., Q. Qureshi & A.R. Rahmani (1999). Conservation status and distribution of swamp francolin in India. *Journal of the Bombay Natural History Society* 96: 16–23.

Javed, S. & A.R. Rahmani (1998). Conservation of the Avifauna of Dudwa National Park, India. *Forktail* 14: 57–66.

Johnsingh, A.J.T., Q. Qureshi, S.P. Goyal, G.S. Rawat, K. Ramesh, A. David, K. Rajapandian & S. Prasad (2004). Conservation status of Tiger and associated species in the Terai Arc Landscape, India. Final Technical Report RR-04/001, Wildlife Institute of India, Dehradun, India, viii+110 pp.

Joshi, K. & D. Bhatt (2011). Birds of three different forest habitats in Nainital district (western Himalaya), Uttarakhand, India. *Indian BIRDS* 7(2): 33–37.

Kalam, A. (2005). Birds of Katerniaghat Wildlife Sanctuary, Bahrich District, Uttar Pradesh, India. *Journal of Indian Birds* 1(4): 74– 76.

Kidwai, Z., M. Matwal, U. Kumar, S. Shrotriya, F. Masood, Z. Moheb, N.A. Ansari & K. Singh (2013). Comparative study of bird community structure and function in two different forest types of Corbett National Park, Uttarakhand, India. *Asian Journal of Conservation Biology* 2(2): 157–163.

MacKinnon, J. & K. Phillips (1993). *A Field Guide to The Birds of Borneo, Sumatra, Java and Bali.* Oxford University Press, Oxford, UK, 491 pp.

Maheswaran, G. & A.R. Rahmani (2005). Breeding biology of the Black-necked Stork *Ephippiorhynchus asiaticus* in Dudhwa National Park, India. *Journal of the Bombay Natural History Society* 102(3): 305–312.

Mandal, K., K. Bhattacharya, P. Chatterjee, P. K. Dey, G. Maheswaran & I. Alam (2018). Aves, pp.831–854. In: *Faunal Diversity of Indian Himalaya.* Zoological Survey of India, Kolkata.

Maurya, K.K. & J. Borah (2013). Tiger status in Valmiki Tiger Reserve, Terai Arc Landscape, Bihar, India, WWF-India, 68 pp. https://www.wwfindia.org/news_facts/wwf_publications/?10821/Status-of-tigers-in-Valmiki-Tiger-Reserve.

Pandey, S., J. Joshua, N.D. Rai, D. Mohan, G.S. Rawat, K. Sankar, M.V. Katti, D.V.S. Khati & A.J.T. Johnsingh (1994). Birds of Rajaji National Park, India. *Forktail* 10: 105–114.

Praveen, J., R. Jayapal & A. Pittie (2019). Updates to the checklist of birds of India and the South Asian region. *Indian BIRDS* 15(1): 1–19.

Rahmani, A.R., G. Narayan, L. Posalind, R. Sankaran & U. Ganguli (1989). Status of the Bengal Florican (*Houbaropsis bengalensis*) in India. *Journal of the Bombay Natural History Society* 88: 349–375.

Rahmani, A.R., M.Z. Islam & R.M. Kasambe (2016). *Important Bird and Biodiversity Areas in India: Priority Sites for Conservation (Revised and updated).* Bombay Natural History Society. Indian Bird Conservation Network, Royal Society for the Protection of Birds & BirdLife International UK, 1992 pp.

Rodgers, W.A. & H.S. Panwar (1988). *Planning a Wildlife Protected Area Network in India. Vol. 2*. Project FO: IND/82/003. FAO, Dehradun, India, 606 pp.

Sethy, J. & N.P.S. Chauhan (2011). Birds of Katerniaghat Wildlife Sanctuary, Uttar Pradesh, India. *Indian Forester* 137(10): 1183–1187.

Shafi, S., K.K. Maurya, P. Chanchani, S. Chandrashekar, A. Kumar, A. Kumar & G. Ojha (2018). Extraordinary discovery in Bihar, India: an apparent White-eared Night Heron *Gorsachius magnificus* in Valmiki Tiger Reserve. *Birding ASIA* 29: 9–10.

Shafi, S., T. Ahmed, M. Anwar & V. Rawat (2020). Summary of recent vulture sightings at the Southern boundary of Corbett Tiger Reserve, Western Terai Arc Landscape, Uttarakhand, India. *Indian Forester* 146(10): 987–991.

Singh, R., D.N. Kour, F. Ahmad & D.N. Sahi (2013). Avifaunal diversity of Patnitop Development Authority (PDA) area, Jammu and Kashmir State. *Journal of Biosphere* 2(1): 62–65.

Sinha, S. (2012). Valmiki: the story of Bihar's forgotten tigers. *Cheetal* 50(2): 1–13.

Sivakumar, K., G.S. Bhardwaj, S. Sen, R. Sharma & O. Dhavale (2014). Status and Habitat Assessment of Bengal Florican *Houbaropsis bengalensis* in the grassland of Uttar Pradesh. Wildlife Institute of India, 84 pp.

Sultana, A. & J.A. Khan (2000). Birds of oak forests in the Kumaon Himalaya, Uttar Pradesh, India. *Forktail* 16: 131–146.

Sultana, A., M.S. Hussain & J.A. Khan (2007). Bird communities of the proposed Naina and Pindari Wildlife Sanctuaries in the Kumaon Himalaya, Uttarakhand, India. *Journal of the Bombay Natural History Society* 104: 19–29.

Tews, J., U. Brose, V. Grimm, K. Tielborger, M.C. Wichmann & M. Schwager (2004). Animal Species Diversity Driven by Habitat Heterogeneity/Diversity: The Importance of Keystone Structures. *Journal of Biogeography* 31: 79–92.

Wikramanayake, E., A. Manandhar, S. Bajimaya, S. Nepal, G. Thapa & K. Thapa (2010). The Terai Arc Landscape: A tiger conservation success story in a human-dominated landscape, pp. 163–173. In: *Tigers of the World. Second edition.* Chapter 10. Elsevier, San Diego, 552 pp.

WWF-India (2007). Strategic Plan for the Terai Arc Landscape- India. Species Conservation Division. WWF-India, 83 pp.

Author details: Shariq Safi is presently employed as a technical assistant for field program at the Dept. of Wildlife Sciences, AMU. He has been actively engaged in the tiger conservation program and his research interests extend to studying lesser carnivores and bird populations both within and outside protected areas. Tanveer Ahmed, PhD in landscape ecology from Aligarh Muslim University, is currently working as project coordinator at the Wildlife Institute of India, Dehradun. Dr Ahmed possesses extensive experience in studying aquatic and terrestrial birds and mammals of the Indian Trans-Himalaya and Terai-Arc landscape, and impact assessment of developmental projects, and river biodiversity assessment. Junid Nazeer Shah, PhD in wildlife sciences, specializes in biodiversity conservation in terrestrial and marine ecosystems. He is currently heading Ajaz Environment Consultants, carrying out projects across the Middle East. With over 20 years of experience, he has led projects across the Middle East, focusing on ecological compliance, EIA, and Coastal Zone Management. His expertise includes long-term monitoring of breeding bird species of global significance. Meraj Anwar, PhD in wildlife science from Wildlife Institute of India, Dehradun. His research focused extensively on wildlife corridors and population estimation of tigers and associated species, human-wildlife mitigation, radio-telemetry on tigers and avifaunal assemblage in the Terai Arc landscape. Currently, he is working as Coordinator for Species Conservation at WWF-India and based out in Haldwani, Uttarakhand. Kamlesh K. Maurya, PhD, is landscape coordinator at WWF- India, and involved in field research on carnivores in India since 2005. His research interest includes population dynamic of carnivores and human-wildlife conflict in human dominated landscapes.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 February 2024 | 16(2): 24730–24736

ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

https://doi.org/10.11609/jott.8700.16.2.24730-24736

#8700 | Received 20 August 2023 | Final received 11 January 2024 | Finally accepted 31 January 2024

OPEN ACCESS

COMMUNICATION

Monitoring observations of the southernmost breeding population of Long-billed Vultures *Gyps indicus* (Scopoli, 1786) (Aves: Acciptriformes: Accipitridae) in the Nilgiri Biosphere Reserve, India

S. Manigandan [1], H. Byju [2] & P. Kannan [3]

[1] D/No 36, Dhoopakandi, Sholur-Kokkal, The Nilgiris, Tamil Nadu 643005, India.
[2] Centre of Advanced Study in Marine Biology, Annamalai University, Parangipettai, Tamil Nadu 608502, India.
[3] Department of Zoology, Thiru.Vi.Ka. Government Arts College, Thiruvarur, Tamil Nadu 610003, India.
[1] mani.wildlife1993@gmail.com (corresponding author), [2] byjuhi@gmail.com, [3] perukannan@gmail.com

Abstract: The Long-billed Vulture (LBV) population was systematically monitored across four nesting colonies in the Nilgiri Biosphere Reserve (NBR) throughout three extended breeding seasons. Breeding success rates between years ranged from 83.33% in 2018–2019 and 62.5% in 2020–2021. Nesting was monitored at the cliff sites, consistent with prior research. Overall population fluctuations were minimal, varying between 21 individuals in 2020–2021, 17 individuals in 2018–2019, and 16 individuals in 2019–2020. There was an apparent impact of forest fires and other human disturbance activities, and certain proactive conservation measures are proposed to help address these. There was indirect evidence of other threats including poison baits targeting wild carnivores and non-steroidal anti-inflammatory drugs (NSAIDs) being widely available for use in domestic livestock. The study endorses the approach of establishing vulture-safe zones, which focus on addressing the local threats. This includes raising awareness about wildfire management, controlling toxic NSAIDs availability that are harmful to vultures, discouraging the illegal use of poison-baits, and highlighting the necessity of monitoring threats posed by power infrastructure. Due to the high mobility of LBVs, all these threats need addressing through large-scale vulture safe zone work (up to 100 km radius) surrounding the breeding colonies to secure the LBV's long-term survival. These conservation actions are urgently needed.

Keywords: Conservation, Critically Endangered, forest fire, livestock, NSAID, poison, vulture safe zone.

Tamil Abstract: நீலகிரி உயிர்க்கோளக் காப்பகத்தில் உள்ள நீண்ட அலகு பினந்தின்னிக் கழுகுகளின் எண்ணிக்கை மூன்று இனப்பெருக்க காலங்களில், நான்கு கூடு கட்டும் காலனிகளில் முறையாக கண்காணிக்கப்பட்டது. ஆண்டுகளுக்கிடையேயான இனப்பெருக்க வெற்றி விகிதங்கள் 2018-2019 இல் 83.33% ஆகவும், 2020-2021 இல் 62.5% ஆகவும் இருந்தன. முந்தைய ஆராய்ச்சிக்கு இணங்க, குன்றின் தளங்களில் கூடு கட்டுவது கண்காணிக்கப்பட்டது. ஒட்டுமொத்த எண்ணிக்கை ஏற்ற இறக்கமாக இருந்தது, இது 2020-2021 இல் 21 ஆகவும், 2018-2019 இல் 17 ஆகவும் மற்றும் 2019-2020 இல் 16 ஆகவும் இருந்தது. காட்டுத்தீ மற்றும் பிற மனித இடையூறு நடவடிக்கைகளின் வெளிப்படையான தாக்கம் இருந்தது, மேலும் இவற்றை நிவர்த்தி செய்ய உதவும் சில பாதுகாப்பு நடவடிக்கைகள் இந்த ஆய்வில் முன்மொழியப்பட்டுள்ளன. வன்மம் காரணமாக வனவிலங்குகளுக்கு எதிராக விஷம் தடவுவது மற்றும் பினந்தின்னிக் கழுகுகளுக்கு கேடு விளைவிக்கும் வலிநிவாரணிகள் (NSAIDs) கால்நடைகளுக்கு பயன்படுத்த பரவலாகக் கிடைக்கின்றன என்பதற்கான மறைமுக சான்றுகள் இருந்தன. உள்ளூர் அச்சுறுத்தல்களை நிவர்த்தி செய்து கழுகு-பாதுகாப்பான மண்டலங்களை நிறுவுவதற்கான அணுகுமுறையை இந்த ஆய்வு ஆதரிக்கிறது மேலும் காட்டுத்தீ மேலாண்மை பற்றிய விழிப்புணர்வை ஏற்படுத்துதல், கழுகுகளுக்கு தீங்கு விளைவிக்கும் வலிநிவாரணிகள் (NSAIDs) கள் கிடைப்பதைக் கட்டுப்படுத்துதல், வன்மம் காரணமாக வனவிலங்குகளுக்கு எதிராக விஷம் தடவுவது கட்டுப்படுத்துதல் மற்றும் மின் உள்கட்டமைப்பினால் ஏற்படும் அச்சுறுத்தல்களைக் கண்காணிப்பதன் அவசியத்தை எடுத்துரைத்தல் போன்ற மேற்கண்ட காரணிகளை பிணதின்னி கழுகுகள் பாதுகாப்பு மண்டலம் திட்டத்தின் மூலம் (100 கி.மீ சுற்றளவு) நிவர்த்தி செய்து நீண்ட அலகு பிணதின்னி கழுகுகளை நீண்ட காலத்திற்கு பாதுகாக்க வேண்டும் என்று இந்த ஆய்வு எடுத்துரைக்கிறது மற்றும் இந்த பாதுகாப்பு நடவடிக்கைகள் அவசரமாக தேவை ஆகும்.

Editor: Chris Bowden, Royal Society for the Protection of Birds (RSPB), Sandy, UK. **Date of publication:** 26 February 2024 (online & print)

Citation: Manigandan, S., H. Byju & P. Kannan (2024). Monitoring observations of the southernmost breeding population of Long-billed Vultures *Gyps indicus* (Scopoli, 1786) (Aves: Acciptriformes: Accipitridae) in the Nilgiri Biosphere Reserve, India. *Journal of Threatened Taxa* 16(2): 24730–24736. https://doi.org/10.11609/jott.8700.16.2.24730-24736

Funding: Self-funded.

Competing interests: The authors declare no competing interests.

Author details: S. Manigandan has a PhD on Vulture studies from Nilgiri Biosphere Reserve and is working with Centre for Wildlife Studies, Bangalore. H. Byju is a researcher presently working on shorebirds on the south east coast of India. His earlier work was on vultures in Nilgiri Biosphere Reserve and presently collaborating with vulture studies on Moyar. P. Kannan is an associate professor in Zoology with an interest on herpetofauna.

Author contributions: SM—conceptualisation and writing; BH—design, writing and editing; PK—writing.

Acknowledgements: We thank the Tamil Nadu Forest Department for providing support and permission to work in the Mudumalai Tiger Reserve. Especially our sincere thanks to R. Kumar and N. Chandran (anti-poaching watchers), for guiding us in the forest. Our sincere gratitude to Arulagam and Bharathidasan for their support during the entire period of fieldwork. Dr. Ramakrishnan, assistant professor at the Government Arts and Science College, Ooty, is also highly appreciated for his guidance and support.

INTRODUCTION

The decline in the population of *Gyps* vultures across the Indian subcontinent is largely attributed to accidental poisoning resulting from their consumption of carcasses contaminated with the non-steroidal anti-inflammatory drug (NSAID) diclofenac (Oaks et al. 2004; Swan et al. 2006). The Long-billed Vulture (LBV) *Gyps indicus,* is one of the three native resident *Gyps* species in India. The LBV breeds in southeastern Pakistan (Collar & Butchart 2013) and peninsular India south of the Gangetic plain up to Delhi (Risebrough 2004), eastward through Madhya Pradesh (Rasmussen & Anderton 2005), Telangana (Manchiryala & Medichet 2014), Andhra Pradesh (Umapathy et al. 2009) and southwards to the Nilgiris (Subramanya & Naveen 2006; Venkitachalam & Senthilnathan 2015; Manigandan et al. 2023), nesting primarily on cliffs and occasionally ruins and has been observed only occasionally nesting in trees in Bikaner, Rajasthan (Rasmussen & Anderton 2005). The Nilgiris is the southern limit of the species. The spectrum of NSAIDs available in the veterinary market within the confines of the Nilgiri Biosphere Reserve (NBR), includes aceclofenac, ketoprofen, nimesulide, and flunixin, all known to be toxic to vultures (Mathesh et al. 2023) and this is a serious concern within the proposed vulture safe zone (VSZ) of southern India (Manigandan 2018). These observations prompted us to further monitor and understand the LBV population within the NBR.

While efforts toward vulture conservation have predominantly centered in the northern and eastern regions of India, with research and captive breeding programs targeted at saving the three Critically Endangered *Gyps* species—the White-rumped Vulture *Gyps bengalensis*, LBV, and Slender-billed Vulture *Gyps tenuirostris* (Prakash et al. 2003; Bowden et al. 2012; Ranade et al. 2023), such initiatives remain scarce in southern India. The prospect of establishing a similar captive breeding centre in the south is currently being deliberated both in Karnataka and in Hyderabad Zoo and is at various stages (MoEFCC 2020). Despite this, a conspicuous dearth of information persists for both the 'Endangered' Egyptian Vulture *Neophron percnopterus* (Byju & Raveendran 2022) and this 'Critically Endangered' species (LBV) within the precincts of the NBR. The present study aims to set some baseline information and evaluate recent LBV population trends, providing some breeding success data, and evaluating conservation challenges for this species in the Tamil Nadu landscape.

Study Area

The NBR (11.5731^{0}N & 76.7558^{0}E), was established in 1986 in the southern Western Ghats and connects the Western Ghats to the Eastern Ghats (Puyravaud & Davidar 2013). Our study was restricted to MTR and Sathya Mangalam Tiger Reserve (STR) of the NBR in Tamil Nadu (Figure 1). This biosphere reserve includes areas of Tamil Nadu, Kerala, and Karnataka states. Among the seven vulture species recorded within the NBR, four are resident—Egyptian Vulture *Neophron percnopterus,* Red-headed Vulture *Sarcogyps calvus,* White-rumped Vulture *Gyps bengalensis,* and Long-billed Vulture *Gyps indicus*; and three are scarce winter migrants—Cinereous Vulture *Aegypius monachus,* Himalayan Griffon Vulture *Gyps himalayensis,* and Eurasian Griffon *Vulture fulvus* (Manigandan et al. 2023).

METHODS

LBV nesting behavior was assessed by a combination of drawing upon prior research (Manigandan et al. 2023), local villager insights from indigenous inhabitants for potential nesting and roosting sites collected, local government officials, forest guards, and researchers of Government Arts College, Ooty along with the authors. Systematic visits were made between October and June, covering the known vulture breeding period in the landscape (Stotrabhashyam et al. 2015). During this period, each LBV nest site location was visited twice (15-day intervals) per month during breeding seasons and assessments were based on the frequency of bird visits to cliffs and on the presence of white droppings visible around the nesting site. These observations were repeated for three successive breeding seasons: 2018–2019, 2019–2020, and 2020–2021. The selection of observation timings, either in the morning (0600–1000 h) or the late afternoon (1700–2000 h) depended on the visibility thereby avoiding some misty mornings and evenings. These designated periods were determined both to optimize visibility due to haze and addressing safety concerns from elephant movement and sloth bears in the region. As LBVs are primarily cliff nesters, the survey focused on cliff- searches and so could potentially have missed tree nesting pairs—although this seems unlikely as we have been collecting secondary information from forest dwellers from indigenous communities which has not revealed any tree-nesting of LBVs. Each nest site was given a reference number for inter-year tracking. Observations were made from carefully selected points that allowed clear observation of the nest contents

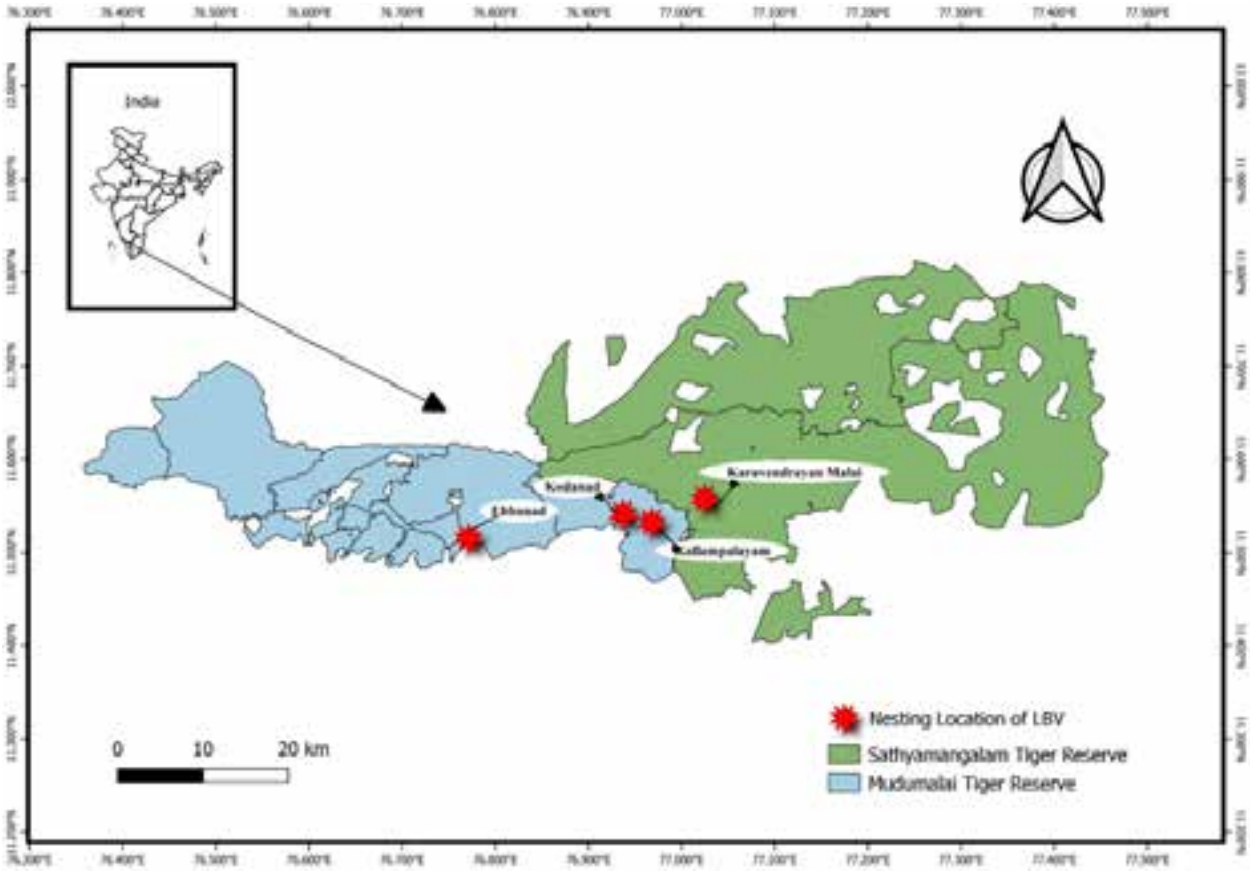


Figure 1. Study area and nesting locations of Long-billed Vultures (LBV) *Gyps indicus* in Nilgiri Biosphere Reserve.

and birds' behaviour. All observations were made using a spotting scope (Nikon Pro Staff 3 16–48 x 60) and binoculars (Nikon Monarch M5 12 x 42 binoculars) from about 100–250 m to minimize disturbance. Also, we noted any potential threats detected near nesting sites. We consulted published literature to assess the availability of NSAIDs in the area (Manigandan 2018). After analyzing the information, we went to nearby villages for further investigation of each of the threats to vultures. We investigated whether vultures had died of poisoning with the community stakeholders along with the details of the mortality of cattle. Between 2018 and 2020, we conducted surveys involving 208 pharmacy shops within the vulture safe zone area. These surveys were carried out covertly, with the help of local community posing as livestock owners. The objective was to assess the presence of NSAIDs that are harmful to vultures in these establishments.

RESULTS AND DISCUSSION

The study identified four distinct nesting colonies of the LBV (Table 1). All breeding sites were on rock cliffs adjacent to the river Moyar or its streams (Images 1, 2). No LBVs were found breeding on trees. The locations of all breeding sites detected together with habitat features, are presented in (Tables 1, 2). Breeding success across the colonies and between years averaged 70.83% (Table 3). The reasons for nest failures were not determined directly, but in the breeding season of 2018–2019, high breeding productivity of 83.33% was observed across all four nesting colonies combined. Subsequently, during the breeding season of 2019–2020, an overall breeding success rate of 66.66% was recorded in the three LBV nesting colonies collectively. However, the breeding success rate dropped to 62.5% in the season of 2020–2021. A new nesting site was found in the 2020–2021 breeding season, but this site did not yield successful breeding (Table 3). The LBV population monitoring revealed only minor fluctuations. The highest count of LBV individuals (21) was documented in the breeding

season of 2020–2021. The previous breeding seasons, 2018–2019 and 2019–2020 had maximum sightings of 17 and 16 individuals, respectively (Table 1).

From our field observations and interactions with local pharmacies, we confirmed that drugs that are harmful to vultures (Nimesulide, ketoprofen, aceclofenac, and flunixin) are still available in villages near the LBV nesting area. We conducted an inspection of nesting trees along major rivers like Moyar, Sigur, and Siriyur, in these areas, and potential nesting places to search for LBV nests. We also interacted with the forest department field staff to find out if there were any LBV nests in trees during our regular monitoring and found no tree-nesting of LBV in the study area. Notably, all identified nests of Kallampalayam and Ebbanad nesting sites were situated on east-facing cliffs.

The LBV population remained relatively stable over the three years. But notably, the Ebbanad nesting colony, in the years 2018–2019 harbored two nests, but only one nest in the subsequent breeding season. This decline was attributed to observed frequent disturbance by visitors from a nearby cottage frequented by tourists that resulted in the birds being repeatedly flushed and may have caused the birds to leave their nesting location. An illegally constructed cottage (Hitten Valley) was located 100–150 m away from the colony with a viewpoint arranged for the tourists. We observed people screaming and shouting during the daytime, followed by campfires in the night. Notably, in the breeding season

Table 1. Population trend of Long-billed Vulture *Gyps indicus* in three breeding seasons from 2018–2021.

Name of the nesting colonies	Long-billed Vulture population		
	2018–2019	2019–2020	2020–2021
Ebbanad	6	3	5
Kodanad	8	8	5
Kallampalayam	3	5	9
Karuvendrayan Malai	0	0	2
Total	17	16	21

Image 1. Long-billed Vulture *Gyps indicus* in the Kallampalayam nesting site.

Image 2. Landscape and Long-billed Vulture *Gyps indicus* nesting location of Kodanadu nesting site.

Table 2. Nesting habitat of Long-billed Vulture (LBV) *Gyps indicus* in the study area.

LBV nesting colony site	Protected area	Type of forest	Elevation (m)	GPS location		Distance from the nearest village
				Latitude N	Longitude E	
Ebbanad	MTR	Dry thorn and moist deciduous	1,064	11.515174°	76.770592°	1.88 km
Kodanad	MTR	Dry thorn and moist deciduous	1,661	11.538914°	76.911514°	2.27 km
Kallampalayam	MTR	Moist deciduous	854	11.532109°	76.967859°	3.11 km
Karuvendrayan Malai	STR	Moist deciduous	830	11.560016°	77.024215°	3.71 km

MTR—Mudumalai Tiger Reserve | STR—Sathya Mangalam Tiger Reserve.

of 2020–2021, after the closure of this cottage, the number of LBV nests increased (from one to two) in the Ebbanad nesting colony (Table 3). The Kodanad nesting colony encountered the impact of the 2019 forest fires as this nesting site has an approximate 50% grass cover in the area. This incident almost certainly caused the LBV pairs to abandon their nests as the nesting sites were surrounded by grassland, and the impact of flames reached the nests in December 2019. We recommend taking proactive steps to prevent fires. To reduce the impact of forest fires on vulture colonies, it is imperative to strategically plan pre-fire activities during non-breeding periods. The Kallampalayam nesting colony exhibited a positive trend, with 100% breeding success rate in 2020–2021. This success is likely due to the colony's limited exposure to forest fires and lower human disturbances, as no signs of human presence were detected near the nesting area during the study period.

Poison baits incident

The regular monitoring led to the discovery of a poison-bait mortality incident within the Karuventrayan malai nesting colony. LBVs were observed incubating during November 2020; however, they were conspicuously absent from this nesting site in December 2020 and January 2021. This deviation from expected nesting behavior prompted further investigation. It was discovered that on 3 December 2020, four Asiatic Wild Dogs had succumbed to a poison-bait incident in the vicinity. Significantly, it was reported by locals that three vultures had also indirectly fallen victim to the poisoning, apparently a case of retaliatory killing of wild carnivores which had recently caused mortality in domestic livestock. Several locals were arrested for this incident by the forest department and this is subject to further investigation. Instances of vulture fatalities due to poison baits necessitate thorough investigations to ascertain the motivation and full circumstances relating to the incidents, and it is often difficult to establish the full story. Identifying the sources and mechanisms of poisoning is essential to allow the implementation of targeted interventions to prevent further losses (Ogada et al. 2012).

Evidence of other threats

Interestingly, the fatality of a Himalayan Griffon Vulture was observed under powerlines, apparently a result of electrocution in NBR (Manigandan et al. 2021) with a burning smell of tissues reported although no tissue testing was done due to a lack of facilities.

The potential accessibility of harmful substances to vultures, specifically from toxic NSAIDs (Nimesulide, ketoprofen, aceclofenac, and flunixin) which were found to be available for use in cattle from local pharmacy outlets adds to the threat to vultures as the covert survey done during the period from the proposed VSZ (Manigandan 2018). Apart from the wider availability of safer drug meloxicam, other harmful drugs sold in the market such as ketoprofen and nimesulide is a major concern in vulture conservation of NBR, as this study concentrated on pharmacies in the districts of Nigiris, Erode, Tirupur and Coimbatore, adjacent to the VSZ. The collaborative efforts of the forest department and local NGOs in monitoring the availability of NSAIDs in pharmacy shops are commendable as they create awareness among the local community, pharmacy shop owners, and staff about the importance of vultures in society and the harmful effects of NSAIDs. However, pharmacy shop owners are only aware of diclofenac and not aware of other harmful drugs (Manigandan et al. 2023). To prevent the accidental poisoning of vultures, it is important to make sure that these substances are not accessed by vultures and above all that they are not used in livestock practices when affordable alternatives like meloxicam and tolfenamic acid are available. Villagers typically bury naturally deceased cattle, while livestock killed by wild animals, particularly those within

Table 3. Breeding success of Long-billed Vultures *Gyps indicus* from 2018–2021 (three seasons).

Name of the nesting colony	2018–2019				2019–2020				2020–2021				Overall %
	Total number of nests with eggs	Number of nests seen with hatchlings	Number of hatchlings successfully fledged	Hatchling success percentage	Total number of nests under incubation	Number of nests seen with hatchlings	Number of hatchlings fledged	Hatchling success percentage	Total number of nests under incubation	Number of nests seen with hatchlings	Number of hatchlings fledged	Hatchling success percentage	
Ebbanad	2	2	2	100	1	1	1	100	2	1	1	50	83.3%
Kodanad	3	2	2	66.66	3	2	2	66.66	2	1	1	50	61%
Kallampalayam	1	1	1	100	2	1	1	50	3	3	3	100	83.3%
Karuvendrayan Malai	-	-	-	-	-	-	-	-	1	0	0	0	0
Total	6	5	5	83.33	6	4	4	66.66	8	5	5	62.5	70.83%

the forest, are left in the open and available to vultures. If such incidents occur near the village, the animals are always buried.

CONCLUSION

To tackle the challenges faced by vulture conservation, the approach of the establishment of vulture-safe zones has been developed (Thapa et al. 2009; Mukherjee et al. 2014; Insua-Cao et al. 2022). Such conservation endeavors are playing a key role in safeguarding the remaining LBV population in NBR, along with the other nesting vulture species in the area, White-rumped Vulture (WRV). The conclusions from this three-year study suggest that vulture safe zone activities may best focus in this area on the following: a) optimizing fire management practices; b) controlling NSAID availability for veterinary use; c) investigating poison baits incidents; and d) monitoring the threat and safety of power infrastructure. Hence, a comprehensive vulture safe zone approach will be needed addressing all of these issues along with raising local awareness of the positive attributes of vultures. Local human disturbance may also be a further threat. The imperative lies in the coordinated commitment of researchers, government agencies, NGOs, and local communities to ensure the long-term survival of LBV populations. In conclusion, this monitoring study demonstrates how local threats can be determined through regular monitoring and follow-up, and how widescale vulture safe zone work is needed to secure the future of vulture populations.

REFERENCES

Bowden, C.G.R., V. Prakash, S. Ranade, A. Routh, R.D. Jakati, R.J. Cuthbert, A.R. Rahmani, R.E. Green, N. Prakash & J. Parry-Jones (2012). Conservation breeding for the future release of the Critically Endangered Asian *Gyps* vultures progress of the program in south Asia and why it is so important. *Journal of the Bombay Natural History Society* 109(1): 43–45.

Byju, H. & N. Raveendran (2022). Egyptian Vultures extending to new landscapes in southern Tamil Nadu: need for measures. Bird-o-soar #170, In: *Zoo's Print* 37(6): 37–40.

Collar, N.J. & S.H.M. Butchart (2013). Conservation breeding and avian diversity: chances and challenges. *International Zoo Yearbook* 48(1): 7–28. https://doi.org/10.1111/izy.12039

Insua-Cao, P., P.R. Sachin, S. Rohan, S. Bharathidasan & S. Prakash (2022). Vulture safe zones of India. Vulture Conservation in Asia. *Hornbill* 113–119.

Manchiryala, R. & R.M. Medicheti (2014). Breeding biology of Critically Endangered Long-billed Vulture (*Gyps indicus*) at a unique site in Telangana State, India. *Ambient Science* 3(1): 49–51. https://doi.org/10.21276/ambi.2016.03.1.nn01

Manigandan, S. (2018). The Survey on prevalence of Non-Steroidal

Anti-Inflammatory Drugs (NSAIDs) in the Nilgiris, Tamil Nadu, pp. 90–93. In: Ramakrishnan, B. (ed.). *Securing Vulture Population in Southern India*. Proceedings of the workshop conducted from 8th to 10th, January, 2018 at Udhagamandalam, The Nilgiris.

Manigandan, S., H. Byju & P. Kannan (2023). Assessing the accuracy of population estimation methods for vulture populations: a case study from the Mudumalai Tiger Reserve, Tamil Nadu, India. *Environmental and Experimental Biology* 21: 45–52. https://doi.org/10.22364/eeb.21.06

Manigandan, S., P. Kannan, H. Byju & S. Bharathidasan (2021). Death of a Himalayan Vulture in South India highlights the potential threat of power infrastructure. *Vulture News* 80: 20–22.

Mathesh K., K. Manickam, J.W. Mallord, K. Mahendran, M.A. Kumar, S. Debasish, C.S. Mohan, V. Beena, P.S. Lakshmi, N. Prakash, R. Shringarpure, M.P. Abhijit M, R.E. Green, V. Naidoo & V. Prakash (2023). Experimental safety testing confirms that the NSAID nimesulide is toxic to *Gyps* vultures in India. *Environmental Toxicology and Pharmacology* 103: 104284. https://doi.org/10.1016/j.etap.2023.104284

MoEFCC (2020). *Action Plan for Vulture Conservation in India, 2020–2025*. Ministry of Environment, Forest and Climate Change, Government of India, 118 pp.

Mukherjee, A., T.H. Galligan, V. Prakash, K. Paudel, U. Khan, S. Prakash, S. Ranade, K. Shastri, R. Dave, P. Donald & C. Bowden (2014). Vulture Safe Zones to save *Gyps* Vultures in South Asia. *Mistnet* 15(3): 4–21.

Oaks, J.L., M.Z. Gilbert, M.Z. Virani, R.T. Watson, C.U. Meteyer, B.A. Rideout, H.L. Shivaprasad, S. Ahmed, M.J. Iqbal Chaudhry, M. Arshad, S. Mahmood, A. Ali & A.A. Khan (2004). Diclofenac residues as the cause of vulture population decline in Pakistan. *Nature* 427: 630–633. https://doi.org/10.1038/nature02317

Ogada, D.L., F. Keesing & M.Z Virani (2012). Dropping dead: causes and consequences of vulture population declines worldwide. *Annals of the New York Academy of Sciences* 1249(1): 57–71. https://doi.org/10.1111/j.1749-6632.2011.06293.x

Prakash V., D.J. Pain, A.A. Cunningham, P.F. Donald, N. Prakash, A. Verma, R. Gargi, S. Sivakumar & A.R. Rahmani (2003). Catastrophic collapse of Indian White-backed *Gyps bengalensis* and long-billed *Gyps indicus* vulture populations. *Biological Conservation* 109(3): 381–390. https://doi.org/10.1016/S0006-3207(02)00164-7

Puyravaud, J.P. & P. Davidar (2013). The Nilgiris Biosphere Reserve: an unrealized vision for conservation. *Tropical Conservation Science* 6(4): 468–476. https://doi.org/10.1177/194008291300600401

Ranade, S., J. Gore & A. Kumar (2023). Breeding of Himalayan Vulture *Gyps himalayensis* Hume, 1869 (Aves: Accipitriformes: Accipitridae) in the Assam State Zoo, Guwahati, Assam, India. *Journal of Threatened Taxa* 15(7): 23601–23605. https://doi.org/10.11609/jott.8607.15.7.23601-23605

Rasmussen, P.C. & J.C. Anderton (2005). *Birds of South Asia. The Ripley Guide, Vols. 1 and 2.* Smithsonian Institution and Lynx Edicions, D.C. and Barcelona, 116 pp.

Risebrough, R. (2004). Conservation biology: Fatal medicine for vultures. *Nature* 427(6975): 596–598. https://doi.org/10.1038/nature02365

Stotrabhashyam, S., B. Reddy, V. Satla & I. Siddiqui (2015). A breeding site record of Long-billed Vulture *Gyps indicus* (Aves: Accipitriformes: Accipitridae) from Bejjur Reserve Forest, Telangana, India. *Journal of Threatened Taxa* 7(1): 6800–6804. https://doi.org/10.11609/JoTT.o4014.6800-4

Subramanya, S. & O.C. Naveen (2006). Breeding of long-billed vulture *Gyps indicus* at Ramanagaram hills, Karnataka, India. *Indian Birds* 2: 32–34.

Swan G., V. Naidoo, R. Cuthbert, R.E. Green, D.J. Pain, D. Swarup, V. Prakash, M.Taggart, L. Bekker, D. Das, J. Diekmann, E. Killian, A. Meharg, R.C. Patra, M. Saini & K. Wolter (2006). Removing the threat of diclofenac to critically endangered Asian vultures. *PLoS Biology* 4(3): e66. https://doi.org/10.1371/journal.pbio.0040066

Thapa, I. (2009). An overview of culture Conservation in Nepal. *The Initiation* 3(2009): 114–118.

Umapathy, G., S. Hussain & S. Shivaji (2009). Status and distribution of vultures in Andhra Pradesh, India. *Forktail* (25): 163–165.

Venkitachalam, R. & N. Senthilnathan (2015). Breeding Record of Indian Vulture (*Gyps indicus*) in Moyar Valley, Tamil Nadu, India. *Current Science* 109(2): 258–259.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 February 2024 | 16(2): 24737–24745

ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

https://doi.org/10.11609/jott.8593.16.2.24737-24745

#8593 | Received 15 June 2023 | Final received 01 August 2023 | Finally accepted 17 December 2023

OPEN ACCESS

COMMUNICATION

Observations on Indian Skimmer *Rynchops albicollis* Swainson, 1838 (Aves: Charadriiformes: Laridae) breeding colonies in Middle Ganges stretch, India

Kumar Ankit [1], Mujahid Ahamad [2], Vivek Ranjan [3], Sanjay Kumar [4], Syed Ainul Hussain [5] & Govindan Veeraswami Gopi [6]

[1,2,3,5,6] Wildlife Institute of India, Chandrabani PO Box #18, Dehradun, Uttarakhand 248001, India.
[4] Lal Bahadur Shashtri Bhawan, Sarojini Naidu Marg, Raj Bhavan Colony, The Mall Avenue, Lucknow, Uttar Pradesh 226027, India.
[1] kumarankit.shiats@gmail.com (corresponding author), [2] mujahid@wii.gov.in, [3] rvivek@wii.gov.in, [4] sanjaykumarias02@yahoo.co.in, [5] hussain@wii.gov.in, [6] gopigv@wii.gov.in

Abstract: Indian Skimmer *Rynchops albicollis* Swainson, 1838 is a riverine habitat specialist bird and a species of significant conservation concern. In 2020 it was up-listed to the 'Endangered' category of the IUCN Red List. Breeding grounds of the species are known from the major rivers of India like Ganga, Chambal, Son, and Mahanadi. We monitored breeding colonies of the species in two breeding seasons (2017 and 2018) in the middle Ganges stretch. We identified nine nesting islands and monitored a total of 111 active nests during the study period. A total of 302 eggs were counted with clutch sizes ranging 1–5 and the mean clutch size of 2.7 (±1.18 SD). We observed a 10% & 7% of hatching and fledgling success rate in 2017 and 10% & 17% in 2018, respectively. Low breeding success was probably due to the severe anthropogenic factors such as egg collection, cattle trampling, and stochastic weather events such as flooding and sand inundation by sand storms in nests. We also recorded instances of nest abandoning because of unknown reasons. This article recommends more surveys to identify new breeding colonies of Indian Skimmer in the middle Ganges and subsequently provide adequate protection to the colonies. We also recommend sensitization programs for different stakeholders to create more awareness for the conservation of this threatened species in the middle Ganges stretch.

Keywords: Breeding birds, breeding phenology, endangered birds, nesting birds, prayagraj, river island, riverine birds, threatened riverine bird, waterbirds.

Editor: S. Balachandran, Rtd. Deputy Director, Bombay Natural History Society, Mumbai, India. **Date of publication:** 26 February 2024 (online & print)

Citation: Ankit, K., M. Ahamad, V. Ranjan, S. Kumar, S.A. Hussain & G.V. Gopi (2024). Observations on Indian Skimmer *Rynchops albicollis* Swainson, 1838 (Aves: Charadriiformes: Laridae) breeding colonies in Middle Ganges stretch, India. *Journal of Threatened Taxa* 16(2): 24737–24745. https://doi.org/10.11609/jott.8593.16.2.24737-24745

Funding: Wildlife Institute of India, Dehradun and National Mission for Clean Ganga, Ministry of Jal Shakti, Government of India.

Competing interests: The authors declare no competing interests.

Author details: KUMAR ANKIT is senior research fellow at Wildlife Institute of India, Dehradun. He is also PhD scholar of AcSIR, Ghaziabad. His specialization is in movement ecology, human-carnivore interaction, water birds and population ecology. MUJAHID AHAMAD is a PhD scholar and currently working as a senior project biologist at the Wildlife Institute of India, Dehradun. He specialized in animal ecology and human-wildlife interaction. VIVEK RANJAN is a PhD scholar at the Wildlife Institute of India working on human-wildlife interaction in human-dominated landscapes. SANJAY KUMAR is IAS of 2002 batch with Uttar Pradesh as home cadre. He is author of many books on birds and nature conservation. He had played a vital role in the field of conservation by providing technical support to the government in establishing ramsar sites, important wetland areas and conservation reserves. SYED AINUL HUSSAIN is the project manager (NMCG) and former scientist-G at the Wildlife Institute of India. His specialization is in wetland ecology and habitat ecology. GOVINDAN VEERASWAMI GOPI is scientist at the Wildlife Institute of India. He is member of different IUCN commissions. His core research interests are in understanding about inland and coastal wetlands and the species that depend on them. He is also involved in assessing developmental projects, teaching, training and supervising in-service officers, master's and PhD students at WII.

Author contributions: KA—conceptualization, data collection, data analysis & analysis, methodology, writing the original draft. MA—data collection and analysis. VR—data collection. SK—conceptualization and data visualization SAH—conceptualization, data visualization investigation, supervision GVG— conceptualization, data visualization investigation, supervision, review & editing.

Acknowledgements: We express our sincere thanks to the director, dean, researchassociate and course director of XV. MSc of Wildlife Institute of India for their support in the study. We are grateful to the National Mission for Clean Ganga and the Ministry of Jal Shakti, Government of India, to fund the fieldwork related to this work. We express our sincere gratitude Uttar Pradesh Forest Department and Prayagraj District Administration for providing permission and logistical support. We acknowledge Mrs. Divya IFS (Former DFO, Prayagraj) for her kind support. We also thank Mr. Vikash Tiwari, Mr. Deepak Dhakad, and Mr. Rajesh Kumar for volunteering in data collection. We are grateful to Ankita Sinha & Naman Goyal for reviewing the manuscript and Ashish Jangid for helping in map preparation.

INTRODUCTION

The Skimmers are a group of birds that belong to the genus *Rynchops* of the family Laridae (BirdLife International 2023). They are known for their uneven bill for foraging on the fishes, insects, and shrimps through skimming on the water surface (Zusi 1996; Martin et al. 2007). Globally, three members of *Rynchops* genus are known—the African Skimmer *Rynchops flavirostris*, the Black Skimmer *Rynchops niger*, and the Indian Skimmer *Rynchops albicollis* (Bhushan 2018). Among them, the Indian Skimmers are globally threatened riverine birds native to southern and southeastern Asia. They have been recently up-listed to the 'Endangered' category of the IUCN Red List because of the declining population trend (Birdlife international 2023). Indian Skimmers are medium, tern-size birds of 40–43 cm in length with a wingspan of around 108 cm (Grimmett et al. 2016; Shaikh et al. 2018). The adults have a drooping orange-red bill with lower mandible projecting beyond the upper mandible (Ali & Ripley 1987). It has a black cap and mantle, and wings contrasting with white underparts (Grimmett et al. 2016). In 2001, the adult population was estimated to be 4,000–6,700 individuals. However, with the recent assessment in 2020, the population estimate of the Indian Skimmer is 2,450–2,900 mature individuals. It is estimated to be 41% decline of the population from 2001 to 2020 (Birdlife International 2023).

Historically, the population was distributed in the major river systems of Myanmar, Cambodia, Vietnam, and the Mekong delta (Sundar 2004). However, the current distribution of the species is believed to be from Pakistan and Nepal, with the stronghold of the population in India and Bangladesh (Rajguru 2017; Debata et al. 2019). In India, the breeding population of the species is known from the major rivers like Chambal, Mahanadi, Ganges, and Son (BirdLife International 2023). However, in recent years non-breeding population are also recorded from the peninsular India, east and west coast, and other wetlands (Gopi & Pandav 2007; Malla et al. 2015; Shaikh et al. 2021). There are also records of wintering and breeding grounds of the species from Bangladesh (Mohsanin 2014; Kabir et al. 2016; Chowdhury et al. 2020; Das et al. 2020). The known breeding grounds of the species reported from India are National Chambal Sanctuary on river Chambal in the state of Uttar Pradesh, Rajasthan and Madhya Pradesh (Sundar 2004; Das 2015; Shaikh et al. 2018; Singh & Sharma 2018), Narora Ramsar Site on river Ganges in Uttar Pradesh (Siddiqui et al. 2007), Son Gharial Wildlife Sanctuary on river Son in Madhya Pradesh (Dilawar & Sharma 2016), and Pong Dam Wildlife Sanctuary in Himachal Pradesh (Fernandes & Besten 2013). However, new breeding records have been reported in the last five years from the middle Ganges stretch (Ankit et al. 2018; Mital et al. 2019) and Mahanadi (Rajguru et al 2017; Debata et al. 2018). The breeding season starts after the winters ranging from February to May in different breeding sites. Indian Skimmers breed in colonies and sometimes with other species like River Tern *Sterna aurantia*, Little Tern *Sternula albifrons*, River Lapwing *Vanellus duvaucelii,* and Small Pratincoles *Glareola lactea* (Rahmani 2012; Rajguru 2017; Ankit et al. 2018; Debata et al. 2019). Generally, Indian Skimmers lay eggs in sandy spits of emerged river islands; the clutch size ranges between 1–5, and both the sexes are involved in incubation and parental care after the hatching of eggs (Shaikh et al. 2018; Debata et al. 2019).

Habitat degradation due to several anthropogenic disturbances resulting in low reproductive success is considered a major cause for the rapid population decline. Also, there are records of stochastic weather events causing nest failure of the species at different breeding sites (Shaikh et al. 2018; Debata 2019). However, the essential information pertaining to the breeding biology, threats to the breeding colonies, and long-term population monitoring are still very limited across its breeding ranges (Rajguru 2017; Debata et al. 2019; Shaikh et al. 2018). After the discovery of new breeding colonies in the middle Ganges stretch in the year 2017, we investigated different aspects of the breeding biology of Indian Skimmer. We also identified threats to the breeding colonies in the middle Ganges stretch by monitoring two breeding seasons, which is far apart from the earlier known breeding grounds of other riverine system.

METHODS

Study Area

This study was carried out in the Prayagraj District (25.4727^{0}N, 81.8783^{0}E) of Uttar Pradesh (formerly Allahabad) (Image 1). The district is known for the confluence of two major rivers of India—Ganges and Yamuna—and the invisible Saraswati. The river Ganges has been divided into three courses—Upper (stretch in mountainous regions of the Himalaya), Middle (stretch of floodplains), and Lower Ganges (stretch after the confluence of major river till it meets the Bay of Bengal) due to its characteristics such as flow, channel width, depth and sedimentation. settings. The Prayagraj

district is adjacent to middle Ganges stretch. Prayagraj experiences three prominent seasons, summer (March–June), monsoon (July–September), and winter (October–February). The average maximum temperature ranges 23°–41°C with 1,027 mm annual rainfall. The district is famous for 'Kumbh Mela' at the confluence point which is known for world's largest human congregation due to traditional beliefs. Additionally, the area also witnesses human gathering round the year due to religious practices, annual 'Magh Mela' during the winter is one of the examples. The Ganges in Prayagraj is also one of the polluted stretches because of several anthropogenic activities, including the effluent discharges from the leather industries of Kanpur city, which is located on the upstream of the river. However, the area supports good biodiversity of riverine species like the Gangetic Dolphin *Platanista gangetica*, Gharial *Gavialis gangeticus*, Marsh Crocodile *Crocodylus palustris,* different species of turtles, fishes, and wetland birds like the River Tern *Sterna aurantia*, Little Tern *Sternula albifrons*, River Lapwing *Vanellus duvacellii,* Small Pratincoles *Glareola lactea*, and Ruddy Shelduck *Tadorna ferruginea.* The dry and hot summer causing low water levels exposes sandbars and river islands, which facilitates breeding riverine birds like Little Tern, River Lapwing, and Indian Skimmer. As a part of an ongoing project on waterbirds, after a few sightings of Indian Skimmer in the confluence area in January 2017, we extensively surveyed a total of 75 km of riverine stretches in Prayagraj district (25 km stretch each upstream and downstream of the river Ganges and 25 km upstream of the Yamuna from the confluence) in January to June in both the year of 2017 and 2018. The banks of the rivers were mostly sandy with intermittent mudflats, cultivations and settlements. There were also exposed river islands mostly in the river upstream of Ganges (from the confluence) due to low water depth.

Observations on nesting birds

The survey method included trail walking along the banks and opportunistic surveys through mechanised boat from February to June. After observing the events of the courtship display and congregation of birds, we considered the river islands as the nesting island of the

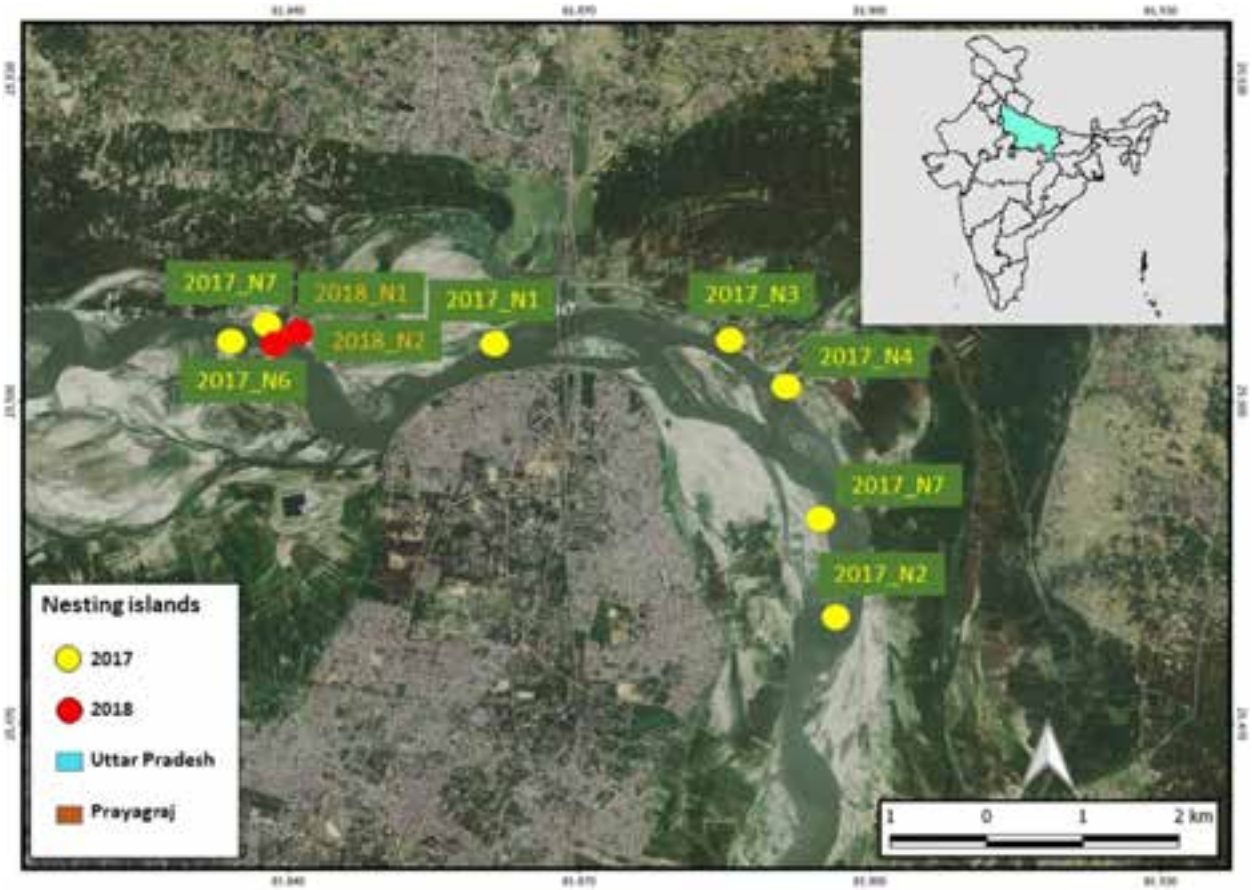


Image 1. Locations of identified nesting islands of Indian Skimmer in Prayagraj in the years 2017 and 2018.

birds. After 3–4 days, we visited the islands to record any breeding activity such as nest preparation. After getting ensured the sign of nest preparation, we considered it as nesting island. we started regular monitoring the nesting islands in the morning (0600–0800 h) or evening time (1600–1800 h) from the river bank using Bushnell 8 × 42 binocular. Only after observing signs of incubation, we visited the nesting islands using a non-motor boat, ensuring minimal disturbance to the breeding birds. Further, we started regularly visiting the nesting island in the morning (0600–0800 h) or evening (1600–1800 hs). Two observers visited the islands and separately recorded the number of individuals, nests, clutch sizes, hatchlings, nest failures, and anthropogenic disturbances. The observer's entry and exit times to the nesting island were fixed. One observer was followed by the second observer in the multiple straight lines with inter-distance of 1.8–2.4 m (n = 8–18 depending on the size of the nesting island). The double observer method ensured the confirmed identification of the nests, and presence of new active nests. Since, most of the islands were having fewer active nests, the double observer method minimised the possibility of double counting or missing of active nests.

We ensured that the observation took minimum possible time while collecting the data, which were around 5–10 min depending on the number of nests and island size. We did not use any invasive techniques to mark the nest or the eggs, and during the observation, precautions were made to minimize the disturbance to the birds. We consciously walked on the islands to minimize the footprints on the island. Same survey and monitoring protocols were used in both the years of the breeding cycle. Successful nest was considered with the minimum one egg hatched in a particular nest and hatching success percentage was calculated as the proportion of number of successful nest and number of nests (Debata et al. 2019). Whereas, the fledgling success was calculated as the proportion of nest with fledglings and number of successful nests. We also analyzed the clutch size the percentage of the nest failure because of the different factors.

RESULTS

Sightings, abundance, and breeding phenology

Sightings of Indian Skimmers were continuous from January to March 2017 & 2018, mostly on flights or during foraging. We recorded the first congregation of the birds on a river island in late March 2017 and early April 2018. Subsequently, we recorded seven and two nesting islands in 2017 and 2018, respectively (Image 1). A total of 356 (n = 232 in 2017, n = 144 in 2018) individuals of Indian Skimmers were observed in the different nesting islands. The sporadic sightings of the birds during the surveys are excluded from the total count. Courtship display, mating, and nest preparation continued between late March and April in both years. However, mating events and nest preparedness were also observed in May and the first week of June 2017 in some nesting islands. In 2017 season, the first clutch was noticed during the first week of April. However, we located nesting in the second week of April in the year 2018. The first hatching of eggs in the nests was observed during mid-May in 2017 and late April 2018 (presuming the first clutch of the season in the last week of March). In 2017, the hatching of eggs was also observed till June in a couple of nesting islands. In May and early June, we observed the dispersal of fledglings from the nesting islands. Both the mating partners were involved in parental care and nest guarding during the breeding cycle.

Active nests and clutch size variation

All the nine nesting islands were approximately in the range of 15 km upstream of river Ganges from the confluence point. We recorded 111 active nests of Indian Skimmers (n = 73 in 2017 and n = 38 in 2018) and these active nests were the shallow depressions in sands, mostly away from the edges of the river islands (Table 1). A total of 302 eggs were laid by the species in the study area (n = 186 in 2017 and n = 116 in 2018) (Table 1). The clutch size varied between 1–4 and 1–5 in different nesting islands of 2017 and 2018 observations, respectively. The mean clutch size was 2.54 (SD ± 1.11) and 3.05 (SD ± 1.27) in the years 2017 and 2018, respectively. We also recorded the active nests and fledglings of River Lapwing, Little Tern, Small Pratincole, and Black-winged Stilt on the nesting islands of Indian Skimmer.

Breeding Success and possible causes of nest failure

Out of all the nine nesting islands in 2017 and 2018, nesting failure was observed in three islands due to anthropogenic and natural causes in the year 2017. The remaining six nesting islands recorded hatching (n = 4 in 2017 and n = 2 in 2018). Among all the monitored active nests, only 10% and 11% of the nest successfully produced chicks in 2017 and 2018 respectively whereas, 10% and 7% survived up to fledgling stage with respect to the number of nests in the year 2017 and 2018,

Table 1. Total number of eggs and active nests and nesting islands description of Indian Skimmers recorded in Prayagraj on different nesting islands in the years 2017 and 2018.

Nesting islands	Total active nest	Total number of eggs	Perimeter of nesting islands (in meters)	Distance from bank (in meters)	Distance from human settlement (in meters)
2017_N1	8	11	1056	187	210
2017_N2	13	42	1934	413	1652
2017_N3	6	15	433	224	1284
2017_N4	31	86	708	220	1794
2017_N5	3	9	225	108	1705
2017_N6	3	8	862	198	1926
2017_N7	9	15	2179	377	1915
2018_N1	26	85	743	197	1553
2018_N2	12	31	509	179	15608

Table 2. Causes of nest failure of Indian Skimmers in Prayagraj in the years 2017 and 2018.

Causes of failure	2017		2018	
	Number of nests	%	Number of nests	%
Egg Stage Failure				
Egg collection	8	12	0	0
Flooding	16	24	0	0
Predation	28	42	0	0
Sand Inundation	0	0	18	60
Cattle trampling	0	0	5	17
Abandoning	14	21	7	23
Chick stage failure				
Abandoning	0	0	2	25
Cattle trampling	0	0	6	75

respectively. The main causes of the nest failure were anthropogenic pressure such as cattle trampling, egg collection, and natural causes include predation, flooding, and sand inundation (Table 2).

DISCUSSION

Long-term ecological monitoring is an essential tool for the conservation of any species. It provides basic ecological information of the targeted species and its associated community in lieu of different environmental conditions. It gradually helps in identifying key conservation priorities and monitoring the effect of change in policy and environment (Havstad & Herrick 2003; Giron-Nava et al. 2017). However, long-term ecological monitoring of the waterbirds and their associated habitats is limited in India (Prasad et al. 2002; Kar et al. 2018; Singh & Sharma 2018; Debata et al. 2019). The riverine systems of India facilitate the occurrence of river-dependent birds by providing shelter, forage, and breeding grounds (Islam & Rahmani 2008; Rajguru 2017; Sinha et al. 2019). Many species of birds are known to utilize the river and its associated habitats to complete partial or entire lifecycles (Page & Gill 1994; Vaughan et al. 2007; Froneman et al. 2011; Rahmani 2012). Additionally, the riverine system has an intricate relationship with humans, which sometimes causes overexploitation and habitat degradation, and can adversely impact the populations of species like the Indian Skimmer and the Black-bellied Tern *Sterna acuticauda* (Kar et al. 2018; Kar & Debata 2019). In our study area, we observed multiple pressures on the river system, which negatively impacts the breeding cycle of Indian Skimmer and may severely affect the species at the population level on a long run.

Population and breeding in the middle Ganges stretch

There were previous sighting and breeding records (Narora-Ramsar Site) of Indian Skimmers from the river Ganges (Siddiqui et al. 2007). The recent breeding records from the middle Ganges stretch is from Prayagraj (Ankit et al. 2018) (Image 2) and Varanasi (Mital et al. 2019). This study and previous records suggest the congregations of the birds in December and January in the middle Ganges stretch (Shukla 2016). Both the years 2017 and 2018, we observed the congregation of more than 100 Indian Skimmers in different Islands. However, the nesting islands were relatively less with respect to the total number of individuals sighted. There may be a possibility that most of the birds used these islands as a stopover site. There was a difference between the nesting islands in the years 2017 and 2018, we presume that after a couple of nest failures these individuals laid their second clutch in our study area hence, we located more breeding colonies in 2017. The records of only two breeding islands in 2018 led to the speculation that there would have been more nesting colonies in the upstream of the Ganges beyond our study area because of the observance of higher number of individuals in one of the nesting islands. These individuals might have shifted to the upstream for breeding as there are observations on breeding Skimmers in upstream of Allahabad recorded by Survey teams of Wildlife Institute of India in Bulandshahr and Farrukhabad districts in between the year 2017 and 2021. The breeding period

Image 2. Series of events recorded for Indian Skimmers in Prayagraj: a—occasional sightings | b—congregation in river islands | c—courtship display | d—mating events | e—laying and incubation of eggs | f—hatching of eggs. © Kumar Ankit.

ranges between February and May, similar to the observation made at different breeding sites (Dilawar & Sharma 2016; Rajguru 2017; Shaikh et al. 2018; Debata et al. 2019). Across the two monitoring years, no nesting islands were observed in the Yamuna stretch, possibly because of the unavailability of river islands as the river Yamuna which had high water levels during both the surveyed years. However, there are recent nesting records have been observed in Yamuna in Prayagraj District (Mani 2023)

Poor breeding success and threats to the breeding colonies

Prayagraj is one of the densely human-populated cities of the Northern-India; hence it poses severe anthropogenic pressure to riverine stretches adjacent to the city. All the nesting islands were in close proximity to the periphery of the city, which has caused the enabling of multiple threats to the breeding colonies. The main reason for the nest failure was due to the anthropogenic pressures followed by the stochastic events that caused low breeding success in the study area (Image 3). Similar threats have also been identified at different breeding sites (Siddiqui et al. 2007; Debata et al. 2018; Shaikh et al. 2018; Mital et al. 2019). The breeding success is very low when compared to the similar study of Debata et al. (2019) in the Mahanadi River in the same breeding season. It highlights the magnitude of anthropogenic pressure on the middle Ganges which may be negatively impacting other riverine species too. Multiple anthropogenic threats were identified that had directly impacted the breeding colonies, such as cattle trampling. It was observed that because of low water depth, cattle use these islands as passage to go from one bank to other for foraging. Additionally, they venture in to the river islands to forage on vegetation growth. We also observed egg collection by the locals. However, no information on consumption or commercial use was available. There are indirect threats such as disturbances because of agricultural activities in the bank of the river and on river islands. The locals grow seasonal crop such as watermelon, pumpkin, and other cucurbitaceous crops of the gourd family on the sandy area of banks and river islands. We haven't recorded any agriculture on the nesting islands but we observed agriculture activity on the nearby banks. Additionally, free-ranging dogs, and boat activity, which may have led to the abandoning of the nests by the breeding pairs.

After the nesting failure in multiple nesting islands due to anthropogenic activities in 2017, we availed help from the forest department and Prayagraj administration for ensuring the protection of the nesting islands through awareness in adjoining villages for farmers working in the adjacent field. Forest officials were deployed in the daytime as nest guardians (near the bank) to minimize the anthropogenic disturbance. No casualty was reported in the breeding island during the night and all the chicks fledged during this phase resulting in no nest failure at the chick stage in the year 2017. In the year 2018, the nest failure and egg

Image 3. Direct and indirect threats observed on the breeding colonies of Indian Skimmer a—Disturbance because of cattle and human | b—Island erosion | c—Disturbance because of free-ranging dogs | d—predation on the eggs by house-crow | e—chick mortality because of cattle trampling | f—inundation of sand in the nest because of rain and wind. © Kumar Ankit.

collection didn't happen probably due to the awareness created among the villagers in and around the nesting islands by the forest department team immediately after the locations were informed to the Forest department. Forest officials were deployed again in the daytime as nest guardians (near the bank) to minimize any sort of anthropogenic disturbance. However, after sunset, we recorded the event of cattle trampling in nesting islands which resulted some casualties on eggs and chick stages. The impact of pollution and prey availability due to fishing was not quantified in this study. This could have been the major cause of abandoning the nesting islands because of low food resources; hence, it needs investigation in the future. However, we observed disturbances to the breeding birds on the nesting islands due to fishing activity of human and boat in the proximity of the nesting islands. There were no instances of river bed material collection observed like in other breeding sites (Shaikh et al. 2018; Debata et al. 2019). However, erosion of non-nesting islands was observed because of increased water current and depth due to both natural and manmade factors, natural factors include unseasonal rainfall and manmade factors include water flow regulation from the upstream of Kanpur barrage for irrigation. However, we don't have data regarding the causes of water flow and water level fluctuation in the study area.

Conservation actions required

The basic ecological knowledge of breeding biology, diet, and movement during the non-breeding period of Indian skimmers is inadequate from all the breeding locations. However, it is notable that emphasis has been given by the scientific community on breeding and non-breeding sites of the species through continuous monitoring on different ecological aspects (Kabir et al. 2016; Rajguru 2017; Shaikh et al. 2018; Debata et al. 2019; Chowdhury et al. 2020). Recently observation has been also made in other rivers like Gomti in Ganga Basin (Chauhan 2023). The continuous monitoring and exploration in the potential breeding areas will unearth more information pertaining to the species for conservation.

The middle Ganges stretch is in lieu of several disturbances around the year. Hence, it becomes crucial to identify the breeding colonies in this particular stretch through continuous surveys and expeditions. Subsequently, nest protection should be provided to the breeding colonies through nest guarding and minimizing the anthropogenic pressure especially fishing during the nesting season. The 'nest guardian' program for protecting Indian skimmer nesting colonies is already in practice in National Chambal Sanctuary (Mishra & Tandon 2021), which can be replicated in the middle Ganges stretch. Sensitization of different stakeholders

through awareness drives, workshops, and community participation can also help in the protection of the nest and nesting islands during the season. Convincing locals and farmers not to do agriculture on river islands can also provide more availability of nesting islands for the Indian Skimmer and other riverine birds during peak breeding periods.

The glimmer of hope is that surveys have been conducted at regular intervals under the objective of biodiversity conservation of National Mission for Clean Ganga program in the past few years. It has helped in the identification of breeding locations of Indian Skimmers along the Ganges. Additionally, community participation programs such as 'Ganga Prahari' under the same project to involve the locals in biodiversity conservation of the river Ganges. However, with all these efforts it is necessary to protect breeding colonies of endangered Indian skimmer in the future which may subsequently help in increasing the population of the species and its survival. The record of the breeding colony from Prayagraj and Varanasi are promising findings that warrant further exploration surveys for more breeding colonies in the future.

REFERENCES

Ali, S. & S.D. Ripley (1987). *Compact Handbook of the birds of India and Pakistan together with those of Bangladesh, Nepal, Bhutan and Sri Lanka. 2nd Edition*. Oxford University Press, Delhi, 737 pp.

Ankit, K., V. Ranjan, M. Ahmad, S. Kumar, S. Hussain & G.V. Gopi (2018). Newly discovered breeding colonies of Indian Skimmer *Rynchops albicollis* in middle Ganges, India. *BirdingASIA* 30: 99–100

Bhushan, B. (2018). Skimmer Bird Beak *(Rynchops)* Surface for Fluid Drag Reduction in Turbulent Flow. *Biomimetics* (p. 563-576).

BirdLife International (2023). Species factsheet: *Rynchops albicollis*. Downloaded from http://www.birdlife.org. on 15 May 2023.

Chauhan, A. (2023). Breeding site of rare Indian skimmers spotted along Gomti in UP's Barabanki. Accessed at https://timesofindia.indiatimes.com/city/lucknow/breeding-site-of-rare-indian-skimmers-spotted-along-gomti-in-ups barabanki/articleshow/98217143.cms?from=mdr. Accessed on 24 February 2023.

Chowdhury, S.U., M. Foysal, N.U. Prince, S. Mohsanin, M.K. Miron & A.B.M.S. Alam (2020). Discovery of a new wintering area for Indian Skimmer *Rynchops albicollis* in Bangladesh. *BirdingASIA* 32: 99–102.

Das, D.K. (2015). Breeding status of Indian Skimmer *Rynchops albicollis* in the National Chambal Sanctuary, India. *Indian BIRDS* 10(2): 53–54.

Das, D.K., A.J. Galib, N. Khandakar, M.H. Rohman & A.H.M.A. Reza (2020). Activity budget of wintering Indian Skimmer *(Rynchops albicollis)* at Damar Char, Bangladesh. *Marine Ornithology* 48: 119–123.

Debata, S. (2019). Impact of cyclone Fani on the breeding success of sandbar-nesting birds along the Mahanadi River in Odisha, India. *Journal of Threatened Taxa* 11(14): 14895–14898. https://doi.org/10.11609/jott.5480.11.14.14895-14898

Debata, S., T. Kar, H.S. Palei & K.K. Swain (2019). Breeding ecology and causes of nest failure in the Indian Skimmer *Rynchops albicollis*. *Bird Study* 66(2): 243–250. https://doi.org/10.1080/00063657.2019.1655526

Debata, S., T. Kar, K.K. Swain & H.S. Palei (2018). The vulnerable Indian Skimmer *Rynchops albicollis* Swainson, 1838 (Aves: Charadriiformes: Laridae) breeding in Odisha, eastern India. *Journal of Threatened Taxa* 9(11): 10961–10963. https://doi.org/10.11609/jott.3445.9.11.10961-10963

Dilawar, M. & V. Sharma (2016). A new breeding location of Indian Skimmer *Rynchops albicollis*, and notes on other birds in Son Gharial Wildlife Sanctuary, Madhya Pradesh, India. *Indian BIRDS* 11(2): 35–38.

Fernandes, M. & J.W.D. Besten (2013). Some interesting breeding records for Pong Dam Wildlife Sanctuary, Himachal Pradesh, India. *Forktail* 29: 141–143.

Froneman, A., M.J. Mangnall, R.M. Little & T.M. Crowe (2001). Waterbird assemblages and associated habitat characteristics of farm ponds in the Western Cape, South Africa. *Biodiversity and Conservation* 10: 251–270. https://doi.org/10.1023/A:1008904421948

Giron-Nava, A., C.C. James, A.F. Johnson, D. Dannecker, B. Kolody, A. Lee, M. Nagarkar, G.M. Pao, H. Ye, D.G. Johns & G. Sugihara (2017.) Quantitative argument for long-term ecological monitoring. *Marine Ecology Progress Series* 572: 269–274.

Gopi, G.V. & B. Pandav (2007). Avifauna of Bhitarakanika mangroves, India. *Zoos' Print Journal* 22(10): 2839–2847.

Grimmett, R., C. Inskipp & T. Inskipp (2011). *Birds of the Indian Subcontinent. 2nd ed*. Oxford University Press & Christopher Helm, London, 528 pp.

Havstad, K.M. & J.E. Herrick (2003). Long-term ecological monitoring. *Arid Land Research and Management* 17(4): 389–400. https://doi.org/10.1080/713936102

Islam, M.Z.U & A.R. Rahmani (2008). *Potential and existing Ramsar sites in India*. Oxford University Press, 592 pp.

Kabir, M.T., S.U. Chowdhury, O. Tareq, A.B.M.S. Alam, S. Ahmed, O. Shahadat & M. Foysal (2016). New breeding records of riverine birds in Bangladesh. *BirdingASIA* 26: 39–42.

Kar, T. & S. Debata (2019). Assemblage of waterbird species in an anthropogenic zone along the Mahanadi River of Odisha, eastern India: Implications for management. *Proceedings of the Zoological Society* 72(4): 355–363. https://doi.org/10.1007/s12595-018-0276-9

Malla, G., P. Ray, P. Bagaria, K. Sivakumar, J.A. Johnson, G.V. Gopi & P. Sathiyaselvam (2015). Does the Indian Skimmer *Rynchops albicollis* have a future in East Godavari District, Andhra Pradesh. *BirdingASIA* 23: 58–59.

Mani, R. (2023). Large nesting site of Indian Skimmer discovered in Prayagraj's Palpur village. https://timesofindia.indiatimes.com/city/allahabad/large-nesting-site-of-indian-skimmer-discovered-in-prayagrajs-palpur-village/articleshow/99743641.cms. Accessed on 25 April 2023.

Martin, G.R., R. Mcneil & L.M. Rojas (2007). Vision and the foraging technique of skimmers (*Rynchopidae*). *Ibis* 149(4): 750–757. https://doi.org/10.1111/j.1474-919X.2007.00706

Mishra, M.C. & A. Tandon (2021). Chowkidar turns conservationist for winged friends in Chambal. https://india.mongabay.com/2021/02/chowkidar-turns-conservationist-for-winged-friends-in-chambal/. Accessed on 1 February 2021.

Mital, A., S.S. Khan & R.S. Kumar (2019). Indian Skimmer *Rynchops albicollis* and other riverine birds on the islands near Turtle Wildlife Sanctuary, Uttar Pradesh. *Indian BIRDS* 15 (2): 64–65.

Mohsanin, S. (2014). Survey of wintering Indian Skimmer *Rynchios albicollis* in Bangladesh. *Birding ASIA* 21: 105–106.

Page, G.W. & R.E. Gill Jr (1994). Shorebirds in western North America: late 1800s to late 1900s. *Studies in Avian Biology* 15: 147–160.

Prasad, S.N., T.V. Ramachandra, N. Ahalya, T. Sengupta, A. Kumar, A.K. Tiwari, V.S. Vijayan & L. Vijayan (2002). Conservation of wetlands of India—a review. *Tropical Ecology* 43(1): 173–186.

Rahmani, A.R. (2012). *Threatened Birds of India: Their Conservation Requirements*. Oxford University Press, New Delhi, xvi + 864 pp.

Rajguru, S.K. (2017). Breeding biology of Indian Skimmer *Rynchops*

albicollis at Mahanadi River, Odisha, India. *Indian BIRDS* 13(1): 1–7.

Shaikh, P., M. Panigrahi & T. Katti (2021). Indian Skimmer *Rynchops albicollis* (Swainson, 1838) Migration in India: Resighting Records of Birds Colour Tagged in National Chambal Sanctuary, Madhya Pradesh, India. *Journal of the Bombay Natural History Society* 118: 25–30.

Shaikh, P.A., A. Mendis, J. Luis, D.K. Das & S. Surve (2018). Status and distribution of Indian Skimmer *Rynchops albicollis* in the National Chambal Sanctuary, India. Final Report submitted to BirdLife International, 46 pp.

Shukla, N. (2016). Chambal loses its rare 'skimmer'. https://timesofindia.indiatimes.com/city/lucknow/chambal-loses-its-rare-skimmer/articleshow/50923409.cms. Accessed on 10 February 2016.

Siddiqui, A.I., J. Pandey & R. Mandal (2007). House-crow: threat to Indian Skimmer. *Mistnet* 8(2): 4–6.

Singh, L.A.K. & R.K. Sharma (2018). Sighting trend of the Indian Skimmer (Charidiformes: Laridae: *Rynchops albicollis* Swainson, 1838) in National Chambal Gharial Sanctuary (1984–2016) reflecting on the feasibility of long-term ecological monitoring. *Journal of Threatened Taxa* 10(5): 11574–11582. https://doi.org/10.11609/jott.3732.10.5.11574-11582

Sinha, A., N. Chatterjee, S.J. Ormerod, B.S. Adhikari & R. Krishnamurthy (2019). River birds as potential indicators of local-and catchment-scale influences on Himalayan river ecosystems. *Ecosystems and People* 15(1): 90–101. https://doi.org/10.1080/26395916.2019.1591508

Sundar, K.S.G. (2004). Observations on breeding Indian Skimmers *Rynchops albicollis* in the National Chambal Sanctuary, Uttar Pradesh, India. *Forktail* 20: 89–90.

Vaughan, I.P., D.G. Noble & S.J. Ormerod (2007). Combining surveys of river habitats and river birds to appraise riverine hydromorphology. *Freshwater Biology* 52(11): 2270–2284. https://doi.org/10.1111/j.1365-2427.2007.01837

Zusi, R.L. (1996). Family Rynchopidae (Skimmers), pp. 668–677. In: delHoyo, J., A. Elliott & J. Sargatal (eds.) *Handbook of the birds of the world. Vol. 3. Hoatzin to Auks*. Lynx Editions, Barcelona, 821 pp.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 February 2024 | 16(2): 24746–24751
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.8810.16.2.24746-24751
#8810 | Received 31 October 2023 | Final received 14 December 2023 | Finally accepted 25 December 2023
OPEN ACCESS
COMMUNICATION

Avifaunal diversity in urban greenspaces within Cotabato city, Mindanao Island, Philippines

Joan Rhea Mae L. Baes [1], Peter Jan D. de Vera [2], John Paul A. Catipay [3], Marian Dara T. Tagoon [4] & Elsa May Delima-Baron [5]

[1] College of Arts and Sciences, Notre Dame University, Cotabato City, 9600 Maguindanao del Norte, Philippines.
[2] Natural Sciences Department, College of Arts and Sciences, Mindanao State University- Maguindanao. Dalican, Datu Odin Sinsuat, 9601 Maguindanao del Norte, Philippines.
[3] Science Department, Senior High School, Notre Dame University. Cotabato City, 9600 Maguindanao del Norte, Philippines.
[4,5] School of Business Management, Education, Arts and Sciences, San Pedro College. Davao City, 8000 Davao del Sur, Philippines.
[5] Research, Publication, and Innovation Center, San Pedro College. Davao City, 8000 Davao del Sur, Philippines.
[1] jrmldd21@gmail.com, [2] peterjandevera0302@gmail.com (corresponding author), [3] catipay.jpa@ndu.edu.ph,
[4] marian.tagoon@gmail.com, [5] elsa.delima.baron@gmail.com

Abstract: Information about the diversity of avifauna in urban green spaces in the Philippines needs to be more extensive. More so, data on birds in green spaces of the country's Bangsamoro Region in Muslim Mindanao (BARMM) remain largely unreported. This gap highlights the need to document the avifaunal diversity in the urban green spaces of Cotabato City. Bird species were accounted for using the point count method from September to December 2021 in three different urban green spaces within the commercial center of Cotabato City. Twenty-one avian species representing 17 families were documented. Among the surveyed three green spaces within Cotabato City, Notre Dame University (NDU) has the highest species richness (N = 20), followed by PC Hill (N = 14), and Mother Barangay Rosary Heights (N = 9). Of the 21 species of birds documented, 19% are Philippine endemic, and all of these were recorded only at Notre Dame University. Data from the present study suggest the capacity of green spaces in urban Cotabato City to cater to different bird species, including the endemic ones. Since the results present preliminary data, intensive surveys can be done on these sites by future researchers. Also, surveying more urban green spaces in Cotabato City may add information on the city's urban birds. Substantial data from these future surveys may be helpful in the urban planning of Cotabato.

Keywords: BARMM, birds, city planning, critically endangered, ecological value, endemic, species richness, urban areas, vegetation.

Editor: H. Byju, Coimbatore, Tamil Nadu, India.

Date of publication: 26 February 2024 (online & print)

Citation: Baes, J.R.M.L., P.J.D. de Vera, J.P.A. Catipay, M.D.T. Tagoon & E.M. Delima-Baron (2024). Avifaunal diversity in urban greenspaces within Cotabato city, Mindanao Island, Philippines. *Journal of Threatened Taxa* 16(2): 24746–24751. https://doi.org/10.11609/jott.8810.16.2.24746-24751

Funding: This research received no external funding.

Competing interests: The authors declare no competing interests.

Author details: See end of this article.

Author contributions: JRMB—paper conceptualization and data collection, writing and editing the manuscript. PJDDV—research design, paper conceptualization, data collection, writing and editing the manuscript, and corresponding journal submission. JPAC—data collection and writing the manuscript. MDTT—paper conceptualization and writing and editing the manuscript. EMDB—paper conceptualization and writing and editing the manuscript.

Acknowledgements: The authors express their gratitude to the Barangay Local Government Units of Cotabato City, Maguindanao del Norte, BARMM for their invaluable support and cooperation in facilitating the conduct of the study within their jurisdiction. The authors would also like to express their sincere gratitude to the local para biologists for their support during the data collection. The authors would also thank Benito Anthony Pingoy for verifying the identified birds in this study. Gratitude is also extended to the reviewers whose suggestions improved this manuscript.

INTRODUCTION

Urban green spaces are locally fragmented and patchy vegetation areas within the city (Li et al. 2019) that provide habitats for different fauna, especially birds (Leveau et al. 2019). These areas come in various forms, including lakes, parks (Sulaiman et al. 2013; Yang et al. 2020), gardens (Parker et al. 2013), school campus vicinity (Ong et al. 1999; Vallejo & Aloy 2014), and hills (Jha 2019; Banzon et al. 2022). Moreover, urban green spaces provide ecosystem services ranging from regulating services (e.g., erosion control) to socio-cultural services (e.g., recreation) (Sultana & Selim 2021). In the Philippines, urban green spaces have been noted to provide opportunities for physical exercise and recreation among city residents (Saloma & Akpendonu 2022).

The island of Mindanao is home to endemic, vulnerable, and economically important species in the Philippines (Amoroso 2000; Tanalgo et al. 2023). Most of these species are birds according to several accounts on the island, which were recorded mostly from Agusan, while information regarding the matter was scant in the Bangsamoro region (Agduma et al. 2023; Cruz et al. 2023). Progressive human activities related to urbanization further put endemic and vulnerable bird species at risk in Mindanao (Bett et al. 2017; Agduma et al. 2023). Habitat loss due to urbanization is one among the drivers of diversity decline (Daipan 2021). Urban green spaces are possible means to find a way around deforestation and related threats especially in already urbanized areas (Wolff et al. 2018). The said urban vegetation may support conservation of birds (Cruz et al. 2023), as it harbors different birds in terms of endemicity depending on habitat type related to the degree of disturbance and land-use (Tanalgo et al. 2015, 2019). Among all wildlife fauna, birds directly benefit from urban green spaces (Muhlbauer et al. 2021; Prihandi & Nurvianto 2022). There are studies done in the Philippines documenting the presence of birds in various urban green spaces (Vallejo & Alloy 2014; Banzon et al. 2022). However, these studies were limited and data can be considered as not encompassing since it covers only limited areas in the country. Thus, there is a need to conduct bird surveys in other urban green spaces in Mindanao, especially in a less studied region of the island such as in the Bangsamoro Autonomous Region Muslim in Mindanao (BARMM).

Cotabato City is an urban area in the BARMM. It is located between the Rio Grande de Mindanao and the Tamontaka River, which makes it a catch basin of floodwater from the Ligawasan marsh in Maguindanao. Ironically, the region is rich in flora and fauna, however, published biological studies in the area remain scanty to date. The latter may be attributed to past and ongoing sociopolitical conflicts in the region. Recently, De Vera et al. (2023) documented 33 non-endemic and 10 endemic bird species from Timaco Hill, an isolated hill considered as Cotabato City's remaining pristine forested area. This study aims to determine the bird species and their diversity in selected urban green spaces within Cotabato City. The local government units and other government and private agencies may benefit from this study by formulating policies and plans that may support wildlife species such as birds within Cotabato City.

MATERIALS AND METHODS

Selection and size estimate of the urban green spaces surveyed

Selected urban green spaces within the commercial center of Cotabato City, Maguindanao del Norte, Philippines were surveyed in this study. The Notre Dame University (NDU), Mother Barangay Rosary Heights (MBRH), and PC Hill were the sites surveyed for birds and were at least 1.25 km (± 0.29) away from each other. These sites were selected based on accessibility, the presence of vegetation patches, and the absence of data on birds (Image 1). Before the survey, permits to enter and consent to conduct the bird survey were secured from the land managers and pertinent offices. All study sites were situated in the commercial area of Cotabato City. Each study site has a unique vegetation and level of disturbance. To determine the approximate land size, GPS coordinates of the perimeter of each urban green space were obtained. Thereafter, the coordinates were plotted on a digital map, then a polygon was drawn and used to determine the size of the surveyed area. The urban green spaces surveyed were described accordingly.

Notre Dame University (NDU)

The Notre Dame University (NDU) (7.2172N, 124.2438W) is characterized by open field with patches of vegetation. Compared to the other urban green spaces surveyed in this study, the NDU has more open spaces. Some sections of manmade paths were covered with large trees such as Acacia and *Albizia saman*. The open spaces were surrounded by infrastructures such as classrooms. The daytime population of NDU is approximately 4,000 which includes students, faculty, staff, and other employees.

Image 1. Location map showing the three urban green spaces surveyed in Cotabato City. (Map generated from QGIS 3.24.1).

PC Hill

The PC Hill (7.2198, 124.2445) is characterized by a secondary growth forest patch. It has one of the highest elevations within the Cotabato City (59 m) along with the Timaco Hill. Trees such as Acacia, *Albizia saman*, and Mahogany *Swietenia mahogani* and grasses and sedges are common along the concrete roads. Residential infrastructures are common in the area with the presence of common fruit-bearing trees such as Mango *Magnifera indica* and Guava *Psidium guajava L.* Vehicles and motorcycles were common in the area.

Mother Barangay Rosary Heights (MBRH)

The Mother Barangay Rosary Heights (MBRH) (7.2116, 124.2438) is characterized by the presence of residential infrastructures with cultivated ornamental shrubs. Tree strands are also observable in the area and are close to residential infrastructures. The presence of trees is also observable along the concrete roads with the presence of grasses and sedges. Open spaces and vegetation are minimal in this area.

Avifaunal species documentation

Avifaunal surveys in the selected sites were conducted by same individual surveyors from September to December 2021. The point count method (Sutherland et al. 2004) was followed to document birds. Fifteen observation points were established within each urban green space within an approximate 200 m interval along existing manmade or natural trails. Avifaunal surveys were done from 0500–0900h with 15 minutes of observation per point. Surveys were done at a slow and constant pace to omit possible observation biases. Birds that were seen and heard through calls within 30 m from the observer were recorded. Species identification and ecological status of birds were done by referring to literature by Kennedy et al. (2000), Allen (2020), and other avifaunal databases (Birdlife International 2022; eBird 2023).

Avifaunal species diversity

The species richness of each urban green space surveyed was determined based on the total number of species accounted for. The percentage of species richness was calculated by dividing the number of species in each urban green space by the total number of bird species in all sites surveyed. Simpson's reciprocal diversity index was used to compare the bird diversity in each urban green space surveyed and this was performed using a free software package, Paleontological Statistics (PAST) version 4.03.

RESULTS AND DISCUSSION

Avifaunal species composition

Twenty-one avifaunal species representing 17 families were documented from the three urban green spaces of Cotabato City from September to December 2021 (Table 1). The campus of NDU had the highest avifaunal species richness (95%), followed by PC Hill (67%), and MBRH (43%) (Table 2). Among the avifauna families, the family Columbidae with three representative species (*Streptopelia tranquebarica*, *Columba liva*, *Geopelia striata*) was observed in all urban green spaces. The occurrence of Columbidae species

Table 1. Bird species observed in different urban green spaces within Cotabato City with notes on IUCN and DAO 2019-09 (Updated National List of Threatened Philippine Fauna and their Categories) status and endemicity.

Family name	Scientific name	Common name	Location		
			MBRH	PC HILL	NDU
Alcedinidae	*Todiramphus chloris* LC/OWS*	Collared Kingfisher	0	0	13
Apodidae	*Collocalia isonota* LC/OWS+	Ridgetop Swiftlet	0	0	1
Ardeidae	*Egretta garzetta* LC/OWS*	Little Egret	0	12	2
Campephagidae	*Lalage nigra* LC/OWS*	Pied Triller	0	8	0
Columbidae	*Streptopelia tranquebarica* LC/OWS*	Red Turtle Dove	3	13	2
Columbidae	*Columba livia* LC/OWS*	Rock Dove	34	28	5
Columbidae	*Geopelia striata* LC/OWS*	Zebra Dove	9	17	21
Corvidae	*Corvus macrorhynchos* LC/OWS*	Large-billed Crow	0	16	21
Dicaeidae	*Dicaeum australe* LC/OWS+	Red-keeled Flowerpecker	0	0	1
Estrildidae	*Lonchura atricapilla* LC/OWS*	Chestnut Munia	13	32	21
Estrildidae	*Lonchura leucogastra* LC/OWS*	White-bellied Munia	0	0	9
Estrildidae	*Lonchura oryzivora* LC/OWS*	Java Sparrow	19	11	26
Hirundinidae	*Hirundo javanica* LC/OWS*	House Swallow	0	13	27
Laniidae	*Lanius cristatus* LC/OWS*	Brown Shrike	0	0	3
Megalaimidae	*Psilopogon haemacephalus* LC/OWS*	Coppersmith Barbet	0	0	1
Nectariniidae	*Cinnyris jugularis* LC/OWS*	Olive-backed Sunbird	19	31	8
Passeridae	*Passer montanus* LC/OWS*	Eurasian Tree Sparrow	35	23	48
Psittaculidae	*Loriculus philippensis* LC/CR+	Philippine Hanging Parrot	0	0	1
Pycnonotidae	*Pycnonotus goiavier* LC/OWS*	Yellow-vented Bulbul	21	44	37
Rhipiduridae	*Rhipidura nigritorquis* LC/OWS+	Philippine Pied Fantail	0	21	18
Sturnidae	*Aplonis panayensis* LC/OWS*	Asian Glossy Starling	27	42	51

LC—Least concern | CR—Critically Endangered | OWS—Other wildlife species | *—non-endemic | +—Endemic. Dark-colored areas indicate a higher individual count per species.

in various urban green spaces in this study conforms with the findings of avifaunal surveys conducted in other urban green spaces of the country. In Davao City, Banzon et al. (2022) documented five species of the family Columbidae in 15 urban green spaces. In Metro Manila, Vallejo et al. (2008), also documented several species of the family Columbidae in the city's last green spaces. In terms of frequency, the *Aplonis panayensis* (n = 120) and *Passer montanus* (n = 106) were commonly encountered among the species accounted for in the urban green spaces surveyed. These findings are also similar to the observations of Banzon et al. (2022) in Davao City and Aida et al. (2016) in urban landscapes of Malaysia. The abundance of *Aplonis panayensis* in urban areas was attributed to its ability to utilize available food resources (Shazali et al. 2016).

Nineteen percent of the avifauna species accounted for are endemic, while 81% are non-endemic (Figure 1). Three of the four (75%) endemic species were documented only in NDU while one species—*Rhipidura nigritorquis* was recorded in PC Hill and NDU. The observed low endemism of avifauna in the present survey conforms with previous avifaunal surveys in urban green spaces in the Philippines (Banzon et al. 2022; de Vera et al. 2023). The vegetation type may play a factor in the low number of endemic birds in urban green spaces (Tanalgo et al. 2015, 2019). Since urban green spaces surveyed in this study lack native habitats, this may explain the low degree of endemic birds being documented.

Nineteen percent of the bird species that were recorded in the urban green spaces of Cotabato City were introduced. Little is known about the possible effects of introduced bird species on native bird species in the country (Gonzales 2006), but introduced birds can be a threat to native birds through the competition for nesting sites, and food (Baker et al. 2014). In addition, based on the DENR-BMP (2019), one Critically Endangered species of bird was spotted in NDU, the Philippine Hanging-Parrot *Loriculus philippensis*.

Table 2. Avian diversity in urban green spaces surveyed within Cotabato City.

Urban green space site	Coordinates	Elevation (m)	Area (m²)	Species richness	Simpson's reciprocal diversity index
NDU	7.2172, 124.2438	6	101, 855.52	20	0.903
PC Hill	7.2198, 124.2445	59	94, 599.97	14	0.9106
MBRH	7.2116, 124.2438	13	95, 723.85	9	0.8601

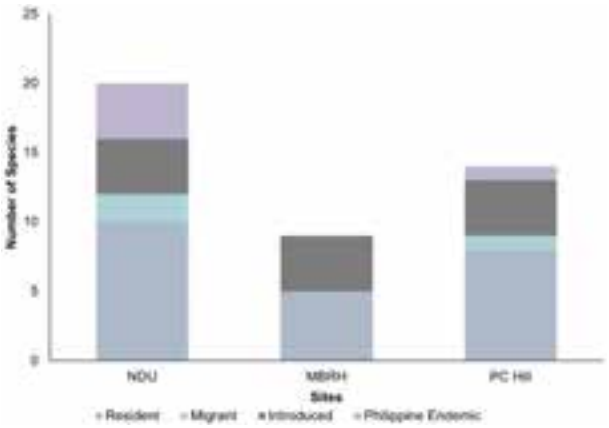


Figure 1. Distribution of endemic and non-endemic bird species in the select urban spaces within Cotabato City.

This species also occurs in other urban areas in the country (Senarillos et al. 2020) and was reported to be threatened due to the unregulated hunting in some areas of the country for the pet trade (Panopio & Pajaro 2014).

Table 2 shows that among the urban green spaces surveyed, PC Hill has the highest diversity (0.9106), followed by NDU (0.903), and the MBRH (0.8601). PC Hill has less vegetation and more residential buildings compared to NDU, however, results showed that it has the highest bird diversity among the urban green spaces surveyed. The results differ to the study conducted in southern Mindanao that reports the positive association of vegetation to avifaunal diversity (see Tanalgo et al. 2015; Gracia et al. 2021). Such observation might be due to limitations of the study such as the time of the day the bird surveys were conducted (0500–0900 h) and the limited number of study sites. Future studies in avifaunal diversity in Cotabato City should consider other urban green spaces and temporal variations.

CONCLUSION

The results of our study showed that most of the birds documented in urban green spaces surveyed in Cotabato City are of Least Concern and non-endemic and few species were recorded as endemic and Critically Endangered. This adds to the existing literature regarding the importance of habitat heterogeneity and restored sites in promoting conservation measures for avifauna diversity in urban green spaces. However, there are still limitations in this study. Several factors may influence bird diversity in urban green spaces. Future studies should consider bird surveys of other urban green spaces outside and within the commercial center of the city. Moreover, other factors such as noise, buildings, and the number of vehicles should also be investigated and determine how these may affect avifauna diversity in urban green spaces of Cotabato City.

REFERENCES

Aida, N., S. Sasidhran, N. Kamarudin, N. Aziz, C.L. Puan & B. Azhar (2016). Woody trees, green space, and park size improve avian biodiversity in urban landscapes of Peninsular Malaysia. *Ecological Indicators*, 69: 176–183. https://doi.org/10.1016/j.ecolind.2016.04.025

Agduma, A.R., F.G. Garcia, M.T. Cabasan, J. Pimentel, R.J. Ele, M. Rubio, S. Murray, B.A. Hilario-Husain, K.C.D. Cruz, S. Abdulla, S.M. Balase & K.C. Tanalgo (2023). Overview of priorities, threats, and challenges to biodiversity conservation in the Southern Philippines. *Regional Sustainability* 4(2): 203–213. https://doi.org/10.1016/j.regsus.2023.05.003

Allen, D. (2020). *Birds of the Philippines. Lynx and BirdLife International Field Guides*. Lynx Edicions, Barcelona, 400 pp.

Amoroso, V.B. (2000). Long-term biodiversity research programme for Mindanao Philippines. *Korean Journal of Ecology* 23(2): 141–147.

Banzon, J.P., B.A. Pingoy, V. de la Rosa, M.C. Otero, T. Sususlan, M.D.T. Tagoon, E.M. Baron & J. Ibañez (2022). Diversity of bird species in urban green spaces of Davao City, Mindanao, Philippines. *Philippine Journal of Science* 151(5): 1943–1952. https://doi.org/10.56899/151.05.32

Baker, J., K. Harvey & K. French (2014). Threats from introduced birds to native birds. *Emu - Austral Ornithology* 114(1): 1–12. https://doi.org/ 10.1071/MU12122

BirdLife International (2022). Important Bird Areas factsheet: Isla Diego de Almagro. http://www.birdlife.org

Bett, M.C., M. Muchai & C. Wawer (2017). Effects of human activities on birds and their habitats as reported by forest user groups in and around North Nandi Forest, Kenya. *Journal of East African Ornithology* 37(2): 24–31.

eBird (2023). *Birdlife International, Royal Society for the Protection of Birds, and eBird Cornell Laboratory for Ornithology*. Retrieved from https://www.birds.cornell.edu/home/

Daipan, B.P.O. (2021). Patterns of forest cover loss in terrestrial key

biodiversity areas in the Philippines: critical habitat conservation priorities. *Journal of Threatened Taxa* 13(13): 20019–20032. https://doi.org/10.11609/jott.6904.13.13.20019-20032

Cruz, K.C.D., S.S. Abdullah, A.R. Agduma & K.C. Tanalgo (2023). Early twenty-first century biodiversity data pinpoint key targets for birds and mammal conservation in Mindanao, Southern Philippines. *Biodiversity* 24(3): 1–18. https://doi.org/10.1080/14888386.2023.2210119

DENR-BMB (2019). Updated National List of Threatened Philippine Fauna and their Categories. Department of Environment and Natural Resources – Biodiversity Management Bureau Administrative Order No. 2019-09. Diliman, Quezon City, Philippines.

De Vera, P.J.D., J.P.C. Catipay, M.D.T Tagoon, E.M. Delima-Baron & B.A. Pingoy (2023). Avian sanctuary within the city in Timaco Hill, Cotabato City, Bangsamoro Autonomous Region in Muslim Mindanao. *Biodiversitas* 24(2): 1004–1009. https://doi.org/10.13057/biodiv/d240240

Gracia, A.G. Jr, A.B. Mohagan, J.C. Burlat, W.L. Yu Jr, J. Mondalo, F.M. Acma, H.P. Lumista, R. Calising & K.C. Tanalgo (2021). Conservation ecology of birds in Mt. Hilong-hilong, a Key Biodiversity Area on Mindanao Island, the Philippines. *Journal of Threatened Taxa* 13(5): 18110–18121. https://doi.org/10.11609/jott.6760.13.5.18110-18121

Gonzales, J.C. (2006). Impact of introduced birds in the Philippines. *Journal of Environmental Science and Management* 9(2): 66–79.

Jha, P.K. (2019). Diversity of birds in the foothills of Phulchoki Hill, Lalitpur, Nepal. *Forestry Journal of Institute of Forestry* 16: 62–71. https://doi.org/10.3126/forestry.v16i0.28354

Kennedy, R.S., P.C. Gonzales, E.C. Dickinson, H. Miranda & T.H. Fisher (2000). *A Guide to the Birds of the Philippines (3rd ed.).* Oxford University Press, New York, 392 pp.

Leveau, L., A. Ruggiero, T.J. Matthews & M.I. Bellocq (2019). A global consistent positive effect of urban green area size on bird richness. *Avian Research* 10(30): 1–14. https://doi.org/10.1186/s40657-019-0168-3

Li, F., W. Zheng, Y. Wang, J. Liang, S. Xie, S. Guo, X. Li & C. Yu (2019). Urban green space fragmentation and urbanization: a spatiotemporal perspective. *Forests* 10(4): 1–20. https://doi.org/10.3390/f10040333

Muhlbauer, M., W. Weisser, N. Muller & S. Meyer (2021). A green design of city squares increases the abundance and diversity of birds. *Basic and Applied Ecology* 56(November): 446–459. https://doi.org/10.1016/j.baae.2021.05.003

Ong, P., M. De Guia & M. Pedregosa (1999). Wildlife inventory of the University of the Philippines (UP) Diliman and the Ateneo de Manila University Campus Diliman, Quezon City, Luzon, Philippines. *Science Diliman* 11(1): 6–20.

Panopio, J.K. & M. Pajaro (2014). *The State of Philippine Birds*. Haribon Foundation for the Conservation of Natural Resources Inc., 44 pp.

Parker, Y., Y. Yom-Tov, T.A. Mozes & A. Barnea (2013). The effect of plant richness and urban garden structure on bird species richness, diversity, and community structure. *Landscape and Urban Planning* 122(February): 185–195. https://doi.org/10.1016/j.landurbplan.2013.10.005

Prihandi, D.R. & S. Nurvianto (2022). The role of urban green space design to support bird community in the urban ecosystem. *Biodiversitas* 23(4): 2137–2145. https://doi.org/ 10.13057/biodiv/d230449

Saloma, C. & E. Akpedonu (2022). Parks, plans, and human needs: Metro Manila's unrealized urban plans and accidental public green spaces. *International Journal of Urban Sustainable Development* 13(3): 715–727. https://doi.org/10.1080/19463138.2021.2021418

Senarillos, T.L., K.M. Pitogo & J. Ibañez (2020). Bird Observations in the Busa Mountain Range, Sarangani Province, Philippines. *Philippine Journal of Science* 150(S1): 347–362. https://doi.org/10.56899/150.S1.25

Shazali, N., J. Mohd-Azlan & A. Tuen (2016). Bird diets in urban environments: the case of the asian glossy starling, Aplonis panayensis, pp. 171–181. In: Das, I. & A.A. Tuen (eds.). *Naturalists, Explorers and Field Scientists in South-East Asia and Australasia* (TOBC, Vol-15. Springer Cham, XI + 283 pp. https://doi.org/10.1007/978-3-319-26161-4_11

Sulaiman, S., N.H.N. Mohamad & S. Idilfitri (2013). Contribution of vegetation in urban parks as habitat for selective bird community. *Procedia* 85(2013): 267–281. https://doi.org/10.1016/j.sbspro.2013.08.358

Sultana, R. & S.A. Selim (2021). Residents' perceptions of the role and management of green spaces to provide cultural ecosystem services in Dhaka, Bangladesh. *Ecology and Society* 26(4): 287–303. https://doi.org/10.5751/ES-12656-260405

Sutherland, W.J., I. Newton & R. Green (2004). *Bird Ecology and Conservation: A Handbook of Techniques*. Oxford University Press, New York, xv + 371 pp. https://doi.org/10.1093/acprof:oso/9780198520863.001.0001

Tanalgo, K.C., J.A.F. Pineda, M.E. Agravante & Z.M. Amerol (2015). Bird diversity and structure in different land-use types in lowland Southcentral Mindanao, Philippines. *Tropical Life Sciences Research* 26(2): 85–103.

Tanalgo, K.C., M.J.M.M. Achondo & A.C. Hughes (2019). Small things matter: the value of rapid biodiversity surveys to understanding local bird diversity patterns in southcentral Mindanao, Philippines. *Tropical Conservation Science* 12: 1–10. https://doi.org/10.1177/1940082919869482

Tanalgo, K.C., K.C. Dela Cruz, A.R. Agduma, J.M.V. Respecio, S.S. Abdullah, R.J. Alvaro-Ele, B.A. Hilario-Husain, M. Manampan-Rubio, S.A. Murray, L.F. Casim, A.M.M. Pantog, S.M.P. Balase, R.M.A. Abdulkasan, C.A.S. Aguirre, N.L. Banto, S.M.M. Broncate, A.D. Dimacaling, G.V.N. Fabrero, A.K. Lidasan, A.A. Lingcob, A. M. Milondaga, K.F.L. Panilla, C.Q.M. Sinadjan & N.D. Unte (2023). The MOBIOS+: A FAIR (Findable, Acessible, Interoperable and Reusable) database for Mindanao's terrestrial biodiversity. *Biodiversity Data Journal* 11: e110016. https://doi.org/10.3897/BDJ.11.e110016

Vallejo, B. Jr. & A. Aloy (2014). Responses of the bird community in the University of the Philippines Diliman after campus redevelopment and the decline of two common urban bird species. *Philippine Science Letters* 7(1): 55–61.

Vallejo, Jr., B.M., A.B. Aloy, P. Ong, A. Tamino & J. Villasper (2008). Spatial patterns of bird diversity and abundance in an urban tropical landscape: The University of the Philippines (UP) Diliman Campus. *Sci Diliman* 20(1): 1–10.

Wolff, P.J., B.A. DeGregorio, V. Rodriguez-Cruz, E. Mulero-Oliveras & J.H. Sperry (2018). Bird community assemblage and distribution in a tropical, urban ecosystem of Puerto Rico. *Tropical Conservation Science* 11: 1–10. https://doi.org/ 10.1177/1940082918754777

Yang, X., X. Tan, C. Chen & Y. Wang (2020). The influence of urban park characteristics on bird diversity in Nanjing, China. *Avian Research* 11(45): 1–9. https://doi.org/10.1186/s40657-020-00234-5

Author details: Baes, J.R.M.L. is a former BS-Biology student from Notre Dame University, Cotabato City. She is a photographer who enjoys capturing wildlife fauna. P.J.D. de Vera is a college instructor and an early career researcher from Mindanao State University - Maguindanao, Philippines. His research interests include biodiversity and ecosystem conservation. J.P.A. Catipay a faculty member of Notre Dame University. His research interests include wildlife biodiversity, physiology and mycology particularly myxomycetes. At present, he is a MSc candidate for Biology minor in Botany in the University of Southern Mindanao. M.D.T. Tagoon is a faculty member of the School of Business Management, Education, and Arts and Sciences of San Pedro College. Her research interests include wildlife biology and biodiversity. She is currently a PhD student in Biology of Central Mindanao University. E.M. Delima-Baron is a biologist who enjoys documenting wildlife fauna and its ecological interactions in various habitat types in urban and non-urban locations. She currently holds the position of Research Director at San Pedro College, Davao City, Philippines.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 February 2024 | 16(2): 24752–24759
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.8452.16.2.24752-24759
#8452 | Received 26 March 2023 | Final received 26 January 2024 | Finally accepted 01 February 2024
OPEN ACCESS
COMMUNICATION

Waterbird count at Narathali waterbody, Buxa Tiger Reserve in northern Bengal for a decade (2009–2019) with a note on raptors

Sachin Ranade [1] & **Soumya Sundar Chakraborty** [2]

[1,2] Vulture Conservation Breeding Center, Buxa Tiger Reserve, Raja Bhat Khawa, Alipurduar, West Bengal 735227, India.
[1] s.ranade@bnhs.org (corresponding author), [2] soumyachkrbrty@yahoo.co.in

Abstract: This study presents insights from a comprehensive analysis of bird counts conducted at Narathali waterbody in Buxa Tiger Reserve between 2009 and 2019. Thirteen bird species were monitored, including six wintering duck species and seven resident waterfowl species. The population trends of these birds remained relatively constant throughout the study period. Additionally, the study documented raptor counts and compiled a checklist of waterbirds observed at the waterbody. These findings enhance our understanding of bird population dynamics in this significant habitat and provide valuable information for the conservation and management of the Buxa Tiger Reserve.

Keywords: Bird population, checklist, Common Moorhen, Ferruginous Duck, population trend, raptors, wintering ducks.

Editor: Anonymity requested. **Date of publication:** 26 February 2024 (online & print)

Citation: Ranade, S. & S.S. Chakraborty (2024). Waterbird count at Narathali waterbody, Buxa Tiger Reserve in northern Bengal for a decade (2009–2019) with a note on raptors. *Journal of Threatened Taxa* 16(2): 24752–24759. https://doi.org/10.11609/jott.8452.16.2.24752-24759

Funding: None.

Competing interests: The authors declare no competing interests.

Author details: Mr Sachin Ranade works as a biologist for last 23 years, looking after the Vulture Conservation Program of BNHS in West Bengal and Assam. Mr. Soumya Sundar Chakraborty serves as the centre manager at the Vulture Conservation Breeding Centre in West Bengal, looking after the breeding and reintroduction of the vultures.

Author contributions: SR planned the study, carried out field work in early years and wrote the manuscript. SSC carried out the field work during the later period.

Acknowledgements: The authors are grateful to the authorities of Buxa Tiger Reserve for the kind permission for the study. Thanks are due to the Bombay Natural History Society, Mumbai and Royal Society for the Protection of Birds, UK for constant support and encouragement.

INTRODUCTION

Long-term bird monitoring is essential for understanding climate change, habitat dynamics, and population trends of the concerned taxa (Gregory et al. 2009; Amat & Green 2010). Northern Bengal has extensive forest cover but retains less water as the soil is coarse and alluvial in nature known as Bhabar soil. Despite heavy rainfall and the presence of rivers and rivulets from the Himalaya, large water bodies are scarce (Champion & Seth 2005). The Buxa Tiger Reserve, representing northern Bengal's rich biodiversity, harbours a small waterbody 'Narathali beel' (Bengali: Beel= Lake) in the Alipurduar district. This small waterbody supports diverse flora and fauna, serving as a crucial habitat for winter migrants and resident waterbirds. The present study provides a 10-year record of bird counts for selected species at Narathali.

Study area

Narathali, a small water body located at Buxa Tiger Reserve in the northeastern corner of West Bengal (26.5152°N, 89.7319°E), is surrounded by rivers Dima, Bala, and Sankosh. While Sankosh remains perennial, the other rivers are seasonal and lack consistent water throughout the year. Due to the coarse nature of the soil, the terrain fails to retain water, resulting Narathali as an exceptional waterbody- attracting numerous waterfowl. This perennial water body, covering an approximate length of 1.3 km and a width of 50 m, is encompassed by small patches of grassland and woodland. The entire ecosystem serves as a crucial habitat for both winter migratory waterbirds and land birds. Various authors have presented bird inventories, with the initial study on waterbirds conducted during 1999–2000, describing Narathali as stagnant water. At the culmination of the rainy season, the water body submerges an area of 0.085 km^2 (Image 1) within its boundaries, highlighting its significance as a dynamic habitat for avian diversity in the region (Sivakumar & Prakash 2004).

METHODS

Throughout the study period from 2009 to 2019, a total of 75 visits were carried out to the Narathali study site during 10 winter seasons, covering the months of November to February. Bird counts were conducted from a designated vantage point, primarily in the morning (n = 69), with only a few counts taking place in the late afternoon (n = 6). The researchers employed telescopes, binoculars, and photography to observe and document the bird species. Accurate species identification was ensured by referring to field guides, namely Grimmett et al. (2011) and Rasmussen & Anderton (2012).

The study focused on monitoring the waterfowl species present at the site, including six winter visitors (Gadwall *Mareca strepera*, Northern Shoveler *Spatula clypeata*, Northern Pintail *Anas acuta*, Common Teal *Anas crecca*, Red-crested Pochard *Netta rufina*, and Ferruginous Duck *Aythya nyroca*) and four resident species (Little Grebe *Tachybaptus ruficollis*, Lesser Whistling-Duck *Dendrocygna javanica*, Cotton Teal *Nettapus coromandelianus*, and Spot-billed Duck *Anas poecilorhyncha*). These waterfowl counts were diligently maintained throughout the entire study duration. For each winter season, the maximum count of each species was recorded, enabling the construction of graphs illustrating the trends observed over the 10 years.

Furthermore, counts of three resident waterbird species (Eurasian Moorhen *Gallinula chloropus*, Purple Swamphen *Porphyrio poliocephalus*, and Bronze-winged Jacana *Metopidius indicus*) were specifically monitored for five years, covering the period from 2015 to 2019. Although a few additional waterfowl and raptor species were documented, their limited sample sizes precluded their inclusion in the graph format. A comprehensive bird list, with a specific emphasis on waterfowl and raptor species, is provided in Table 1, serving as a valuable reference for future analysis and documentation.

RESULTS

The wintering duck species at Narathali (Figure 1)

Gadwall *Mareca strepera*: Common (Range 12–50, Average 26.9, Median 25, n = 10)

A widespread winter visitor in India, the species was represented by 12 to 50 individuals at the water body. Its trend appears to be constant.

Northern Shoveller *Spatula clypeata*: Fairly Common (Range2–4, Average 2.8, Median 3, n = 5)

A widespread winter visitor in India, the species was represented by two to four individuals at the water body. Its trend appears to be constant.

Northern Pintail *Anas acuta*: Fairly Common (Range 2–10, Average 5.5, Median 6, n = 6)

A widespread winter visitor in India, the species was represented by two to 10 individuals at the water body. Its trend appears to be constant.

Common Teal *Anas crecca*: Uncommon (Range 7–55, Average 27.5, Median 24, n = 4)

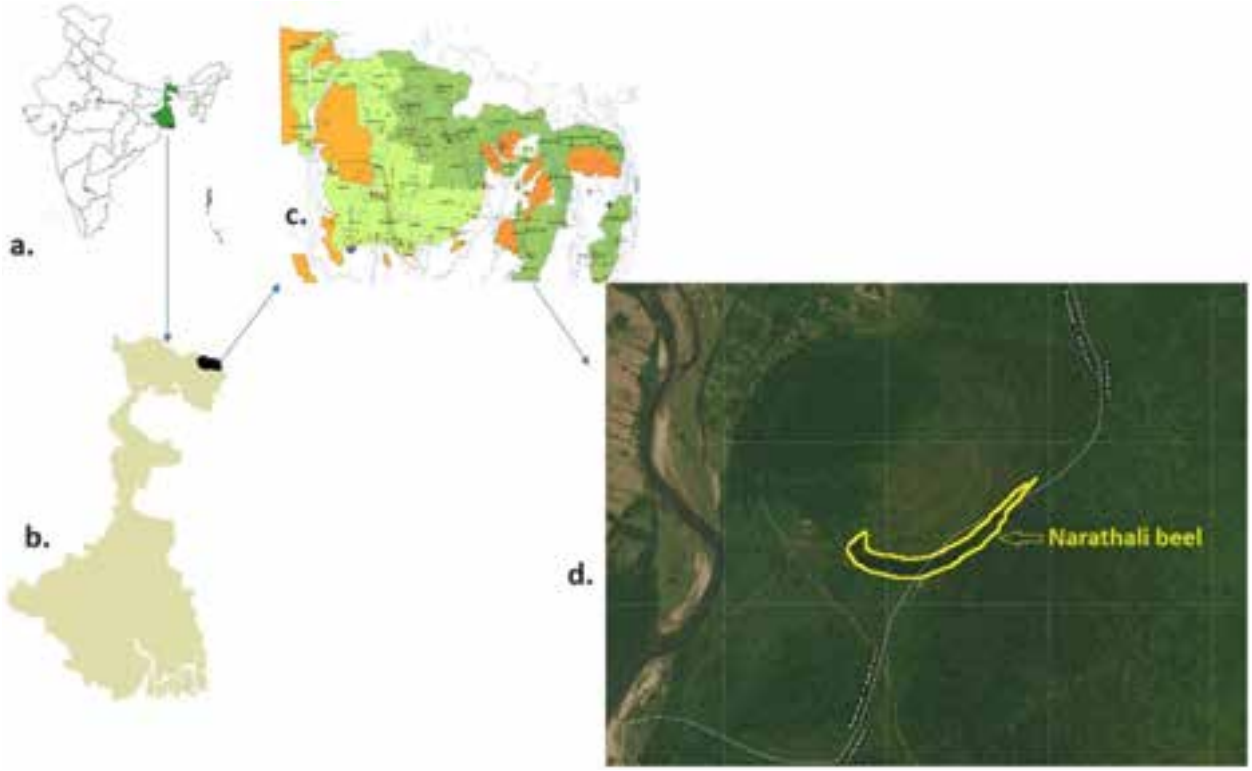


Image 1. Narathali Waterbody, Buxa Tiger Reserve, Alipurduar West Bengal. (a—West Bengal in India | b—Buxa Tiger Reserve in West Bengal | c—Narathali in the Buxa Tiger Reserve | d—The Narathali beel).

A widespread winter visitor in India, the species was represented by seven to 55 individuals at the water body. Its trend appears to be constant.

Red-crested Pochard *Netta rufina*: Uncommon (Range 2–6, Average 3.6, Median 3, n = 5)

A widespread winter visitor in India, the species was represented by two to six individuals at the water body. It's interesting to see that this species got attracted to Narathali in the last three years of the observation.

Ferruginous Duck *Aythya nyroca*: Common (Range 14–60, Average 35.2, Median 36, n = 10)

A Near-Threatened species (BirdLife International 2019), a widespread winter visitor in India, the species was represented by 14 to 60 individuals and the trend appears to be stable.

The resident duck species and Grebe at Narathali (Figure 2)

Little Grebe *Tachybaptus ruficollis*: Common (Range: 28–37, Average 31.4, Median 29, n = 5)

A widespread resident in India, the species was represented by 28 to 37 individuals at the water body. Its trend appears to be constant throughout the observations.

Lesser Whistling-Duck *Dendrocygna javanica*: Common (Range 46–1000, Average 171.3, Median 74, n = 10)

A widespread resident in India, the species was represented by 46 to 1000 individuals at the water body. Its trend appears to be increasing. In 2019, a melanistic individual was noted in the flock (Image 2). During the last season, a population of about 1,000 individuals was noted.

Cotton Teal *Nettapus coromandelianus*: Common (Range 5–33, Average 19, Median 20, n = 7)

A widespread resident in India, the species was represented by 5–33 individuals at the water body. Its trend appears to be constant.

Spot-billed Duck *Anas poecilorhyncha*: Common (Range 8–50, Average 28.9, Median 26, n = 10)

A widespread resident in India, the species was represented by 8–50 individuals at the water body. Its trend appears to be constant.

Three resident waterfowl species monitored at Narathali (Figure 3)

Bronze-winged Jacana *Metopidius indicus*: Common (Range 15–25, Average 19, Median 17, n = 5)

A widespread resident in India, the species was represented by 15–25 individuals at the water body. Its trend appears to be constant.

Table 1. List of birds at Narathali Waterbody in Buxa Tiger Reserve, West Bengal.

	Family	Common name	Scientific name	Abundance	Migrant/Resident status
1	Podicipedidae	Little grebe	*Tachybaptus ruficollis*	Common	Resident
2	Phalacrocoracidae	Little cormorant	*Microcarbo niger*	Common	Resident
3	Anhingidae	Darter	*Anhinga melanogaster*	Uncommon	Resident
4	Ardeidae	Little Egret	*Egretta garzetta*	Fairly Common	Resident
5	Ardeidae	Grey Heron	*Ardea cinerea*	Rare	Winter Visitor
6	Ardeidae	Purple Heron	*Ardea purpurea*	Rare	Resident
7	Ardeidae	Great Egret	*Egretta alba*	Uncommon	Resident
8	Ardeidae	Intermediate Egret	*Egretta intermedia*	Uncommon	Resident
9	Ardeidae	Eastern Cattle Egret	*Bubulcus coromandus*	Common	Resident
10	Ardeidae	Indian Pond-Heron	*Ardeola grayii*	Common	Resident
11	Ardeidae	Yellow Bittern	*Ixobrychus sinensis*	Rare	Resident
12	Ardeidae	Chestnut Bittern	*Ixobrychus cinnamomeus*	Rare	Resident
13	Ciconiidae	Asian Openbill-Stork	*Anastomus oscitans*	Common	Resident
14	Ciconiidae	Lesser adjutant stork	*Leptoptilos javanicus*	Fairly Common	Resident
15	Anatidae	Lesser Whistling-Duck	*Dendrocygna javanica*	Common	Resident
16	Anatidae	Greylag Goose	*Anser anser*	Irregular	Winter Visitor
17	Anatidae	CottonTeal	*Nettapus coromandelianus*	Common	Resident
18	Anatidae	Gadwall	*Mareca strepera*	Common	Winter Visitor
19	Anatidae	Falcated Duck	*Mareca falcata*	Irregular	Winter Visitor
20	Anatidae	Eurasian Wigeon	*Mareca penelope*	Uncommon	Winter Visitor
21	Anatidae	Mallard	*Anas platyrhynchos*	Uncommon	Winter Visitor
22	Anatidae	Indian Spot-billed Duck	*Anas poecilorhyncha*	Common	Winter Visitor
23	Anatidae	Northern Shoveler	*Spatula clypeata*	Fairly Common	Winter Visitor
24	Anatidae	Northern Pintail	*Anas acuta*	Fairly Common	Winter Visitor
25	Anatidae	Common Teal	*Anas crecca*	Uncommon	Winter Visitor
26	Anatidae	Red-crested Pochard	*Natta rufina*	Uncommon	Winter Visitor
27	Anatidae	Common Pochard	*Aythya ferina*	Irregular	Winter Visitor
28	Anatidae	Ferruginous Duck	*Aythya nyroca*	Common	Winter Visitor
29	Accipitridae	Oriental Honey-Buzzard	*Pernis ptylorhynchus*	Rare	Resident
30	Accipitridae	Black-winged Kite	*Elanus caeruleus*	Rare	Resident
31	Accipitridae	Black Kite	*Milvus migrans*	Common	Resident
32	Accipitridae	Grey-headed Fish-Eagle	*Ichthyophaga ichthyaetus*	Rare	Resident
33	Accipitridae	Crested Serpent-Eagle	*Spilornis cheela*	Common	Resident
34	Accipitridae	Shikra	*Accipiter badius*	Uncommon	Resident
35	Accipitridae	Himalayan Buzzard	*Buteo burmanicus*	Irregular	Winter Visitor
36	Accipitridae	Black Eagle	*Ictinaetus malayansis*	Uncommon	Winter Visitor
37	Accipitridae	Greater Spotted Eagle	*Clanga clanga*	Irregular	Winter Visitor
38	Accipitridae	Steppe Eagle	*Aquila nipalensis*	Rare	Winter Visitor
39	Pandionidae	Western Osprey	*Pandion haliaetus*	Common	Winter Visitor
40	Falconidae	Collared Falconet	*Microhierax caerulescens*	Rare	Resident
41	Falconidae	Common Kestrel	*Falco tinnunculus*	Rare	Winter Visitor
42	Falconidae	Red-headed Falcon	*Falco chicquera*	Rare	Resident

	Family	Common name	Scientific name	Abundance	Migrant/Resident status
43	Rallidae	White-breasted Waterhen	*Amaurornis phoenicurus*	Common	Resident
44	Rallidae	Purple Swamphen	*Porphyrio poliocephalus*	Common	Resident
45	Rallidae	Common Moorhen	*Gallinula chloropus*	Common	Resident
46	Rallidae	Eurasian Coot	*Fulica atra*	Common	Resident
47	Jacanidae	Pheasant-tailed Jacana	*Hydrophasianus chirurgus*	Rare	Resident
48	Jacanidae	Bronze-winged Jacana	*Metopidius indicus*	Common	Resident
49	Charadriidae	Red-Wattled Lapwing	*Vennalus indicus*	Common	Resident
50	Alcedinidae	White-throated Kingfisher	*Halcyon smyrnensis*	Common	Resident
51	Scolopacidae	Common Greenshank	Tringa nebularia	Common	Winter Visitor
52	Scolopacidae	Green Sandpiper	Tringa ochropus	Common	Winter Visitor
53	Scolopacidae	Wood Sandpiper	Tringa glareola	Common	Winter Visitor

Abundance categories based on sightings in the seasons: Common—8–10 times out of 10 seasons | Fairly common—6–8 times out of 10 seasons | Uncommon—4–5 times out of 10 seasons | Rare—2–3 times out of 10 seasons | Irregular—once in ten seasons.

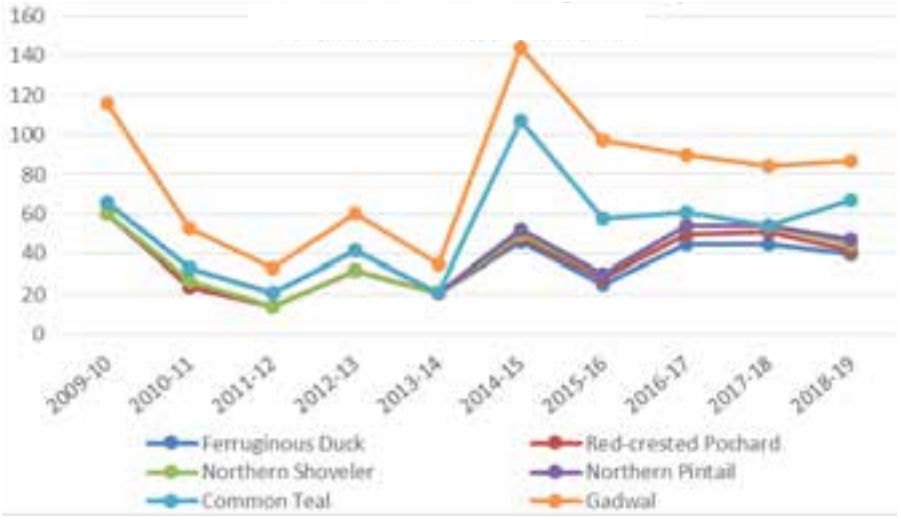


Figure 1. Maximum count of six wintering duck species at Narathali during 2009–2019 (10 seasons).

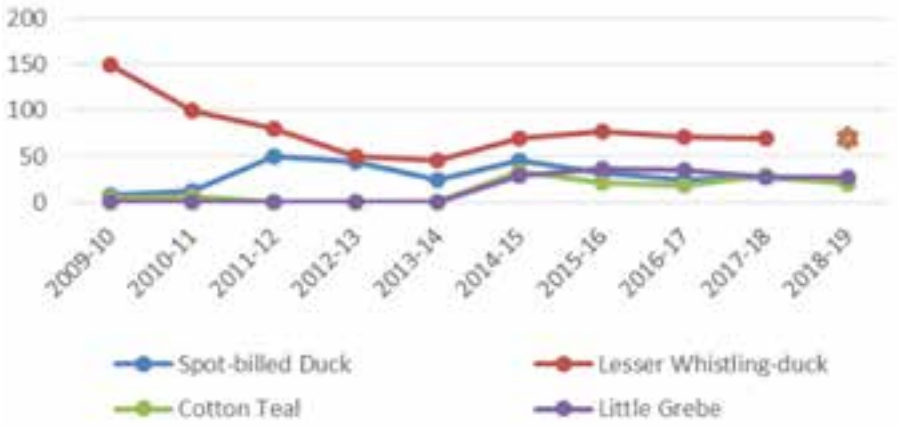


Figure 2. Maximum count of three resident duck species and Little Grebe during the winter season, 2009–2019 at Narathali (10 seasons).
***—About 1000 Lesser Whistling Ducks during 2019–2020**

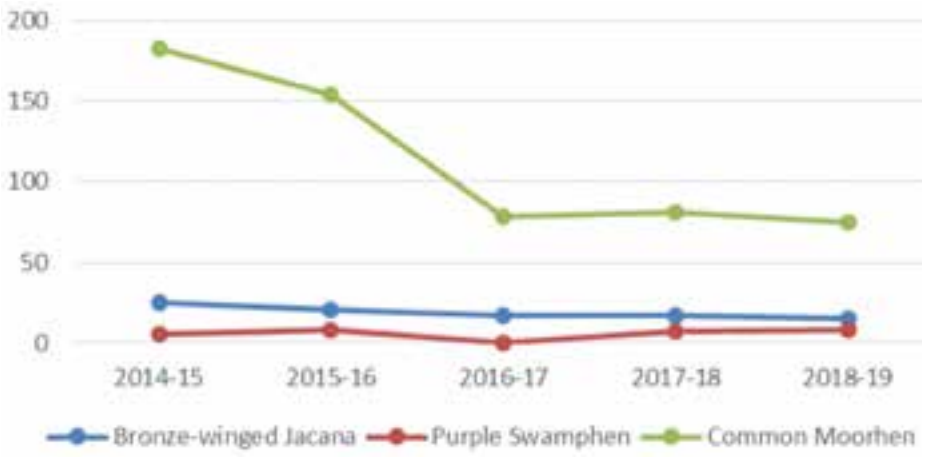


Figure 3. Maximum count of three resident wader species during the winter season, 2015–2019 at Narathali.

Purple Swamphen *Porphyrio poliocephalus*: Common (Range 5–8, Average 7, Median 8, n = 4)

A widespread resident in India, the species was represented by 5–8 individuals at the water body. Its trend appears to be constant.

Common Moorhen *Gallinula chloropus*: Common (Range 40–183, Average 114, Median 81, n = 5)

A widespread resident in India, the species was represented by 40–183 individuals at the water body. Its trend appears to be declining at Narathali.

Other winter visitor duck species observed at Narathali:

Mallard *Anas platyrhynchos* and Eurasian Wigeon *Anas penelope* were sighted only in the years 2016–19. The Falcated Duck *Mareca falcata* (Image 3), Greylag Goose *Anser anser* (2013–14) and Common Pochard *Aythya ferina* (2014–15) were sighted during only one season.

Raptor species

There were nine species of raptors recorded in the area as regular visitors. Two of them were wetland dependent fish-eating eagles while rest seven species were not dependent on wetlands yet were indicators of the biodiversity and quality of the whole protected habitat. The Osprey *Pandion haliaetus* was found during all of the 10 years. The water body supported one or two individuals. The Grey-headed Fish-Eagle *Haliaeetus ichthyaetus* was recorded in the years 2016, 17 and 19. The raptors Oriental Honey-buzzard *Pernis ptilorhynchus*, Shikra *Accipiter badius* and Crested Serpent-Eagle *Spilornis cheela* were also sighted regularly. The Black Kite *Milvus migrans* had a nest on a tree and could be sighted throughout the year for 10 seasons. The Steppe Eagle *Aquila nipalensis,* Himalayan Buzzard *Buteo burmanicus*, and Black Eagle *Ictinaetus malaiensis* were winter visitors in the area and were not uncommon.

DISCUSSION

The water source, it's quality and quantity matter a lot for waterfowl. This specialized avifauna is one of the indicators of the health of the ecosystem as well as pollution (Ormerod & Tyler 1993; Amat & Green 2010; Rajpar & Zakaria 2011; Zhang & Ma 2011; Ogden et al. 2014). Allen et al. (1996) had published a detailed checklist of birds in the Buxa Tiger Reserve. There were 28 species of waterbirds recorded at Narathali during 2000–01 (Sivakumar & Prakash 2004). The current study recorded 53 avian species which is the result of a longer duration of study period. It is interesting to note that during those years, the Ferruginous Duck was noted at Rydak and Dima rivers but not at Narathali. The species has been attracted to the Narathali and has become a regular visitor to the *beel* during 2009–19. The Red-crested Pochard is also a regular visitor since 2017 but was absent during 2009–2016. Sivakumar & Prakash (2004) recorded the Goosander (Common Merganser) *Mergus merganser* in Narathali, but we could not find it in the habitat. We have noted the species in the Rydak River at Bhutan-ghat in the Buxa Tiger Reserve from 2015–2019. The Bhutan-ghat has clear fresh water and icy torrential streams which is the favoured habitat of the species (Ali & Ripley 1983; Rasmussen & Anderton 2012). Out of the six wintering species monitored in this study, Ferruginous Duck is in the Near Threatened category and the global population is on the decline

Image 2. Melanistic Lesser Whistling-Duck *Dendrocygna javanica* at Narathali.

Image 3. Falcated Duck *Mareca falcata* at Narathali, during January 2014.

(BirdLife International 2019). The rest five species are in the Least Concern category. While globally, the Northern Shoveler and Northern Pintail populations are on the decline, the trend in the population of Common Teal and Red-crested Pochard is unknown, whereas the Gadwall population is increasing. In the case of the resident waterfowl, the Little Grebe, Lesser Whistling-duck and Spot-billed Duck are also in the Least Concern category but have the global population on the decline, while the trend in the population of Cotton Teal is unknown (BirdLife International 2016). The highest bird count of Lesser Whistling Duck shoot up to about 1,000 individuals during 2019 which could be an abnormally high number, hence it was not considered in the graph (Figure 2). The Population trend in Bronze-winged Jacana and Purple Swamphen is stable at Narathali, both of them listed under the Least Concern category and their global population trend is unknown. The Common Moorhen is also in the Least Concern category and the global population is stable though the local population counts are declining. One may conclude that most of these waterbirds are common birds yet showing various degrees of decline (BirdLife International 2016, 2021). In the case of Mallard, Eurasian Wigeon, Falcated Duck, and Greylag Goose, the species were known as rare species in northern Bengal (Allen et al 1996; Rahmani & Islam 2008).

The raptors at Narathali were fairly constant, although low in number. The Osprey appeared during all 10 seasons indicating sufficient food supply for a couple of individuals in the form of fish fauna. The Grey-headed Fish-Eagle has done a comeback in recent years. Earlier, it was recorded as a fairly common species (Allen et al. 1996). While the global population trend for the Osprey is increasing, the Grey-headed Fish Eagle is on the decline whereas the Oriental Honey Buzzard, Shikra, and Crested Serpent Eagle have stable populations (BirdLife International 2021).

The observation and records of waterbirds have been carried out for 10 winter seasons (November–February) from 2009 to 2019 for the first time in this region. The trends in the population are fairly stable. One of the reasons the species are attracted to this water body could be the poor condition of water bodies in human habitation. The Rasik beel –a waterbody in the Cooch Behar district is located about 30 km from Narathali. It is an interesting example of attracting migratory waterbirds by scientific management of the waterbody and the waterfowl numbers varying accordingly. The waterbody supported Sarus Crane (*Antigone antigone*) till 1990 (Das et al. 2013). In the first-ever systematic bird survey, 138 species of birds were recorded out of which 88 were water dependent bird species. This survey was carried out by Himalayan Nature and Adventure Foundation (HNAF 2001). Out of 165 bird species, 67 water-dependent bird species were recorded by Das et al. (2011). The overall number of bird species in the checklist increased, but the number of water bird species declined which is a cause of concern. There is a possibility of the swing of bird populations from Rasik beel to Narathali or similar locations in protected areas, and a future extensive study on the effects of urbanization around Buxa Tiger Reserve is necessary (Wang et al 2021). In the case of Narathali, the Forest department maintains the water body by removing the Water Hyacinth *Eichhornia crassipes* that would clog it. Removal of the clogging vegetation before the winter seems to attract the population of migratory waterbirds. We believe the slight peak in the bird count of all wintering ducks was due to the timely removal of the Water Hyacinth in the year 2014-15 (Figure 1). This ten-year study emphasizes importance of wetlands in protected areas for migratory and resident waterbirds.

REFERENCES

Ali, S. & S.D. Ripley (1983). *Handbook of the Birds of India and Pakistan together with those of Bangladesh, Nepal, Bhutan and Sri Lanka.* Compact ed. Oxford University Press, Delhi, 737 pp.

Allen, D., J. Anderton & K. Kazmeirczak (1996). Report on an ornithological visit to Buxa Tiger Reserve, West Bengal, India, 17 February to 6 March 1992. *Forktail* 12: 31–48

Amat, J.A. & A.J. Green (2010). Waterbirds as Bioindicators of Environmental Conditions, pp. 23–29. In: Hurford C., M. Schneider & C. Ian (eds.). *Conservation Monitoring in Freshwater Habitats A Practical Guide and Case Studies.* Springer Dordrecht Heidelberg London New York, 409 pp.

BirdLife International (2021) IUCN Red List for birds. Downloaded from http://www.birdlife.org on 28 April 2021.

BirdLife International (2016). *Nettapus coromandelianus*. The IUCN Red List of Threatened Species 2016: e.T22680090A92842427. https://doi.org/10.2305/IUCN.UK.2016-3.RLTS.T22680090A92842427.en. Downloaded on 28 April 2021.

BirdLife International (2019). *Aythya nyroca*. The IUCN Red List of Threatened Species 2019: e.T22680373A152620862. https://doi.org/10.2305/IUCN.UK.2019-3.RLTS.T22680373A152620862.en. Downloaded on 16 July 2020.

Champion, H.G. & S.K. Seth (2005). *A Revised Survey of the Forest types of India*. Government of India. Natraj Publishers, New Delhi, 404 pp.

Das, D., P. Mitra, A. Sen & P. Jha (2011). Faunal Diversity in the Rasik Beel Wetland Complex (Tufanganj, India), pp. 437–456. In: Gupta, V.K. & A.K. Verma (eds.). *Animal Diversity, Natural History and Conservation. Vol-1*. Daya Publication House, Delhi, 480 pp.

Das, D., A. Sen & P. Mitra (2013). Major Fauna of Rasik Beel (West Bengal). Occasional Paper 343. Zoological Survey of India, Kolkata, India, 76 pp.

Das, D., P. Mitra & A. Sen (2013). Diversity and distribution of bird species in Cooch Behar District of West Bengal. *Indian Journal of Social and Natural Sciences* 2(1): 94–10.

Gregory, R.D., S.G. Willis, F. Jiguet, P. Vořišek, A. Klvaňová, A.V. Strien, B. Huntley, Y.C. Collingham, D. Couvet & R.E. Green (2009). An indicator of the impact of climatic change on European bird populations. *PLOS ONE* 4(3): e4678. https://doi.org/10.1371/journal.pone.0004678

Grimmett, R., C. Inskipp & T. Inskipp (2011). *Birds of the Indian Subcontinent.* Oxford University Press, New Delhi, 528 pp.

HNAF (2001). Survey report of migratory and residential birds of Rasik Beel. Himalayan Nature and Adventure Foundation, Siliguri, 10 pp.

Ogden, J.C., J.D. Baldwina, O.L. Bass, J.A. Browder, M.I. Cook, P.C. Fredericke, P.E. Frezzaf, R.A. Galvez, A.B. Hodgsonh, K.D. Meyer, L.D. Oberhofer, A.F. Paul, P.J. Fletcher, S.M. Davis & J.J. Lorenz (2014). Waterbirds as indicators of ecosystem health in the coastal marine habitats of southern Florida: 1. Selection and justification for a suite of indicator species. *Ecological Indicators* 44: 148–163. https://doi.org/10.1016/j.ecolind.2014.03.007

Ormerod, S.J. & S.J. Tyler (1993). Birds as indicators of changes in water quality, pp. 179–216. In: Furness R.W. & J.J.D. Greenwood (eds.). *Birds as Monitors of Environmental Change*. Chapman & Hall, x+356 pp.

Rahmani, A.R. & M.Z. Islam (2008). *Duck, Geese, and Swans of India: Their Status and Distribution*. Indian Bird Conservation Network; Bombay Natural History Society, Royal Society for the Protection of Birds, and BirdLife International. Oxford University Press, 374 pp.

Rajpar, M.N. & M. Zakaria (2011). Bird species abundance and their co-relationship with microclimate and habitat variables at Natural Wetland Reserve, Peninsular Malaysia. *International Journal of Zoology* 2011: 1–17. https://doi.org/10.1155/2011/758573

Rasmussen, P.C. & J.C. Anderton (2012). *Birds of South Asia: The Ripley Guide.* 1st ed. Smithsonian Institution and Lynx Editions, Washington, D.C. and Barcelona: 2 volumes. 378 pp; 683 pp.

Sivakumar, S. & V. Prakash (2004). Water birds of Buxa Tiger Reserve West Bengal. *Zoo's Print Journal* 19(4): 1451–1452. https://doi.org/10.11609/JoTT.ZPJ.1052.1451-2

Wang, X., X. Li, X. Ren, M.V. Jackson, R.A. Fuller, D.S. Melville, T. Amano & Z. Ma (2021). Effects of anthropogenic landscapes on population maintenance of Waterbirds. *Conservation Biology* 36(2) https://doi.org/10.1111/cobi.13808

Zhang, W.W. & J.Z. Ma (2011). Waterbirds as bioindicators of wetland heavy metal pollution. *Procedia Environmental Sciences* 10: 2769–2774.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 February 2024 | 16(2): 24760–24768
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.8755.16.2.24760-24768
#8755 | Received 28 September 2023 | Final received 04 February 2024 | Finally accepted 15 February 2024
OPEN ACCESS
COMMUNICATION

First confirmed reproduction by a translocated female Siamese Crocodile *Crocodylus siamensis* (Crocodylidae: Crocodilia) with observations of nest attendance and nest-associated fauna

Steven G. Platt [1], Sounantha Boutxakittilath [2], Oudomxay Thongsavath [3], Samuel C. Leslie [4], Lonnie D. McCaskill [5], Randeep Singh [6] & Thomas R. Rainwater [7]

[1,2,3,4] Wildlife Conservation Society–Lao Program, P.O. Box 6712, Vientiane, Lao PDR.
[5] Wildlife Conservation Society, Prospect Park Zoo, Prospect Park Zoo, 450 Flatbush Avenue, Brooklyn, New York 11225, USA.
[6,7] Tom Yawkey Wildlife Center & Belle W. Baruch Institute of Coastal Ecology and Forest Science, Clemson University, P.O. Box 596, Georgetown, South Carolina 29442, USA.
[1] sgplatt@gmail.com, [2] sboutxakittlah@wcs.org, [3] oThongsavath@wcs.org, [4] sleslie@wcs.org, [5] lmccaskill@wcs.org, [6] usalligator55@gmail.com, [7] trrainwater@gmail.com (corresponding author)

Abstract: The Siamese Crocodile *Crocodylus siamensis* is considered one of the most imperiled and poorly-studied crocodilians in the world. Translocations (reintroductions) - often in conjunction with head-starting of juveniles - are a critical component of efforts to restore viable wild populations of *C. siamensis*. We here report the first confirmed nesting by a known-age, head-started, and translocated female *C. siamensis* together with observations of nest attendance and nest-associated fauna based on camera trap imagery. Our observations occurred in the Greater Xe Champhone Wetland Complex (GXCWC) in Savannakhet Province, Lao PDR. GXCWC encompasses 45,000 ha of seasonally inundated natural and anthropogenic wetlands, agricultural ecosystems, scrubland, and forest. While collecting eggs for incubation in May 2022, we were able to identify a unique series of notched tail scutes on a female *C. siamensis* as she aggressively defended a nest. From these markings we determined the female was hatched on 11 August 2012 (age = 9.75 years) and released in March 2014, approximately 3.5 km from the nest site. A game camera placed at the nest on 11 May 2022 and recovered on 5 July 2022 (34 trap nights) recorded 1724 images. These images indicated the female remained in attendance at the nest throughout the monitoring period. Camera trap imagery captured eight nest repair events and two nest defense events; during the latter the female defended the nest from village dogs. Eleven species of nest-associated fauna were recorded by the game camera, including eight and three species of birds and mammals, respectively. Our observations are the first confirmed nesting by a head-started, translocated female *C. siamensis* indicating these are effective conservation strategies for restoring wild populations. We also unequivocally established that head-started female *C. siamensis* are capable of reproducing when nine-years-old.

Keywords: Behavior, camera trap, commensal fauna, conservation, head-starting, Lao PDR, nest defense, nest predation, reintroduction, Xe Champhone.

Editor: Raju Vyas, Vadodara, Gujarat, India.

Date of publication: 26 February 2024 (online & print)

Citation: Platt, S.G., S. Boutxakittilath, O. Thongsavath, S.C. Leslie, L.D. McCaskill, R. Singh & T.R. Rainwater (2024). First confirmed reproduction by a translocated female Siamese Crocodile *Crocodylus siamensis* (Crocodylidae: Crocodilia) with observations of nest attendance and nest-associated fauna. *Journal of Threatened Taxa* 16(2): 24760–24768. https://doi.org/10.11609/jott.8755.16.2.24760-24768

Funding: Agence Française de Dévelopement, European Union, St. Augustine Alligator Farm, and Wildlife Conservation Society.

Competing interests: The authors declare no competing interests.

Author details & **Author contributions:** See end of this article.

Acknowledgements: Our Government of Lao counterparts at the Provincial and District Offices of Agriculture and Forestry in Savannakhet Province are thanked for facilitating fieldwork. Cassandra Paul, Kent Vliet, Lewis Medlock, and Ruth Elsey provided literature, Robert Tizard identified many of the birds photographed by our camera trap, and insightful comments by Lewis Medlock improved an early draft of this manuscript. Finally, the many VCT members deserve special mention for their field assistance, enthusiasm, and continuing dedication to crocodile conservation in Laos. This paper represents technical contribution number 7221 of the Clemson University Experimental Station.

AFD AGENCE FRANÇAISE DE DÉVELOPPEMENT
Co-funded by the European Union
Alligator Farm The Zoo for You!
WCS
YAWKEY FOUNDATION

Translocations (defined as the human mediated movement of organisms from one area with release into another area; IUCN 2013) – often undertaken in combination with captive-breeding and head-starting of juveniles – are playing an increasingly important role in the conservation of reptiles, including crocodilians (Germano & Bishop 2008; Ewen et al. 2014; Burke 2015). In many cases, translocation may be the only remaining option for reestablishing depleted or extirpated populations (Marsh & Trenham 2001; Stofer 1999). Among crocodilians, translocation of both head-started juveniles and adults is a strategy being used to successfully restore ecologically functional and demographically viable populations of several threatened species (e.g., Munoz & Thorbjarnarson 2000; Daltry & Starr 2010; Xing 2010; Manalo & Alcala 2015; Sam et al. 2015; Kar 2022).

There is no standardized definition of success regarding wildlife translocation because of varying time scales and differences in life history traits among target organisms (Seddon 1999; Germano et al. 2014; Miller et al. 2014; Burke 2015). However, a translocation can ultimately be considered successful only when a viable, self-sustaining population becomes established in the wild (Griffith et al. 1989; Dodd & Seigel 1991). As a first step towards achieving this objective, translocated individuals must demonstrate competency in the wild, such that they survive, grow, and reproduce (Alberts 2007; Roe et al. 2015). Common demographic indicators of near-term success include positive survival rates and reproduction by founder females (Armstrong & Seddon 2008; Ewen et al. 2014; Miller et al. 2014; Elsey et al. 2015; Platt et al. 2022b).

The Siamese Crocodile *Crocodylus siamensis* (Schneider, 1801) is a large (total length [TL] to ca. 4.0 m) mound-nesting crocodilian that occurs or formerly occurred in freshwater habitats of mainland Southeast Asia (Thailand, Laos, Vietnam, Cambodia) and the Sundaic Islands of Java and Borneo (Platt et al. 2019). Populations throughout this geographic range are now greatly diminished as a result of habitat destruction, commercial hunting for skins, direct persecution because of perceived danger to humans and livestock, and illegal collection to stock crocodile farms (Platt et al. 2019). Consequently, *C. siamensis* is ranked as Critically Endangered on the IUCN Red List of Threatened Species and considered one of the most imperiled crocodilians in the world (Platt et al. 2019). Despite this parlous conservation status, very little is known about the ecology of wild *C. siamensis*, including many aspects of reproduction (Platt et al. 2019). This dearth of information is lamentable because such basic natural history data are a necessary prerequisite for designing and implementing effective conservation strategies for endangered species (Dayton 2003).

In Lao PDR (hereafter Laos), the conservation status of *C. siamensis* is particularly tenuous with small, fragmented populations that show little or no evidence of recruitment, restricted to Attapu, Khammouane, Salavan, and Savannakhet provinces (Platt et al. 2022a). In the early 2000s, surveys conducted by the Wildlife Conservation Society-Lao Program (WCS), working in collaboration with the Government of Laos, identified several small populations of *C. siamensis* in the Xe Champhone wetlands of Savannakhet Province that would likely benefit from conservation efforts (Bezuijen et al. 2013). Importantly, most of these populations already received some degree of *de facto* protection from the widespread local belief that crocodiles embody the spirits of dead ancestors and to harass, harm, or kill a crocodile could bring divine retribution in the form of misfortune, illness, or even death to the individual and community (Baird 2001; Platt et al. 2018a). Local proscriptions protecting crocodiles notwithstanding, numbers were low and population recruitment was lacking because of poor nesting success.

In 2010, we launched a community-based crocodile conservation project in Savannakhet Province with the ultimate objective of restoring a demographically viable population of *C. siamensis* in the Greater Xe Champhone Wetland Complex (GXCWC; Platt et al. 2014, 2022a), which encompasses 45,000 ha of seasonally inundated natural and anthropogenic wetlands, agricultural ecosystems, scrubland, and forest (for detailed site description see IUCN 2011; Platt et al. 2018b). As part of our project, local Village Conservation Teams (VCTs) search for crocodile nests and assist us with egg collection, incubation, and head-starting of juvenile crocodiles (Platt et al. 2022a). To briefly summarize, we search for crocodile nests during May-August, collect the eggs, and transport these to a village facility for incubation. Upon hatching, we permanently mark each hatchling by notching a unique series of double and single caudal scutes (Rainwater et al. 2007). We then head-start juveniles for approximately 32 months (TL ca. 70–100 cm) before releasing them into a densely vegetated reservoir near Tan Soum Village (Platt et al. 2014, 2022a). In 2014, we were forced to terminate our efforts after donor funding was unexpectedly cancelled; however, the project resumed in 2019 (Platt et al. 2022a). To date (September 2023), we have translocated 143 head-started *C. siamensis* into GXCWC, including 65 and

78 crocodiles released in 2013–2014 and 2022–2023, respectively.

We here report the first confirmed nesting by a known-aged, head-started, and translocated female *C. siamensis* together with observations of nest attendance and nest-associated fauna based on camera trap imagery. We broadly define nest attendance as a suite of parental behaviors that includes females maintaining and defending the nest, remaining near the nest, opening the nest when eggs hatch, and transporting hatchlings to water (Merchant et al. 2018; Murray et al. 2019). We follow Merchant et al. (2014) and characterize nest-associated fauna as wild and domestic vertebrates present on or in close proximity to the nest mound. We then categorize these associations according to Rainwater et al. (2024) as 1) feeding/foraging – the animal probed the nesting substrate**,** pursued prey or actively consumed food items on or near the nest; 2) loafing – the animal slept, sat, stood, rested, or preened (birds only) on or adjacent to the nest; 3) traveling – the animal moved across or close to the nest; 4) predation – an animal removed or attempted to remove crocodile eggs from the mound for consumption. We classified photorecords of crocodile behavior and nest-associated fauna as independent detections when the time interval between sequential photographs was ≥ 30 minutes (e.g., O'Brien et al. 2003; Ngoprasert et al. 2019).

On 21 May 2022, a VCT found an active crocodile nest in dense vegetation along the shore of Kout Jek (16.3730°N; 105.2221°E; elevation = 132 m), an oxbow lake in the Champhone River floodplain. Accompanied by the VCT, we returned to the nest on 24 May 2022 to collect the clutch. The nest (approximate dimensions = 100 cm wide × 60–70 cm high) was constructed in a dense thicket (vegetative canopy cover = 100%) at the base of a bamboo clump and on top of a nest mound built during the previous nesting season (2021), and consisted of leaves, woody debris, and soil. At the time of our visit the nest was located ca. 5.0 m from the edge of the lake. We previously visited this nest earlier in the year (15 February 2022) and recovered a clutch of 12 badly decomposed eggs from the 2021 nesting season. According to the VCT, the nest was inundated by seasonal floodwaters in July 2021, resulting in the loss of the complete clutch (see Joanen et al. 1977).

When we arrived at the nest (ca. 1500 h; 24 May 2023), the female crocodile (TL ca. 2.1 m) was lying in a well-defined "form" beneath a tangled mass of vines about 2.0 m away from the mound. As we drew closer to the nest, she crawled on top of the mound and exhibited aggressive behavior (loud hissing, forward lunges, and jaw claps) directed at ourselves (Image 1a–b). When the female ascended the mound, we could clearly discern the three notched double and single caudal scutes allowing us to determine the identification number of this individual. A subsequent search of our database indicated the female crocodile was hatched on 11 August 2012 (age = 9.75 years) and released near Tan Soum Village in March 2014. The straight-line distance from the release site to Kout Jek is 3.5 km.

Using long bamboo poles, we were able to direct the female away from the nest, allowing us to open the mound and collect the eggs. The clutch consisted of 30 eggs with a mean (± 1SD) length, width, and mass of 74.1 ± 1.9 mm, 45.3 ± 1.0 mm, and 90.9 ± 4.1 g, respectively. At the request of the VCT and in accordance with local religious practices (Platt et al. 2018a), we left three non-viable eggs in the nest to appease the female crocodile. We transported the remaining eggs to our facility in Tan Soum Village for processing and incubation. Based on the presence/absence of opaque bands on the eggshells (Ferguson 1985), we determined the clutch contained only 2 (6.6%) viable eggs. The extent of opaque banding on the viable eggs suggested the clutch was deposited between 15–17 May. Prior to departing the nest site, we restored the physical structure of the mound and mounted a Moultrie Series A game camera on a post approximately 3.0 m from the nest. This game camera uses motion and passive infrared sensors to detect wildlife. The Moultrie Series A game camera has a trigger speed of 0.5 second, a flash and detection range of 21 m, and captures 26 megapixel images. The camera trap was aimed at the nest and programmed to take three photographs at 1-minute intervals when activated. In response to rapidly rising seasonal floodwaters that threatened to inundate the area, we returned and recovered the game camera on 5 July 2022. As during our initial visit, the female aggressively defended the nest when we approached. During 34 trap-nights of operation, the game camera recorded 1724 images.

Our camera trap imagery indicated the female remained in attendance at the nest at least intermittently throughout the 34-day monitoring period. When present, the female was concealed beneath the vine tangle where we encountered her on 24 May 2023. Because our camera was aimed at the nest rather than at the vine thicket, the female usually escaped detection, but was occasionally photographed when moving. In some images only the tail or tip of her snout is visible. Between 28 May and 16 June (1223 to 2113 h), our camera recorded eight nest repair events during which the female climbed onto the nest and employed

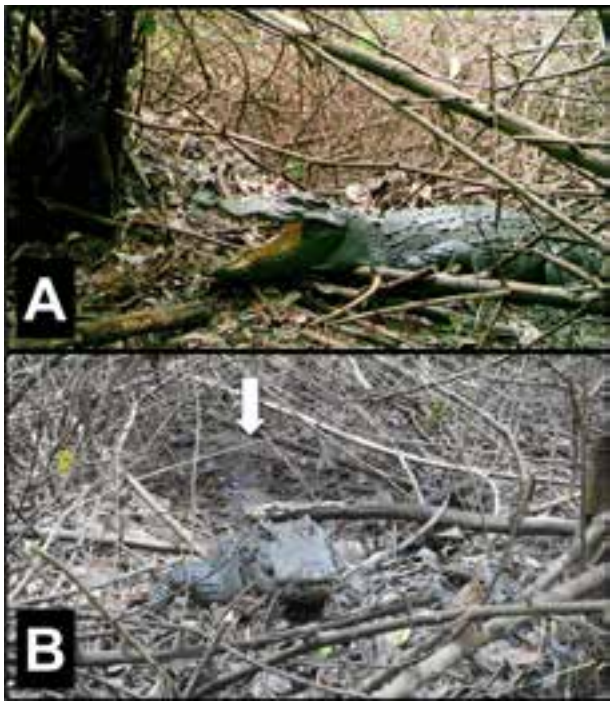


Image 1a–b. Female Siamese Crocodile defending the nest from approaching researchers. Nest mound at the base of bamboo clump at left: a—Female climbing atop nest mound to deter researchers attempting to extract the clutch | b—The white arrow denotes the well-defined "form" beneath the vine tangle where the female remained in attendance at the nest throughout much of the monitoring period. © Wildlife Conservation Society.

Table 1. Nest-associated fauna (wild and domestic vertebrates) recorded by a camera trap deployed at a Siamese Crocodile *Crocodylus siamensis* nest in the Xe Champhone Wetlands (Savannakhet Province, Laos) during 34 trap nights of monitoring (24 May–5 July 2022). Each detection represents one or more sequential photographs separated by a time interval of ≥30 minutes (see text).

Species	Number of detections	Type of association
Birds		
Black-headed Bulbul *Brachypodius melanocephalus*	1	Traveling
Blue-winged Pitta *Pitta moluccensis*	2	Loafing
Hill Blue Flycatcher *Cyornis whitei*	1	Loafing
Pied Fantail *Rhipidura javaniea*	1	Foraging and Loafing
Red Junglefowl *Gallus gallus*	5	Foraging
Verditer Flycatcher *Eumyias thalassinus*	1	Loafing
White-breasted Waterhen *Amauornis phoenicurus*	8	Foraging and Traveling
White-rumped Shama *Copsychus malabaricus*	1	Foraging
Mammals		
Unidentified Rat Rodentia	9	Traveling
Domestic Dog *Canis familiaris*	2	Predation (attempted)
Domestic Cattle *Bos taurus × indicus*	8	Loafing

her rear legs to scrape leaf litter, woody debris, and soil onto the flanks of the mound (Image 2a–c). We assume the nest repair behavior was triggered by our opening the mound to remove the clutch. Notably, nest repair occurred despite our careful efforts to restore the physical integrity of the mound after removing the clutch. We also recorded six instances (1323 to 1826 h; 10 June to 3 July 2023) where the female was atop or beside the mound without effecting repairs. Finally, our camera recorded two nest defense events (1519 to 1520 h on 22 June 2023 and 1245 to 1250 h on 4 July 2023) directed towards village dogs (*Canis familiaris* [Linnaeus, 1758]) (Image 3). In both events the dogs approached to within ca. 2 m of the female and nest and then hastily withdrew without attempting to open the mound. In the second event the female left the nest and pursued the dog for a short distance (< 2m). Our game camera also recorded eleven species of nest-associated fauna, including eight and three species of birds and mammals, respectively (Table 1; Image 4a–h). With the exception of the village dogs, in no cases was the female observed reacting to the presence of nest-associated fauna.

To our knowledge, these observations represent the first confirmed nesting by a head-started *C. siamensis* released into the wild. Head-starting and translocation are the cornerstones of *C. siamensis* restoration efforts throughout Southeast Asia (Polet 2002; Temsiripong 2007; Daltry & Starr 2010; Sam et al. 2015), and while reproduction by translocated females is generally assumed (Platt et al. 2019), confirmation has not been forthcoming until now. Successful recruitment of captive-reared females into wild breeding populations has likewise been verified for other species of translocated crocodilians (Elsey et al. 2000; Larriera et al. 2006; Elsey 2007; Elsey et al. 2015; Platt et al. 2016; Leiva et al. 2019). Collectively, this growing body of evidence indicates that captive-reared, head-started crocodilians are not only able to survive and forage in the wild but also reproduce, suggesting these are effective conservation strategies for restoring wild populations.

Our observations also unequivocally establish that head-started and translocated female *C. siamensis* are capable of reproducing at the age of nine-years-old. Moreover, if the clutch of decomposing eggs we recovered from the mound in February 2022 (from the 2021 nesting season) was deposited by the same female defending the nest in May 2022, she reproduced when only eight-years-old. Although captive-reared female *C. siamensis* on commercial farms in Cambodia

and Thailand occasionally begin reproducing in as little as 6–7 years (Platt et al. 2011; Yosapong Temsiripong, pers. comm.), sexual maturity in the wild is probably attained between 10–15 years or perhaps later (Youngprapakorn et al. 1971). Accelerated growth and early reproduction by female crocodilians has been reported for several species that were reared in captivity before being translocated (e.g., *Alligator mississippiensis* [Daudin, 1801] and *Caiman latirostris* [Daudin, 1801]) and is probably commonplace among head-started crocodilians (Elsey et al. 2000; Larriera et al. 2006). Decreasing the time required for translocated females to begin producing offspring has the potential to increase population growth rates, thereby lessening the likelihood that stochastic demographic events will negatively impact translocation outcomes (Elsey et al. 2000; Larriera et al. 2006).

The aggressive nest defense exhibited by the female crocodile is only the second instance of this behavior (see also Platt et al. 2020) we witnessed during visits to 31 *C. siamensis* nests to collect eggs for incubation (2011–13 and 2019–23). Although nest attendance and defense are probably universal among the Crocodylia (Grigg & Kirschner 2015), these behaviors are poorly documented in *C. siamensis*. Similar to our observations, the few previous reports of nest attendance behaviors involved female *C. siamensis* defending nests against researchers; Kanwatanakid-Savini et al. (2012) found a female concealed in dense grass beside a nest in Thailand, Bezuijen et al. (2013), stated that a nest in Laos was "fiercely guarded by a female", and Platt et al. (2020) described an aggressive encounter with a large female at another nest in Laos. That said, aggressive nest defense directed towards humans is probably an unreliable index of attendance behavior because female crocodilians may selectively avoid humans, and yet still defend nests against smaller predators (Kushlan & Kushlan 1980; Hunt & Ogden 1991). Tellingly, in a recent aerial survey conducted in GXCWC using drones (Platt et al. 2023), we observed female crocodiles at 60% of the nests, suggesting nest attendance behavior is more commonplace among *C. siamensis* than hitherto recognized. Although our camera trap imagery appears to be the first showing a wild female *C. siamensis* undertaking nest repairs, attending female *A. mississippiensis* (Dietz & Hines 1980; Joanen & McNease 1989; Hunt & Ogden 1991) and Spectacled Caiman (*Caiman crocodilus* [Linnaeus, 1758]) (González-Desales et al. 2023) are reported to reshape and add material to nest mounds opened by predators.

The camera trap imagery we obtained during a relatively brief monitoring period (34 days) is the first to document fauna associated with *C. siamensis* nests. Our findings are consistent with other reports that describe a diversity of vertebrates using crocodilian nest mounds as

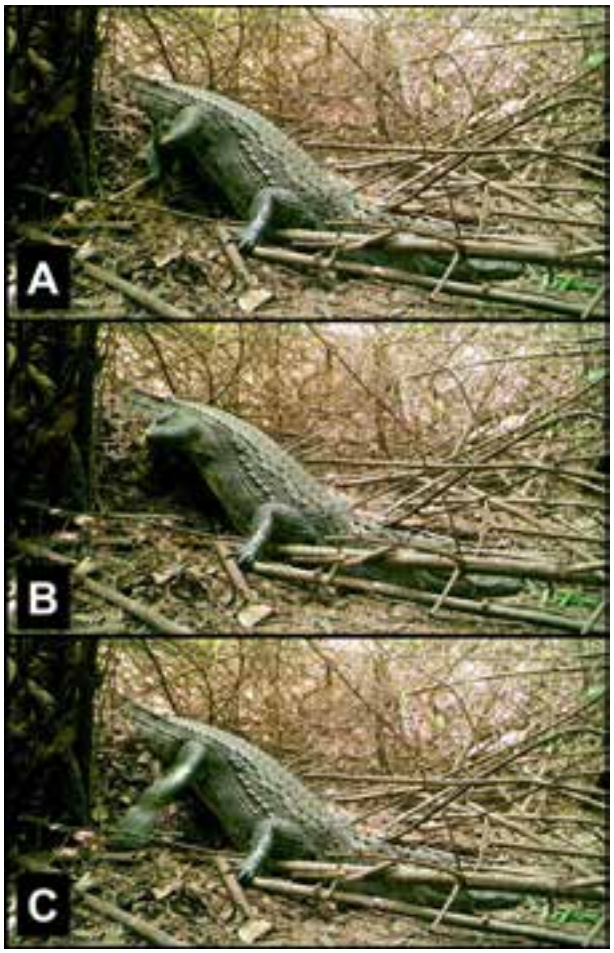


Image 2a–c. The sequence of images showing female Siamese Crocodile repairing nest after the mound was opened and clutch removed by researchers. © Wildlife Conservation Society.

Image 3. Female Siamese Crocodile defending nest from village dog. © Wildlife Conservation Society.

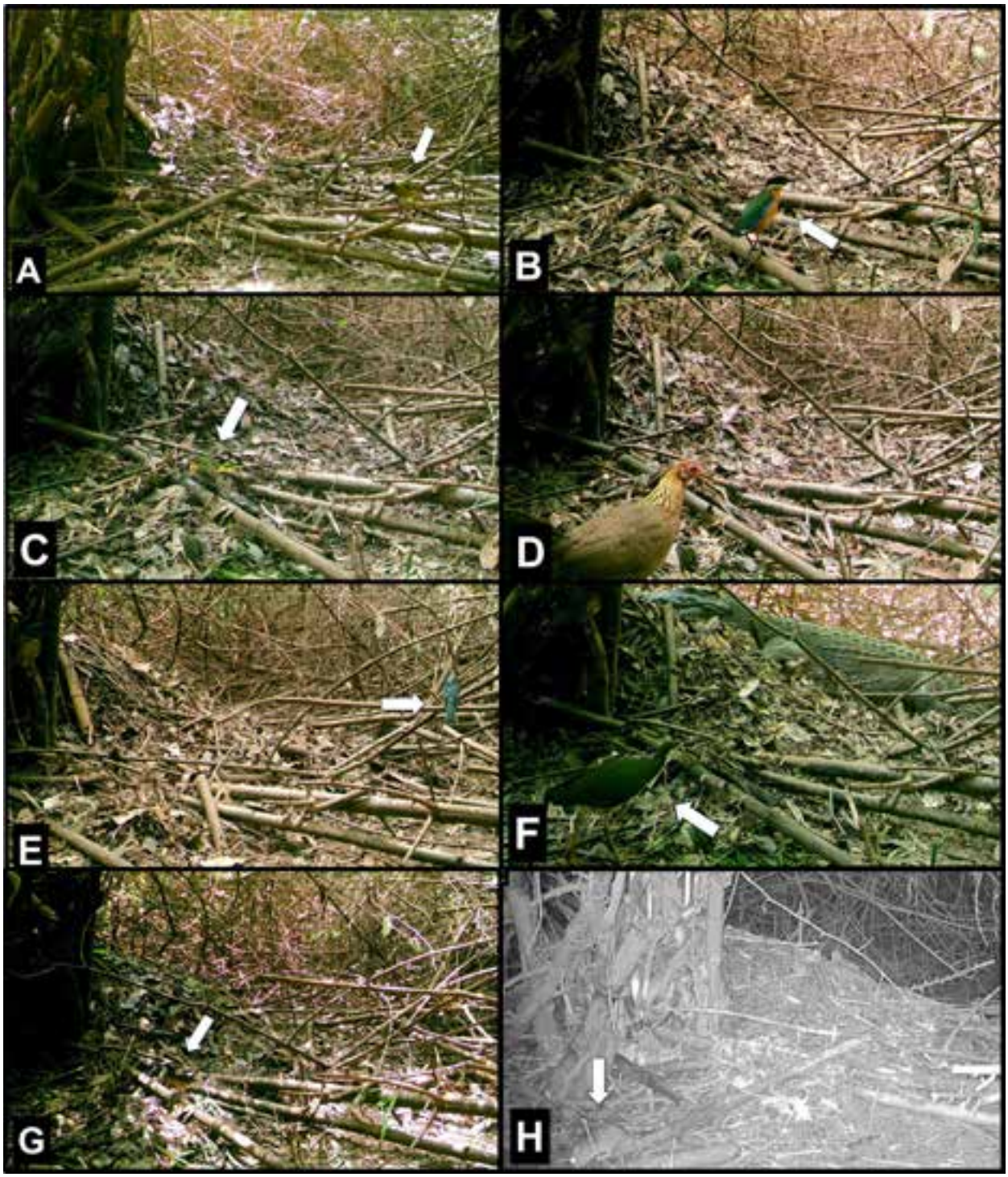


Image 4a–h. Examples of fauna associated with Siamese Crocodile nest during a 34-day monitoring period (24 May–5 July 2023): a—Black-headed Bulbul | b—Blue-winged Pitta | c—Hill Blue Flycatcher | d—Red Junglefowl | e—Verditer Flycatcher | f—White-breasted Waterhen | g—White-rumped Shama | h—Unidentified species of rat. © Wildlife Conservation Society.

feeding and loafing platforms, foraging substrates, and nesting sites (Merchant et al. 2014; Eversole & Henke 2018; Escobedo-Galván et al. 2019; Platt et al. 2021; González-Desales et al. 2020; Rainwater et al. 2024). Characterizing the associations of the six species of passerines we recorded at the nest proved challenging owing to the limited number of images that we obtained; however, most birds appeared to be loafing or traveling.

In contrast, Red Junglefowl (*Gallus gallus* [Linnaeus, 1758]) and White-breasted Waterhen (*Amaurornis phoenicurus* [Pennant, 1769]) were foraging on and around the nest mound. While crocodilian nest mounds harbor an abundance of potential invertebrate prey for birds (Medem 1971; Staton & Dixon 1977; Merchant et al. 2014; Platt et al. 2021; Rainwater et al. 2024), foraging at the mound also entails some degree of risk because crocodilians (including *C. siamensis*; Sam et al. 2015) frequently prey on birds (Gabrey & Elsey 2017). An unidentified species of rat(s) was the nest associate most frequently recorded by our camera. Although some rodents are predators of crocodile eggs (Webb et al. 1977; Hunt & Ogden 1991; Platt et al. 2021), our images indicated the rats traveled across the nest and through the area without attempting to breach the mound and consume eggs. Free-ranging dogs are known predators of crocodile eggs (Vyas 2010; Somaweera et al. 2013), and we consider the two instances when village dogs approached the nest as attempted predation events thwarted by the aggressive response of the attending female. In contrast, the presence of domestic cattle at the nest on numerous occasions (in one series of images sleeping cattle remained at the nest for almost five hours) elicited no response from the female crocodile suggesting these large mammals were not perceived as a threat to the nest. Likewise, González-Desales et al. (2023) speculated that female *C. crocodilus* attending nests learned to differentiate between potential egg predators and harmless species.

In closing, we caution that our camera trap imagery almost certainly represents an incomplete record of events transpiring at the nest during the monitoring period. The passive infrared sensors in camera traps detect animals based on a combination of heat and motion, and the effectiveness of these sensors depends on multiple factors such as distance from the camera to the target individual, body size (i.e., larger individuals generate more heat), and ambient temperature. As such, passive infrared sensors are very effective at detecting large mammals, but less reliable for detecting small-bodied endotherms and ectotherms (Hobbs & Brehme 2017), including crocodilians (Merchant et al. 2012; Charruau & Henaut 2012; Combrink et al. 2016). Given the technical constraints associated with passive infrared sensors, our camera trap likely either failed to capture or incompletely captured instances of crocodilian behavior and nest-associated fauna, especially smaller species of birds and mammals.

REFERENCES

Alberts, A.C. (2007). Behavioral considerations for headstarting as a conservation strategy for endangered Caribbean Rock Iguanas. *Applied Animal Behavior Science* 102: 380–391.

Armstrong, D.P. & P.J. Seddon (2008). Directions in reintroduction biology. *Trends in Ecology and Evolution* 23: 20–25. https://doi.org/10.1016/j.tree.2007.10.003

Bezuijen, M.R., J.H. Cox, Jr., J.B. Thorbjarnarson, C. Phothitay, M. Hedermark & A. Rasphone (2013). Status of Siamese Crocodile (*Crocodylus siamensis*) Schneider, 1801 (Reptilia: Crocodylia) in Laos. *Journal of Herpetology* 47: 41–65.

Baird, I.G. (2001). The protected crocodiles, wetlands, and forests at Ban Beung Buoa Thong and Ban Nao Neua, Xaibouli District, Savannakhet Province, southern Lao PDR. *Crocodile Specialist Group Newsletter* 20(2): 22–24.

Burke, R.L. (2015). Head-starting turtles: learning from experience. *Herpetological Conservation and Biology* 10: 299–308.

Charruau, P. & Y. Henaut (2012). Nest attendance and hatchling care in wild American crocodiles (*Crocodylus acutus*) in Quintana Roo, Mexico. *Animal Biology* 62: 29–51.

Combrink, X., J.K. Warner & C.T. Downs (2016). Nest predation and maternal care in the Nile Crocodile (*Crocodylus niloticus*) at Lake St. Lucia, South Africa. *Behavioural Processes* 133: 31–36. https:// doi.org/10.1016/beproc.2016.10.014

Daltry, J.C. & A. Starr (2010). Development of a re-introduction and re-enforcement program for Siamese Crocodiles in Cambodia, pp. 118–123. In: Soorae, P.S. (ed.). *Global Re-Introduction Perspectives: Additional Case Studies from Around the Globe*. SSC Re-Introduction Specialist Group, Abu Dhabi, UAE.

Dayton, P.K. (2003). The importance of the natural sciences to conservation. *American Naturalist* 162: 1–13.

Deitz, D.C. & T.C. Hines (1980). Alligator nesting in north-central Florida. *Copeia* 1980: 249–258.

Dodd, C.K., Jr. & R. A. Seigel (1991). Relocation, repatriation, and translocation of amphibians and reptiles: Are they conservation strategies that work? *Herpetologica* 47: 336–350.

Elsey, R.M. (2007). Precocious reproductive development in a farm-raised and released American Alligator, *Alligator mississippiensis*. *Herpetological Bulletin* 102: 11–14.

Elsey, R.M., V. Lance & L. McNease (2000). Evidence of accelerated sexual maturity and nesting in farm-released alligators in Louisiana, pp. 244–255. In: Grigg, G.C., F. Seebacher & C.E. Franklin (eds.). *Crocodilian Biology and Evolution*. Surrey Beatty & Sons, Chipping Norton, Australia, 446 pp.

Elsey, R.M., C. Wall & M. Wall (2015). *Alligator mississippiensis* (American Alligator). Nesting by a reintroduced female. *Herpetological Review* 46: 622–623.

Escobedo-Galván, A.H., R.M. Elsey, F. McCann, F.G. Cupul-Magaña & M.A. López-Luna (2019). Putting eggs in one big basket: communal egg-laying between long-lived reptiles. *North-Western Journal of Zoology* 15: 96–100.

Eversole, C.B. & S.E. Henke (2018). Effects of red imported fire ants (*Solenopsis invicta*) presence on success and depredation of American alligator (*Alligator mississippiensis*) nests: Potential value of a non-native invasive species. *Herpetological Review* 49: 22–25.

Ewen, J.G., P.J. Soorae & S. Canesa (2014). Reintroduction objectives, decisions, and outcomes: global perspectives from the herpetofauna. *Animal Conservation* 17: 74–87. https://doi.org/10.1111/acv.12148

Ferguson, M.W.J. (1985). The reproductive biology and embryology of the crocodilians, pp. 330–491. In: Gans, C., F.S. Bilet & P.F.A. Maderson (eds.). Biology of the Reptilia. Vol. 14. John Wiley & Sons, New York. 692 pp.

Gabrey, S.W. & R.M. Elsey (2017). Birds in the diet of American Alligators. *Journal of Louisiana Ornithology* 10: 1–10.

Germano, J.M. & P.J. Bishop (2008). Suitability of Amphibians and Reptiles for translocation. *Conservation Biology* 23: 7–15. https://doi.org/10.1111/j.1523-1739.2008.01123x

Germano, J., J. G. Ewen, H. Mushinsky, E. McCoy & L. Ortiz-Catedral (2014). Moving towards greater success in translocations: recent advances from the herpetofauna. *Animal Conservation* 17: 1–3. https://doi.org/10.1111/acv.12172

González-Desales, G.A., P. Charruau, M.M. Zarco- González & O. Monroy-Vilchis (2023). Factors influencing egg predation of two species of crocodilians in Mexico. *Herpetological Conservation and Biology* 18: 404–414.

González-Desales, G.A., L.A. Tello-Sahagún, C.P. Cadena-Ramírez, M.A. López-Luna, A. Buenrostro-Silva, J. García-Grajales, M.C. González-Ramón, J.E. Morales-Mavil, P. Charruau, L. Sigler, A. Rubio-Delgado, M.M. Zarco- González & O. Monroy-Vilchis (2020). Egg predation and vertebrates associated with wild crocodilian nests in Mexico determined using camera traps. *Journal of Natural History* 54: 1813–1826. https://doi.org/10.1080/00222933.2020.1829723

Griffith, B., J.M. Scott, J.W. Carpenter & C. Reed (1989). Translocation as a species conservation tool: Status and strategy. *Science* 245: 477–480.

Grigg, G. & D. Kirschner (2015). *Biology and Evolution of Crocodylians*. Cornell University Press, Ithaca, New York, USA, 649 pp.

Hobbs, M.T. & C.S. Brehme (2017). An improved camera trap for amphibians, reptiles, small mammals, and large invertebrates. *PLoS ONE* 12(10): e0185206. https://doi.org/10.1371/journal.pone.0185026

Hunt, R.H. & J.J. Ogden (1991). Selected aspects of nesting ecology of American Alligators in the Okefenokee Swamp. *Journal of Herpetology* 25: 448–453.

IUCN (2011). *Baseline Report: Xe Champhone Wetland, Champhone and Xonbuly Districts, Savannakhet Province, Lao PDR*. Mekong Water Dialogues Project. IUCN Publications, Gland, Switzerland, 58 pp.

IUCN (2013). *Guidelines for reintroductions and other conservation translocations. Version 1.0.* IUCN Species Survival Commission, Gland, Switzerland, 72 pp.

Joanen, T. & L. McNease (1989). Ecology and physiology of nesting and early development of the American alligator. *Integrative and Comparative Biology* 29: 987–998.

Joanen, T., L. McNease & G. Perry (1977). Effects of simulated flooding on alligator eggs. *Proceedings Annual Conference Southeastern Association of Fish & Wildlife Agencies* 31: 334–342.

Kar, S. (2022). Nesting trend of Esturaine Crocodile, *Crocodylus porosus*, in the forest blocks of Bhitarkanika Wildlife Sanctuary/ National Park, Odisha, India. *Crocodile Specialist Group Newsletter* 41(4): 13–14.

Kanwatanakid-Savini, C., M. Pliosungnoen, A. Pattanavibool, J.B. Thorbjarnarson, C. Limlikhitaksorn & S.G. Platt (2012). A survey to determine the conservation status of Siamese crocodiles in Kaeng Krachan National Park, Thailand. *Herpetological Conservation and Biology* 7: 157–168.

Kushlan, J.A. & M.S. Kushlan (1980). Function of nest attendance in American Alligators. *Herpetologica* 36: 27–32.

Larriera, A., P. Siroski, C.L. Pina & A. Imhof (2006). Sexual maturity of farm-released *Caiman latirostris* (Crocodylidae: Alligatoridae) in the wild. *Herpetological Review* 37: 26–28.

Leiva, P.M.L., M.S. Simoncini, T.C.G. Portelinha, A. Larriera & C.I. Pina (2019). Size of nesting female Broad-snouted Caiman (*Caiman latirostris* Daudin 1802). *Brazilian Journal of Biology* 79: 139–143. https://doi.org10.1590/1519-6984.180892

Manalo, R.J. & A.C. Alcala (2015). Conservation of the Philippine Crocodiles *Crocodylus mindorensis* (Schmidt 1935): *in-situ* and *ex-situ* measures. *International Zoo Yearbook* 49: 113–124. https://doi.org/10.1111/izy.12080

Marsh, D.M. & P.C. Trenham (2001). Metapopulation dynamics and amphibian conservation. *Conservation Biology* 15: 40–49.

Medem, F. (1971). The reproduction of the Dwarf Caiman *Paleosuchus palpebrosus*, pp. 159–165. In: *Crocodiles: Proceedings of the 1st Working Meeting of the IUCN Crocodile Specialist Group*. IUCN Publications, Morges, Switzerland.

Merchant, M., C.M. Murray & A. Cooper (2014). American Alligator nests as microhabitat for a diversity of vertebrates. *Herpetological Review* 45: 201–208.

Merchant, M., D. Savage, A. Cooper, J.M. Slaughter, J.J. Perkins & C.M. Murray (2018). Nest attendance patterns in the American alligator (*Alligator mississippiensis*). *Copeia* 106: 421–426. https://doi.org/10.1643/CH-17-7-709

Merchant, M., D. Savage, A. Cooper, M. Slaughter & C. Murray (2012). Assessment of nest attendance of the American alligator (*Alligator mississippiensis*) using a modified motion-sensitive camera trap, pp. 205. In: *Crocodiles: Proceedings of the 21st Working Meeting of the Crocodile Specialist Group*. IUCN–The World Conservation Union, Gland, Switzerland.

Miller, K.A., T. Bell & J.M. Germano (2014). Understanding publication bias in reintroduction biology by assessing translocations of New Zeeland's herpetofauna. *Conservation Biology* 28: 1045–1056. https://doi.org/10.1111/cobi.12254

Munoz, M. del C. & J. Thorbjarnarson (2000). Movement of captive-released Orinoco Crocodiles (*Crocodylus intermedius*) in the Capanaparo River, Venezuela. *Journal of Herpetology* 34: 397–403.

Murray, C.M., B.I. Crother & J.S. Doody (2019). The evolution of crocodilian nesting ecology and behavior. *Ecology and Evolution* 10: 131–149. https://doi.org/10.1002/ece3.5859

Ngoprasert, D. & G.A. Gale (2019). Tiger density, dhole occupancy, and prey occupancy in the human disturbed Dong Phayayen-Khao Yai Forest Complex, Thailand. *Mammalian Biology* 95: 51–58. https://doi.org/10.1016/j.mambio.2019.02.003

O'Brien, T.G., M.F. Kinnard & H.T. Wibisono (2003). Crouching tigers, hidden prey: Sumatran tiger populations in a tropical forest landscape. *Animal Conservation* 6: 131–149.

Platt, S.G., S. Boutxakittilath, O. Thongsavath, S.C. Leslie & L. McCaskill (2022a). Restoring the Critically Endangered Siamese Crocodile to the Xe Champhone Wetlands in Lao PDR (2019-2022). *Crocodile Specialist Group Newsletter* 41(4): 6–13.

Platt, S.G., F. Li, Q. He, J. Wang & S. Lu (2016). Reproduction in a reintroduced population of Chinese Alligators. *Crocodile Specialist Group Newsletter* 35(3): 11–15.

Platt, S.G., L. McCaskill, T.R. Rainwater, Y. Temsiripong, M. As-singkily, B.K. Simpson & M.R. Bezuijen (2019). Siamese Crocodile *Crocodylus siamensis*, pp. 120–132. In: S.C. Manolis & C. Stevenson (eds.), *Crocodiles: Status Survey and Conservation Action Plan*, 4th Edition. IUCN Crocodile Specialist Group, Darwin, Australia. Available: https://www.iucncsg.org

Platt, S.G., V. Monyrath, H. Sovannara, L. Kheng & T.R. Rainwater (2011). Nesting phenology and clutch characteristics of captive Siamese Crocodiles (*Crocodylus siamensis*) in Cambodia. *Zoo Biology* 30: 1–12.

Platt, S.G., T.R. Rainwater & S.T. McMurry (2021). Fauna associated with the nests of *Crocodylus moreletii* and *Crocodylus moreletii* × *acutus* in Belize. *Journal of Natural History* 55: 133–149. https://doi.org/10.1080/00222933.2021.1895350

Platt, S.G., S.H.N. Aung, M.M. Soe, T. Lwin, K. Platt, A.D. Walde & T.R. Rainwater (2022b). Reproduction of translocated *Geochelone platynota* (Testudines: Testudinidae) at two wildlife sanctuaries in Myanmar. *Salamandra* 58: 161–165.

Platt, S.G., O. Thongsavath, C.D. Hallam & T.R. Rainwater (2020). *Crocodylus siamensis* (Siamese Crocodile). Nesting and nest attendance. *Herpetological Review* 51: 588–590.

Platt, S.G., O. Thongsavath, P. Outhanekone & T.R. Rainwater (2018a). Notes on traditional ecological knowledge and ethno herpetology of Siamese crocodiles in Lao, PDR. *Crocodile Specialist Group Newsletter* 37(4): 6–12.

Platt, S.G., O. Thongsavath, C. Pothitay, C. Holmes, L. McCaskill & T.R. Rainwater (2018b). A status assessment and long-term conservation plan for Siamese Crocodiles in the Xe Champhone Ramsar Site, Savannakhet Province, Lao PDR, pp. 219–237. In: *Crocodiles: Proceedings of the 25th Working Meeting of the IUCN Crocodile Specialist Group*. IUCN Publications, Gland, Switzerland.

Platt, S.G., O. Thongsavath, P. Sisavath, P. Outhanekone, A.

McWilliams & C.D. Hallam (2014). Community-based Siamese Crocodile conservation in Lao PDR. *Crocodile Specialist Group Newsletter* 33(2): 22–27.

Platt, S.G., J.C. White, S. Boutxakittilath, D. Phasavath, O. Thongsavath, L.D. McCaskill, S.C. Leslie & T.R. Rainwater (2023). Evaluating the use of a quad-copter drone to detect Siamese Crocodile nests in Lao, PDR, with incidental observations of female nest attendance. *Reptiles & Amphibians* 30(1): el9950. https://doi.org/10.17161/randa.v30i1.19950

Polet, G. (2002). *Crocodylus siamensis* re-introduced in Cat Tien National Park. *Crocodile Specialist Group Newsletter* 21: 9–10.

Rainwater, T.R., T.H. Wu, A.G. Finger, J.E. Cañas, L. Yu, K.D. Reynolds, G. Coimbatore, B. Barr, S.G. Platt, G.P. Cobb, T.A. Anderson & S.T. McMurry (2007). Metals and organochlorine pesticides in caudal scutes of crocodiles from Belize and Costa Rica. *Science of the Total Environment* 373: 146–156.

Rainwater, T.R., R. Singh, C.A. Tuten, A.M. Given, P.W. Gibbons, B. Song, S.G. Platt, P.M. Wilkinson & C.M.B. Jachowski (2024). Fauna associated with American Alligator (Alligator mississippiensis) nests in coastal South Carolina, USA. *Animals* 14(4): 620. https://doi.org/10.3390/ani14040620

Roe, J.H., M.R. Frank & B.A. Kingsbury (2015). Experimental evaluation of captive-rearing practices to improve success of snake reintroductions. *Herpetological Conservation and Biology* 10: 711–722.

Sam, H., L. Hor, R. Nhek, P. Sorn, S. Heng, B. Simpson, A. Starr, S. Brook, J.L. Frechette & J.C. Daltry (2015). Status, distribution and ecology of the Siamese Crocodile *Crocodylus siamensis* in Cambodia. *Cambodian Journal of Natural History* 2015: 153–164.

Seddon, P.J. (1999). Persistence without intervention: assessing success in wildlife reintroductions. *Trends in Ecology and Evolution* 14: 503.

Somaweera, R., M. Brien & R. Shine (2013). The role of predation in shaping crocodilian natural history. *Herpetologica* 27: 23–51.

Staton, M.A. & J.R. Dixon (1977). *Breeding biology of the Spectacled Caiman,* Caiman crocodilus crocodilus*, in the Venezuelan Llanos*. United States Fish and Wildlife Service, Research Report No. 5, Washington, D.C., 23 pp.

Stofer, A. (1999). Gene flow and endangered species translocations: a topic revisited. *Biological Conservation* 87: 173–190.

Temsiripong, Y. (2007). Re-introduction of captive-raised Siamese Crocodiles in Thailand. *Re-introduction News* 28: 55–57.

Vyas, R. (2010). Mugger (*Crocodylus palustris*) population in and around Vadodara City, Gujarat States, India. *Russian Journal of Herpetology* 17: 43–50.

Webb, G.J.W., H. Messel & W.E. Magnusson (1977). The nesting of *Crocodylus porosus* in Arnhem Land, Northern Australia. *Copeia* 1977: 238–249.

Xing, J.H. (2010). Chinese Alligator, *Alligator sinensis*, pp. 5–9. In: S.C. Manolis & C. Stevenson (eds.). *Crocodiles: Status Survey and Conservation Action Plan. 3rd Edition*. Crocodile Specialist Group, Darwin, 108 pp.

Youngprapakorn, U., J.A. McNeely & E.W. Cronin (1971). Captive breeding of crocodiles in Thailand, pp. 98–101. In: *Crocodiles: Proceedings of the 1st Working Meeting of the IUCN Crocodile Specialist Group*. IUCN Publications, Morges, Switzerland.

ບົດຄັດຫຍໍ້: ແຂ້ນ້ຳຈືດພັນສະຫຍາມ (Crocodylus siamensis) ຖືເປັນຊະນິດແຂ້ທີ່ມີຄວາມສ່ຽງ ແລະ ມີການສຶກສາຄົ້ນຄວ້າໜ້ອຍທີ່ສຸດຊະນິດໜຶ່ງໃນທົ່ວໂລກ. ມີການເຄື່ອນຍ້າຍ (reintroductions) ຫຼາຍຄັ້ງທີ່ມີການເຮັດ head-starting ຂອງໂຕອ່ອນ ເຊິ່ງເປັນອົງປະກອບໜຶ່ງທີ່ສຳຄັນໃນຄວາມພະຍາຍາມເພື່ອການຟື້ນຟູປະຊາກອນທີ່ຢູ່ໃນທຳມະຊາດຂອງ C. siamensis ຂອງພູມິພາກອາຊີຕາເວັນອອກສຽງໃຕ້. ເຊິ່ງພວກເຮົາໄດ້ລາຍງານ ແລະ ຢັ້ງຢືນ ການເຮັດຮັງວາງໄຂ່ເປັນເທື່ອທຳອິດ ໂດຍ C. siamensis ໂຕແມ່ທີ່ມາຈາກການເຮັດ head-starting ແລະ ປ່ອຍຄືນສູ່ທຳມະຊາດ, ລວມເຖິງການສັງເກດການເຂົ້າຮັງ ໂດຍອາໄສພາບຖ່າຍຈາກ camera trap ເຊິ່ງການຕິດຕາມ ແລະ ສັງເກດພຶດຕິກຳດັ່ງກ່າວນີ້ໄດ້ເຮັດຢູ່ເຂດດິນບໍລິເວນນ້ຳເຊຈຳພອນ Greater Xe Champhone (GXCWC) ແຂວງ ສະຫວັນນະເຂດ, ສປປ ລາວ. GXCWC ມີເນື້ອທີ່ທັງໝົດ 45,000 ເຮັກຕາ ກວມເອົາພື້ນທີ່ດິນບໍລິເວນນ້ຳຕາມທຳມະຊາດ ແລະ ພື້ນທີ່ນ້ຳຖ້ວມຕາມລະດູການ, ພື້ນທີ່ເຮັດການກະສິກຳຂອງປະຊາຊົນ, ປ່າໄມ້ພຸ່ມຂະໜາດນ້ອຍ ແລະ ປ່າໄມ້. ໃນລະຫວ່າງທີ່ເກັບໄຂ່ມາຟັກ ຊ່ວງເດືອນ ພຶດສະພາ ປີ 2022 , ພວກເຮົາສາມາດຢັ້ງຢືນຕຳແໜ່ງຮອຍທີ່ຖືກຕັດເທິງເກັດຫາງ ເຊິ່ງມີລັກສະນະສະເພາະຢູ່ທີ່ຫາງຂອງ C. siamensis ໂຕແມ່ໃນເວລາທີ່ມັນຂຶ້ນມາປົກປ້ອງຮັງ, ຈາກສັນຍາລັກດັ່ງກ່າວພວກເຮົາພົບວ່າແຂ້ໂຕແມ່ ແມ່ນແຂ້ນ້ອຍທີ່ຟັກອອກໃນວັນທີ 11 ສິງຫາ 2012 (ອາຍຸ = 9.75 ປີ) ແລະ ປ່ອຍຄືສະທຳມະຊາດໃນເດືອນ ມີນາ 2014 ໄກຈາກບໍລິເວນປ່ອຍປະມານ 3.5 ກິໂລແມັດ. ພວກເຮົາໄດ້ຕິດຕັ້ງ Camera trap ໃນວັນທີ 11 ພຶດສະພາ 2022 (ເປັນເວລາ 34 ຄືນ)ບັນທຶກຮູບພາບໄດທັງໝົດ 1,724 ຮູບ. ຮູບເຫຼົ່ານີ້ສະແດງໃຫ້ເຫັນວ່າແຂ້ໂຕແມ່ຍັງຢູ່ເຝົ້າຮັງຕະຫຼອດໄລຍະເວລາໃນການຕິດຕາມ, ຮູບພາບຈາກກ້ອງດັກຖ່າຍຍັງສາມາດບັນທຶກພາບການຂຶ້ນມາສ້ອມແຊມຮັງໄດ້ 8 ຄັ້ງ ແລະ ການປ້ອງກັນຮັງ 2 ຄັ້ງ. ໃນຊ່ວງທ້າຍແຂ້ໂຕແມ່ໄດ້ປົກປ້ອງຮັງຈາກໝາຂອງຊາວບ້ານ, ນອກຈາກນີ້ຍັງສາມາດບັນທຶກພາບສັດຊະນິດອື່ນທີ່ເຄື່ອນໄຫວໃນບໍລິເວນຮັງໄຂ່ແຂ້ອີກ 11 ຊະນິດ ລວມທັງນົກ ແລະ ສັດລ້ຽງລູກດ້ວຍນ້ຳນົມ 8 ແລະ 3 ຊະນິດຕາມລຳດັບ. ການຕິດຕາມຂອງພວກເຮົາຖືເປັນການຢັ້ງຢືນການເຮັດຮັງຄັ້ງທຳອິດ ຂອງ C. siamensis ໂຕແມ່ທີ່ມາຈາກ head-starting, ເຊິ່ງເປັນໂຕຊີ້ວັດວ່າຂະບວນການເຫຼົ່ານີ້ເປັນວິທີການອະນຸລັກທີ່ມີປະສິດທິຜົນໃນການຟື້ນຟູປະຊາກອນແຂ້ໃນທຳມະຊາດ. ນອກຈາກນີ້ພວກເຮົາຍັງສາມາດລະບຸໄດ້ຢ່າງຊັດເຈນດ້ວຍວ່າ C. siamensis ໂຕແມ່ທີ່ມາຈາກ head-starting ສາມາດຂະຫຍາຍພັນໄດ້ເມື່ອມີອາຍຸຮອດເກົ້າປີ.

Author details: Steven G. Platt is the associate conservation herpetologist with Wildlife Conservation Society (WCS) in Southeast Asia. He is responsible for conservation projects involving endangered turtles and crocodilians in Myanmar, Laos, Cambodia, and Thailand. Sounantha Boutxakittilath is the chief biodiversity conservation officer with the WCS-Lao Program in Savannakhet and responsible for all aspects of the Siamese Crocodile Conservation Project. Oudomxay Thongsavath is the project manager for the WCS Savannakhet Landscape Program and directs efforts to protect and restore wetlands in and around the Xe Champhone Ramsar Site. He is currently enrolled in a graduate program at Cornell University in New York, USA. Samuel C. Leslie worked for over a decade on conservation projects in the Mekong Basin, facilitating participatory management and governance of wetland biodiversity. He served as the technical director for WCS Savannakhet Landscape Program between 2019 and 2023 and is currently pursuing graduate education in the United States. Lonnie D. McCaskill was the assistant director and general curator for the WCS Zoological Programs in New York until his retirement in 2023. He was formerly the AZA Studbook Keeper for Siamese Crocodile, and currently serves as the IUCN Crocodile Specialist Group Co-chair for Southeast and South Asia. He has been involved in translocating Siamese Crocodiles in Cambodia and Laos since 2004. Randeep Singh is a wildlife biologist with Clemson University's Baruch Institute of Coastal Ecology and Forest Science in Georgetown, South Carolina, USA. Since 2019, he has conducted research on the nesting ecology of American alligators in coastal landscapes. Thomas R. Rainwater is a research scientist with the Tom Yawkey Wildlife Center and Clemson University's Baruch Institute of Coastal Ecology and Forest Science in Georgetown, South Carolina, USA. Much of his current research focuses on the biology, ecotoxicology, and conservation of crocodilians.

Author contributions: Steven G. Platt—Conceived and designed the study, conducted fieldwork, analyzed data, wrote the manuscript, and secured funding. Sounantha Boutxakittilath—Conducted fieldwork, analyzed data, and assisted with manuscript preparation. Oudomxay Thongsavath—Conducted fieldwork, assisted with manuscript preparation, and secured funding. Samuel C. Leslie—Conducted fieldwork and secured funding. Lonnie D. McCaskill—Conducted fieldwork and assisted with manuscript preparation. Randeep Singh—Designed the study, analyzed data, prepared figures, and assisted with manuscript preparation. Thomas R. Rainwater—Conceived and designed the study, analyzed data, prepared figures, and wrote the manuscript. All authors reviewed and approved the final draft of the manuscript.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 February 2024 | 16(2): 24769–24774

ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

https://doi.org/10.11609/jott.8749.16.2.24769-24774

#8749 | Received 21 September 2023 | Final received 06 January 2024 | Finally accepted 21 January 2024

OPEN ACCESS

COMMUNICATION

Erode Ground Gecko *Cyrtodactylus speciosus* (Beddome, 1870) (Squamata: Gekkonidae) from peri-urban common-lands of Coimbatore, India, with comments on habitat associations

S.R. Ganesh [1], N.A. Swaathi [2] & Usha Ravindra [3]

[1] Kalinga Foundation, Guddekere, Agumbe, Shivamogga, Karnataka 577411, India.
[2] Zoo Outreach Organisation (Zooreach), 3A2 Varadharajulu Nagar, FCI Road, Ganapathy, Coimbatore, Tamil Nadu 641006, India.
[1] snakeranglerr@gmail.com (corresponding author), [2] swaathi891@gmail.com, [3] usha@zooreach.org

Abstract: We report the Erode Ground Gecko *Cyrtodactylus speciosus* (Beddome, 1870), a rare, hill forest-dwelling species, from two sites in the northern periphery of Coimbatore city. These two sites, viz., Nallusamy checkdam (Site–1) and Sarkar Sama Kulam (Site–2) are lakes with remnant vegetation belts, surrounded by pastures, farmlands, and villages. From 100 hours of observations during a six-month period (April–September 2023) in these two sites, we report 14 sightings of *C. speciosus* including gravid females, juveniles, and subadults indicating a persistent breeding population. The encounter rate estimates ranged from 5 h (in Nallusamy checkdam; n = 10/50 h) to 12½ h (in Sarkar Sama Kulam; n = 4/50 h), averaging at about 7 h (pooled; n = 14/100 h) to get one sighting of *C. speciosus*. Our sightings of *C. speciosus* in peri-urban common lands abutting a city, calls for intensified biodiversity surveys and enhanced protections of such remnant vegetation belts, often presumed to have low or marginalised conservation values.

Keywords: Farmland, Nallusamy checkdam, Sarkar Sama Kulam, Tamil Nadu, wetland.

Editor: Anonymity requested.

Date of publication: 26 February 2024 (online & print)

Citation: Ganesh, S.R., N.A. Swaathi & U. Ravindra (2024). Erode Ground Gecko *Cyrtodactylus speciosus* (Beddome, 1870) (Squamata: Gekkonidae) from peri-urban common-lands of Coimbatore, India, with comments on habitat associations. *Journal of Threatened Taxa* 16(2): 24769–24774. https://doi.org/10.11609/jott.8749.16.2.24769-24774

Funding: BOSCH.

Competing interests: The authors declare no competing interests.

Author details: Dr. S.R. Ganesh is the director of research, Kalinga Foundation in Agumbe. He conducts research on reptiles and amphibians of southern India. His research themes include documenting the diversity of under-explored ecoregions, updating and refining species characterizations, and elucidating modern-day distribution patterns with respect to southern India's herpetofauna. Ms. N.A. Swaathi, is a budding biologist interested in reptiles. She interned under the wetland restoration project of Zoo Outreach Organisation, funded by BOSCH and is set to study and work more on reptiles, especially snakes. Ms. Usha, Ravindra is a wildlife conservationist & researcher at Zoo Outreach Organisation, Tamil Nadu, India. As a part of their 1OCEAN project, she is trying to conserve bycatch species in marine fisheries. She is also assisting the South Asian Invertebrate Specialist Group (SAsISG) to conserve invertebrates.

Author contributions: All authors equally contributed in fieldwork, travel and data collection. NS and UR did data compilation and analysis under the supervision of SRG. SRG led the writing with inputs from NS and UR. All authors equally contributed to proofreading; and have read and approved the final file.

Acknowledgements: We thank BOSCH for funding this study that is a part of wetland restoration project executed by Zoo Outreach Organisation, Coimbatore. Thanks to Dr Sanjay Molur for entrusting this work to us and for supporting and encouraging us. Thanks to Priyanka Iyer, Pooja Patil, and S. Sushanth for accompanying us during some of the night surveys. SRG thanks Sanjay Molur, Ishan Agarwal, and Achyuthan Srikanthan for sharing details on the Erode Ground Gecko and the director, SACON and officer-in-charge, ZSI Chennai for permitting specimen examinations at their institutes. SRG is grateful to the founder director and trustees of the Kalinga Foundation, Agumbe for encouraging his collaborative research activities.

INTRODUCTION

The Erode Ground Gecko *Cyrtodactylus speciosus* (Beddome, 1870) is a species of nocturnal, terrestrial, oviparous, gekkonid lizard endemic to parts of southern India (Beddome 1870; Agarwal et al. 2016, 2023a). It was first described as *Gymnodactylus speciosus* based on the holotype BMNH 1946.9.4.88 (Natural History Museum, London) collected from "tope near Erode" (Beddome 1870). Then it was synonymised with *C. collegalensis* (Beddome, 1870), another closely-related gecko that is morphologically similar and geographically proximate to *C. speciosus* (see Agarwal et al. 2016 and references therein). Agarwal et al. (2016) clarified the afore-mentioned taxonomic complications in this group and also resurrected, redescribed, and illustrated this poorly-known species based on its partly damaged holotype. This species still remains unseen from its stated type locality 'Erode' thus far, despite some surveys in hills nearby (see Ganesh et al. 2018). Agarwal et al. (2016) allocated populations from North Coimbatore Taluk (100 airline km south-west of the type locality, 'Erode') to *C. speciosus*. Agarwal et al. (2023a) reported genetic similarity between populations from Coimbatore and Shevaroys (that are some 180 km apart, passing through Erode; also see Ganesh & Arumugam 2016) and interchangeably represented *C. speciosus* both with and without 'cf.' prefix, indicating taxonomic uncertainty.

As for its distribution, the new specimens of Agarwal et al. (2016) were from Maruthamalai and Anaikatti hills, just to the north-west of Coimbatore (Ishan Agarwal and N.S. Achyuthan pers. comm. to SRG in April 2023). Agarwal et al. (2023a) reported a genetically-similar population from Shevaroys – the base of Yercaud near Salem. Our perusal of museum registry and related data mining revealed *C. speciosus* collections from North Coimbatore (CAS Herp 94157; California Academy of Sciences, USA), Udumalpet (CAS Herp 91458), Aliyar (ZSI/SRS/VRL 156, unreg.; Zoological Survey of India, Chennai), and Anaikatti (SACON VR-5a-b; Salim Ali Centre for Ornithology & Natural History, Coimbatore) (http://portal.vertnet.org/search?q=collegalensis; Ganesh et al. 2020; SRG unpub. Data). Taken together, populations across potential barriers such as Cauvery River (Shevaroys) and Palghat Gap (Aliyar, Udumalpet) have been treated as *C. speciosus*. *C. speciosus* and a few other southern Indian congeners, especially in the *C. collegalensis* complex were reported to have a marked affinity to hilly forest terrains (Agarwal & Karanth 2015). Agarwal et al. (2016) while remarking on their excursions in Erode to re-sight topotypical *C. speciosus* stated that Erode is a large town surrounded by agricultural matrix and that their brief surveys did not yield findings of any *Cyrtodactylus* or "suitable habitat" indicating that farmlands are not the ideal habitats for *C. speciosus*. Murali (2023) reported *C.* cf. *speciosus* from coastal plains of Thanjavur, again within unmanaged arid scrublands. In this note, we report our findings of living populations of *C. speciosus* sensu Agarwal et al. (2023a) in peri-urban common-lands of Coimbatore.

MATERIALS & METHODS

During April–September 2023, for six months, as part of biodiversity assessment of degraded landscapes, we conducted series of night surveys at two wetland sites in northern fringes of Coimbatore. We sighted *C. speciosus* (Image 1) in these sites, 3½ km apart, ear-marked for wetland restoration in peri-urban north Coimbatore, viz., Site–1 Nallusamy checkdam (11.1103 °N, 76.9940 °E; 435 m elevation) in Keeranatham village and Site–2 Sarkar Sama Kulam or SS Kulam for short (11.1228 °N, 77.0216 °E; 420 m) in Kondayampalayam village (Image 2), Coimbatore district, Tamil Nadu, India.

RESULTS

From about 100 h of survey, we obtained 14 sightings of *C. speciosus* of varying sexes and maturity levels (Table 1), with an encounter rate of about 7 h survey to get 1 sighting, in these sites.

Site 1, Nallusamy checkdam

On 8–9 April 2023, during 1830–0030 h (18 man h; 3 persons) visual encounter survey a total of four sightings, including two gravid females (bulged belly, absence of femoral pores, and hemipenal bulges), one adult male (presence of femoral pores and hemipenal bulges) and one unsexed (escaped before restraint) individual were documented. The two gravid females were sighted at short distance (10 m away) and time (15 min. apart) intervals. When seen from below, two ova were visible through the distended belly skin in both the female geckoes. On 30 May and 2 June 2023, during 1900–2200 h (18 man h; 3 persons) visual encounter surveys, no sightings of the gecko could be obtained. The area was quite wet and slushy with many temporary rainwater puddles due to rains and the survey time also experienced drizzles. On 2 and 3 August 2023, during 1945–2145 h (12 man h; 3 persons) visual encounter

Image 1. *Cyrtodactylus speciosus* sightings (top left to bottom right)—adult male dorsal and ventral views (note hemipenal bulge at tail base); gravid female dorsal and ventral views (note distended belly and feebly visible ova); juvenile and subadult next to an Indian Rs.2/- coin of about one inch diameter (for size comparison). © S.R. Ganesh.

Table 1. Sightings of *Cyrtodactylus speciosus* in the plains of peri-urban northern Coimbatore; left columns Site-1 (Nallusamy checkdam); right columns Site-2 (Sarkar Sama Kulam); #-gravid; *-adults.

Months	Survey (man h)		Males*		Females*		Unsexed*		Subadults		Juveniles		Total no.	
April	18	0	1	0	2#	0	1	0	0	0	0	0	4	0
May–June	18	18	0	0	0	0	0	0	0	0	0	0	0	0
August	12	20	0	0	0	0	3	0	2	2	1	2	6	4
September	2	12	0	0	0	0	0	0	0	0	0	0	0	0
Total	50	50	1	0	2	0	4	0	2	2	1	2	10	4

survey, six sightings, including three unsexed subadults (organ under-developed), two unsexed adults (escaped before restraint) and one unsexed juvenile (escaped before restraint) were documented. In August, the geckoes were sighted on the vegetated bunds of the ploughed lands. They were seen entering cracks and holes in the ground upon our approach with spot-lights. Individuals were seen at the base of shrubs and plants under the cover of the shrubby top layer. Subadults were sighted in grassy patches. Juvenile was sighted in thick leaf-litter. On 2 September 2023, during 1915–2015 h (2 man h; 2 persons), no gecko of the target species was

sighted. In Site–1, from 50 h survey, 10 sightings were obtained, equating to 5 h survey to get 1 sighting of *C. speciosus*.

Site 2, Sarkar Sama Kulam

On 29 May and 3 June 2023, during 1900–2200 h (18 man h; 3 persons) visual encounter surveys, no sightings of the gecko was obtained. Due to rains, the area was wet and partly inundated. On 4 August 2023, during 2100–2300 h (6 man h; 3 persons), two juveniles (distinctly small body size, proportionally larger head and eyes, contrastingly coloured body pattern patches), and one subadult (milder features of juveniles present) were sighted. The area was dry lake bed with *Acacia* and *Prosopis* trees and thorny scrub thickets close by. Sightings of the geckoes were on small green herb patches of creeper-like plants growing in dried up waterbodies and its fringes. Juveniles were faster in their locomotion, than the adults seen. On all occasions, the young ones were aware of our presence and approach and were scurrying away from us, trying to crawl into and hide into the ground vegetation. On 5 August 2023, during 2000–0000 h (12 man h; 3 persons), one subadult was sighted, in a similar area. On 6 August 2023, during 2030–2330 h (6 man h; 2 persons), no gecko of the target species was sighted. On 1 September 2023, during 1945–2345 h (12 man h; 3 persons), no gecko of the target species was sighted. In Site–2, from 50 h survey, four sightings were obtained, equating to 12½ h survey to get one sighting of *C. speciosus*.

In both these sites, the general habitat consisted of a mix of farmlands (of paddy and coconut trees), dried-up lake with bund, open grasslands with thorny shrubs and sparse stony mounds. The areas have alluvial soil and gravelly sand and were often interspersed with garbage dumps, electric towers, tar roads, and fences.

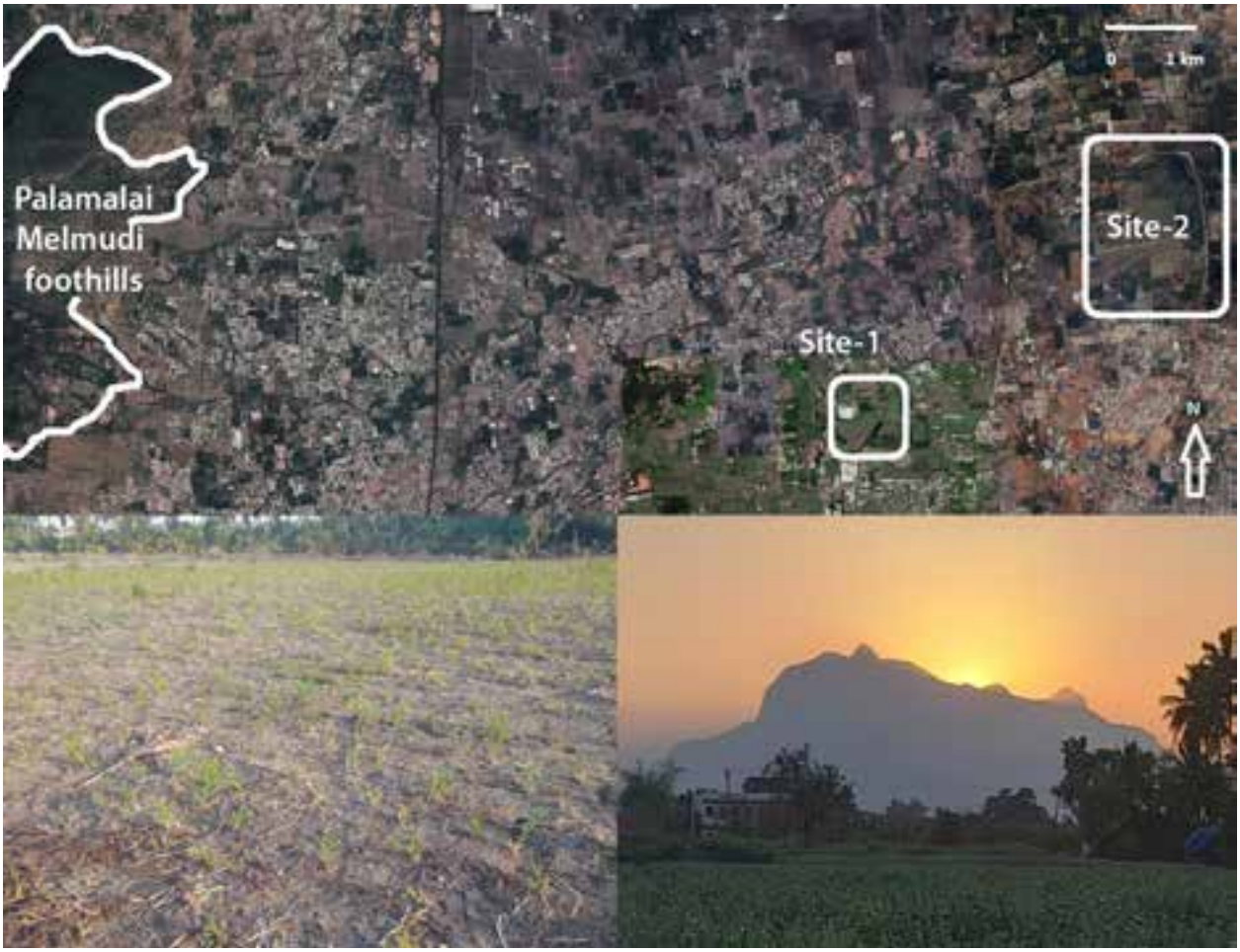


Image 2. *Cyrtodactylus speciosus* habitat and range (top left to bottom right)—Satellite map showing Site–1 (Nallusamy checkdam) and Site–2 (SS Kulam) roughly ear-marked by outline as well as eastern foothills of Palamalai-Melmudi ranges, a region of its known distribution. © S.R. Ganesh.

The surveyed sites were water bodies that are either live (Site 1) or dried up (Site 2). On the sides of the lake bunds there were open grounds, fallow lands, pastures, and farmlands. On multiple occasions during the early evenings goats, buffaloes, and cows were seen reared by local shepherds in both the sites. The precise immediate microhabitats, i.e., the resting substrates of the geckos were bare ground having sparse scrub, grass patches, debris of plant matter, and gravel. The general area was a fallow land covered with low dense bushes grown on and around muddy bunds, bordering agricultural fields. All the target geckoes were seen active at night on ground of unploughed patches bordering cultivated farmlands, across the bunds.

Syntopic gecko species sighted in both the sites were *Hemidactylus frenatus* Schlegel, *H. triedrus* (Daudin), *H. leschenaultii* Dumeril & Bibron, *H. parvimaculatus* Deraniyagala, and *H.* cf. *sankariensis* Agarwal, Bauer, Giri & Khandekar. From inaturalist we found that *C. speciosus* has also been recorded in Ondipudur Weaver's colony (11.001044 °N 77.057633 °E), a southeastern suburb of Coimbatore (https://www.inaturalist.org/observations/94402766 accessed in September 2023). Upon a visit there, we found the habitat to be similar to the ones at the surveyed sites 1 and 2. It was also learnt that *C. speciosus* has been sighted in Ganapathy (11.0355 °N, 76.9790 °E) which today is a much more urbanized, core part of Coimbatore city, during the early 1990s (Sanjay Molur pers. comm. in April 2023). Coimbatore district includes parts of Siruvani hills (>1,200 m) of the Western Ghats and the typical southern Indian plains (here, at ≈400 m) with dry evergreen vegetation as the natural climax flora (Chandrabose 1981; Kiruthika et al. 2017).

DISCUSSION

We identified the geckoes as *C. speciosus* following Agarwal et al. (2016) who studied the Coimbatore population on both morphological and molecular lines. This includes a caveat, as stated by Agarwal et al. (2016), that these are not topotypical populations from the broad locality – Erode (also see Agarwal et al. 2023a). The Coimbatore populations showed diagnostic features of *C. speciosus* sensu Agarwal et al. (2016) and did not show any non-diagnostic features that potentially resemble or overlap with regional, allopatric congeners (after Agarwal et al. 2023b). The Coimbatore geckoes exhibited two equidistant (rarely three) dark transverse cross bars on trunk (vs. one in *C. aravindi*; two much broader bars in *C. rishivalleyensis*; irregular broken-up bars in *C. srilekhae*; multiple series of large ovoid paired spots in *C. collegalensis*, *C. chengodumalaensis*, *C. irulaorum*, *C. relictus*, and *C. varadgirii*); uniform dorsal scalation (vs. not so in *C. nebulosus*, *C. jeyporensis*, and *C. chengodumalaensis*).

Agarwal et al. (2023) reported that Coimbatore and Shevaroys populations of *C. speciosus* grouped together in their molecular phylogenetic analysis. Additionally, Murali (2023) reported *C.* cf. *speciosus* from "unmanaged arid scrublands" within the compounds of an old, stable, cattle breeding farm (estd. 1954, Govt. of Tamil Nadu) in Echankottai near Thanjavur, in the eastern coastal plains. This indicates that this species (complex) also occurs in the plains of southern India. But yet, despite surveys in the adjacent cashew and sugarcane fields, no *Cyrtodactylus* spp. were found (Murali 2023), indicating its stenotopic nature. Seen against this backdrop, our finding of *C. speciosus* in the farmland precincts in the plains (400 m) opens possibilities for a probable population contiguity between these degraded and distant (180 km) localities.

And the vital aspect of our finding is the persistence of *C. speciosus* in the mediocre remnant vegetation patches intermixed with anthropic land uses and even human habitation. Unlike the commensally *Hemidactylus* geckoes, *C. speciosus* being a strictly terrestrial gecko, gets affected and displaced by habitat loss by building construction. So it has been rightly assessed as an endangered species (Achyuthan et al. 2021). Related congeners were also reported to occur near cities, viz., *C. collegalensis* near Mysuru, *C. srilekhae* near Bengaluru, *C. chengodumalaensis* near Kozhikode, *C. irulaorum* near Chennai, and *C. varadgirii* near Mumbai (Agarwal 2016; Agarwal et al. 2016, 2023a,b).

Hence the presence of *C. speciosus* near Coimbatore is consistent with previous such observations. Regarding other aspects of natural history, Guptha (1998) recorded this species (as *Geckoella collegalensis*) based on an adult and a juvenile seen on 11 October 1997 in the rocky outcrops of Anaikatti slopes (600–700 m). In our case juveniles were seen somewhat earlier, in early August, more or less coinciding with the reported observation (Guptha 1998). This indicates a breeding population of *C. speciosus* in peri-urban common lands of Coimbatore, warranting more such surveys in nearby places to accord greater protection and scientifically-informed management to such remnant habitat patches.

REFERENCES

Achyuthan, N.S., S.R. Ganesh & V.B. Giri (2021). *Cyrtodactylus speciosus*. The IUCN Red List of Threatened Species 2021: e.T127941306A127941328. https://doi.org/10.2305/IUCN.UK.2021-3.RLTS.T127941306A127941328.en. Accessed on 25 August 2023.

Agarwal, I. & K.P. Karanth (2015). A phylogeny of the only ground-dwelling radiation of *Cyrtodactylus* (Squamata, Gekkonidae): diversification of *Geckoella* across peninsular India and Sri Lanka. *Molecular Phylogenetics and Evolution* 82: 193–199.

Agarwal, I. (2016). Two new species of ground-dwelling *Cyrtodactylus* (*Geckoella*) from the Mysore Plateau, south India. *Zootaxa* 4193(2): 228–244.

Agarwal, I., Z.A. Mirza, S. Pal, S.T. Maddock, A. Mishra & A.M. Bauer (2016). A new species of the *Cyrtodactylus* (*Geckoella*) *collegalensis* (Beddome, 1870) complex (Squamata: Gekkonidae) from western India. *Zootaxa* 4170(2): 339–354.

Agarwal, I., P.K. Umesh, S. Das, A.M. Bauer & A. Khandekar (2023a). A New Spotted Species of the *Cyrtodactylus (Geckoella) collegalensis* (Beddome, 1870) (Reptilia: Squamata) Complex from Coastal Kerala, Southwestern India. *Journal of Herpetology* 57(1): 75–86.

Agarwal, I., T. Thackeray & A. Khandekar (2023b). Two new spotted species of the *Cyrtodactylus (Geckoella) collegalensis* (Beddome, 1870) complex from the south-eastern coast of India (Reptilia: Squamata). *Vertebrate Zoology* 73: 475–498.

Beddome, R.H. (1870). Descriptions of new reptiles from the Madras Presidency. *Madras Monthly Journal of Medical Sciences* 2: 169–176.

Chandrabose, M. (1981). Floristic studies in Coimbatore city and its environs. *Nelumbo* 23(1-2): 96–99.

Ganesh, S.R. & M. Arumugam (2016). Species richness of montane herpetofauna of southern Eastern Ghats, India: a historical resume and a descriptive checklist. *Russian Journal of Herpetology* 23(1): 7–24. https://doi.org/10.30906/1026-2296-2016-23-1-7-24

Ganesh, S.R., A. Kalaimani, P. Karthik, N. Baskaran, R. Nagarajan & S.R. Chandramouli (2018). Herpetofauna of Southern Eastern Ghats, India–II; from Western Ghats to Coromandel Coast. *Asian Journal of Conservation Biology* 7(1): 28–45.

Ganesh, S.R., S. Bhupathy, P. Karthik, G.B. Rao & S. Babu (2020). Catalogue of herpetological specimens from peninsular India at the Sálim Ali Centre for Ornithology & Natural History (SACON), India. *Journal of Threatened Taxa* 12(9): 16123–16135. https://doi.org/10.11609/jot.6036.12.9.16123-16135

Guptha, B.K. (1998). Notes on occurrence and growth in *Geckoella collegalensis* (Beddome, 1870). *Hamadryad* 23(1): 77.

Kiruthika, K., M. Sulaiman & R. Gopalan (2017). Additions to the flora of Coimbatore hills, Tamil Nadu, India. *Journal of Threatened Taxa* 9(2): 9881–9884. https://doi.org/10.11609/jott.2991.9.2.9881-9884

Murali, G. (2023). New locality record of Forest Spotted Gecko *Cyrtodactylus (Geckoella) cf. speciosus* (Beddome, 1870) (Reptilia: Squamata: Gekkonidae) from Thanjavur, in the eastern coastal plains of Tamil Nadu, India. *Journal of Threatened Taxa* 15(10): 24120–24124. https://doi.org/10.11609/jott.8612.15.10.24120-24124

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 February 2024 | 16(2): 24775–24785
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.8524.16.2.24775-24785
#8524 | Received 13 May 2023 | Final received 11 January 2024 | Finally accepted 30 January 2024
OPEN ACCESS
COMMUNICATION

Assessment of diversity of Odonata fauna in selected sites of Purba Barddhaman district, West Bengal, India

Sulagna Mukherjee [1] & **Rabindranath Mandal** [2]

[1] Department of Zoology, The University of Burdwan, Golapbag, Purba Bardhaman, West Bengal 713104, India.
[2] P.G. Department of Zoology, Hooghly Mohsin College, College Road, Chinsurah, Hooghly, West Bengal 712101, India.
[1] sulagna211@gmail.com (corresponding author), [2] rabindranathmandal869@gmail.com

Abstract: Purba-Barddhaman, a newly emerged district of West Bengal was surveyed for listing its odonate diversity. The district is located in southern West Bengal, and two major rivers, Damodar and Ajay, run through it. It also has a lot of small rivers, perineal and seasonal water bodies, grasslands, marshes, and agricultural fields, making it a great place for odonates. Five different sites of the district were surveyed by direct search and opportunistic sighting methods for a period of two years (March 2021 to February 2023) and odonate diversity was listed. We have found a total of 47 species belonging to 35 genera and six families from this district. The most diverse family was Libellulidae, with 24 species. A few major findings from this study were *Macrogomphus montanus*, *Platygomphus dolabratus*, *Lathrecista asiatica*, *Libellago indica*, and *Agriocnemis kalinga*. This is the first systematic study of odonates from this district, and it illustrates the value of this densely populated district for further exploration due to its high agricultural fertility.

Keywords: Agricultural land, Ajay River, Anisoptera, Damodar River, Gangetic plane, riverbed, seasonal pool, Zygoptera.

Editor: Ashish D. Tiple, Dr. R.G. Bhoyar Arts, Commerce and Science College, Wardha, India. **Date of publication:** 26 February 2024 (online & print)

Citation: Mukherjee, S. & R. Mandal (2024). Assessment of diversity of Odonata fauna in selected sites of Purba Barddhaman district, West Bengal, India. *Journal of Threatened Taxa* 16(2): 24775–24785. https://doi.org/10.11609/jott.8524.16.2.24775-24785

Funding: We would like to thank the University of Burdwan and Hooghly Mohsin College for basic infrastructure and funding of the study.

Competing interests: The authors declare no competing interests.

Author details: Sulagna Mukherjee did her bachelors from Burdwaan Raj College and MSc in zoology from the Department of Zoology, the University of Burdwan with molecular biology and genetics as special paper. She always had an interest studying the animal world from ecological and behavioural perspective which led her to pursue her PhD in the ecology and behaviour of odonates. Dr. Rabindranath Mandal is a senior professor in the Department of Zoology, Hooghly Mohsin College. Previously, he worked in the Department of Biological Sciences in Presidency University. He did his PhD from the University of Calcutta and he was the first recipient of D. N. Roychowdhury memorial medal in Entomology.

Author contributions: SM did the field work, data collection, preservation of samples, analysis, and manuscript writing. RM helped in manuscript preparation and supervised the work.

Acknowledgements: We would like to thank Mr. Kushankur Bhattacharyya, Mr. Shuvendu Das, Mr. Kalyan Ghosh and Mr. Souvick Mukherjee for their tireless help in collecting field data and preservation of field samples. We acknowledge Mr. Amar Nayak for sharing all his knowledge and expertise in this field. We are grateful to the Department of Zoology, The University of Burdwan for providing us a suitable platform to carry forward the work.

INTRODUCTION

The amphibiotic order Odonata, including dragonflies and damselflies, attracts a lot of attention due to the vibrant colours and exquisite flight patterns (Andrew et al. 2008). They are predominantly found in tropical subtropical and oriental regions, although a small number of species have also been found in the temperate zone, specifically in Japan and China (Kalkman et al. 2008) and are found in close proximity of freshwater body, including streams, lakes, marshes, or transient stagnant rainfall pools. They are hemimetabolous insects that go through three life cycle stages: a brief egg stage (a few weeks), the longest larval stage (ranging from months to year) (Stoks & Córdoba-Aguilar 2012), and finally reaching adulthood. Odonata larvae are aquatic and must go through several moult stages (e.g., 10 moults) before becoming terrestrial flying adults (Stoks & Córdoba-Aguilar 2012; Tiple et al. 2012) and their crucial role is notified in the food web and ecosystem as predators (both nymphs and adults). Odonates are considered as excellent model for studying insect evolution and ecology due to their phenotype and ecological diversity (Tiple & Koparde 2015; Bybee et al. 2016) and reliable bioindicators (Tiple et al. 2013; Siddika et al. 2017).

Globally, 6,406 species in 693 genera of odonates have been reported (Paulson & Schorr 2023) of which, 498 species and 27 subspecies in 154 genera and 18 families are known from India (Babu 2019; Tiple et al. 2022). By recording approximately 22 species from Kolkata, Selys (1891) launched the study of Odonata in West Bengal and subsequently, Mitra (2002) reported 65 species from the District, Howrah and Kolkata. Srivastava & Sinha (1993) documented 178 species in West Bengal, (Srivastava 1993). Recent studies on the Odonata fauna of Purba Mednipur by Payra & Tiple (2019) and Pahari et al. (2019) recorded 49 and 45 species, respectively. Dwari & Mondal (2018) documented 17 species from the agricultural fields of the Howrah district and 63 Odonata species were reported from the industrial areas of Paschim Barddhaman district, by Nayak & Roy (2016, 2021). Paschim Medinipur was explored by Jana et al. (2021) and 19 species of damselflies were recorded. Odonata diversity of Chinsurah, Baidyabati and Purbasthali were documented by Ghosh (2022) with the finding of 40 species. Latest updated checklist of odonates of West Bengal consists of 240 species from 114 genera (Dawn 2021, 2022).

MATERIALS AND METHODS

Study area

Burdwan district was bifurcated into two districts Purba and Paschim Barddhaman on 7April 2017. These two districts are topographically different. Paschim Barddhaman is predominantly arid region with dry deciduous forests, patchy grasslands and two major rivers Damodar and Ajay, whereas Purba Barddhaman extends towards the Gangetic delta, which is more humid and dominated by flat alluvial plainlands. Purba Barddhaman lies almost in the middle of southern West Bengal, consisting of several perennial freshwater bodies, adjacent to major rivers like the Ajay, Damodar, and Ganges and small streams like Khari, Kunur, Banka, Kana Damodar to name a few. Bibliographic data on odonata species implies no such comprehensive record or published checklist from Purba Barddhaman district (all the information were collected from www.purbabardhaman.nic.in.).

Purba Barddhaman district is encircled by six distinct districts: Murshidabad and Birbhum are located in the north, Nadia covers the east, and south is bounded by Hooghly and a portion of Bankura, and the west side by Paschim barddhaman. The district covers an area of approximately 5,432.69 Km^2 and is located between 23°53'-22°56' N and 88°25'-87°56' E (purbabardhaman.nic.in). Annual rainfall ranges from 1,200 to 1,400 mm (Ruidas et al. 2021).

Five different sites (Image 1), which covers a significant part of the district and the district bordering areas, were surveyed for the study of Odonata distribution and abundance. The details of each site are described in the Table. 1.

Sampling, Documentation, and Identification

Extensive field work was carried out from March 2021, to catalogue the diversity, distribution patterns of odonates in various niches and habitats at bordering areas of adjacent districts by potent described methodology.

The survey of odonate fauna was carried out throughout the year from March 2021 to February 2023. Data was gathered between 0700 h and 1400 h. Each of the sites were visited at least once in each month (2–5 hours of observation on each day). Each of the sampling area covered at least 1.5 km^2 (150 ha) of land or more. Among each of the study sites there were multiple small patches which were surveyed separately and samples were collected using proper labels (e.g., Site 1, pond 1 near XX village or river) and photographs of each of

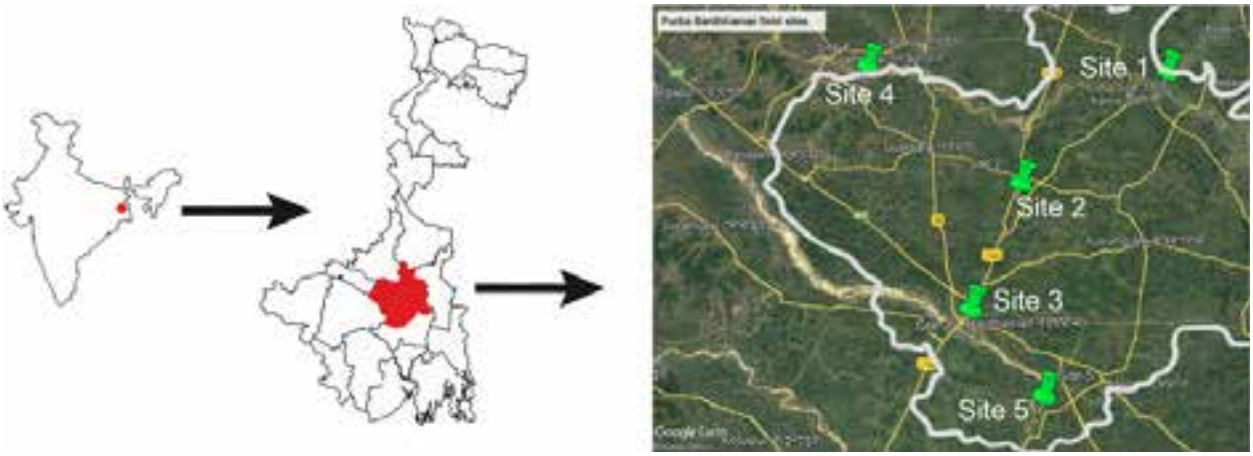


Figure 1. Field site: Panel (a) shows the geographical location of PurbaBarddhaman district within India (shown as red dot). Panel (b) shows the centralised position of PurbaBarddhaman district in southern part of West Bengal (the boundary of the district is filled in red). Panel (c) shows the geographical location of five field sites. The sites are namely site 1 Katwa and surroundings, site 2 Bhatar, Karjana and surroundings, site 3 Bardhaman town and surroundings, site 4 Ausgram and surroundings, site 5 Jamalpur, Raina and surroundings.

Table 1. A brief description of selected study sites along with the co-ordinates and habitat types.

Site	Latitude(N)	Longitude (E)	Sub-sites	Habitat types
Site 1: Katwa	23.6404°	88.1299°	Ajay river bank, Bank of Ganges near Nayachar	Grasslands, river bank, few seasonal and few perennial waterbodies, dry deciduous forest patches
Site 2: Bhatar	23.4191°	87.9163°	Bhatar village, Karjana pakhiralay	Seasonal marshes and water puddles, seven perennial ponds with low to moderate hydrophyte population, paddy fields, mango groves, Khori River bank and surrounding grasslands.
Site 3: Bardhaman	23.2324°	87.8615°	Bardhaman University campus, Agricultural University campus, Bhatchhala, Damodar bank and DVC canal areas at Palla-Srirampur, Hatshimul, Barshul, Rathtala	Dry deciduous forest patches with high canopy and moderate understory, more than 15 perennial ponds with low to moderate hydrophyte population, seasonal pools and marshes, bamboo groves, Damodar River bank, DVC canal bank and surrounding areas
Site 4: Aushgram	23.5256°	87.6630°	Uttar Ramnagar, Gopalpur, Ullaspur, Maliyara, Malacha Ajay river bank and surrounding areas	Bamboo groves, paddy fields, 11 different perennial ponds, Ajay River bank, dry deciduous forest patches, shrubland areas near Ajay River and two different irrigation canals.
Site 5: Jamalpur	23.0736°	87.8918°	Dadpur, Sarangpur	DVC canal banks (dense patches of mixed trees with thick understory), Damodar River banks, grasslands, seasonal puddles, four different perennial ponds.

those sites were taken along with co-ordinates using Angle Cam software. The sampling was conducted using the line transect approach (Burnham et al. 1980) and the opportunistic sighting method. For line transect method the lines were of a length of 0.5 to 1 km and number of lines varied from 2–5 in each site according to habitat and accessibility. Walking with uniform speed was used to cover the whole transect line, and all Odonata species on either side of the line were recorded. Photographs taken from a variety of viewpoints were used for documentation. Canon 80D and Nikon D500 cameras were used for taking photographs of individual sightings in field and collected samples. Collected photographic data as well as samples (both dry and wet) were assembled, and specified into monsoon, post monsoon, and pre-monsoon season. Odonate identification was primarily performed in the field with field identification guide, previous literatures describing Odonata species, and websites such as www.indianodonata.org and (Fraser 1933a,b, 1936; Subramanian 2009). Some of the species which were difficult to identify instantly, so the cryptic specimens were captured by insect net. The damselflies were preserved in 70% alcohol in 5 ml plastic vials, and the dragonflies were collected in butter paper envelopes for further dry preservation. Dragonfly specimens were stretched with the help of insect pin to display all the key characters for identification. Identification was done with the help of taxonomic keys (Fraser 1933). Taxonomy and systematic arrangements were followed by Subramanian & Babu (2017).

Image 1. Different habitats from the sampling areas across five sites: The photographs show different habitats from the areas sampled across five different sites in Purba Bardhaman district. The habitats were diverse ranging from river banks to seasonal pools and canopy covered shrubland areas. All the photographs have the unique name code for each of the microhabitats along with the GPS location. Photographs were taken using Anglecam software. Photograph courtesy © Kushankur Bhattacharyya.

RESULTS

The data from all of the sites revealed a total of 47 species, 35 genera, and six families. The sites chosen contained 32 species under the suborder Anisoptera and 15 species under the suborder Zygoptera. The Libellulidae family was found to be the most abundant (24 species). Together with the Libellulidae, other families were also found, including Coenagrionidae (11 species), Gomphidae (5 species), Aeshnidae (3 species), Platycnemididae (3 species), and Chlorocyphidae (1 species). The detailed record of the species along with its occurrence in different seasons and in different sites is listed in Table 1.

Suborder Zygoptera Selys, 1854

Family Chlorocyphidae Cowley, 1937

***Libellago indica* Fraser, 1928**

Labrum dark brownish-yellow, abdomen 14–16 mm, black in colour with yellow markings on the sides of segments and broad mid-dorsal black stripes, differentiating it from *Libellago lineata*. Brown eyes. Black prethorax with citron yellow markings. Black thoracic segments with citron or greenish yellow markings. Legs are black, wings are hyaline, and the bases of all have a little amber tinge. Forewing's apical black patch is noticeably longer (See Image 4d).

Family Coenagrionidae Kirby, 1890

***Agriocnemis kalinga* Nair & Subramanian, 2014**

A small damselfly, possibly the smallest described from India to date, with an abdomen measuring about 13–14 mm and a hindwing measuring 8–11 mm. The superior anal appendages are longer than the inferior ones, and the male's tergum 2 is marked with a distinctive cobra hood-like pattern. The ground colour is bright yellow with black on the dorsum, yellow pterostigma, with a bright yellow tip. The males on the other hand are dark green coloured with a black line running through the dorsal side of the abdomen. The anal appendages on occasions appeared yellow or orangish-yellow and the thorax also had black line markings (Image 4a).

Suborder Anisoptera Selys, 1854

Family Gomphidae Rambur, 142

***Platygomphus dolabratus* Selys, 1854**

Abdomen is about 41 mm. Bright yellow labium, labrum, and face. Fronts are completely yellow; vertex is black with a sizable yellow mark behind the ocelli; and the occiput is a bright yellow. Bottle-green eyes. Prothorax

Image 2. Odonata of Purba Barddhaman: a—*Macrogomphus montanus* (side view) | b—*Macrogomphus montanus* (dorsal view) | c—*Macrogomphus montanus* (side view of head and thorax close-up) | d—*Macrogomphus montanus* (anal appendages close-up) | e—*Platygomphus dolabratus* | f—*Paragomphus lineatus*. Photograph courtesy @ Kushankur Bhattacharyya.

is black on dorsum, sides yellow. Thorax is yellow with black markings. Wings hyaline that occasionally have a slight yellow hue. Legs are yellow with black markings. Anal appendages have a black border and are yellow or yellowish-brown in colour (Image 2e).

***Macrgomphus montanus* Selys, 1869**

Length of abdomen, 45 mm. Black head with yellow markings. Labrum has two oval basal patches, as does the entire labium. Brown colored occiput. Unmarked prothorax is black in colour. Stripes are visible on the black thorax. Widely yellow sides with two neatly marked black lateral sutures. Hyaline, palely enfumed, brown wings with a tight reticulation. Dark blackish-brown legs. Black abdomen with yellow markings. The apical half of the divaricate, point-tipped anal appendages are thick at the base (Image 2a,b,c,d).

DISCUSSION

This is the first comprehensive study of odonate diversity to cover a significant portion of the Purba Barddhaman district, though there were some individual sighting reports from a few small pockets and another study that covered Purbasthali, within the district's territory (Ghosh 2022). We attempted to incorporate various types of habitats in this study, ranging from seasonal pools to perennial rivers, resulting in the listing of 47 species from 35 genera. Our results were in cohesion with the detailed report by Dawn (2022).

It reveals from the results (see Table. 2) that the family Aeshnidae is noticed in Site 1, 2, 3, 4 but not in 5; out of which *Anax indicus* (Lieftinck, 1942) appeared to be a more common species and is noticed in Site 1, 2 & 3 site in monsoon period but *Anax guttatus* (Bermeister, 1839) and *Gynacantha* sp. in Site 3 during post monsoon period. *Anax indicus* was found mostly flying over small waterbodies and sometimes hanging from the leaves or branches of mango trees. *Gynacantha* sp. was found in the middle of Barddhaman town near an old house.

Five different species were found under family Gomphidae and among them, *Ictinogomphus rapax* (Rambur, 1842) and *Paragomphus lineatus* (Selys, 1850) were found in all seasons near large waterbodies and canals. *Macrogomphus montanus* (Selys, 1869) was

Image 3. Odonata of Purba Barddhaman: a—*Anax guttatus* | b—*Tramea basilaris* | c—*Lathrecista asiatica* | d—*Rhodothemis rufa*.

only found in Site 3 during monsoon in the shades of shrubby patch with high canopy trees over the shrubby patch. This species was reported only twice from West Bengal before this study (from Kolkata in 2002 and from Paschim Barddhaman in 2021) (Mitra 2002; Nayak & Roy 2021).

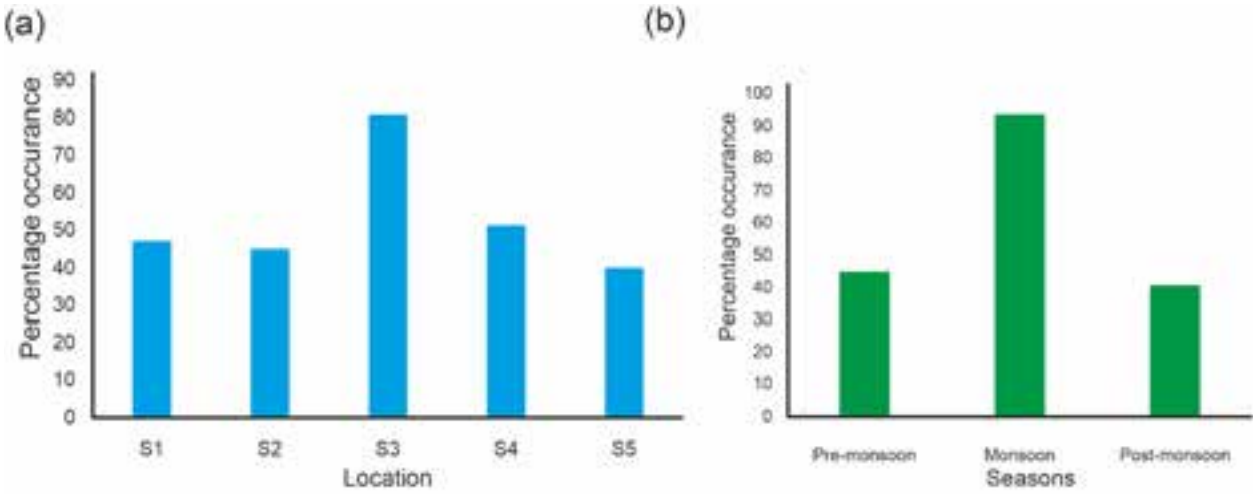


Figure 2. Percentage of odonate diversity from different sites and in different seasons.
The bar graphs in panel (a) shows percentage of odonates found in different field sites. S1, S2, S3, S4, S5 denotes Site 1, 2, 3, 4, 5, respectively.
The bar graphs in panel (b) shows percentage of odonates found in different seasons. Each season is denoted by different colour
These are Bar graphs plotting the respective percentages. The X axis shows locations (panel (a)), and seasons (panel (b)). The Y axis shows the percentage of occurrence of species from different locations and different seasons.

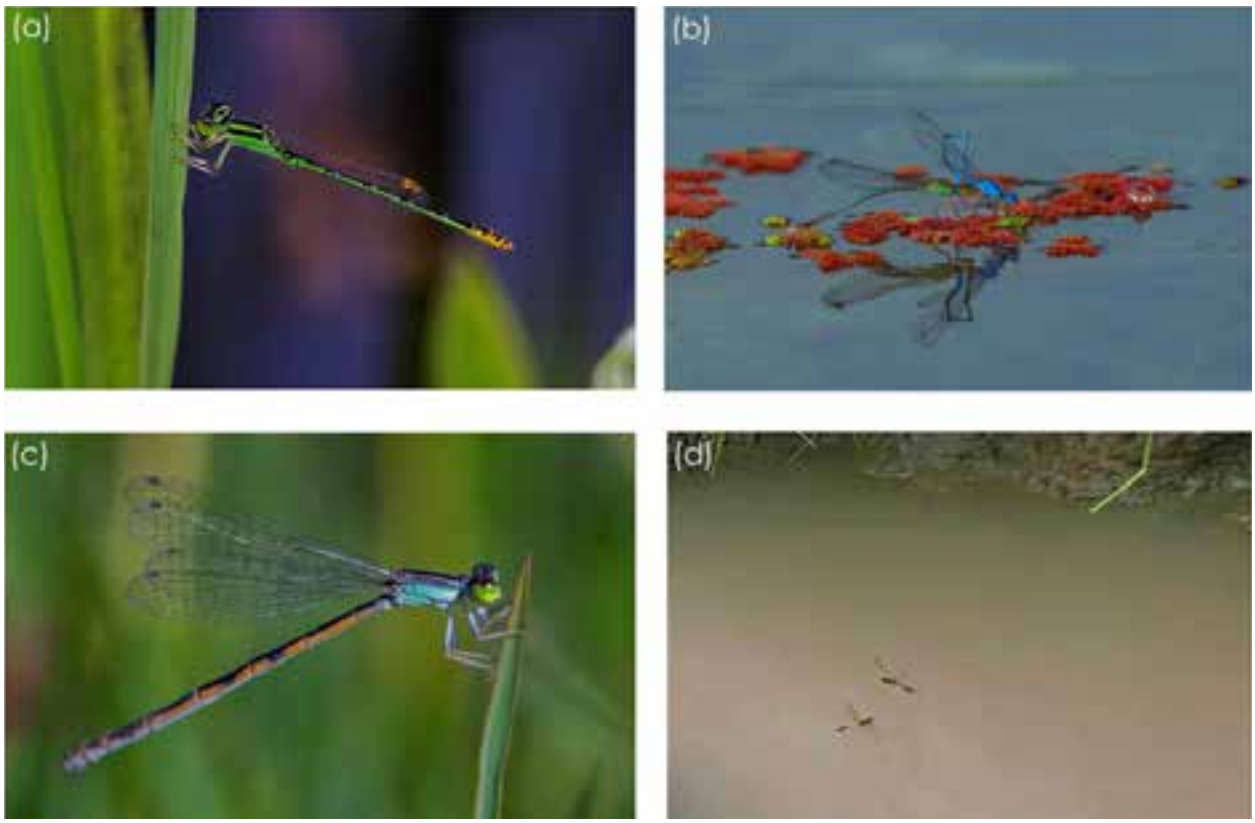


Image 4. Odonata of Purba Barddhaman: a—*Agriocnemis kalinga* male, panel | b—*Amphiallagma parvum* male and female | c—*Ischnura nursei* female | d—*Libellago indica*. © a-c—Kushankur Bhattacharyya, d—Kalyan Ghosh.

Image 5. Odonata of Purba Barddhamaan: a—*Gynacantha* sp. | b—*Macrodiplax cora* | c & d—*Pseudocopera ciliata* | e—*Pseudagrion decorum* | f—*Brachydiplax chalybea*. © Kushankur Bhattacharyya.

A total of 24 species belonging to Libellulidae family of Anisoptera were recorded from the study areas, making it the most abundant family. *Pantala flavescens* (Fabricus, 1798) and *Urothemis signata* (Rambur, 1842) are available in pre monsoon and monsoon period with *P. flavescens* mostly flying in good numbers at a height near waterbodies, whereas *U. signata* was mostly seen sitting atop small shrubby patches. *Orthetrum sabina* (Drury, 1770) was seen very commonly and across seasons, and on some occasions seen feeding on other Odonata species like *Brachythemis contaminata* (Fabricus, 1793) was often seen sitting on small hydrophytes in small and stagnant waterbodies. It often showed obelisk posture while sitting. *Potamarcha congener* (Rambur, 1842) was often seen sitting on wires or dry bamboo sticks. *Crocothemis servilia* (Drury, 1770) was very commonly found near waterbodies even in the banks of rivers and *Diplacodes trivialis* (Rambur, 1842) was often found sitting on the ground and feeding on mosquitos, mayflies and other small insects. *Brachydiplax sobrina* (Rambur, 1842) was found near waterbodies with loads of hyacinths and shady areas; *Tramea basilaris* (Palisot

Table 2. List of Odonates found and their seasonal occurrence.

	Species	Site of occurrence	Season of occurrence
	Suborder: Anisoptera		
	Family: Aeshnidae		
01	*Anax indicus* Lieftinck, 1942	S1, S2, S3	Monsoon
02	*Anax guttatus* Burmeister, 1839	S4	Post-monsoon
03	*Gynacantha dravida* Lieftinck,1960	S3	Post-monsoon
	Family: Gomphidae		
04	*Cyclogomphus ypsilon* Selys, 1854	S2, S3	Monsoon
05	*Ictinogomphus rapax* Rambur, 1842	S1, S2, S3, S4	All season
06	*Macrogomphus montanus* Selys, 1869	S3	Monsoon
07	*Paragomphus lineatus* Selys, 1850	S1, S2, S3	All season
08	*Platygomphus dolabratus* Selys, 1854	S1	Monsoon
	Family: Libellulidae		
09	*Acisoma panorpoides* Rambur, 1842	S3, S4, S5	Pre-monsoon, Monsoon
10	*Aethriamanta brevipennis* Rambur, 1842	S2, S3	Monsoon
11	*Brachydiplax chalybea* Brauer, 1868	S1, S3	Monsoon
12	*Brachydiplax farinosa* Krüger 1902	S3	Monsoon
13	*Brachydiplax sobrina* Rambur, 1842	S1, S3, S4	Monsoon, Post-monsoon
14	*Brachythemis contaminata* Fabricius, 1793	S2, S3, S4, S5	All season
15	*Bradinopyga geminata* Rambur, 1842	S1, S2, S3	Pre-monsoon, Monsoon
16	*Crocothemis servilia* Drury, 1773	S1, S3, S4, S5	All season
17	*Diplacodes nebulosa* Fabricius, 1793	S3	Monsoon
18	*Diplacodes trivialis* Rambur, 1842	S1, S3, S4, S5	All season
19	*Lathrecista asiatica* Fabricius, 1798	S3	Monsoon
20	*Macrodiplax cora* Brauer, 1867	S3, S5	Monsoon
21	*Neurothemis fulvia* Drury, 1773	S2, S3	Monsoon
22	*Neurothemis tullia* Drury, 1773	S3, S4	Pre-monsoon, Monsoon
23	*Orthetrum sabina* Drury, 1770	S1, S2, S3, S4, S5	All season
24	*Pantala flavescens* Fabricius, 1798	S1, S2, S3, S4, S5	Pre-monsoon, Monsoon
25	*Potamarcha congener* Rambur, 1842	S1, S2, S3, S4, S5	All season
26	*Rhodothemis rufa* Rambur, 1842	S3, S4, S5	Pre-monsoon, Monsoon
27	*Rhyothemis variegata* Linnaeus, 1763	S2, S3, S4	Pre-monsoon, Monsoon
28	*Tholymis tillarga* Fabricius, 1798	S1, S3, S4	All season
29	*Tramea basilaris* Palisot de Beauvois, 1805	S2, S3, S4, S5	Monsoon, Post-monsoon
30	*Tramea limbata* Desjardins, 1832	S1	Monsoon, Post-monsoon
31	*Trithemis pallidinervis* Kirby, 1889	S2, S4	Monsoon
32	*Urothemis signata* Rambur, 1842	S1, S2, S3, S4, S5	Pre-monsoon, Monsoon
	Suborder: Zygoptera		
	Family: Chlorocyphidae		
33	*Libellago indica* Fraser 1928	S1	Monsoon
	Family: Coenagrionidae		
34	*Agriocnemis kalinga* Nair & Subramanian, 2015	S3	Monsoon
35	*Agriocnemis pygmaea* Rambur, 1842	S1, S3, S4	All season
36	*Amphiallagma parvum* Selys, 1876	S1, S2, S3	All season
37	*Ceriagrion cerinorubellum* (Brauer, 1865)	S3, S5	Monsoon
38	*Ceriagrion coromandelianum* Fabricius, 1798	S1, S2, S3, S4, S5	Pre-monsoon, Monsoon
39	*Ischnura nursei* Morton, 1907	S3	Monsoon
40	*Ischnura rubilio* Selys, 1876	S1, S2, S3, S4, S5	Pre-monsoon, Monsoon
41	*Ischnura senegalensis* Rambur, 1842	S1, S3, S4, S5	All season
42	*Pseudagrion decorum* Rambur, 1842	S2, S4	Monsoon, Post-monsoon
43	*Pseudagrion microcephalum* Rambur, 1842	S5	Monsoon, Post-monsoon
44	*Pseudagrion rubriceps* Selys, 1876	S1, S2, S3, S4	Monsoon, Post-monsoon
	Family: Platycnemididae		
45	*Onychargia atrocyana* Selys, 1865	S2, S3, S4	All season
46	*Copera marginipes* Rambur, 1842	S3	Pre-monsoon
47	*Pseudocopera ciliata* Selys, 1863	S1, S2, S3	All season

de Beauvois, 1805) was mostly seen flying at a height. *Indothemis limbata* (Selys, 1891) was found only in Site 1.

During pre-monsoon and post-monsoon period *Acisoma panorpoides* (Rambur, 1842) was noticed near ponds with loads of hyacinth and other hydrophytes, with very less open water surface. *Bradinopyga geminata* (Rambur, 1842) was mostly found inside the Barddhaman town sitting on walls, sometimes well camouflaged. *Neurothemis tullia* (Drury, 1773) was not so common and was seen in grassy areas near waterbodies on a few occasions. *Rhodothemis rufa* (Rambur, 1842) and *Rhyothemis variegata* (Linnaeus, 1763) in Site 3, 4 ,5 and Site 2, 3, 4, respectively. *Tholymis tillarga* (Fabricus, 1798) was mostly found active during late afternoon and during daytime sitting in the shades.

Among suborder Zygoptera, *Libellago indica* (Fraser, 1928) belonging to Chlorocyphidea family and

Pseudocopera ciliata (Selys, 1863) of Platycnemididae family were found in monsoon only in Site 1 & 2. Eleven species of family Coenagrionidae are recorded of which *Ischnura senegalensis* (Rambur, 1842) and *Agriocnemis pygmaea* (Rambur, 1842) were found across seasons very commonly. *Agriocnemis pygmaea* was found mostly in shallow water patches sitting on vegetation. During pre-monsoon and monsoon *Ceriagrion coromandelianum* (Fabricus, 1798) and *Ischnura rubilio* (Selys, 1876) were noticed in all sites; whereas during monsoon and post monsoon period *Pseudagrion rubriceps* (Selys, 1876) was often observed guarding its mate or in tandem with the female and in very few occasions laying eggs on submerged twigs. *Pseudagrion decorum* (Rambur, 1842) was found near perennial waterbodies and small seasonal village ponds but *Pseudagrion microcephalum* (Rambur, 1842) was found near the Damodar River only. Other species like *Agriocnemis kalinga* Nair & Subramanian 2014, *Amphiallagma parvum* (Selys, 1876) were found in open water puddles and large waterbodies with grasses and other hydrophytes, whereas *Ceriagrion cerinorubellum* (Brauer, 1865) was found in shady areas and bushes. *Ischnura nursei* (Morton, 1907) was only found near Damodar River along with other damselflies like *Agriocnemis pygmaea*.

It appeared from the recorded data (Figure 2) of studied area that monsoon is the favourable period for completion of their life cycle, although they were noticed as well as were seen to breed throughout the seasons selectively. Highest percentage (85%) of species are recorded from Site 3 and 51.06%, 46.80%, 44.68%, & 31.91% from Site 4, 1, 2, & 5, respectively.

A possible limitation to the study is that many small pockets of the district which covers a number of other water bodies both seasonal and perennial were not surveyed, though we tried to cover as much area as possible. Future exploration of these sites and beyond can extend the list further and make the data even more robust. Seasonal variation of Odonata species and relative abundance in different locations are two other aspects that has to be investigated further.

The study overall sets a stepping stone for further studies related to the fascinating world of Odonates from this district and also advocates about greater possibilities of the district to have a secured place in the Odonata map of West Bengal.

REFERENCES

Andrew, R.J., K.A. Subramaniam, & A.D. Tiple (2008). *A Handbook on Common Odonates of Central India*. Published by South Asian Council of Odonatology, 65 pp.

Babu, R. & K.A. Subramanian (2019). Dragonflies and Damselflies (Insecta: Odonata) of India, pp 29–45. In: Ramani, S., P. Mohanraj & H.M. Yeshwanth (eds.). *Indian Inescts*. CRC Press, 472 pp.

Burnham, K.P., D.R. Anderson & J.L. Laake (1980). Estimation of Density from Line Transect Sampling of Biological Populations. *Wildlife Monographs* (72): 3–202.

Bybee, S., A. Córdoba-Aguilar, M.C. Duryea, R. Futahashi, B. Hansson, M.O. Lorenzo-Carballa & M Wellenreuther (2016). Odonata (dragonflies and damselflies) as a bridge between ecology and evolutionary genomics. *Frontiers in Zoology* 13(1): 46. https://doi.org/10.1186/s12983-016-0176-7

Dawn, P. (2021). A new species of *Cephalaeschna* Selys, 1883 (Odonata: Anisoptera: Aeshnidae) from Neora Valley National Park, West Bengal, India, with notes on *C. acanthifrons* Joshi & amp; Kunte, 2017 and *C. viridifrons* (Fraser, 1922). *Zootaxa* 4949(371-380). https://doi.org/10.11646/zootaxa.4949.2.10

Dawn, P. (2022). Dragonflies and damselflies (Insecta: Odonata) of West Bengal, an annotated list of species. *Oriental Insects* 56(1): 81–117. https://doi.org/10.1080/00305316.2021.1908188

Dwari, S. & A.K. Mondal (2018). Odonata (Dragonfly and Damselfly) diversity of Howrah District, West Bengal. *Advances in Bioresearch* 9(5): 54–65. https://doi..org/10.15515/abr.0976-4585.9.5.5465

Fraser, F.C. (1933a). Fauna of British India, Odonata, Vols. 1–2, Tayler and Francis Ltd., London, 423 pp.

Fraser, F.C. (1933b). Fauna of British India, Odonata, Vols. 1–2, Tayler and Francis Ltd., London, 398 pp.

Ghosh, K. (2022). Odonata Diversity in The Gangetic Plain of West Bengal. *Indian Journal of Entomology* 85(3): 743–747. https://doi.org/10.55446/IJE.2022.172

Jana, P.K., P.H. Mallick & T. Bhattacharya (2021). A study on the community structure of damselflies (Insecta: Odonata: Zygoptera) in Paschim Medinipur, West Bengal, India. *Journal of Threatened Taxa* 13(7): 18809–18816. https://doi.org/10.11609/jott.6683.13.7.18809-18816

Kalkman, V.J., V. Clausnitzer, K.-D.B. Dijkstra, A.G. Orr, D.R. Paulson & J. van Tol (2008). Global diversity of dragonflies (Odonata) in freshwater pp. 351–363. In: Balian, E.V., C. Lévêque, H. Segers & K. Martens (eds.). *Freshwater Animal Diversity Assessment*. Springer Netherlands, Dordrecht.

Mitra, T.R. (2002). Endemic Odonata of India. *Records of the Zoological Survey of India* 100(3–4): 189. https://doi.org/10.26515/rzsi/v100/i3-4/2002/159599

Nayak, A.K. & S. Roy (2021). Further additions to the Odonata (Insecta) fauna of Asansol-Durgapur Industrial Area, Paschim Bardhaman, India. *Journal of Threatened Taxa* 13(6): 18631–18641. https://doi.org/10.11609/jott.6547.13.6.18631-18641

Nayak, A.K. & U.S. Roy (2016). An observation on the Odonata fauna of the Asansol-Durgapur Industrial Area, Burdwan, West Bengal, India. *Journal of Threatened Taxa* 8(2): 8503–8517. https://doi.org/10.11609/jott.2572.8.2.8503-8517

Pahari, P.R., S.S. Mandal, S. Maiti & T. Bhattacharya (2019). Diversity and community structure of Odonata (Insecta) in two land use types in Purba Medinipur District, West Bengal, India. *Journal of Threatened Taxa* 11(6): 13748–13755. https://doi.org/10.11609/jott.4139.11.6.13748-13755

Paulson, D., Schorr, M., Abbott, J., Bota-Sierra, C., Deliry, C., Dijkstra, K.-D. and Lozano, F. (Coordinators). 2023. World Odonata List. OdonataCentral, University of Alabama. Available at: https://www.odonatacentral.org/app/#/wol/

Payra, A. & A.D. Tiple (2019). Odonata fauna in adjoining coastal areas of Purba Medinipur district, West Bengal, India. *Munis Entomology & Zoology* 14(2): 358–367.

Ruidas, D., S.C. Pal, A.R.Md.T. Islam & A. Saha (2021). Characterization

of groundwater potential zones in water-scarce hardrock regions using data driven model. *Environmental Earth Sciences* 80(24): 809. https://doi.org/10.1007/s12665-021-10116-8

Siddika, A., B. Bhattacharjee, P. Chakraborty, C.K. Sarkar, M. Asik, S.M. Khan & A. Samadder (2017). Diurnal variation in the activities of three common odonate species at their natural habitat. International Journal of Experimental Research and Review14: 34–38.

Stoks, R. & A. Córdoba-Aguilar (2012). Evolutionary Ecology of Odonata: A Complex Life Cycle Perspective. *Annual Review of Entomology* 57(1): 249–265. https://doi.org/10.1146/annurev-ento-120710-100557

Selys, L.E.D. (1891). Odonates in 'Viaggio Di Leonardo Fea in Birmania e Regional Viccine, Annali. Mus. civ. Stor.nat. *Giacomo Doria* 2(10): 433–518.

Subramanian, K.A. (2009). Dragonflies of India-A Field Guide. Vigyan Prasar, Department of Science and Technology, Govt. of India, 168pp. http://www.vigyanprasar.gov.in/digilib/

Srivastava,V. (1993). Fauna of West Bengal: Insecta: Apterygota, Exopterygota, Orthoptera, Dermaptera, Dictyoptera, Isoptera. Zoological Survey of India, The Survey, 1993; Original from. Digitized, Sep 4, 2009, Cornell University.

Tiple, A.D. & P. Koparde (2015). Odonata of Maharashtra, India with Notes on Species Distributon. *Journal of Insect Science* 15(1): 1–10. https://doi.org/10.1093/jisesa/iev028

Tiple, A.D., R.J. Andrew, K.A. Subramanian & S.S. Talmale (2013). Odonata of Vidarbha region, Maharashtra state, central India. *Odonatologica* 42: 237–245.

Tiple, A.D., S. Paunikar & S.S. Talmale (2012). Dragonfies and Damselfies (Odonata: Insecta) of Tropical Forest Research Insttute, Jabalpur, Madhya Pradesh, central India. *Journal of Threatened Taxa* 4(4): 2529–2533. https://doi.org/10.11609/JoTT.o2657.2529-33

Tiple, A., V. Sharma & S.V. Padwad (2022). Dragonfies and damselfies (Insecta: Odonata) of Jabalpur, Madhya Pradesh, India. *Journal of Threatened Taxa* 14(2): 20740–20746. https://doi.org/10.11609/jot.7306.14.3.20740-20746

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 February 2024 | 16(2): 24786–24794
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.8137.16.2.24786-24794
#8137 | Received 10 August 2022 | Final received 24 December 2023 | Finally accepted 31 January 2024
OPEN ACCESS
COMMUNICATION

A preliminary assessment of butterfly diversity from Mekhliganj town, Cooch Behar District, West Bengal, India

Abhirup Saha [1], Prapti Das [2] & Dhiraj Saha [3]

[1,2,3] Insect Biochemistry and Molecular Biology Laboratory, Department of Zoology, University of North Bengal, Raja Rammohunpur, P.O. NBU, District Darjeeling, West Bengal 734013, India.
[1] rs_abhirup@nbu.ac.in, [2] rs_prapti@nbu.ac.in, [3] dhirajsaha@nbu.ac.in (corresponding author)

Abstract: In the present study, butterfly diversity from Mekhliganj town, which is located on the Teesta River bank of Cooch Behar District, West Bengal, India was studied. A total of 55 species of butterflies were recorded from the two study sites, out of which 22 species were observed for the first time from Cooch-Behar District, not recorded earlier. Out of these, five recorded species were legally protected under the Wildlife (Protection) Act (WPA), 1972 like *Chliaria othona, Lampides boeticus,* and *Hypolimnas misippus*. Therefore, efforts should be made for habitat conservation of the Teesta River bank.

Keywords: Butterfly diversity, checklist, conservation, diversity and abundance, environment, India, indicator species, Lepidoptera, Mekhliganj, pollinator species

Abbreviations: M—Moderate | R—Rare | VC—Very Common | WPA—Wildlife Protection Act | TA—Town Area | RB—River Bank.

Editor: Monsoon Jyoti Gogoi, Bokakhat, Assam, India. **Date of publication:** 26 February 2024 (online & print)

Citation: Saha, A., P. Das & D. Saha (2024). A preliminary assessment of butterfly diversity from Mekhliganj town, Cooch Behar District, West Bengal, India. *Journal of Threatened Taxa* 16(2): 24786–24794. https://doi.org/10.11609/jott.8137.16.2.24786-24794

Funding: This study has not been funded by any commercial or non-commercial agencies.

Competing interests: The authors declare no competing interests.

Author details: Abhirup Saha is currently working as a research scholar in the Insect Biochemistry and Molecular Biology Laboratory at the University of North Bengal. Concurrently, Prapti Das is pursuing her doctoral studies within the same laboratory. Both individuals are under the guidance of Professor Dhiraj Saha, who holds a professorial position within the Department of Zoology. Professor Dhiraj Saha completed his doctoral research on the tea pest prevalent in northern West Bengal. The focus of their laboratory's current research endeavors lies in the examination of various mosquito vectors and their resistance profiles across different regions of north Bengal. Additionally, the laboratory diligently documents the diversity of different pollinator species within the surrounding vicinity. Professor Dhiraj Saha's contributions to the field of entomology have been recognized with the prestigious Prof. T. N. Ananthakrishnan Award for Insect Research by the Society of Medical Arthropodologists (SOMA) during the 14th International Conference of Medical Arthropodology.

Author contributions: Conceptualization: AS and DS, Data curation: AS, Formal analysis: AS and PD, Investigation: AS, Methodology: AS, Software: AS, Supervision: DS, Validation: AS and PD, Visualization: AS, DS and PD, Writing-original draft: AS and PD, Writing- review and editing: AS, PD and DS. All authors read and approved the final manuscript.

Acknowledgements: The authors would like to acknowledge Mr. Abhisekh Subba (Zoological Survey of India), Mr. Subhajit Das (Department of Zoology, University of North Bengal), and Mr. Alinda Ghosh (Cooch Behar Panchanan Barma University) for help in the preparation of figures.

INTRODUCTION

Butterflies play a number of critical roles in the maintenance of environmental quality in terrestrial ecosystems (Ghazoul 2002). Conservation biologists now utilize numerous species of butterflies to identify the important habitats that must be protected because they are highly sensitive to environmental parameters such as temperature, light, humidity, and rainfall (Spitzer et al. 1997; Thomas 2005; Bonebrake et al. 2010; Brereton et al. 2011). As an important pollinator, they face numerous conservation challenges as a result of the ongoing augmentation of anthropogenic activities such as industrialization, urbanization, usage of numerous pesticides in various agricultural, horticultural fields, deforestation along with monoculture plantation and overgrazing (Tiple et al. 2007; Roy et al. 2012, 2022).

There are over 18,000 species of butterflies worldwide, out of which around 1,300 butterfly species are found in India (Samanta et al. 2017; Smetacek 2017). The northern region of West Bengal, which includes the districts of Cooch-Behar, Jalpaiguri, Darjeeling, Dakshin Dinajpur, Uttar Dinajpur, Alipurduar, Malda, and Kalimpong is well-known for its diverse fauna and flora (Pal 2017). However, very few studies of butterfly diversity from this area have been documented.

In this present study, butterfly diversity was studied in the town of Mekhliganj, which is located in the Cooch Behar District. Some authors have previously reported 66 species of butterflies from other areas of the Cooch-Behar District (Das et al. 2020; Roy et al. 2022), however, their diversity from Mekhliganj town remains undocumented and hence the present study was taken up. For this study, two geographically distinct sites were chosen.

MATERIALS AND METHODS

The butterfly diversity was studied at two geographically different study locations in the Mekhliganj city. Mekhliganj is a municipal city in Cooch Behar District located in northern part of West Bengal, covering an area of 3.88 km^2, situated between 26.35°N and 88.92°E (Directorate of Census Operations V, West Bengal 2011). Field studies for butterfly diversity was conducted between January 2020 to August 2021. During this time each study site was visited twice a month from 0800 h to 1200 h. Butterflies were surveyed and photographed in these study areas. Butterfly survey and counting was conducted using the Pollard walk method (Pollard 1977). Butterflies were counted within 5 m on both sides of the transect walk. Photographs of butterfly specimens were taken with a NIKON D3500 DSLR camera.

Site 1: Town area (TA) consisted of ephemeral water bodies, ponds, marshes, bushes, wetlands, trees and shrubs, tea gardens and agricultural lands that are adjacent to human populations. Site 2: River bank (RB) is located in the Teesta riverbank (120–130 m from the water), and comprised of shrubs, agricultural grounds, aquatic plants and grasses as well as a few human settlements. The study area locations are listed in the Table 1 and photographs are given in the Images 1 & 2.

Three short forms were used to examine the occurrence status of each butterfly species. Butterflies that were very common and plentiful were designated as VC (more than 100), moderately abundant butterflies were designated as M (more than 30) and rare butterflies were designated as R (less than 30). Not even a single butterfly was harmed or killed during this study.

The colour patterns and wing designs of common butterflies were used to identify them on the spot. Other butterflies were carefully identified through photographs. Standard guides of entomological specialists, published literatures (Samanta et al. 2017; Mukherjee & Mondal 2020), field guide books (Smetacek 2017) and some websites (Know your insects 2022; Butterflies of India 2022) were used to confirm the identification of the butterfly species. Data analysis & all the diversity indices like Shannon Weiner index, Margalef index, and evenness index were calculated using PAST software version 4.10.

RESULTS

In the present study, a total of 55 species were recorded belonging to 44 genera of five families namely, Papilionidae, Hesperiidae, Pieridae, Lycaenidae, and Nymphalidae. Most number of species belonged to the family Nymphalidae (22 species) whereas least number of species belonged to the family Papilionidae (three species) (Image 3–5). A total of 53 species of butterflies were observed from TA whereas, 42 species were observed from RB (Table 2).

In both the study sites, family Nymphalidae was the most abundant: 21 species from TA (39%) & 19 species from RB (45%), followed by Lycaenidae: 11 species from TA (21%) & seven species from RB (17%), Pieridae: 10 species from TA (19%) & eight species from RB (19%), Hesperiidae: eight species from TA (15%) & six species

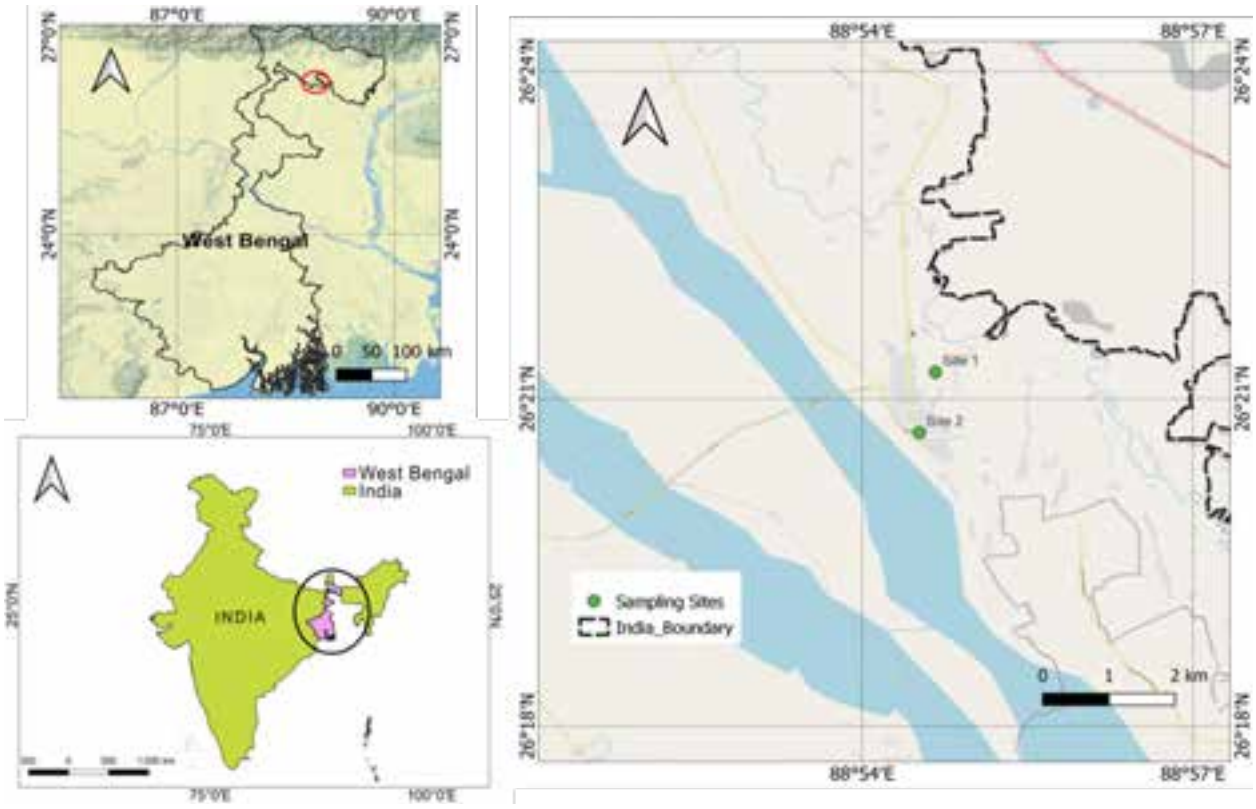


Image 1. Locations and study sites in Mekhliganj. (Site 1 = Town Area and Site 2 = River Bank) (This map was created using QGIS software version 3.22. Shape files of India and West Bengal were downloaded from: https://www.naturalearthdata.com/downloads/10m-cultural-vectors/).

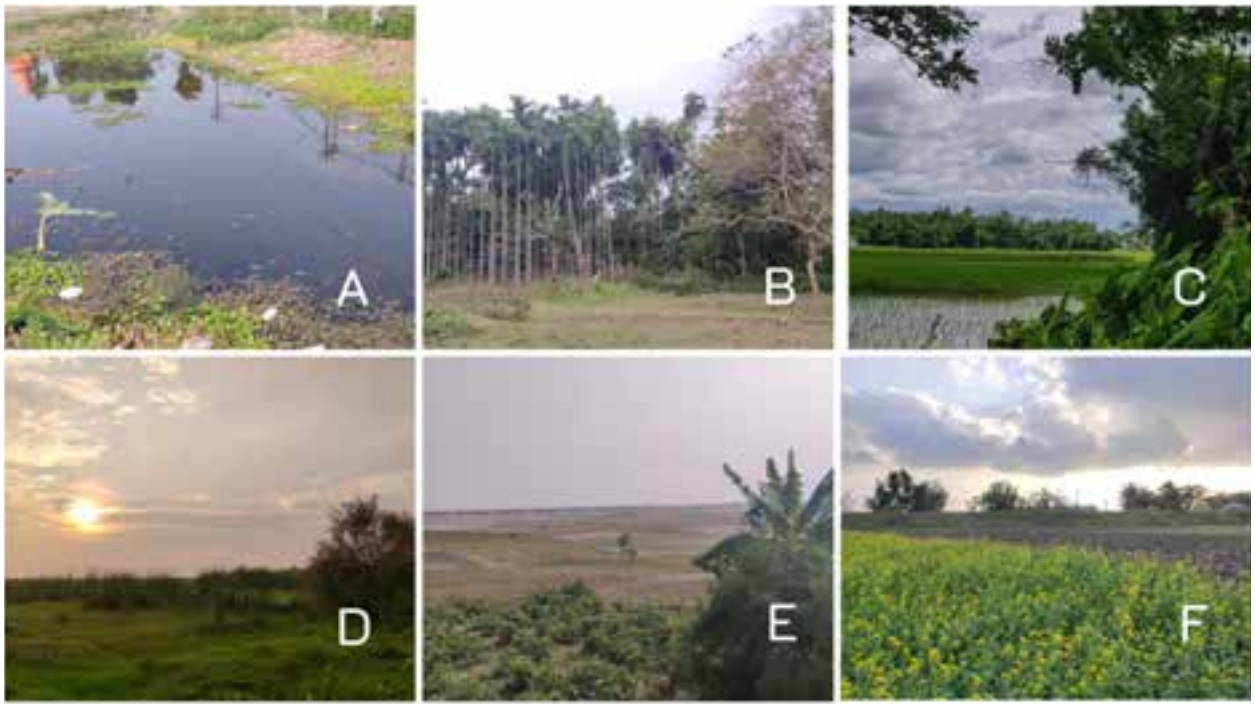


Image 2. Study areas from Mekhliganj. Photograph A, B & C represent Town Area and photograph D, E & F represent River Bank.

Table 1. A brief representation of the selected sampling sites with their habitat types and locations.

Sampling site	Location	Description
TA	26.358°N, 88.906°E	Ephemeral water bodies, ponds, wetlands, shrubs, small and large trees, agricultural lands in close proximity to human settlements.
RB	26.359°N 88.896°E	Riverbed (120–130 meter far from water), bushes, agricultural lands, aquatic plants and grasses, few human settlements.

from RB (14%), and Papilionidae: three species from TA (6%) & two species from RB (5%) (Table 3; Figures 1, 2). During the study period, some butterfly species were observed more frequently than others. Family-wise occurrence of all the butterflies is summarized in Table 2.

Results showed that alpha diversity of TA was little higher than the RB (comparing Shannon Weiner index).

Table 2. Checklist of the butterflies reported from Mekhliganj.

	Family	Common name	Scientific name	Occurance		Status
				TA	RB	
1	Papilionidae	Common Mormon	*Papilio polytes*	√	√	VC
		Lime Butterfly	*Papilio demoleus*	√	√	M
		Tailed Jay	*Graphium agamemnon*	√	-	R
2	Hesperiidae	Grass Demon	*Udaspes folus*	√	√	VC
		Straight Swift	*Parnara guttatus*	√	√	VC
		Chestnut Bob	*Iambrix salsala*	√	-	R
		Dark Palm Dart	*Telicota bambusae*	√	√	M
		Pale Palm Dart	*Telicota colon*	√	√	M
		Common Redeye	*Matapa aria*	√	√	M
		Fulvous Pied Flat	*Pseudocoladenia dan*	√	-	R
		Common Dartlet	*Oriens gola*	√	√	VC
3	Pieridae	Mottled Emigrant	*Catopsilia pyranthe*	√	√	VC
		Common Emigrant	*Catopsilia pomona*	√	√	VC
		Striped Albatross	*Appias libythea*	√	√	VC
		Eastern Striped Albatross	*Appias olferna*	√	√	VC
		Common Grass Yellow	*Eurema hecabe*	√	√	VC
		Tree Yellow	*Gandaca harina*	√	√	M
		The Common Jezebel	*Delias eucharis*	√	-	M
		Red-Spot Jezebel	*Delias descombesi*	√	-	R
		Psyche	*Leptosia nina*	√	√	VC
		Asian Cabbage White	*Pieris canidia*	√	√	M
4	Lycaenidae	Slate Flash	*Rapala manea*	√	-	R
		Common Pierrot	*Castalius rosimon*	√	√	VC
		Orchid Tit	*Chliaria othona*	√	-	R
		Apefly	*Spalgis epius*	√	-	M
		Common Hedge Blue	*Acytolepis puspa*	√	-	R
		Pale Grass-Blue	*Pseudozizeeria maha*	√	√	VC
		Lesser Grass-Blue	*Zizina otis*	√	√	VC
4	Lycaenidae	Common Imperial	*Cheritra freja*	√	√	M
		Pea Blue	*Lampides boeticus*	-	√	M
		Lime Blue	*Chilades lajus*	√	√	M
		Common Cerulean	*Jamides celeno*	√	√	M
		Dark Cerulean	*Jamides bochus*	√	-	M
5	Nymphalidae	Common Bushbrown	*Mycalesis perseus*	√	√	VC
		Long-brand Bushbrown	*Mycalesis visala*	√	√	VC
		Common Four-ring	*Ypthima huebneri*	√	√	VC
		Common Five-ring	*Ypthima baldus*	√	√	VC
		Common Baron	*Euthalia aconthea*	√	√	M
		Plain Tiger	*Danaus chrysippus*	√	√	M
		Striped Tiger	*Danaus genutia*	√	√	M
		Blue Tiger	*Tirumala limniace*	√	√	M
		Common Palmfly	*Elymnias hypermnestra*	√	√	VC
		Common Castor	*Ariadne merione*	-	√	R
		Common Indian Crow	*Euploea core*	√	√	M
		Common Evening Brown	*Melanitis leda*	√	√	VC
		Common Leopard	*Phalanta phalantha*	√	-	R
		Grey Pansy	*Junonia atlites*	√	√	M
		Peacock Pansy	*Junonia almana*	√	√	VC
		Lemon Pansy	*Junonia lemonias*	√	√	M
		Common Sailor	*Neptis hylas*	√	√	M
		Yellow Coster	*Acraea issoria*	√	-	R
		Danaid Eggfly	*Hypolimnas misippus*	√	√	M
		Great Eggfly	*Hypolimnas bolina*	√	-	R
		Extra Lascar	*Pantoporia sandaka*	√	√	M
		Commander	*Moduza procris*	√	√	R

VC—Very Common | M—Moderate | R—Rare.

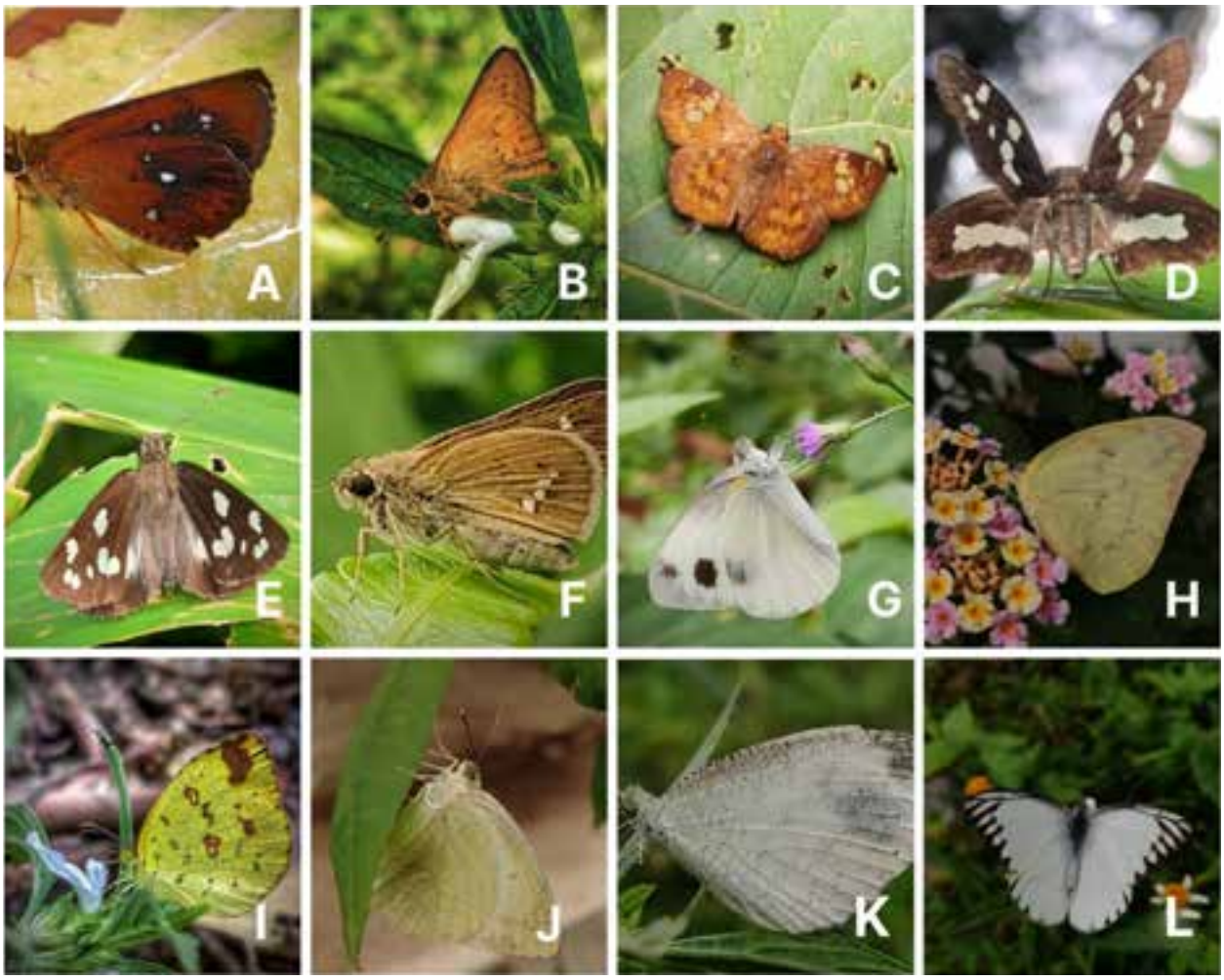


Image 3. Butterflies of the family Hesperiidae and Pieridae recorded during the study.
A—Chestnut Bob *Iambrix salsala* | B—Dark Palm Dart *Telicota bambusae* | C—Fulvous Pied Flat *Pseudocoladenia dan* | D–E. Grass Demon *Udaspes folus*: D—view from lower side, E—view from upper side | F—Straight Swift *Parnara guttatus* | G—Asian Cabbage White *Pieris canidia* | H—Common Emigrant *Catopsilia pomona* | I—Common Grass Yellow *Eurema hecabe* | J—Mottled Emigrant *Catopsilia pyranthe* | K—Psyche *Leptosia nina* | L—Striped Albatross *Appias libythea*. © Abhirup Saha.

Margalef index showed higher diversity in TA (6.967) compared to RB (5.865). On the other hand, dominance was more in RB (0.05728) than TA (0.04523). Evenness index for both the study sites were close to each other. The Berger-Parker index, which indicates single taxa dominance was higher in RB (0.1454) compared to TA (0.1182). Table 5 summarises the different diversity indices of the butterflies from the two study sites.

DISCUSSIONS

As per our knowledge, this study is the first of its kind from this town and will shed some light on the region's ecosystem health and macro fauna conservation needs. Previously, three studies regarding butterfly diversity in Cooch Behar District were carried out. Thirty-three species out of a total 55 species of butterflies recorded during this study were also reported in those studies (Das et al. 2020; Roy et al. 2022). Whereas, 22 species were observed for the first time from Cooch Behar District, which were not recorded by previous authors (Das et al. 2020; Roy et al. 2022). These are – *Parnara guttatus*, *Iambrix salsala*, *Telicota bambusae*, *Telicota colon*, *Matapa aria*, *Pseudocoladenia dan* & *Oriens gola* from family Hesperiidae; *Rapala manea*, *Chliaria othona*, *Spalgis epius*, *Zizina otis*, *Cheritra freja*, *Lampides boeticus* & *Jamides celeno* from family Lycaenidae; *Mycalesis perseus*, *M. visala*, *Ariadne merione*, *Junonia lemonias*, *Acraea issoria*, *Pantoporia sandaka* & *Moduza procris* from family Nymphalidae, and *Gandaca harina* from family Pieridae.

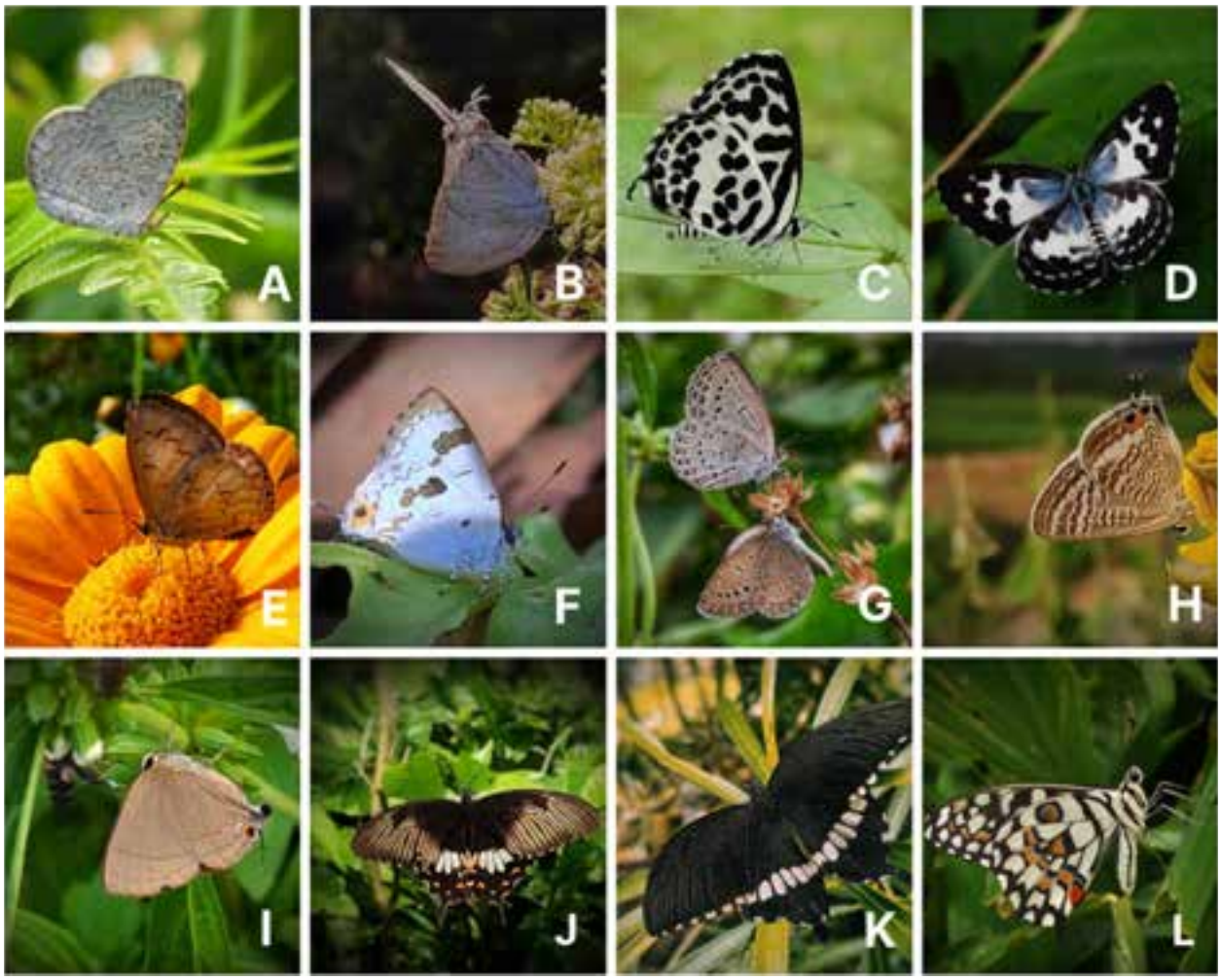


Image 4. Butterflies of the family Lycaenidae and Papilionidae recorded during the study.
A—Apefly *Spalgis epius* | B—Common Imperial *Cheritra freja* | C–D—Common Pierrot *Castalius rosimon*: C. underside. D. upper side | E—Common Hedge Blue *Acytolepis puspa* | F—Orchid Tit *Chliaria othona* | G—Pale Grass Blue *Pseudozizeeria maha* | H—Pea Blue *Lampides boeticus* | I—Slate Flash *Rapala manea* | J-K—Common Mormon *Papilio polytes*: J—Female. K—Male | L—Lime Butterfly *Papilio demoleus*. © Abhirup Saha.

Moreover, the number of species recorded in this study is consistent with other studies regarding butterfly diversity in various locations of West Bengal with similar landscape patterns (Ghosh & Siddique 2005; Mukherjee et al. 2015; Ghosh & Saha 2016; Mandal 2016; Mukherjee et al. 2016; Dey et al. 2017; Samanta et al. 2017; Das 2018; Pahari et al. 2018; Mahata et al. 2020; Mukherjee & Mondal 2020). The number of species recorded from the two study sites differed slightly maybe because TA was topographically more diverse than RB and also maybe TA was more suitable to support the host plants of the recorded butterfly species.

A total of five species were found to be included under the Wildlife (Protection) Act (WPA), 1972 (Table 4), viz., *Chliaria othona* included under schedule I and *Lampides boeticus* included under schedule II from family Lycaenidae*; Euploea core* included under schedule IV and *Hypolimnas misippus* included under schedule II from family Nymphalidae and *Appias libythea* included under schedule IV from family Pieridae.

The high diversity of butterfly fauna of Mekhliganj indicates the presence of preferable vegetation for different butterfly species. However, gradual urbanization of the town can lead to the disposal of host plants of butterflies resulting in decreased butterfly diversity.

CONCLUSION

The present study is a preliminary record of butterfly diversity from Mekhliganj town of Cooch

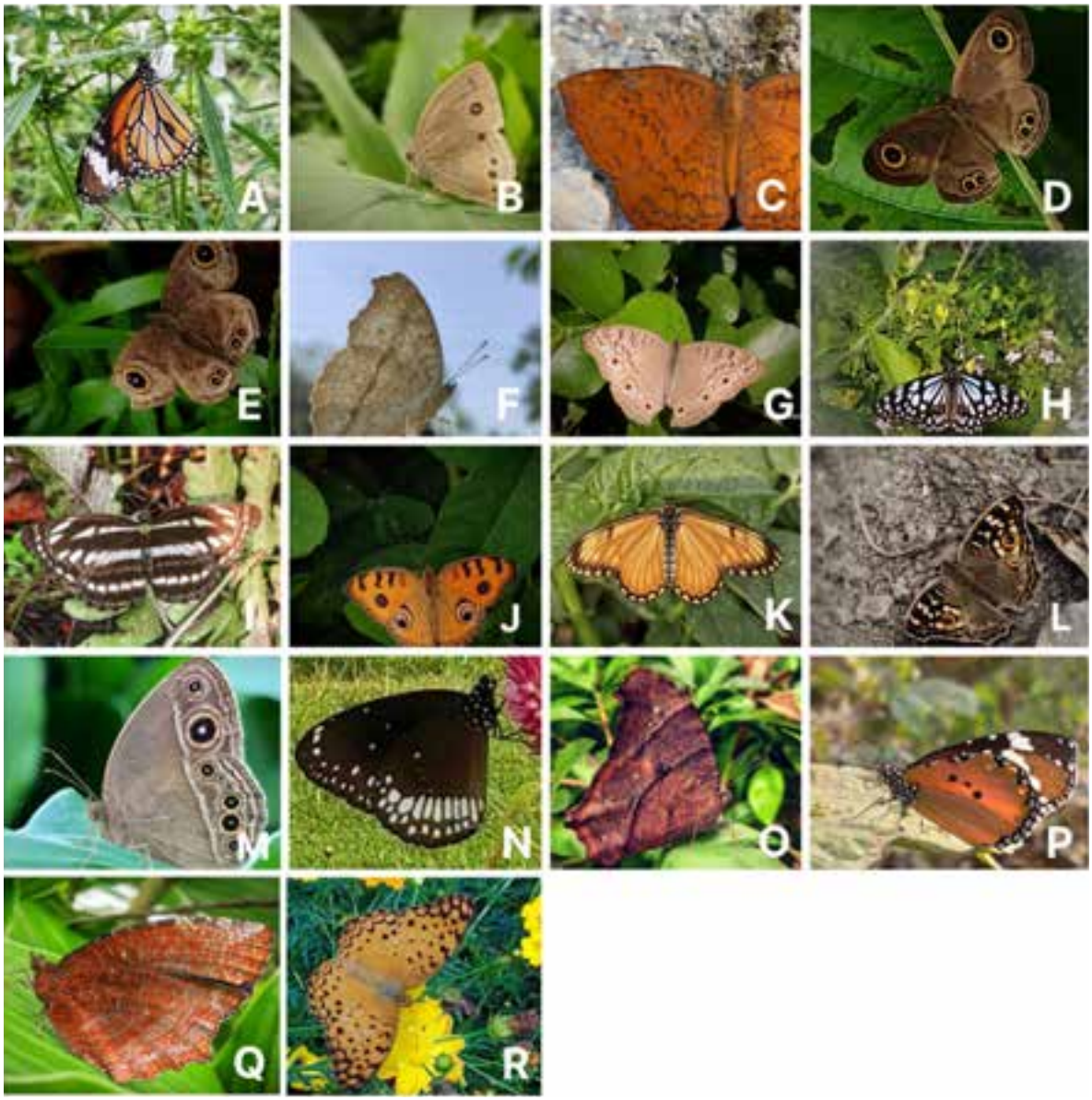


Image 5. Some butterflies of the family Nymphalidae recorded during the study.
A—Striped Tiger *Danaus genutia* | B—Long-brand Bushbrown *Mycalesis visala* | C—Common Castor *Ariadne merione* | D—Common Four-ring *Ypthima huebneri* | E—Common Five-ring *Ypthima baldus* | F-G. Grey Pansy *Junonia atlites*: F—underside | G. upper side | H. Blue Tiger *Tirumala limniace* | I— Common Sailor *Neptis hylas* | J—Peacock Pansy *Junonia almanac* | K—Yellow Coster *Acraea issoria* | L—Lemon Pansy *Junonia lemonias* | M—Common Bushbrown *Mycalesis perseus* | N—Common Crow *Euploea core* | O—Common Evening Brown *Melanitis leda* | P—Plain Tiger *Danaus chrysippus* | Q—Common Palmfly *Elymnias hypermnestra* | R—Common Leopard *Phalanta phalantha*. © Abhirup Saha.

Behar District. As the current study was restricted to two sites only, butterfly diversity may vary in other sites of the town. However, this study will help to get an idea of the diversity of butterflies from the study area. Moreover, first report of 22 butterfly species like *Parnara guttatus*, *Iambrix salsala*, *Telicota bambusae*, *Rapala manea*, *Chliaria othona*, *Spalgis epius*, *Zizina otis*, *Cheritra freja*, *Ariadne merione*, *Junonia lemonias*, *Acraea issoria*, *Pantoporia sandaka*, *Moduza procris*, and *Gandaca harina*. from this region shows that there is need of more studies on diversity of Lepidoptera in other sites of Mekhliganj as well as entire Cooch Behar District. Investigating the butterfly fauna is crucial for recognizing and safeguarding diverse habitats facing potential anthropogenic changes, as these insects serve as potential pollinators for their nectar plants and indicate the condition of the overall ecosystem health.

Table 3. Relative abundance of different butterfly families from the study sites.

Family	Total number of genera recorded from both the sites	Total number of species	
		TA	RB
Hesperiidae	07	08	06
Nymphalidae	16	21	19
Pieridae	07	10	08
Lycaenidae	11	11	07
Papilionidae	02	03	02

Table 4. List of butterflies from Mekhliganj included under Indian Wildlife (Protection) Act, 1972 (WPA).

	Family	Common name	Scientific name	WPA Schedule (1972)
1	Lycaenidae	Orchid Tit	*Chliaria othona*	I (Part IV)
		Pea Blue	*Lampides boeticus*	II (Part II)
2	Nymphalidae	Danaid Eggfly	*Hypolimnas misippus*	II (Part II)
		Common Indian Crow	*Euploea core*	IV
3	Pieridae	Striped Albatross	*Appias libythea*	IV

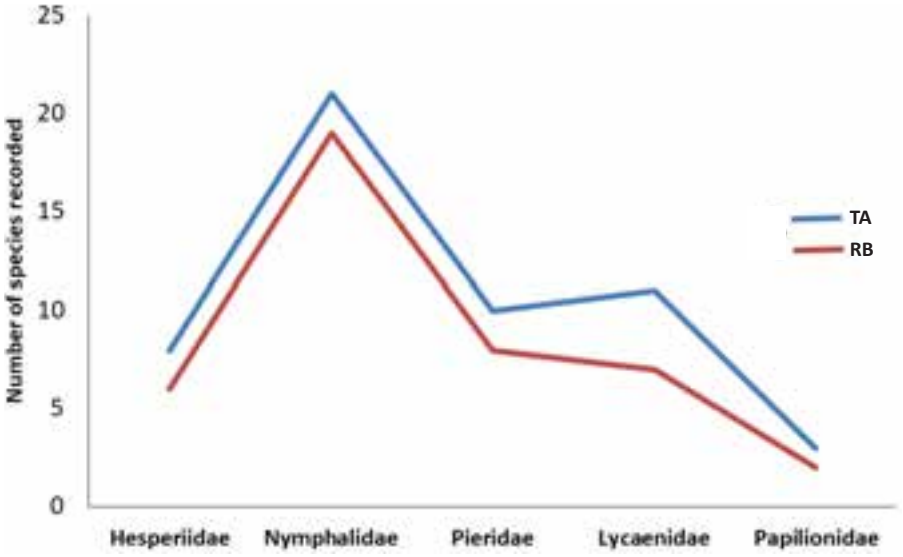


Figure 1. Comparative abundance of recorded species among different butterfly families between Town Area (TA) and River Bank (RB).

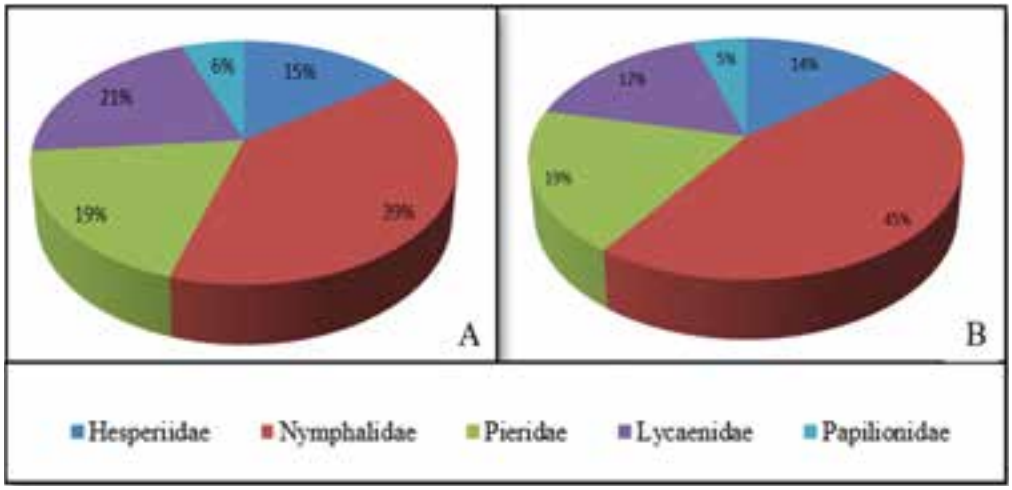


Figure 2. Family-wise percent distribution of butterflies from Town Area (A) and River Bank (B).

Table 5. Site-wise diversity indices for butterfly species from Mekhliganj.

	Town Area	River Bank
Taxa_S	53	42
Simpson_1-D	0.9548	0.9427
Shannon_H	3.461	3.23
Dominance_D	0.04523	0.05728
Evenness_e^H/S	0.601	0.6017
Margalef	6.967	5.865
Berger-Parker	0.1182	0.1454

REFERENCES

Bonebrake, T.C., L.C. Ponisio, C.L. Boggs & P.R. Ehrlich (2010). More than just indicators: a review of tropical butterfly ecology and conservation. *Biological conservation* 143(8): 1831–1841. https://doi.org/10.1016/j.biocon.2010.04.044

Brereton, T., D.B. Roy, I. Middlebrook, M. Botham & M. Warren (2011). The development of butterfly indicators in the United Kingdom and assessments in 2010. *Journal of Insect Conservation* 15(1): 139–151. https://doi.org/10.1007/s10841-010-9333-z

Butterflies of India (2022). https://www.ifoundbutterflies.org/. Accessed 29 March 2022.

Das, D. (2018). Butterfly (Lepidoptera: Rhopalocera) diversity in relation to habitat utilization at Jagannath Kishore College, Purulia, West Bengal (India*). Journal of Insect Biodiversity* 7(1): 1–16. https://doi.org/10.12976/jib/2018.07.1.1

Das, D., A. Sen & P. Mitra (2020). Major fauna of Rasik Beel Wetland Complex (WB). *Zoological Survey of India* 343: 1–76.

Dey, P., A. Pyra & K. Mandal (2017). A study on butterfly diversity in Singur, West Bengal, India. *E-planet* 15(1): 73–77.

Directorate of Census Operations V, West Bengal (2011). *District Census Handbook Koch Bihar*, Census of India 2011, Series 20, Part XII A pp.593–595.

Ghazoul, J. (2002). Impact of logging on the richness and diversity of forest butterflies in a tropical dry forest in Thailand. *Biodiversity & Conservation* 11(3): 521–541. https://doi.org/10.1023/A:1014812701423

Ghosh, S. & S. Saha (2016). Seasonal diversity of butterflies with reference to habitat heterogeneity, larval host plants and nectar plants at Taki, North 24 Parganas, West Bengal, India. *World Scientific News* 50: 197–238.

Ghosh, S. & S. Siddique (2005). Butterfly diversity in and around urban Kolkata. *Records of the Zoological Survey of India* 104(3–4): 111–119.

Know your insects (2022). https://www.knowyourinsects.org/. Electronic version accessed 21 January 2022.

Mahata, A., N.P. Mishra & S.K. Palita (2020). Butterflies (Lepidoptera: Rhopalocera) of the undivided Midnapore District, West Bengal, India: a preliminary report. *Journal of Threatened Taxa* 12(17): 17347–17360. https://doi.org/10.11609/jott.5142.12.17.17347-17360

Mandal, S. (2016). Butterflies of the rice research station and adjoining locality in Chinsurah, West Bengal, India. *Journal of Threatened Taxa* 8(5): 8804–8813. https://doi.org/10.11609/jott.2815.8.5.8804-8813

Mukherjee, K. & A. Mondal (2020). Butterfly diversity in heterogeneous habitat of Bankura, West Bengal, India. *Journal of Threatened Taxa* 12(8): 15804–15816. https://doi.org/10.11609/jot.5136.12.8.15804-15816

Mukherjee, S., G. Aditya, P. Basu & G.K. Saha (2016). Butterfly diversity in Kolkata metropolis: a synoptic check list. *Check List* 12(2): 1858. https://doi.org/10.15560/12.2.1858

Mukherjee, S., S. Banerjee, G.K. Saha, P. Basu & G. Aditya (2015). Butterfly diversity in Kolkata, India: An appraisal for conservation management. *Journal of Asia-Pacific Biodiversity* 8(3): 210–221. https://doi.org/10.1016/j.japb.2015.08.001

Pahari, P.R., N.P. Mishra, A. Sahoo & T. Bhattacharya (2018). A study on the butterfly diversity of Haldia industrial belt and adjacent rural area in Purba Medinipur district, West Bengal, India. *World Scientific News* 97: 207–224.

Pal, A. (2017). Dragonflies and damselflies of University of North Bengal campus, West Bengal, India with new distribution record of *Agriocnemis kalinga* Nair & Subramanian, 2014. *Journal of Threatened Taxa* 9(12): 11067–11073.

Pollard, E. (1977). A method for assessing changes in the abundance of butterflies. *Biological conservation* 12(2): 115–134. https://doi.org/10.1016/0006-3207(77)90065-9

Roy, G.C., A. Miah, S. Roy, D. Roy, D. Kar, S. Banerjee & M. Gupta (2022). Diversity and Abundance of butterfly as an environmental indicator at Dinhata Subdivision, Cooch Behar, West Bengal, India. *Notulae Scientia Biologicae* 14(1): 11156. https://doi.org/10.15835/nsb14111156

Roy, U.S., M. Mukherjee & S.K. Mukhopadhyay (2012). Butterfly diversity and abundance with reference to habitat heterogeneity in and around Neora Valley National Park, West Bengal, India. *Our Nature* 10(1): 53–60. https://doi.org/10.3126/on.v10i1.7751

Samanta, S., D. Das & S. Mandal (2017). Butterfly fauna of Baghmundi, Purulia, West Bengal, India: a preliminary checklist. *Journal of Threatened Taxa* 9(5): 10198–10207. https://doi.org/10.11609/jott.2841.9.5.10198-10207

Smetacek, P. (2017). *A naturalist's guide to the butterflies of India, Pakistan, Nepal, Bhutan, Bangladesh and Sri Lanka*. 1st ed. John Beaufoy Publishing Limited.

Spitzer, K., J. Jaroš, J. Havelka & J. Lepš (1997). Effect of small-scale disturbance on butterfly communities of an Indochinese montane rainforest. *Biological Conservation* 80(1): 9–15. https://doi.org/10.1016/S0006-3207(96)00079-1

Thomas, J.A. (2005). Monitoring change in the abundance and distribution of insects using butterflies and other indicator groups. *Philosophical Transactions of the Royal Society B: Biological Sciences* 360(1454): 339–357. https://doi.org/10.1098/rstb.2004.1585

Tiple, A.D., A.M. Khurad & R.L. Dennis (2007). Butterfly diversity in relation to a human-impact gradient on an Indian university campus. *Nota Lepidopterologica* 30(1): 179.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 February 2024 | 16(2): 24795–24803

ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

https://doi.org/10.11609/jott.8582.16.2.24795-24803

#8582 | Received 09 June 2023 | Final received 13 January 2024 | Finally accepted 30 January 2024

OPEN ACCESS

COMMUNICATION

Utilization of *Afzelia africana* Sm. ex Pers. (Magnoliopsida: Fabales: Fabaceae) in Nigeria and its implications for conservation

Samuel Oloruntoba Bamigboye [1], Muhali Olaide Jimoh [2], Falilat Abeni Lawal [3], Zainab Temitope Osiyemi [4], Charles Petrus Laubscher [5] & Learnmore Kambizi [6]

[1,2,3,4] Department of Plant Science, Faculty of Science, Olabisi Onabanjo University 2002, Ago-Iwoye, Nigeria.
[5,6] Department of Horticultural Sciences, Faculty of Applied Sciences, Cape Peninsula University of Technology, Bellville, 7535, South Africa.
[1] reachtoba@gmail.com (corresponding author), [2] moajay006@gmail.com, [3] falilatabeni@gmail.com, [4] osiyemizainab3@gmail.com,
[5] laubscherc@cput.ac.za, [6] kambizil@cput.ac.za

Abstract: This study investigated the ethnobotanical uses of *Afzelia africana* Sm. ex Pers., a threatened tree species in Nigeria to determine the impact of uses of this species on the risk of its extinction. Ethnobotanical surveys were conducted by means of semi-structured questionnaires with the local community called Ijebu Igbo in Ogun state of Nigeria and a total of 60 respondents were interviewed from this community. Herbalists, artisans, Islamic scholars, traders, and retirees were interviewed to document their knowledge of the uses of *A. africana.* This study revealed that there are different uses of *A. africana*, among which its spiritual and medicinal uses were the most dominant. An unsustainable harvest of *A. africana* for these uses will aggravate the decline of its population, thereby increasing the risk of extinction. This study recommends local awareness of the indigenous people of possible ways this species can be utilized in a sustainable manner to prevent its extinction.

Keywords: Anthropogenic forces, biodiversity loss, endangered species, ethnobotany, extinction risk, indigenous knowledge, overharvesting, population decline, traditional knowledge, threats,

Editor: Shiny Mariam Rehel, Keystone Foundation, Kotagiri, India.

Date of publication: 26 February 2024 (online & print)

Citation: Bamigboye, S.O., M.O. Jimoh, F.A. Lawal, Z.T. Osiyemi, C.P. Laubscher & L. Kambizi (2024). Utilization of *Afzelia africana* Sm. ex Pers. (Magnoliopsida: Fabales: Fabaceae) in Nigeria and its implications for conservation. *Journal of Threatened Taxa* 16(2): 24795–24803. https://doi.org/10.11609/jott.8582.16.2.24795-24803

Funding: Department of Horticultural Sciences, Faculty of Applied Sciences, Cape Peninsula University of Technology.

Competing interests: The authors declare no competing interests.

Author details: Samuel Oloruntoba Bamigboye holds a PhD and his expertise is in plant conservation focusing on extinction risk in African threatened endemic plant taxa. He is currently a lecturer in Nigeria. His current research in Nigeria focuses on plant people interface and the conservation implications. Falilat Abeni Lawal just completed bachelors degree in plant science at Olabisi Onabanjo University in Nigeria. She is interested in furthering her career in plant science and environmental management related discipline. Zainab Temitope Osiyemi currently holds a bachelor degree in plant science. She is interested in research relating to human uses of biological resources. Charles P. Laubscher holds a PhD as a professor of horticultural sciences. His research field is aligned with ecological conservation of threatened species and cultivation studies of wild edible species in aid of food security in drought-stricken regions. His has extensive publication and postgraduate supervision records and active in numerous international collaborative agreements. Dr Muhali Jimoh is a botanist with a special interest in plant physiology and metabolomics. Dr Jimoh is a lecturer in the Department of Plant Science, at Olabisi Onabanjo University, Ago-Iwoye, Nigeria, and external supervisor to the Cape Peninsula University of Technology, South Africa. He has supervised four master's students to completion. Prof Learnmore Kambizi is a professor in Cape Peninsula University of Technology, South Africa. His research interests is in utilization and conservation of medicinal plants on a local and international level. He is the first director of African Centre for Herbal Research based in Nigeria.

Author contributions: Samuel Oloruntoba Bamigboye designed the project, and wrote the first draft of the manuscript and also assisted with the survey. Muhali Olaide Jimoh did the data analysis and proof reading. Falilat Abeni Lawal lead the survey team and documented information from the respondents, Zainab Temitope Osiyemi assisted in collecting data from the respondent, Charles Petrus Laubscher assisted in editing the manuscript, Learnmore Kambizi assisted in final editing of the manuscript.

Acknowledgements: We wish to Acknowledge Department of Horticultural Sciences, Faculty of Applied Sciences, Cape Peninsula University of Technology for providing support for the payment of the Article processing Charges for this study.

INTRODUCTION

Utilization and sustainability of biological resources are to be given high level consideration in controlling the risk of plant extinction because anthropogenic activities have been a major player in the subject of biodiversity conservation (Marchese 2015). Human craves to satisfy their needs in terms of food, medicine, shelter, clothing, and horticulture have increased decline in plant species globally (Haines-Young & Potschin 2010; Pimm 2021). And if these needs for resources are not effectively managed, the damage to global biodiversity might be beyond control in decades to come.

Perspectives of the indigenous knowledge holders is important in sustainable utilization and protection of biological resources (Cuni-Sanchez et al. 2016; Mensah et al. 2017). The interaction of local people with their natural environment is a factor that affects biodiversity conservation (Houdanon et al. 2018; Rasethe et al. 2022). Several plant species are sources of ecosystem services for many communities and the perception of the beneficiaries of these services is extremely important for the sustainability of these species (Brockerhoff et al. 2017). Some economic uses of plant resources in communities include timber production, medicine, firewood, and charcoal, and these are causing habitat degradation and gradual increase in extinction risk of many plant taxa (Diaz et al. 2019). Climate regulation, soil and environmental regulation are some of the ecological importance of indigenous trees in communities where the species exists (Byabashaija et al. 2004). Lack of sustainable utilization of species of trees will promote decline of their populations and this will further result in loss of ecosystem services (Jiao et al. 2019).

Afzelia africana (African Mahogany) is a tree species of high economic and ecological importance. It belongs to the family of Fabaceae (Oshingboye et al. 2017). It is highly desired for timber production (Balima et al. 2022), and currently listed as 'Vulnerable' on the IUCN Red List (Hills 2020; Bamigboye et al. 2022). Anthropogenic factors identified as a threat to this species are timber production, medicinal uses, livestock feeding and habitat destruction (Bamigboye et al. 2022). There are excessive threats to natural distribution of *Afzelia africana* in Africa due to international timber trade of this species (Mensah et al. 2014; Assogbadjo et al. 2017). The trade of this species as brown wood transcends Africa to Asia, Europe and the United States of America (Biara et al. 2021).

Afzelia africana is a widely harvested species for many ethnobotanical uses. It is being used for medicinal purposes to treat many ailments locally which include headache, Malaria, ulcer, chronic cough, tooth ache, hemorrhoids, stomach ache and Meningitis (Balima et al. 2018; Houehanou et al. 2023). The leaves are source of food for humans and livestock (Nzekwe et al. 2016; Avornyo et al. 2018). The main aim of this study is to conduct ethnobotanical surveys in a local community called Ijebu igbo in Nigeria to determine the perception of local people on the utilization of *Afzelia africana*. This is to determine the risk of extinction of this species based on the local uses and also make recommendations on the sustainability of this species in Nigeria. The specific objectives of this study are as follows: (i) to determine the diverse utilization of *Afzelia africana* and to understand how this utilization will increase the risk of extinction in a community in Ogun state Nigeria, (ii) to understand the usage of parts of this plant species that are heavily harvested by the local people to meet several human demands in the community where this study was conducted, (iii) to determine how the harvesting of different parts of *Afzellia africana* will affect its sustainability and regeneration potential, and (iv) to make recommendations on how the perspective of the local people can be integrated into plans and policies that will protect and minimize the risk of extinction of *Afzelia africana*.

MATERIALS AND METHODS

Study area

This study was conducted in Ijebu Igbo (Coordinates: 6.9792° N, 3.9980° E), Ogun-State, Nigeria. The natural vegetation is predominately deciduous forest (Bayewu et al. 2014). Ijebu Igbo in Ogun State Nigeria has an average temperature between 21°C–32°C (Bayewu et al. 2014). There are many indigenous people residing in this area. The main livelihood option in the region is timber harvesting (Olanipekun 2022). Majority of the natural forests have been converted to several farmlands and heavy deforestation occurs in this area because of timber trade.

Data collection

A semi structured questionnaires were administered to 60 people in the study area on the uses of *Afzelia africana* in their local community. The justification of the sample size is that only people who could identify the plant and gave their consent to be interviewed were the only respondents captured in this study. This survey was conducted in Yoruba, the local language of

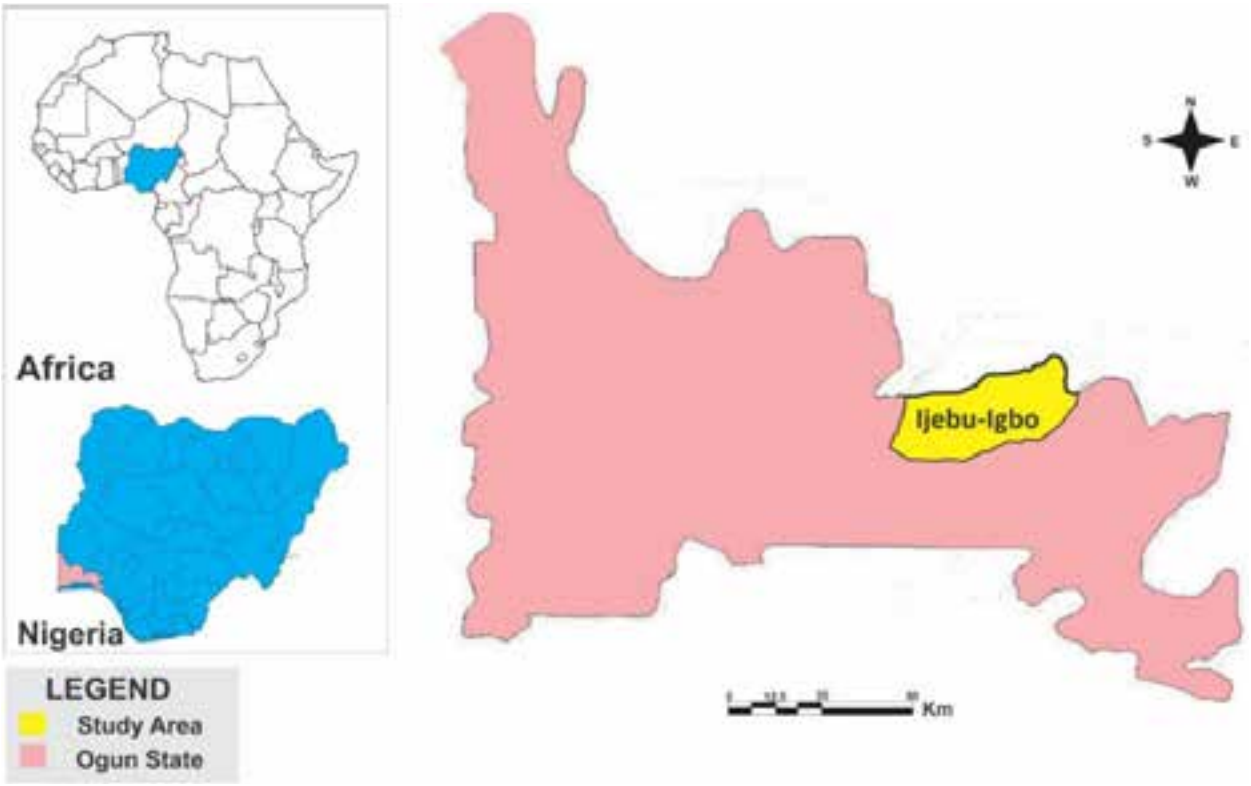


Figure 1. Map of the study area where the ethnobotanical survey of Afzelia africana was conducted.

the indigenous people in this community. Photographs of the species were taken along during the survey for identification and some of the indigenous knowledge holders volunteered to go and identify the species in the wild. *Afzelia africana* is called Apa in this community. All the respondents identified this species through this local name.

Data analysis

Descriptive statistics was used to analyze the data. Quantifications was done in percentages in which the percentages of respondents who mentioned different use categories was determined. The percentages that mentioned the parts of *Afzelia africana* being used for several purposes was calculated. The percentage of respondents that mentioned if the species is rare or not was calculated.

RESULTS

The highest percentage of the respondents mentioned that *Afzelia africana* is used for spiritual purpose. This implies that this plant species is common in this community for its spiritual uses (Figure 2). The spiritual uses mentioned includes warding off spiritual attacks, spiritual protection from evil spirits, money rituals and charm for having good luck. The parts used for spiritual purpose are the leaves, stem, bark, roots and the seeds.

After the spiritual purpose the medicinal uses were the second most mentioned by the respondents (Figure 2). The medicinal uses mentioned are wound healing, easing childbirth, treating eye infection, gonorrhea, enhancing male sexual performance, treating lap inflammation and curing food poison. This revealed there is a wide range of medicinal uses of this plant species with the bark, root, leaves and seeds used for various medicinal purposes (Table 1; Figure 3).

The seed of *Afzelia africana* is a source of food for human consumption as reported in this study (Table 1; Figure 3). It is being uses locally for soup making and added to other food items for human consumption. Also, there are other uses which include furniture making, timber production and as a source of firewood mentioned by the respondents (Figure 2). Individuals of this species are taken out completely for timber production through the use of the industrial saw. The stem cut down are broken into smaller pieces with axe for producing firewood. This is a common practice

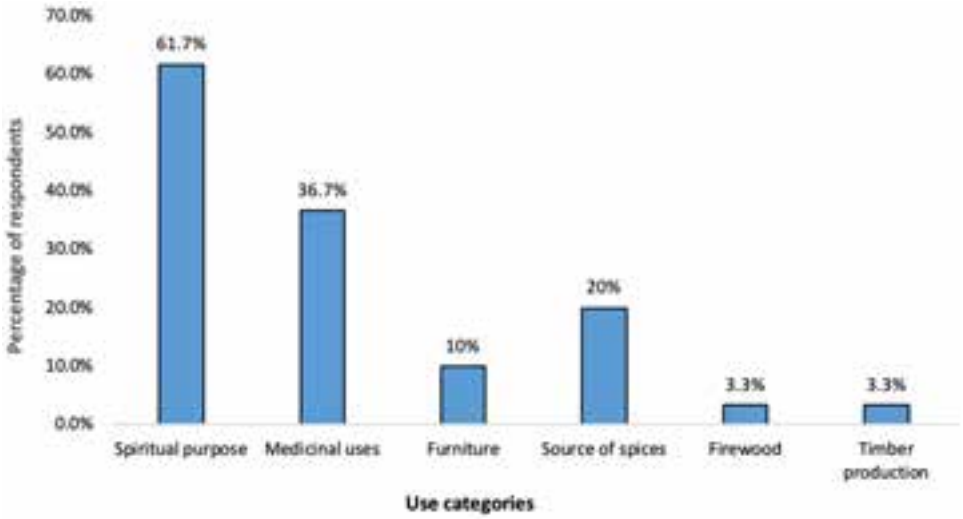


Figure 2. Percentages of respondents that mentioned different use categories of *Afzelia Africana*.

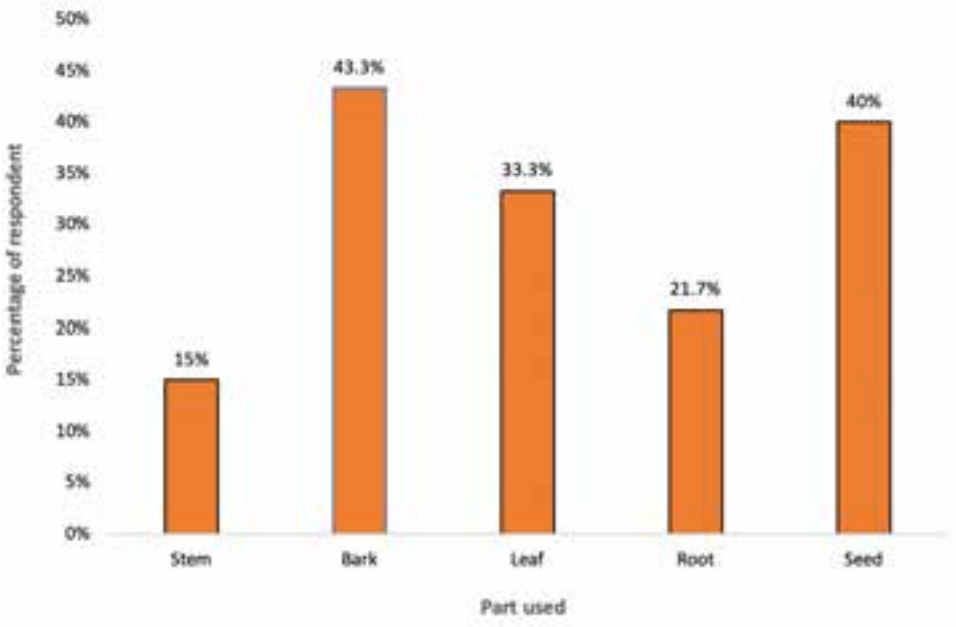


Figure 3. Percentages of respondents that mentioned different parts of *Afzelia africana* used for different purposes.

throughout the year round. Because individuals being removed for timber production and firewood in the wild are not being replaced by planting, this practice becomes unsustainable. This contributes to the population decline of this species.

Half of the respondents believed that *Afzelia africana* is becoming rare within the community (Figure 4). Although a few respondents do not know whether it is rare or not but the result can still be justified that there is possibility of increase in decline of the population of this species within this community.

DISCUSSION

Harvesting of *Afzelia africana* for spiritual purpose

There are many spiritual beliefs that are being attached to plants (Gupta 1971, 1996; Negi 2005). Many cultures around the world believe that plants have several spiritual uses (Kandari et al. 2014; Kawa 2016; Bamigboye et al. 2017; Aziz et al. 2020). The main use category mentioned by most of the respondents in this study was the use of *Afzelia africana* for spiritual purpose

Table 1. Demographic information on the respondents, the use categories of *Afzelia africana* mentioned, parts used mentioned and perception of rarity of the respondent regarding the species.

	Gender	Occupation	Age	Uses	Part used	Is the plant rare or not?
1	Male	Carpenter	54	Furniture, medicine	Stem, leaves	Not rare
2	Male	Unknown	49	Firewood	Stem	Not rare
3	Male	Farmer	61	Cooked as soup, medicine (leaves boiled and administered orally to improve men sexual performance)	Seed, leaves	Not rare
4	Female	Market woman	48	Cooked as soup, medicine	Leaves, seed	Not rare
5	Female	Market woman	39	Cooked as soup, medicine	Leaves, seed	Rare
6	Male	Unknown	62	Spiritual purpose, medicine (Gonorrhea)	Leaves, seed	Unknown
7	Male	Driver	54	Spiritual purpose, medicine (Roots for treating wound)	Bark, root	Not rare
8	Female	Trader	59	Cooked as soup	Seed	Not rare
9	Male	Trader	49	Medicine (Gonorrhea), spiritual purpose	Leaves, bark	Rare
10	Male	Trader	67	Furniture, cooked as soup	Seed, stem	Rare
11	Male	Farmer	68	Cooked as soup	Seed	Not rare
12	Male	Herbalist	51	Spiritual purpose, medicine (Gonorrhea)	Bark, leaves	Not rare
13	Male	Pastor/farmer	63	Spiritual purpose, medicine (bark is boiled and administered to babies orally to strengthen their bones, roots used for treating unknown illness)	Seed, bark, root	Rare
14	Male	Herbalist	58	Spiritual purpose	Seed, leaves	Not rare
15	Male	Herbalist	61	Spiritual purpose, medicine (roots use for enhancing sexual performance in men)	Bark, seed, leaves, root	Rare
16	Male	Herbalist	56	Spiritual purpose, Medicine (roots used for treating wounds)	Leaves, root	Not rare
17	Female	Trader	53	Cooking	Seed	Unknown
18	Female	Trader	47	Cooking, medicine	Seed, leaves	Rare
19	Male	Drummer	55	Furniture	Stem	Not rare
20	Male	Driver	62	Medicine (roots used for treating wounds)	Roots	Unknown
21	Female	Trader	Unknown	Cooking	Seed	Rare
22	Male	Unknown	70	Spiritual purpose	Seed, stem	Rare
23	Female	Trader	45	Cooking	Seed	Not rare
24	Female	Trader	56	Cooking, medicine	Seed, leaves	Not rare
25	Male	Herbalist, Mechanic	40	Spiritual purpose	Bark, root	Rare
26	Female	Herbalist	80	Spiritual purpose, medicine (healing of eyes)	Seed,	Not rare
27	Male	Farmer	58	Spiritual purpose	Bark	Not rare
28	Male	Herbalist	55	Medicine (for curing poison)	Bark	Rare
29	Male	Herbalist	55	Spiritual purpose	Bark	Rare
30	Male	Farmer	58	Spiritual purpose	Bark, seed	Rare
31	Male	Herbalist	85	Medicine (Wound healing, lap inflammation cure)	Seed	Rare
32	Male	Herbalist	54	Spiritual purpose, furniture	Bark	Rare
33	Male	Islamic scholar	45	Spiritual purpose, furniture	Leaves, bark	Not rare
34	Male	Islamic scholar	40	Spiritual purpose	Leaves	Rare
35	Male	Islamic scholar	55	Spiritual purpose	Stem,	Not rare
36	Male	Farmer	56	Spiritual purpose	Seed, bark	Not rare
37	Male	Herbalist	50	Spiritual purpose	Bark	Rare
38	Male	Islamic scholar	42	Spiritual purpose	Bark	Rare
39	Male	Islamic scholar	40	Spiritual purpose	Leaves, roots	Rare
40	Male	Islamic scholar	45	Medicine (Ease childbirth)	Seed, leaves, root	Rare

	Gender	Occupation	Age	Uses	Part used	Is the plant rare or not?
41	Male	Herbalist	50	Spiritual purpose	Root, leaves	Rare
42	Male	Herbalist	60	Spiritual purpose	Bark	Unknown
43	Male	Herbalist	55	Spiritual purpose, Medicine (aphrodisiac)	Root	Unknown
44	Male	Herbalist	50	Spiritual purpose	Seed	Unknown
45	Male	Herbalist	65	Spiritual purpose	Bark	Unknown
46	Male	Farmer/ Herbalist	56	Furniture, medicine (aphrodisiac), spiritual purpose	Seed, bark, root	Unknown
47	Female	Traditional nurse	54	Spiritual purpose	Leaves	Rare
48	Male	Trader	65	Spiritual purpose	Leaves, roots, bark	Rare
49	Male	Islamic scholar	48	Spiritual purpose	Bark	Rare
50	Female	Herbalist	58	Spiritual purpose	Bark	Rare
51	Male	Herbalist	45	Spiritual purpose	Bark	Not rare
52	Female	Trader	40	Spiritual purpose	Bark	Rare
53	Male	Islamic scholar	50	Spiritual purpose	Bark	Not rare
54	Female	Trader	56	Medicine (Rheumatism)	Bark	Rare
55	Female	Trader	55	Cooking	Seed	Not rare
56	Male	Carpenter	42	Firewood	Stem	Not rare
57	Male	Herbalist	60	Spiritual purpose	Bark	Rare
58	Male	Islamic scholar	48	Spiritual purpose	Seed	Rare
59	Male	Carpenter	Unknown	Timber production	Stem	Rare
60	Female	Trader	50	Timber production, medicine	Stem, root, leaves	Rare

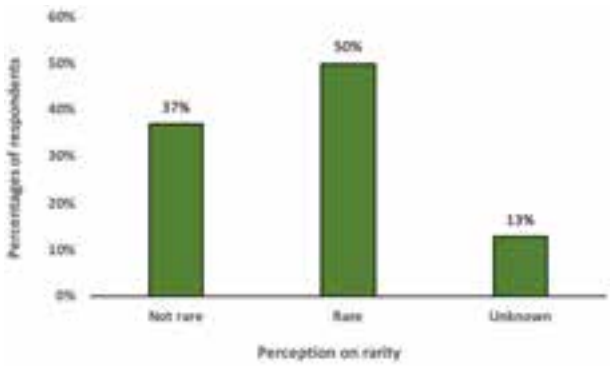


Figure 4. Percentages of respondents that showed their knowledge on rarity of Afzelia africana where this study was conducted.

(Figure 2). A study conducted by Balima et al. (2018) on ethnobotany of *Afzelia africana* in Burkina Faso revealed that after fodder and medicine, the most common uses of this species were the use for spiritual purpose. This revealed in a community in Burkina Faso, *Afzelia africana* is known for spiritual uses but not as common as medicinal and fodder while in Ijebu Igbo a small community in Nigeria where this study was conducted *Afzelia africana* is more popular for spiritual uses than uses for medicine and fodder (Figure 2). Studies have shown that certain communities preserve some plant species due to some spiritual perception attached to the plant species (Shukla & Gardner 2006; Irakiza et al. 2016; Rankoana 2016; Yeshi et al. 2021). Also, the study by Balima et al. (2018) further revealed that *Afzelia africana* is protected in the traditional agroforest systems in Burkina Faso due to the spiritual belief attached to this plant. This implies that the spiritual perception of this plant species might contribute to the local conservation of this species.

Harvesting of *Afzelia africana* for medicinal uses

Plant harvest for medicinal purposes keeps generating concerns in biodiversity conservation (Jimoh et al. 2023). Continuous harvest of threatened species for medicinal uses will keep aggravating the decline of their populations (Williams et al. 2013; Bamigboye et al. 2017; van Wyk & Prinsloo 2018). Harvest for medicinal uses have been identified as a threat to *Afzelia africana* (Bamigboye et al. 2022). Next to spiritual purpose, harvest for medicinal uses was the most mentioned by the respondents in this study (Figure 2). Continuous harvest of this species for medicinal purpose will

increase the risk of extinction of this species if not done in a sustainable manner.

Bark harvesting of *Afzelia africana*

Bark harvesting have been a practice responsible for plant species extinction (Bamigboye et al. 2018). Bark harvesting can lead to death of individuals of tree species and it can result into poor regeneration of tree species (Tshisikhawe et al. 2012). Nacoulma et al. (2016) revealed that bark harvesting of *Afzelia africana* reduced its fruit production, thereby affecting its reproduction. This study identified bark harvesting of *Afzelia africana* for spiritual and medicinal purpose as common practice in this community where this study was conducted (Table 1; Figure 3). The practice of bark harvesting will reduce the regeneration potential of this species if they are not done in a sustainable way.

Harvesting of *Afzelia africana* for timber production

Harvest of tree taxa for timber production poses threats to the survival of many tree species and it has exterminated many populations of tree taxa hence increase their risk of extinction (Edward et al. 2014; Bont et al. 2020). The economic viability of this adventure has made many people defer regulations and engage in indiscriminate harvest of so many trees which is contributing to biodiversity loss (Frey et al. 2021). From ecological perspective, arboreal species that survive based on the presence of these trees have to migrate through ecological corridors due to habitat fragmentation (Arroyo-Rodríguez & Mandujano 2009). The susceptibility of these species to habitat fragmentation is due to the practice of removing individuals of tree species from the wild for timber production. Some studies have reported *Afzelia africana* being excessively harvested for timber production and also project this practice as the main threats to this species (Mensah et al. 2014; Assogbadjo et al. 2017; Biara et al. 2020). In a bit of a contrary, this study found this plant to be more desired in Ijebu Igbo, Ogun-State, Nigeria where this study was conducted for spiritual and medicinal purposes more than that for timber production (Figure 2). This implies that there may be less popularity of this species for timber production in this area or the spiritual belief attached to the plant might have restricted the practice of harvesting this species for timber production.

Perception on rarity of *Afzelia africana*

Perception on rarity is extremely important in biodiversity. Species perceived to be rare can become target of harvest for economic gains thereby increasing their risk of population decline (Courchamp et al. 2006; Hall et al. 2008). Online and offline resources consulted on this subject could not reveal that *Afzelia africana* is currently protected in Nigeria. Based on the current perception on the rarity of the species (Figure 4) in this study, it is recommended that *Afzelia africana* should be protected in Nigeria.

CONCLUSION

This study revealed that several parts of *Afzelia africana* are being harvested for different purposes which might keep declining the populations of this species in the wild. Intensive harvest over time will further aggravate the risk of extinction of *Afzelia africana* in Nigeria. This study recommends that further studies on population ecology of *Afzelia africana* should be carried out to determine the current status of this species in terms of conservation in Nigeria. There is a need for creating local awareness among the indigenous people on the need to conserve this species. Prohibition of indiscriminate harvest of *Afzelia africana* should be enacted by local conservation authorities. Local cultivation of *Afzelia africana* within the region of this study should be encouraged to prevent extirpation of this species and also improve its regeneration in Nigeria.

REFERENCES

Arroyo-Rodríguez, V. & S. Mandujano (2009). Conceptualization and measurement of habitat fragmentation from the primates' perspective. *International Journal of Primatology* 30: 497–514.

Assogbadjo, A.E., S. Mensah & R.G. Kakaï (2017). The relative importance of climatic gradient versus human disturbance in determining population structure of *Afzelia africana* in the Republic of Benin. *Southern Forests* 79(2) 1–17. https://doi.org/10.2989/20702620.2016.1255406

Avornyo, F.K., R.B. Zougmore, S.T. Partey & K. Tengan (2018). Candidate fodder trees and shrubs for sustainable ruminant production in northern Ghana. *Livestock Research for Rural Development* 30(9): 1–8.

Aziz, M.A., A.M. Abbasi, Z. Ullah & A. Pieroni (2020). Shared but threatened: The heritage of wild food plant gathering among different linguistic and religious groups in the Ishkoman and Yasin Valleys, North Pakistan. *Foods* 9(5): 601.

Bont, L.G., M. Fraefel, F. Frutig, S. Holm, C. Ginzler & C. Fischer (2022). Improving forest management by implementing best suitable timber harvesting methods. *Journal of Environmental Management* 302: 114099.

Balima, L.H., B.M.I. Nacoulma, S.S. Da, A. Ouédraogo, D. Soro & A. Thiombiano (2022). Impacts of climate change on the geographic distribution of African Oak Tree (*Afzelia africana* Sm.) in Burkina Faso, West Africa. *Heliyon* 8(1): e08688. https://doi.org/10.1016/j.heliyon.2021.e08688

Balima, L.H., B.M.I. Nacoulma, M.R.M. Ekué, F.N.G. Kouamé & A. Thiombiano (2018). Use patterns, use values and management

of *Afzelia africana* Sm. in Burkina Faso: Implications for species domestication and sustainable conservation. *Journal of Ethnobiology and Ethnomedicine* 14(1): 23. https://doi.org/10.1186/s13002-018-0221-z

Bamigboye, S.O., S.A. Odewo., M.O. Jimoh., I.A. Lasisi & B.O. Momo (2022). Studies on extinction risk of genus *Afzelia* in Nigeria from biogeographical perspective. Nigerian *Annals of Pure and Applied Sciences* 5(1): 291–199.

Bamigboye, S.O., P.M. Tshisikhawe & M.A. Bonta (2018). Review of extinction risks in South African cycads used for traditional medicine. *South African Journal of Botany* 115: 279. https://doi.org/10.1016/j.sajb.2018.02.016

Bamigboye, S.O., P.M. Tshisikhawe & P.J. Taylor (2017). Detecting threat to *Encephalartos transvenosus* (Limpopo Cycad) through indigenous knowledge in Limpopo Province, South Africa. *Indian Journal of Traditional Knowledge* 16(2): 251–255.

Bayewu O.O., M.O. Oloruntola., G.O. Mosuro., I.O. Folorunso & A.U. Kolawole (2014). Evaluation of resistivity anisotropy of parts of Ijebu Igbo, southwestern, Nigeria using azimuthal resistivity survey (ARS) method. *Journal of Geography and Geology* 6(4): 1916– 9787.

Biara, E.A., S. Egeru, J. Mensah, M.M. Biira & M.M. Kadigo (2021). Socio-economic factors influencing *Afzelia africana* Sm. use value and traditional knowledge in Uganda: implications for sustainable management. *Environmental Development and Sustainability* 23: 2261–2278. https://doi.org/10.1007/s10668-020-00673-6

Brockerhoff, E.G., L. Barbaro, B. Castagneyrol, D.I. Forrester, B. Gardiner, J.R. González-Olabarria, P.O.B. Lyver, N. Meurisse, A. Oxbrough, H. Taki, & I.D. Thompson (2017). Forest biodiversity, ecosystem functioning and the provision of ecosystem services. *Biodiversity and Conservation* 26: 3005–3035. https://orcid.org/10.1007/s10531-017-1453-2

Byabashaija, M.D., J.F.O. Esegu, J.M. Kidiya, M. Basoga & R.K. Ondia (2004). Traditional uses of indigenous tree species. *Uganda Journal of Agricultural Sciences* 9: 367–371.

Courchamp, F., E. Angulo, P. Rivalan, R.J. Hall, L. Signoret, L. Bull & Y. Meinard (2006). Rarity value and species extinction: the anthropogenic Allee effect. *Public Library of Science Biology* 4(12): 2405–2410. https://doi.org/10.1371/journal.pbio.0040415

Cuni-Sanchez A., M. Pfeifer, R. Marchant & N.D. Burgess (2016). Ethnic and locational differences in ecosystem service values: insights from the communities in forest islands in the desert. *Ecosystem Services* 19: 42–50. https://doi.org/10.1016/j.ecoser.2016.04.004

Dıaz, S., J. Settele, E.S. Brondızio, H.T. Ngo, J. Agard & A. Arneth (2019). Pervasive human-driven decline of life on Earth points to the need for transformative change. *Science* 366(6741): 3100. https://doi.org/10.1126/science.aax3100

Edward, D.P., J.A. Tobias, D. Sheil, E. Meijaard & W.F. Laurance (2014). Maintaining ecosystem function and services in logged tropical forests. *Trends in Ecology and Evolution* 29(9): 511–520. https://doi.org/10.1016/j.tree.2014.07.003

Frey, G.E., S. Charnley & J. Makala (2021). Economic viability of community-based forest management for certified timber production in southeastern Tanzania. *World Development* 144: 105491. https://doi.org/10.1016/j.worlddev.2021.105491

Gupta, S.M. (1971). *Plant Myths and Traditions in India*. Brill, Leiden, xii + 117 pp.

Gupta, S.M. (1996). *Plants in Indian Temple Art*. BR Publishing Corporation, India, 256 pp.

Haines-Young, R. & M. Potschin (2010). The links between biodiversity, ecosystem services and human well-being. *Ecosystem Ecology: A New Synthesis* 1: 110–139.

Hall, R.J., E.J. Milner-Gulland & F. Courchamp (2008). Endangering the endangered: the effects of perceived rarity on species exploitation. *Conservation Letters* 1(2): 75–81. https://doi.org/10.1111/j.1755-263X.2008.00013.x

Hills, R. (2020). *Afzelia africana*. The IUCN Red List of Threatened Species 2020: e.T33032A67742420. https://doi.org/10.2305/IUCN.UK.2020-3.RLTS.T33032A67742420.en. Accessed on 19 February 2024.

Houdanon, R.D., S. Mensah, C. Gnangle, N.S. Yorou & M. Houinato (2018). Ecosystem services and biomass stock from bamboo stands in central and southern Benin, West Africa. *Energy, Ecology and Environment* 3: 185–194. https://doi.org/10.1007/s40974-018-0084-0

Houehanou, T.D., K. Prinz, D. Koua, F. Hellwig, A. Ebou, G. Gouwakinnou, A.E. Assogbadjo, R.L.G. Kakaï & A. Zézé (2023). Genetic diversity and population structure of a threatened tree species *Afzelia africana* Sm. ex Pers. among climatic zones for conservation challenges in Benin (West Africa). *Genetic Resources and Crop Evolution* 70(6): 1617–1632. https://doi.org/10.1007/s10722-022-01523-2

Irakiza, R., M. Vedaste, B. Elias, B. Nyirambangutse, N.J. Serge & N. Marc (2016). Assessment of traditional ecological knowledge and beliefs in the utilization of important plant species: The case of Buhanga saed forest, Rwanda. *Koedoe* 58(1): 1–11.

Jiao, Y., Y. Ding, Z. Zha & T. Okuro (2019). Crises of biodiversity and ecosystem services in satoyama landscape of Japan: a review on the role of management. *Sustainability* 11(2): 454. https://doi.org/10.3390/su11020454.

Jimoh, M.A., M.O. Jimoh, S.A. Saheed, S.O. Bamigboye, C.P. Laubscher & L. Kambizi (2023). Commercialization of Medicinal Plants: Opportunities for Trade and Concerns for Biodiversity Conservation. In: Kambizi, L. & C. Bvenura (eds.). Sustainable Uses of Medicinal Plants. Taylor & Francis, CRS Press: Boca Raton, FL, 678 pp.

Kandari, L.S., V.K. Bisht, M. Bhardwaj & A.K. Thakur (2014). Conservation management of sacred groves, myths and beliefs of tribal communities: a case study from north-India. *Environmental Systems Research* 3(16): 1–10. https://doi.org/10.1186/s40068-014-0016-8

Kawa, N.C., 2016. How religion, race, and the weedy agency of plants shape Amazonian home gardens. *Culture Agriculture Food and Environment* 38(2): 84–93. https://doi.org/10.1111/cuag.12073

Marchese, C. (2015). Biodiversity hotspots: A shortcut for a more complicated concept. *Global Ecology and Conservation*, 3: 297-309. https://doi.org/10.1016/j.gecco.2014.12.008

Mensah, S., R. Veldtman, A.E. Assogbadjo, C. Ham, R.G. Kakaï & T. Seifert (2017). Ecosystem service importance and use vary with socio-environmental factors: A study from household-surveys in local communities of South Africa. *Ecosystem Services* 23: 1–8. https://doi.org/10.1016/j.ecoser.2016.10.018

Mensah, S., T.D. Houehanou, E.A. Sogbohossou, A.E. Assogbadjo & R.G. Kakaï (2014). Effect of human disturbance and climatic variability on the population structure of *Afzelia africana* Sm. ex pers. (Fabaceae–Caesalpinioideae) at country broad-scale (Bénin, West Africa). *South African Journal of Botany* 95: 165–173. https://doi.org/10.1016/j.sajb.2014.09.008

Nacoulma, B.M.I., A.M. Lykke, S. Traoré, B. Sinsin & A. Thiombiano (2016). Impact of bark and foliage harvesting on fruit production of the multipurpose tree *Afzelia africana* in Burkina Faso (West Africa). *Agroforestry System* 94: 597–606. https://doi.org/10.1007/s10457-016-9960-9

Negi, C.S. (2005). Religion and biodiversity conservation: not a mere analogy. *International Journal of Biodiversity Science and Management* 1(2): 85–96. https://doi.org/10.1080/17451590509618083

Nzekwe, U., G.C. Ajuziogu, E.U. Njoku, G.I. Okafor, M.B. Sani, C.C. Onyeke, C.C. Onyeonagu, A.A. Ohaneje & C.S. Eze (2016). Nutritional food content of seed and effects of five different growing media on the seed germination and seedling growth of *Afzelia africana* SM Caesalpiniaceae. *African Journal of Biotechnology* 15(11): 384–391. https://doi.org/10.5897/AJB2015.14418

Olanipekun, L. (2022). Indigenous crime control in selected communities of ijebu north local government area of ogun state. *Spectrum Journal of Innovation, Reforms and Development* 21: 25–41.

Oshingboye, A., G. Nodza., T. Onuminya & O. Ogundipe (2017). Evaluating the utility of *rbcL* in identifying Nigerian species of the genus *Afzelia* Sm. Fabaceae (Caesalpinioideae). *Turkish Journal of*

Botany 41(5): 455–463. https://doi.org/10.3906/bot-1610-9

Pimm, S. L. (2021). What we need to know to prevent a mass extinction of plant species. *Plants, People, Planet* 3(1): 7-15. https://doi.org/10.1002/ppp3.10160

Rankoana, S. (2016). Sustainable use and management of indigenous plant resources: a case of mantheding community in Limpopo Province, South Africa. *Sustainability* 8(3): 221. https://doi.org/10.3390/su8030221

Rasethe, M., M. Potgieter & M. Pfab (2022). The utilization of selected threatened or protected plant species; a case of Limpopo Province, South Africa. *Sustainability* 14(3): 1–19. https://doi.org/10.3390/su14031073

Shukla, S. & J. Gardner (2006). Local knowledge in community-based approaches to medicinal plant conservation: Lessons from India. *Journal of Ethnobiology and Ethnomedicine* 2(1): 20–29. https://doi.org/10.1186/1746-4269-2-20

Tshisikhawe, M.P., M.W. van Rooyen & R.B. Bhat (2012). An evaluation of the extent and threat of bark harvesting of medicinal plant species in the Venda Region, Limpopo Province, South Africa. *Phyton International Journal of Experimental Botany* 81: 89–100.

van Wyk, A.S. & G. Prinsloo (2018). Medicinal plant harvesting, sustainability and cultivation in South Africa. *Biological Conservation* 227: 335–342. https://doi.org/10.1016/j.biocon.2018.09.018

Williams, V.L., J.E. Victor & N.R. Crouch (2013). Red listed medicinal plants of South Africa: Status, trend and assessment challenges. *South African Journal of Botany* 86: 23–35. https://doi.org/10.1016/j.sajb.2013.01.006

Yeshi, K., J. Aagaard-Hansen & P. Wangchuk (2021). Medicinal, nutritional, and spiritual significance of plants in Bhutan: their biodiscovery potential and conservation status, pp. 1–25. In: Abbasi, A.M. & R.W. Bussmann (eds). *Ethnobiology of Mountain Communities in Asia*. Springer Nature Switzerland, xiv + 439 pp. https://doi.org/10.1007/ 978-3-030-55494-11

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 February 2024 | 16(2): 24804–24806
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.7338.16.2.24804-24806
#7338 | Received 16 April 2021 | Final received 18 December 2023 | Finally accepted 08 January 2024
SHORT COMMUNICATION

OPEN ACCESS

Gastrointestinal parasites of the Indian Flying Fox *Pteropus medius* in Nagpur City: a seasonal study through faecal sample analysis

Ruchika R. Sangale [1] & **Priya Gawande** [2]

[1] Department of Animal Reproduction Gynaecology and Obstetrics, Post Graduate Institute of Veterinary and Animal Sciences, Akola, Maharashtra 444001, India.
[2] Department of Veterinary Parasitology, Nagpur Veterinary College, Nagpur Maharashtra 440006, India.
[1] ruchikasangle96@gmail.com (corresponding author), [2] priya.gawande5@gmail.com

Abstract: The Indian Flying Fox *Pteropus medius*, among the largest Indian fruit eating bats, is commonly observed with unhurried wing beats at dusk and tends to roost during the day in sizable, noisy colonies situated on trees within bustling towns and villages. Notably, these colonies are prevalent in busy areas of Nagpur city, particularly on expansive Banyan Trees *Ficus bengalensis* and Pangom Oil Trees *Millettia pinnata*, owing to the consistent availability of fruits and flowers throughout the year. This study focuses on evaluating gastrointestinal helminth infection in fruit-eating bats during the summer, monsoon, and winter seasons in Nagpur city, Maharashtra. A total of 58 samples were collected, processed, and examined using the double sedimentation technique. Of these, 46 samples (80.01%) tested positive for *Ascaris* spp. eggs, with a higher percentage during the monsoon season. Additionally, during the peak summer season, a juvenile flying fox from one of the colonies was rescued in a dehydrated state, displaying crusty scab-like lesions on the wing's anterior and posterior regions. Subsequent examination revealed the presence of the ectoparasite *Macronyssus* spp. on body of the juvenile Indian Flying Fox.

Keywords: *Ascaris* spp., Banyan Tree, dehydration, ectoparasite, helminths, *Macronyssus* spp., mites, nematode, Pangom Oil Tree, sedimentation technique.

Bats, belonging to the order Chiroptera, represent the only volant mammals globally, encompassing 1,116 species. They are further classified into Megachiroptera (fruit bats) and Microchiroptera (insectivorous bats), based on their feeding habits and morphological adaptations. Constituting 20% of the world's mammals, bats play crucial roles as pollinator, seed disperser, and influencing germination of local plant communities (Digana et al. 2000; Louis et al. 2008). Their significance extends in structuring and regenerating forest, especially in cleared areas (Gorghov et al. 1993; Rainey et al. 1995). Beyond ecological contributions, bats provide economic benefits such as biological pest control, guano mining, and support for tourism, education, and research.

Despite these positive aspects, some bat species can have negative effects, causing damage to humans, livestock, crops, buildings, and infrastructure. They may also pose risks such as airplane strikes, disease transmission, and contamination (Louis et al. 2008). Furthermore, bat population is appeard to be declining due to various human-induced environmental stresses and misbeliefs, including habitat destruction, disturbance to caves, food resource depletion, overhunting, pesticide use, and the spread of parasitic and infectious diseases. In view of their overlooked importance, bat conservation becomes imperative (Dittmar et al. 2009).

This study aims to assess major gastrointestinal helminth infections in fruit-eating bats during the summer, winter, and monsoon season, contributing to our understanding of bat health and ecosystem dynamics.

Editor: Anonymity requested.

Date of publication: 26 February 2024 (online & print)

Citation: Sangale, R.R. & P. Gawande (2024). Gastrointestinal parasites of the Indian Flying Fox *Pteropus medius* in Nagpur City: a seasonal study through faecal sample analysis. *Journal of Threatened Taxa* 16(2): 24804–24806. https://doi.org/10.11609/jott.7338.16.2.24804-24806

Funding: Self-funded.

Competing interests: The authors declare no competing interests.

Acknowledgements: R. Sangle and P. Gawande are thankful to NGO, WILD-CER, and Dr. Bahar Baviskar for timely guidance and support.

Material and Methods

Samples were collected from the different roosting sites. Amongst them two sites located at 21.158°N, 79.068°E, are close to the Maharashtra State Veterinary Council office (MSVC), and one additional site (21.158°N, 79.064°E) near Nagpur's High Court area (Image 1). The fresh samples were collected twice a week early in the morning (7:00 AM- 8:00 AM) using forceps and placed in labeled sterile plastic bottles, and routinely processed for helminthic ova using the double sedimentation technique. This method concentrates eggs for observation under a microscope (10x). To execute the technique, placed 5 g of fecal sample in a beaker, mixed thoroughly with 10–15 ml of water, repeated the process until level reached to 50 ml, and then poured through a wire mesh sieve into a sedimentation flask. Filled to the brim and left to settle for 20 minutes. Immediately decanted the supernatant, the 15 ml of water added to the sedimentation flask and shaken, Supernatant poured into a beaker, and allowed to settle for 20 more minutes, and decanted again. Finally, last single drop of sediment was taken and placed on a glass slide, covered with a glass slip, and examined under the microscope (10x) for ova (Image 2). Ectoparasites were collected from rescue juvenile flying fox during clinical examination. The collected ectoparasites kept in glycerol, and directly mounted on a microscope slide, covered, and examined (Soulsby 1982).

Results and Discussion

A total of 58 samples were collected over one calendar year from three roosting sites of Indian Flying Foxes (refer to Table 1). Among them, 46 samples tested positive for the presence of helminthic ova, specifically *Ascaris* spp., in alignment with the findings of Louis et al. (2008). The seasonal prevalence of endoparasitic infection was notably higher during the monsoon season, consistent with the results reported by Fowler (1986).

Ectoparasites, identified as *Macronyssus* spp. mites (Image 3), were collected from rescued juvenile flying foxes, a pattern observed similarly by Radovsky & Krantz (1998). The mites were noted infesting bats, appearing as tiny moving specks or red 'jewels' (Radovsky 1967). *Macronyssus* spp. mites were significantly present on wing membrane areas posterior to the radius ulna and within the fur. Protonymph stages were predominantly found on wing membranes, while adult mites concentrated more on the head, as reported by Spears et al. (1999).

Conclusion

Primary goal of study was the seasonal fecal sample analysis for intestinal parasite of the Indian Flying Fox *Pteropus medius*, for contributing valuable current insights into the prevalent gastrointestinal parasites affecting free-roaming bat populations. The findings revealed that 80.01% of faecal samples were infected with the gastrointestinal parasite *Ascaridia* spp., aligning with Fowler's (1986) observations. The endoparasitic infection originates from environmental contamination, possibly through polluted water or food sources. In

Image 1. Map showing the study area - Marked with pointing arrows roosting sites of the Indian Flying Fox, Nagpur, Maharashtra, India. © Google maps.

Table 1. The number of faecal samples collected and samples positive for *Ascaris* spp.

Season	No. of samples	No. of samples positive for *Ascaris* spp.	Percentage of positive samples
Summer	19	15	78.94 %
Monsoon	18	17	94.44 %
Winter	21	14	66.66 %
		Average percent	**80.01%**

Image 2. Ova of *Ascaris* sp. © Priya Gawande.

this study, the nematode infection was commonly found probably due to its direct life cycle involving no intermediate host and easy transmitted by oro-fecal route through contaminated feed, water, and soil and has the potential to accumulate in a free-ranging flying fox population (Fowler 1986). Moreover, further studies are required to rule out the role in zoonotic transmission. Additionally, the study documented *Macronyssus* spp. mites. These parasites feed on their host's blood and lymph and can complete their life cycle partially outside the host (Dittmar et al. 2009; Radovsky 2010). This finding is notable due to *Macronyssus* spp.'s known distribution in Europe and its original host being the bat *Nyctalus leisleri*, according to Fain et al. (2003).

Image 3. Mite *Macronyssus* sp. © Priya Gawande.

References

Digana, P.M.C.B., W.B.Yapa, P.V. Randeniya & W.D. Ratnasooriya (2000). Roost selection of Sri Lankan bats. Proceeding of the 1st Annual Sessions, University of Colombo, Sri Lanka, 39 pp.

Dittmar, K., C.W. Dick, B.D. Patterson, M.F. Whiting & M.E. Gruwell (2009). Pupal deposition and ecology of bat flies (Diptera: *Streblidae*) in a Mexican cave habitat. *Journal of Parasitology* 95(2): 308–314. https://doi.org/10.1645/GE-1664.1

Fain, A., G. Walter & M. Heddergott (2003). A new species of *Macronyssus kolenati* (Acari: *Macronyssidae*) from Leisler's Bat, *Nyctalus leisleri* (Mammalia: *Chiroptera*) in Germany. *International Journal of Acarology* 29: 55–61.

Fowler, M.E. (1986). *Zoo Wild Animal Medicine 2nd Edition*. Saunders Company, Hong Kong, 316 pp.

Gorghov, L., F. Cornejo, C.A. Scorra & M.J. Amarillo (1993). The role of seed dispersal in the natural regeneration of rain forest after strip-cutting in the Peruvian Amazon. *Vegetatio* 107: 339–349. https://doi.org/10.1007/BF00052233

Louis, J.R., P.P. Mohan, C. Mahendran, A. Venhatesan, K. Prabhu, B. Ravichandran & S. Molur (2008). A survey of the roosting sites of Indian Flying Fox *Pteropus giganteus* in and around Coimbatore and Palakkad districts, India. *Bat Net* 9(1): 11–12.

Radovsky, F.J. (1967). The *Macronyssidae* and *Laelapidae* (Acarina: *Mesostigmata*) parasites on bats. University of California Publications in Entomology 46. University of California Press, viii + 288 pp.

Radovsky, F.J. & G.W. Krantz (1998). A new genus and species of predaceous mite in the parasitic family *Macronyssidae* (Acari: *Mesostigmata*). *Journal of Medical Entomology* 35(4): 527–537.

Radovsky, F.J. (2010). Revision of genera of the Parasitic mite family *Macronyssidae* (Mesostigmata: *Dermanyssoidea*) of the world. Indira Publishing House, Michigan, 170 pp.

Rainey, W.E., E.D. Pierson, T. Elmqvist & P.A. Cox (1995). The role of flying foxes (*Pteropodidae*) in oceanic island ecosystems of the Pacific. *Symposia of the Zoological Society of London* 67: 79–96.

Soulsby, E.J.L. (1982). *Helminths, Arthropods and Protozoa of Domesticated Animals, 7th edition*. Bailliere Tindall, 809 pp.

Spears, R.E., L.A. Durden & D.V. Hagan (1999). Ectoparasites of Brazillian free-tail bats with emphasis on anatomical site preferences for *Chiroptonyssus robustipes*; Class: Macronyssidae. *Journal of Medical Entomology* 36(4): 481–485.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 February 2024 | 16(2): 24807–24811
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.8853.16.2.24807-24811
#8853 | Received 23 November 2023 | Final received 15 December 2023 | Finally accepted 29 January 2024
OPEN ACCESS
SHORT COMMUNICATION

Plagiochila javanica (Sw.) Nees & Mont. (Marchantiophyta: Plagiochilaceae) rediscovered from the Western Ghats after 180 years

M.S. Sajitha [1], C.N. Manju [2], B. Mufeed [3], K.P. Rajesh [4] & K.K. Rawat [5]

[1,2,3] Bryology Division, Department of Botany, University of Calicut, Calicut University P.O, Malappuram District, Kerala 679635, India.
[4] Department of Botany, the Zamorin's Guruvayurappan College (affiliated to the University of Calicut), GA College PO, Kozhikode, Kerala 673014, India.
[5] Plant Diversity, Systematics and Herbarium Division, CSIR-National Botanical Research Institute (NBRI), Lucknow, Uttar Pradesh 226001, India.
[1] sajimenon.saradha@gmail.com (corresponding author), [2] manjucali@gmail.com, [3] mufeednaja@gmail.com,
[4] kprajesh.botany@gmail.com, [5] drkkrawat@rediffmail.com

Abstract: *Plagiochila javanica*, a widespread Asiatic member of the liverwort family Plagiochilaceae, is rediscovered from Western Ghats of Kerala, India after about 180 years of its first record from the country. The present discovery is a new record for Kerala state. A detailed description along with illustrations and images of the species are provided.

Keywords: 900 kandi, India, Kerala, liverwort, new record, Wayanad district.

Plagiochilaceae, one of the largest families of liverworts, consists of 82 members from India (Singh et al. 2016). The present taxon, *Plagiochila javanica* (Sw.) Nees & Mont. (sect. *Vagae* Lindenb.; Söderström et al. 2016) was described over 240 years ago from Indonesia (Java) as *Jungermannia javanica* Sw. (Swartz 1781: 35) and was transferred to the genus *Plagiochila* by Nees von Esenbeck & Montagne (1836: 52). Montagne (1842) subsequently reported the species from Nilgiri Hills from Western Ghats, where it had been collected from avalanche by the Swiss botanist and horticulturalist George Samuel Perrottet (1790–1870). Chopra (1943) and Parihar et al. (1994) wrongly listed the species from western Himalayas; Bapna & Kachroo (2000) described it from both western Himalaya and Nilgiri Hills but the taxon is totally omitted by Kachroo (1973) in his enumerations. Verma et al. (2015) mentioned the occurrence of this species in Nilgiri hills based on Montagne (1842). After the original collection, there is no other report of this species based on fresh collections from anywhere in India. Hence the present collection of this species from Wayanad district of Kerala is its rediscovery in Indian bryoflora after more than 180 years and is a new record for Kerala state.

Editor: Tamás Pócs, Eszterházy Károly University, Eger, Hungary.

Date of publication: 26 February 2024 (online & print)

Citation: Sajitha, M.S., C.N. Manju, B. Mufeed, K.P. Rajesh & K.K. Rawat (2024). *Plagiochila javanica* (Sw.) Nees & Mont. (Marchantiophyta: Plagiochilaceae) rediscovered from the Western Ghats after 180 years. *Journal of Threatened Taxa* 16(2): 24807–24811. https://doi.org/10.11609/jott.8853.16.2.24807-24811

Funding: Council of Scientific & Industrial Research (CSIR).

Competing interests: The authors declare no competing interests.

Acknowledgements: Sajitha is thankful to CSIR,New Delhi for the award of Research Fellowship. Manju and Mufeed are thankful to the DST-SERB for funding the Core Research Grant in the Department of Botany,University of Calicut. We acknowledge the authorities of the Department of Botany, University of Calicut for the facilities provided. We thank the Kerala Forest & Wildlife Department for giving permission to visit the field and its staff members at Meppadi range in Wayanad district for the support during the field studies. We also thank the Aranyakam Nature Foundation for the support during the field study. KPR & KKR are thankful respectively to the authorities of the Zamorin's Guruvayurappan College, Kozhikode, Kerala, India and CSIR-National Botanical Research Institute (NBRI), Lucknow, Uttar Pradesh, India for the support.

Materials and Methods

The plant was collected from "900 Kandi", a tourist spot in Wayanad District in the Western Ghats of Kerala, India. The specimen was collected in June 2023 from a rock surface. Its morphological characters were studied using a Leica S Apo Stereo Microscope and anatomical features with an Olympus CX21liLED Compound microscope. The digital images with appropriate scales were made using a Magcam DC5 5.1MP, 1/2.5 CMOS Sensor camera with Magnus Analytics MagVision (x64.4.8.15674.2-01991008) software. Line diagrams were based on digital microscopic images. The collected specimens were air dried and kept in herbarium packets of standard size. The voucher specimens were deposited in the University of Calicut Herbarium (CALI).

Taxonomic treatment

Plagiochila javanica (Sw.) Nees & Mont., Ann. Sci. Nat., Bot., sér. 2, 5: 52. 1836. *Jungermannia javanica* Sw., Meth. Musc. 35. 1781. – Type: Indonesia, Java, *Thunberg s.n*. (ex herb. Swartz, S, H-SOL) (Figure 1; Image 1).

Plants medium sized, 3.0–3.6 cm long and 5 mm wide (with leaves), yellowish-green, soft textured, not glossy; leafy stems erect from short creeping rhizomatous caulids, branching terminal (dichotomous) as well as lateral-intercalary (only to one side), rhizoids absent on aerial shoots, stem light brown, dorsally exposed and fully hidden ventrally. Branches as strong as main stem, apices attenuate. Stem in cross section 11–13 cells across, cortex 2–3 layered, cells 9.8–14 x 4.2–12 µm, thick-walled; medullary cells 13.9–20.5 x 10.0–16.0 µm, thin-walled. Leaves imbricate to contiguous normally and towards the tip it is contiguous to remote , obliquely horizontally spreading, oblong-ovate to broadly ovate, 1.5–1.7 mm long, 0.8–1.2 x 0.5–0.6 mm wide, dorsal margin straight with a partially concave basal part, longly decurrent, entire or with 1–2 teeth near apex, ventral margin arched, slightly overlapping with opposite leaf base, moderately decurrent, incurved at base, with 9–11 teeth; teeth 2–5 cells long, 2–3 cells wide at base, leaf apex toothed with 2–3 small teeth, the apical teeth not larger than those of the ventral margin 2 cells long and 2 cells wide. Cells near leaf apex 16.5–22.8 x 11.2–16.5 µm, median cells 21.5–30.0 x 11.5–19.0 µm, basal cells 23.0–34.8 x 16–22.5 µm, trigones small in median leaf cells, medium-sized in basal cells; paraphyllia absent; underleaves very small, 2–3 lobed. Sexual and asexual reproductive structures not observed.

Habitat: The species was found in west coast semi evergreen forest at an altitude of 1,180 m, growing in a rocky patch, associated with a number of other bryophytes like *Racopilum orthocarpum* Wilson ex Mitt., *Thuidium koelzii* H.Rob., *Cephalozia darjeelingensis* Udar & D.Kumar, *Pinnatella* sp., *Trichostomum tortelloides* (Broth. & Dixon) R.H.Zander, and *Fissidens pallidinervis* Mitt.

Distribution: In India this species was earlier known from the Western Ghats of Nilgiri hills (Montagne 1842). The present record is from "900 Kandi" in Wayanad District. *Plagiochila javanica* is widely distributed in southeastern Asia and the Pacific, where it is known from Thailand (Sukkharak et al. 2014), Vietnam (GBIF), Malaysia, Indonesia (Sumatra, Java, Kalimantan, Sulawesi, Bali, Sunda Islands), Papua New Guinea, Solomon Islands, Fiji and Samoa (Piippo 1989, 1993).

Representative specimens examined: India, Kerala: Wayanad District, on the way to "900 Kandi", on rock, 1,180 m elevation, 10.vi.2023, Mufeed B. & K.P. Rajesh 195157, 195180a (CALI).

Discussion

A total of 17 species of *Plagiochila* are distributed all over southern Western Ghats (Nilgiri Hills) (Srivastava et al. 2006; Verma et al. 2015), with a maximum number coming under section *Vagae* Lindenb., viz., *Plagiochila beddomei* Steph., *P. indica* Mitt. ex Steph., *P. nepalensis Lindenb., P. peradenyensis Schiffn., P. subtropica Steph., P. junghuhniana Sande* Lac. and *P. javanica* (Sw.) Nees & Mont. (Söderström et al. 2016). *P. palangiensis* S.C. Srivast., K.K. Rawat & P.K. Verma coming under sec. *Zanteniae* (Inoue) Inoue is endemic to the southern Western Ghats (Nilgiri Hills) (Srivastava et al. 2006) and *P. sisparensis* Steph. under sect. *Tayloriae* is endemic to Western Ghats-Sri Lanka hotspot (Verma et al. 2015). According to Inoue (1984), *P. javanica* is characterized by its distinct rhizomatous caulids, terminal and intercalary branching, contiguous to imbricate leaves with a shouldered but not ampliate ventral base, ventral margin curved at basal half with variable number of teeth and with teeth at leaf apex not larger than those of the leaf margin, and with vestigial underleaves. *P. javanica* has frequent branching as described by Inoue (1984) and the present collection shows very few branching. The Indian plants are comparatively smaller than the description by Inoue (1984), this may be due to the habitat variation. The large number of synonyms (see Inoue 1984; Piippo 1989; So 2000) indicates that the species is morphologically highly variable.

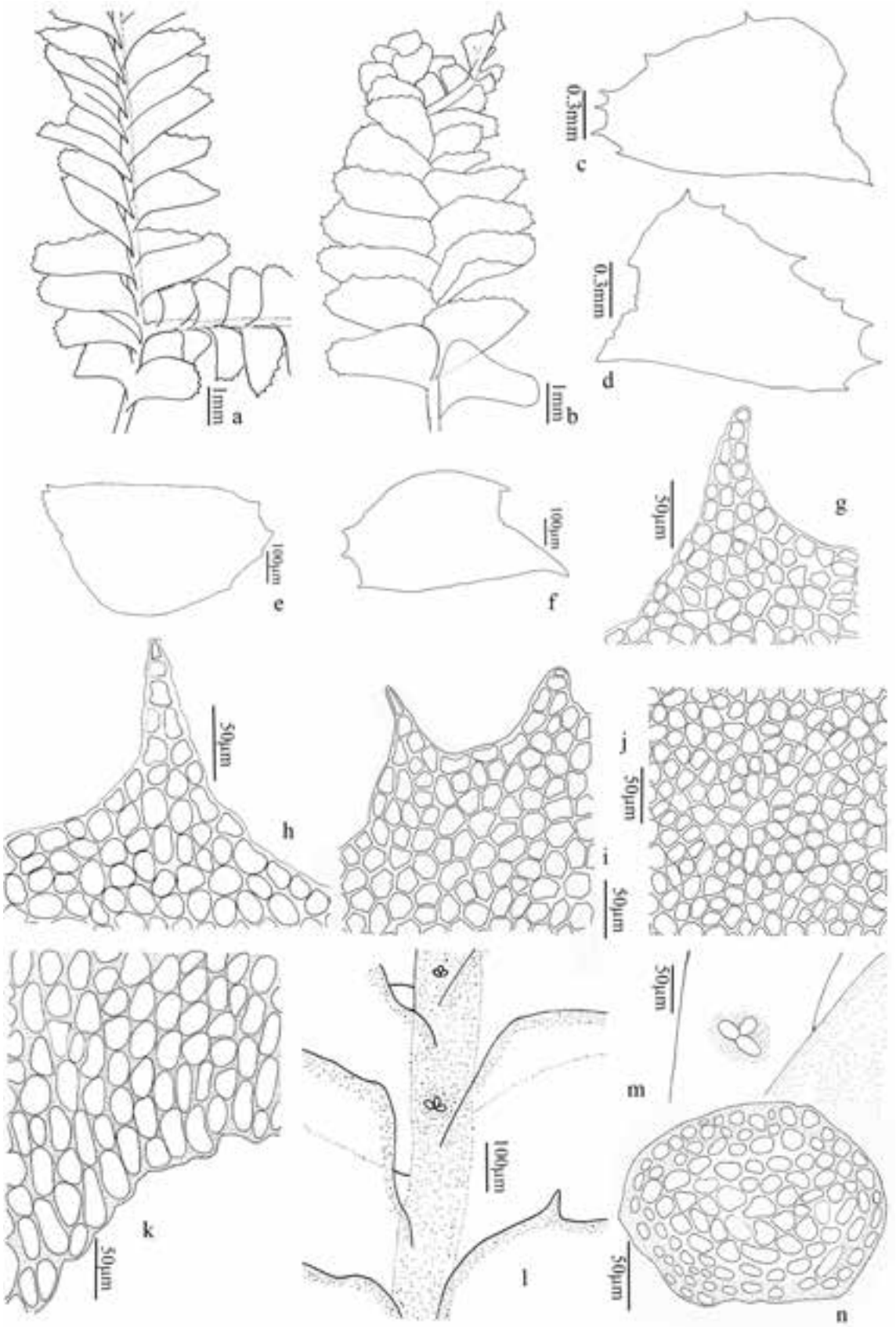


Figure 1. ***Plagiochila javanica*** **(Sw.) Nees & Mont.: a—dorsal view of plant | b—ventral view of plant | c–f—leaves | g–i—apical spines of leaf | j—median cells of leaf | k—basal cells of leaf | l & m—underleaves on stem surface | n—stem cross section. Illustration by M.S. Sajitha.**

Image 1. ***Plagiochila javanica*** **(Sw.) Nees & Mont.: a—habit | b—plant | c—dorsal view of shoot | d—ventral view of shoot | e–i—leaves | j–l—leaf marginal teeth | m—basal part of leaf | n—median cells of leaf | o—basal cells of leaf | p—underleaf on stem | q—underleaf enlarged | r—stem cross section. © M.S. Sajitha.**

References

Bapana, K.R. & P. Kachroo (2000). *Hepaticology in India – I*. Himanshu Publications, Udaipur, 491 pp.

Chopra, R.S. (1943). A census catalogue of Indian hepatics. *Journal of the Indian Botanical Society* 22: 237–259.

Inoue, H. (1984). *The Genus Plagiochila (Dum.) Dum. In Southeast Asia.* Academia Scientific Book, Tokyo, 142 pp. https://doi.org/10.18942/bunruichiri.KJ00001078477

Kachroo, P. (1973). Hepaticae of India – a taxonomic survey and census III. Plagiochilaceae through Pleuroziaceae. *Kashmir Journal of Science* 1: 141–161.

Montagne, C. (1842). Cryptogamae Nilgherienses seu plantarum cellularium in montibus peninsulae indicae Neel-Gherries dictis à Cl. Perrottet.collectarum. *enumeration Annales des Sciences Naturelles Botaniques* 17: 12–23.

Parihar, N.S., B. Lal & N. Katiyar (1994). *Hepatics and Anthocerotes of India. A new annotated checklist*. Indian Universities Press, Allahabad, 106 pp.

Piippo, S. (1989). Bryophyte flora of the Huon Peninsula, Papua New Guinea. XXX. Plagiochilaceae (Hepaticae). *Annales Botanici Fennici* 26: 183–236.

Piippo, S. (1993). Hepatics from the Solomon Islands I. *Nova Hedwigia* 56: 355–365.

Singh, D.K., S.K. Singh & D. Singh (2016). *Liverwort and Hornworts of India, An Annotated Checklist*. Botanical Survey of India, Kolkata, 439 pp.

So, M.L. (2000). *Plagiochila* sect. *Contiguae* (Hepaticae) in Australasia and the Pacific, with description of *Plagiochila subjavanica* sp. nov. *Australian Systematic Botany* 13(5): 808–815. https://doi.org/10.1071/SB00011

Söderström, L., A. Hagborg, M.V. Konrat, S. Bartholomew-Began, D. Bell, L. Briscoe, E. Brown, D.C Cargill, D.P. Costa, B.J. Crandall-Stotler, E.D. Cooper, G. Dauphin, J.J. Engel, K. Feldberg, D. Glenny, S.R. Gradstein, X. He, J. Heinrichs, J. Hentschel, A.L. Ilkiu-Borges, T. Katagiri, N.A. Konstantinova, J. Larraín, D.G. Long, M. Nebel, T. Pócs, F. Puche, E. Reiner-Drehwald, M.A.M. Renner, A. Sass-Gyarmati, A. Schäfer-Verwimp, J.G.S. Moragues, R.E. Stotler, P. Sukkharak, B.M. Thiers, J. Uribe, J. Vana, J.C. Villarreal, M. Wigginton, L. Zhang & R.L Zhu (2016). World checklist of Hornworts and Liverworts. *Phytokeys* 59: 1–828. https://doi.org/10.3897/phytokeys.59.6261

Srivastava, S.C., K.K. Rawat & P.K. Verma (2006). An interesting *Plagiochila* from Kodaikanal (India). *National Academy Science Letters* 29: 267–270.

Sukkharak, P., A. Likananonn & S. He (2014). A preliminary study of bryophytes in the Khao Soi Dao wildlife sanctuary, Chanthaburi Province, Thailand. *Songklanakarin Journal of Science and Technology* 36(5): 527–534.

Verma, P.K., K.K. Rawat & A. Alam (2015). *Plagiochila sisparensis* Steph.—a vulnerable liverwort from Nilgiri Hills, Western Ghats. *Plant Science Today* 2(4): 151–153. https://doi.org/10.14719/pst.2015.2.4.147

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 February 2024 | 16(2): 24812–24815
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.8823.16.2.24812-24815
#8823 | Received 10 November 2023 | Final received 21 January 2024 | Finally accepted 04 February 2024
OPEN ACCESS
SHORT COMMUNICATION

A new record of genus *Synedrus* Graham, 1956 with description of male of *Synedrus kasparyani* Tselikh, 2013 from India

Mubashir Rashid [1] & **Arvind Kumar** [2]

[1,2] Forest Entomology Discipline, Forest Research Institute, Dehradun, Uttarakhand 248006, India.
[1] mubashirchapoo10@gmail.com, [2] arvind.ento@gmail.com (corresponding author)

Abstract: The genus *Synedrus* Graham, 1956 is recorded from India for the first time. The male of *Synedrus kasparyani* Tselikh, 2013 is described. Additional characters and images of female are also provided.

Keywords: Biocontrol, citrus, diversity, Pteromalidae, parasitoids, Rutaceae, taxonomy.

The genus *Synedrus* Graham, 1956 based on the type species *Synedrus cavigena* Graham, 1956 was described from France. The genus is represented by only three species, viz: *Synedrus crassicornis* Graham, 1992 (from France); *Synedrus kasparyani* Tselikh, 2013 (from Russia & South Korea), and *Synedrus transiens* (Walker, 1835) (from Bulgaria, Czech Republic, Czechoslovakia, Netherlands, Sweden, United Kingdom, and Russia).
As such there is no host record for the species of *Synedrus* Graham, 1956 except *Synedrus transiens* (Walker, 1835) has been found to be associated with Fagaceae family (*Quercus* sp.) (Noyes, 2019). In the present study, both male and female specimens of *Synedrus kasparyani* Tselikh, 2013 were found to be associated with Rutaceae family (*Citrus* sp.).

Materials and Methods

The specimens were collected during field survey from Jammu & Kashmir in June 2021 with aspirator from Citrus and preserved in 80% alcohol. Specimen were examined under MAGNUS MSZ-Bi binocular microscope at FRI, Dehradun and genus level identification was done with the key of Bouček & Rasplus (1991); species level identification was done with that of Tselikh (2013) and Graham (1969). For the better description of the characters, photographs have been taken under Leica M-205C trinocular stereo zoom microscope fitted with HD camera, and images were analyzed with LAC-16 image analyzing software at systematic laboratory, Forest Entomology Discipline, ICFRE-FRI, Dehradun.

Morphological terminology follows Gibson (1997). Following abbreviations used in this paper are: POL—posterior ocellar line, the minimum distance between the posterior ocelli | OOL—ocello-ocular line, the minimum distance between the posterior ocellus and eye | F1–F6, funicular segments (antennal segments between anelli and clava); FW—forewing | SMV—submarginal vein | MV—marginal vein | PMV—postmarginal vein | STV—stigmal vein |T1–T6—tergum 1 to 6.

Specimen deposition: The specimens were deposited in National Forest Insect Collection (NFIC), Forest Research Institute, Dehradun, India and accession number was obtained.

Editor: P.M. Sureshan, Zoological Survey of India, Calicut, India.

Date of publication: 26 February 2024 (online & print)

Citation: Rashid, M. & A. Kumar (2024). A new record of genus *Synedrus* Graham, 1956 with description of male of *Synedrus kasparyani* Tselikh, 2013 from India. *Journal of Threatened Taxa* 16(2): 24812–24815. https://doi.org/10.11609/jott.8823.16.2.24812-24815

Funding: None.

Competing interests: The authors declare no competing interests.

Acknowledgements: Authors would like to thanks Director Forest Research Institute for providing research facilities.

Result and Discussion

Synedrus Graham, 1956

Genus *Synedrus* Graham, 1956 can be identified by the combination of characters: antennal formula 11353, while 11263 in male, 3rd anelli quadrate in female with micropilosity extending up to base of clava; pronotal collar carinate in both sexes; scutellum convex in profile/ lateral view. Nucha reticulate and long, median carina absent; traces of transverse carina are present; petiole transverse; stigma of FW moderately capitate; PMV longer than MV.

The male specimen of *Synedrus kasparyani* Tselikh, 2013 has been described here and the notes and illustrations of female specimen has been provided.

Synedrus kasparyani Tselikh, 2013

2013. Tselikh, E.V. Chalcid wasps of the family Pteromalidae (Hymenoptera, Chalcidoidea) of the Kuril Islands. *Entomologicheskoe Obozrenie*. 92(3): 620–621.

Synedrus kasparyani has been described from Russia based on the female type. It is first time recorded from India and its detailed morphological diagnostic note is provided here.

Female: (Image 1A–L). Body length 2.3 mm.

Coloration: Head, mesosoma golden yellow, gaster green with golden reflection; Eyes cupreous, ocelli silvery white; mandibles yellowish except teeth testaceous; palpi yellowish; antennae with scape and pedicelpale yellowish, anelli & flagellum brownish; FW hyaline, veins paler; legs with all coxae concolorous with mesosoma, rest of legs yellowish except tips of tarsal segments brown. Sculpture: Head strongly & uniformly reticulate, clypeal margin demarcated from face with striae radiating from face, clypeal region comparatively smoother from rest of face, reticulation on gena finer; mesosoma strongly but nonuniformly reticulate, mesoscutum and scutellum with deep & strong reticulation, axillar reticulation broader but superficial, axillula with small reticulation; mesoscutum & dorsellum smooth & shiny, nucha strongly reticulate, callus smooth.

Additional characters

Head: white curved hairs present on head; Antennae 11353, 3rd anelli quadrate; maxillary palpi 4-segmented; genal suture prominent.

Mesosoma: pronotal collar much narrower than mesoscutum, hind margin of mid lobe of mesoscutum produced, prepectus small, median carina absent, metanotum including dorsellum smooth & shiny; plicae sharply present, traces of transverse carina are present, spiracles oblong are of normal size, a spine or finger-nail like structure is present on both the sides of callus, long white hairs present on both sides of callus; FW bare in basal part, basal setal line present, cubital setal line absent, SMV 0.36x as long as FW length, stigma of FW moderately capitate, uncus present, short marginal fringes also present.

Metasoma: T1 longest, its hind margin slightly produced; hind margin of each tergite with at least one row of white setae, hypopygium reaching half of gaster (base of T4); ovipositor, exerted outside last tergite.

Material examined: 2 female, India: Jammu & Kashmir: Hidyal; 23.vi.2021; coll. Mubashir Rashid; Accession number- FRI/NFIC/22304-A,B.

Biology: Specimens were collected from *Citrus* sp.

Synedrus kasparyani Tselikh, 2013

Description: Male: (Image 2A–I). Body length 1.97 mm.

Color: (Image 2A–I). Head, mesosoma metallic green with diffuse coppery lustre, mandibles yellowish-brown except teeth brownish, eyes dark brown; antennae brownish with scape yellowish and pedicel testaceous; FW hyaline, veins brown. Legs with all coxae concolorous with mesosoma, proximal part of hind femur testaceous, rest of legs yellowish, tips of tarsal segments brown. Gaster bluish blackish or brownish with median part yellowish.

Sculpture: Head and mesosoma strongly and uniformly reticulate except clypeal region smooth with striae radiating from mouth margin, reticulation on malar region finer, axillar edges smooth; frenal area and nuchal reticulation same; metanotum, dorsellum, and callus smooth.

Head: (Image 2B–E). Clypeal margin with broad and short tooth, clypeal region distinctly separated from face with striae radiating from mouth margin. Head in frontal view 1.36x as broad as head height and dorsally 2.22x as broad as long; eyes 2.47x as long as broad; malar space 0.53x as long as eye length; antennal toruli-vertex 0.61x as long as antennal toruli-clypeus; distance between eyes 0.62x as long as head breadth; POL 1.27x OOL; temple 0.18x as eye length. Genal suture strongly present; Mandibles with four teeth each. Antennae (Images 2D,E) 11263, inserted nearly in the middle of face with scape reaching or slightly above median ocelli, antennal scrobes shallow, all flagellar segments hairy, distinctly longer than broad; pedicel somewhat globular, F1 approximately 2x pedicel, clava longer than two preceding flagellar segments combined (F5+F6).

Mesosoma: (Image 2F–H). Mesosoma, 1.6x as long

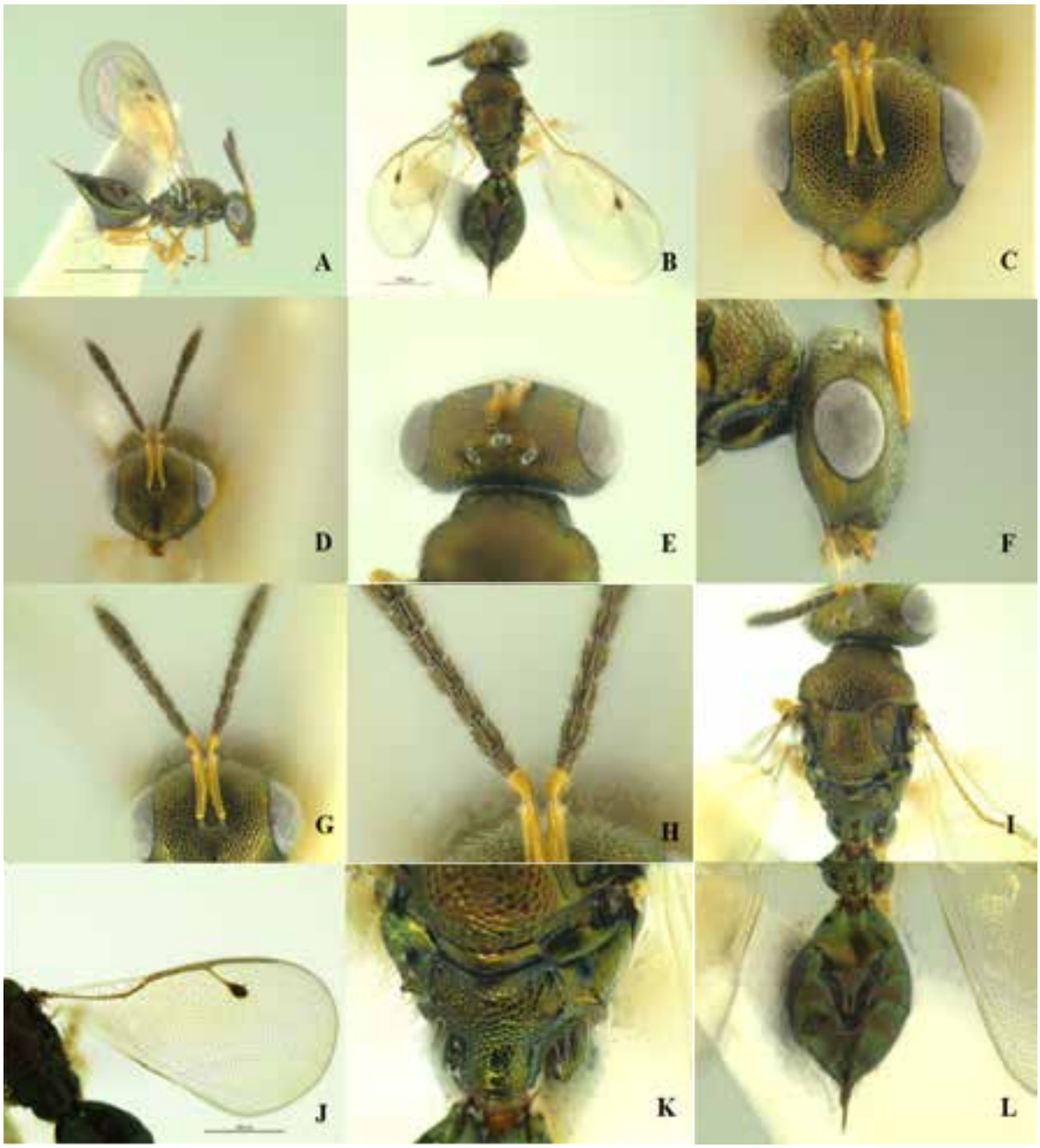


Image 1. *Synedrus kasparyani* Tselikh. Female: A—body profile | B—body dorsal view of the body | C & D—head in frontal view | E—head in dorsal view | F—head in lateral view | G & H—antennae | I—mesosoma | J—forewing | K—propodeum | L—metasoma. © Mubashir Rashid & Arvind Kumar.

as broad; pronotum short, carinate, 0.11x as long as mesoscutum; mesoscutum 0.56x as long as broad, notauli incomplete; scutellum 1.08x as long as broad, axillar groove anteriorly wide apart so that scutellum broadly borders on mesoscutum. Propodeum (Image 2G) with median carina absent, plicae sharply present, traces of transverse carina are present, spiracular sutures broad and oval; spine like structure (Image 2G) present on both sides of callusas in female; nucha reticulate and long. FW (Image2H) hyaline, veins brown, 2.15x as long as broad; SMV 0.35x as long as FW; MV longer than STV (1.16X) but shorter than PMV, MV 0.76x as long as PMV; STV 0.65x PMV; stigma of FW moderately capitate and brown. Basal cell with few setae; costal cell with few scattered setae; speculum broad and closed below.

Metasoma: (Image 2). Gaster elongate (4.02x as long

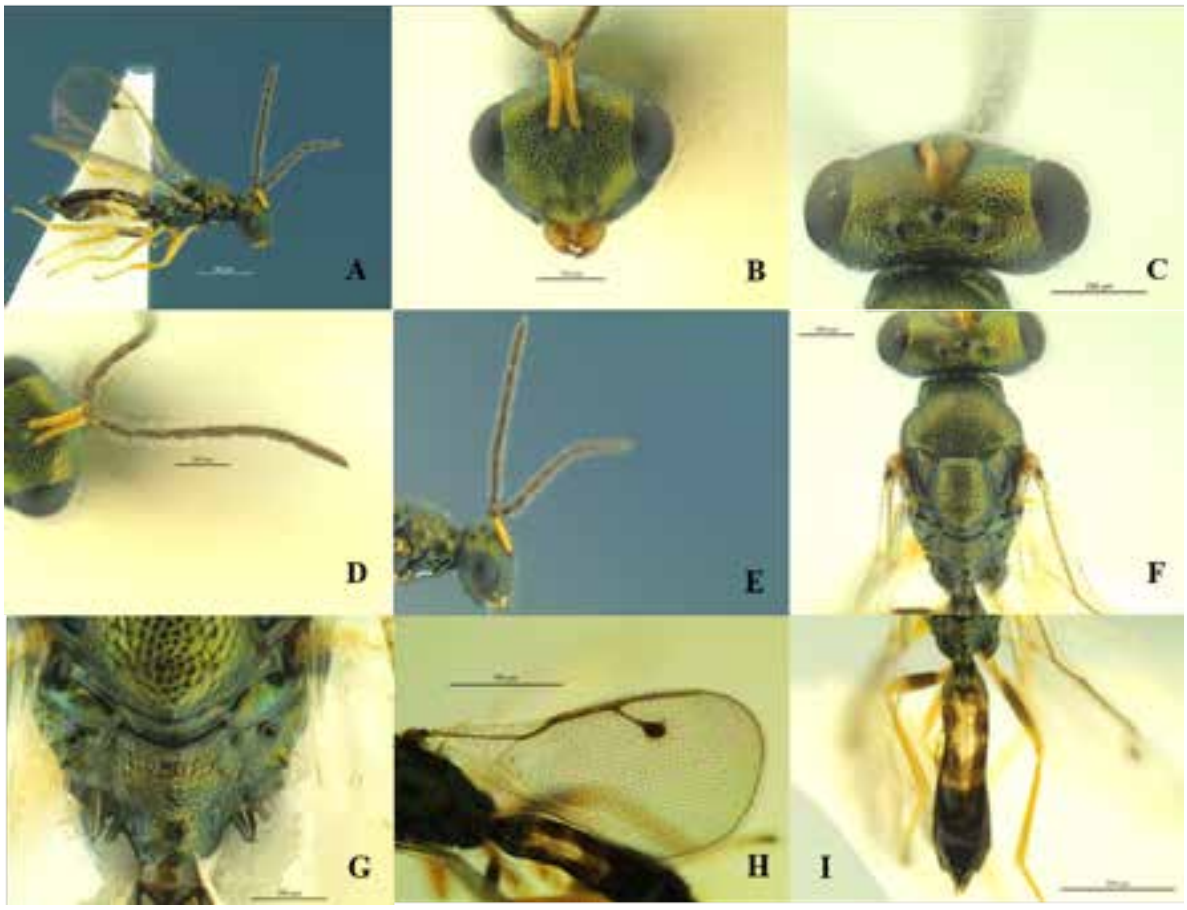


Image 2. ***Synedrus kasparyani*** **Tselikh. Male: A—body profile | B—head infrontal view | C—head in dorsal view |D & E—antennae | F—mesosoma | G—propodeum | H—forewing | I—metasoma. © Mubashir Rashid & Arvind Kumar.**

as broad), dorsally bluish or blackish or brownish with median part yellowish, distinctly longer than mesosoma (1.35x), a row of white hairs present on each tergite.

Material examined: 2 males, India: Jammu & Kashmir: Hidyal; 23.vi.2021; coll. Mubashir Rashid; Accession number- FRI/NFIC/22304-C, D.

Distribution: Russia (only female); South Korea; India: Jammu & Kashmir (new record both male and female).

Biology: Not known. Associated with citrus plant and collected with the help of aspirator.

Discussion

The female specimen of *Synedrus kasparyani* Tselikh was described by Tselikh in 2013 from Russia and the male specimen of *Synedrus kasparyani* Tselikh is described for the first time, collected from Jammu & Kashmir, India, and the genus *Synedrus* Graham is recorded first time from India.

References

Bouček, Z. & J.Y. Rasplus (1991). Illustrated key to West-Palaearctic genera of Pteromalidae (Hymenoptera: Chalcidoidea). *Institut National de la Recherche Agronomique, Paris,* 140 pp.

Gibson, G.A.P. (1997). Annotated Keys to the Genera of Nearctic Chalcidoidea (Hymenoptera) Chapter 2. Morphology and Terminology, pp. 16–44. In: Gibson, G.A.P., J.T. Huber & J.B. Woolley (eds.). *Annotated Keys to the Genera of Nearctic Chalcidoidea (Hymenoptera).* National Research Council of Canada, NRC Research Press, Ottawa Canada, xi + 794 pp.

Graham, M.W.R.de V. (1956). A revision of the Walker types of Pteromalidae (Hym., Chalcidoidea). Part I (including descriptions of new genera and species). *Entomologist's Monthly Magazine* 92: 97.

Graham, M.W.R.de V. (1992). A new species of *Synedrus* (Hym., Pteromalidae) from France. *Entomologist's Monthly Magazine* 128: 23.

Tselikh, E.V. (2013). Chalcid wasps of the family Pteromalidae (Hymenoptera, Chalcidoidea) of the Kuril Islands. *Entomologicheskoe Obozrenie* 92(3): 620–621.

Walker, F. (1835). Monographia Chalciditum (continued). *Entomological Magazine* 3(2): 192.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 February 2024 | 16(2): 24816–24818
ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)
https://doi.org/10.11609/jott.8798.16.2.24816-24818
#8798 | Received 20 October 2023 | Final received 11 January 2024 | Finally accepted 23 January 2024
OPEN ACCESS
NOTE

Hunteria zeylanica (Retz.) Gardner ex Thwaites (Magnoliopsida: Gentianales: Apocyanaceae)—new addition and first genus record to the flora of Karnataka

G. Ramachandra Rao

Centre for Urban Ecology, Biodiversity, Evolution & Climate change (CUBEC), JAIN (Deemed to be University), 319, 25th Main Road, KR Layout, JP Nagar Phase 6, Bengaluru, Karnataka 560078, India.
ramachandra.rao@jainuniversity.ac.in

Hunteria is a genus of Apocynaceae comprising 13 species and was first described in 1824 by Roxburgh (POWO 2023). In southern India it is mainly represented by the tree species *Hunteria zeylanica* (Retz.) Gardner ex Thwaites which is native to eastern Africa and to Indo-Malaysia (WCSP 2023). In southern India, it is recorded from the evergreen forests of Kerala and Tamil Nadu. During the field work in Dodmane Ghat of Uttara Kannada district, Karnataka, a small tree was collected from the wet evergreen forest area. On closer identification with local flora (Gamble 1921; Saldanha 1984–1996; Bhat 2003; Punekar & Lakshminarasimhan 2011) and further confirmation from Botanical Survey of India, southern regional centre, Coimbatore, it was confirmed to be *Hunteria zeylanica* (Retz.) Gardner ex Thwaites. Its earlier distribution was reported from the southern Western Ghats of Wayanad, Palakkad, Thrissur, Idukki, Kollam, & Thiruvananthapuram districts of Kerala and Kanyakumari & Tirunelveli of Tamil Nadu (Sasidharan 2011). The present study reports this evergreen tree *Hunteria zeylanica* (Retz.) Gardner ex Thwaites, for the first time from Karnataka part of the Western Ghats.

Systematic treatment

Hunteria zeylanica (Retz.) Gardner ex Thwaites, Enum. Pl. Zeyl. 191. 1860. *Cameraria zeylanica* Retz., Obs. Bot. 4: 24. 1786. *Hunteria corymbosa* Roxb., Fl. Ind. 1: 695. 1832; Hook. f., Fl. Brit. India 3: 637. 1882; Gamble, Fl. Pres. Madras 808 (568). 1923; Vajr., Fl. Palghat Dist. 281. 1990. *Hunteria roxburghiana* Wight, Ic. t. 1294. 1846; Mohanan, Fl. Quilon Dist. 253. 1984; Pandurangan et al., Journ. Econ. Tax. Bot. 6: 271. 1985; Manilal, Fl. Silent Valley 174. 1988; M. Mohanan & Henry, Fl. Thiruvanthapuram 291. 1994; Subram., Fl. Thenmala Div. 219. 1995; Sasidh. & Sivar., Fl. Pl. Thrissur For. 280. 1996; Sasidh., Fl. Shenduruny WLS 203. 1997; Sasidh., Fl. Parambikulam WLS 189. 2002; Ratheesh Narayanan, Fl. Stud. Wayanad Dist. 520. 2009; Nayar et al. 2014.

Small evergreen tree 12 m tall; bark greyish-brown, lenticellate; milky latex from plant parts. Leaves

Editor: Kannan C.S. Warrier, ICFRE - Institute of Forest Genetics and Tree Breeding, Coimbatore, India. **Date of publication:** 26 February 2024 (online & print)

Citation: Rao, G.R. (2024). *Hunteria zeylanica* (Retz.) Gardner ex Thwaites (Magnoliopsida: Gentianales: Apocyanaceae)—new addition and first genus record to the flora of Karnataka. *Journal of Threatened Taxa* 16(2): 24816–24818. https://doi.org/10.11609/jott.8798.16.2.24816-24818

Funding: The Ministry of Environment, Forests and Climate Change, Government of India and Minor research grant, JAIN (Deemed-to-be University) Bengaluru.

Competing interests: The author declares no competing interests.

Acknowledgements: Author is grateful to Head of office, BSI, SRC, Coimbatore, Dr. W. Arisdason, Scientist 'E', Dr. Benjamin Franklin, BSI for plant species species verification and herbarium deposition. I thank officers and forest officials from Karnataka forest department for timely help and logistics. Sincere thanks to Mr. Akhil C A, KFRI, for various assistance. Author thanks Dr T V Ramachandra, C.E.S., I.I.Sc., for support and encouragement. Also, thanks to Mr. Vishnu D, Mrs. Gayatri Naik, and Mr. Srikanth Naik for technical and field assistance.

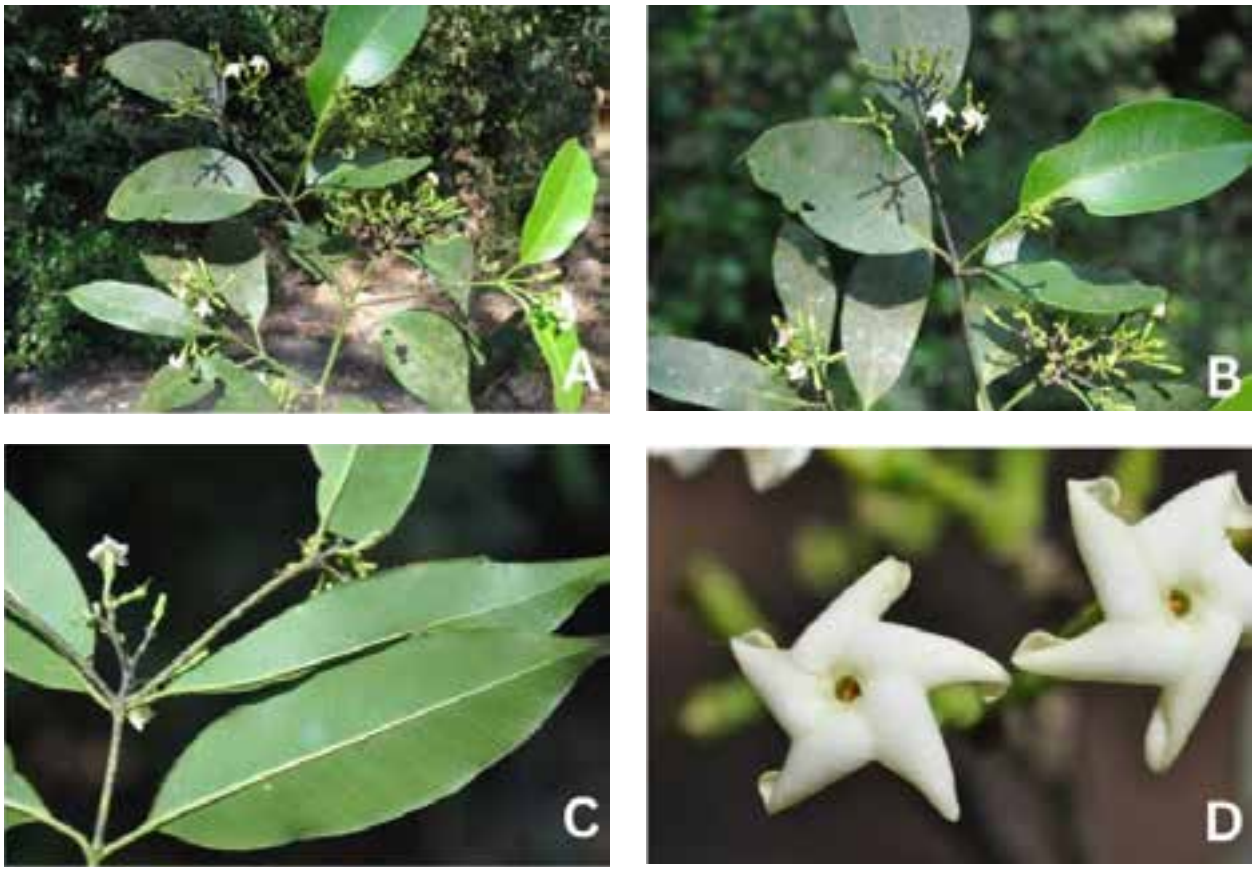


Image 1. *Hunteria zeylanica*: A—Flowering leafy twig from the locality | B—Flowering twig close up | C—Leaf close up dorsal side | D—Flower close up. © G. Ramachandra Rao.

simple, opposite, estipulate; petioles 1.2–1.6 cm long, glabrous, slender; lamina 9–15 x 3–5.5 cm, elliptic to elliptic-oblong; base acute or obtuse; apex acuminate; margin entire, slightly wavy, glabrous, coriaceous, shining above; lateral nerves many, slender, glabrous, looped near margin forming intramarginal nerve, intercostae reticulate, obscure. Flowers white, slightly fragrant, bisexual, in terminal to sub-terminal cymes; peduncles c.2 cm long. Calyx lobes five, small, 0.8 cm long, eglandular. Corolla salver shaped, lobes creamy white, acuminate, tips folded and twisted; tube 0.8 mm long; stamens five, inserted at the dilation of the tube, anthers lanceolate, apiculate, orange-brown, filaments hairy below. Carpels two, free, ovules two–four in each cell; style greenish, stigma yellowish-green, conical. Fruit of two fleshy berries.

Specimens collected: 178273 (MH) (Image 1), 2016, Karnataka: Dodmane Ghat, Uttara Kannada district, coll. G.R. Rao.

Habitat: Evergreen to semi-evergreen forests.

Flowering and Fruiting: February–June.

Distribution: Eastern Africa and Indo-Malesia.

Note: This plant slightly differs from southern Western Ghats population with having more broader leaves and corolla more twisted and white with folded petal.

Habitat and associated plants: The tree species occurred in evergreen forest along with several other trees such as *Diospyros paniculata, D. pruriens, Holigarna grahamii, Hydnocarpus pentandra, Hopea ponga,* and *Syzygium gardneri*. Only two trees of *Hunteria zeylanica* were encountered in the region, and were not found elsewhere even after extensive surveys in Uttara Kannada district. Though this species has Indo-Malesian distribution, in India it has a narrow distribution with very small population surviving in the central Western Ghats, Karnataka, while the other populations are in states of Kerala and Tamil Nadu. Presently the tree species is in a protected forest and is found intact with no immediate threat. But as the numbers are very small, these trees can swiftly cascade towards their inevitable extinction due to anthropogenic pressures such as habitat loss by land encroachment for *Areca* cultivation along water courses, even inside protected areas. Hence

more studies on their distribution, population, and regeneration studies may throw light on mitigating the crisis and planning conservation measures.

References

Bhat, K.G. (2003). *Flora of Udupi*. Indian Naturalist, Udupi, 913 pp.

Gamble, J.S. (1921). *Flora of the Presidency of Madras*. Adlard & Co., London, 408 pp.

Mohanan, C.N. (1984). Studies on the flora of Quilon District, Kerala. Ph.D. Thesis, Madras University, Madras.

Mohanan, M. & A.N. Henry (1994). *Flora of Thiruvananthapuram*. Botanical Survey of India. Calcutta, 621 pp.

Manilal, K.S. (1988). *Flora of Silent Valley Tropical Rain Forests of India*. Calicut University, Calicut, 398 pp.

Nayar, T.S., A.R. Beegam & M. Sibi (2014). *Flowering Plants of the Western Ghats, India. Volume 1. Dicots*. Jawaharlal Nehru Tropical Botanic Garden and Research Institute, Palode, Thiruvananthapuram, 934 pp.

Pandurangan, A.G., C.N. Mohanan & N.C. Nair (1985). Rare or little known vascular plants from Idukki Hydro-electric Project Area, Kerala, India. *Journal of Economic and Taxonomic Botany* 6: 271–274.

POWO (2023). Plants of the Word Online. Facilitated by the Royal Botanical Gardens, Retrieved September 19, 2023. https://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:79369-1

Punekar, A.S. & P. Lakshminarasimhan (2011). *Flora of Anshi National Park, Western Ghats-Karnataka*. Biospheres Publication, Pune, Maharashtra, India, 804 pp.

Narayan, R. (2009). Floristic Studies in Wayanad District. Ph.D. Thesis. University of Calicut.

Saldanha, C.J. (1984–1996). *Flora of Karnataka Vol. I & II*. Oxford & IBH Publishing Co., New Delhi.

Sasidharan, N. (1997). Studies on the flora of Shenduruny Wildlife Sanctuary with emphasis on endemic species. KFRI Research Report No. 128. Kerala Forest Research Institute, Peechi.

Sasidharan, N. (2002). Floristic studies in Parambikulam Wildlife Sanctuary, Kerala Forest Research Report No. 246, Kerala Forest Research Institute, Peechi, 365 pp.

Sasidharan, N. (2011). Flowering plants of Kerala. DVD, V 2, KFRI. http://www.keralaplants.in/flowering-plants-kerala-dvd.aspx

Sasidharan, N. & V.V. Sivarajan (1996). *Flowering Plants of Thrissur Forests*. Scientific Publishers, Jodhpur, 579 pp.

Subramanian, K.N. (1995). *Flora of Thenmala Division (& its Environs)*. International Book Distributors, Dehra Dun, 519 pp.

Wight, R. (1848). *cones plantarum Indiae orientalis.* Vol. 4, part 2. J.R.I. Wood, Madras, India.

Journal of Threatened Taxa is indexed/abstracted in Bibliography of Systematic Mycology, Biological Abstracts, BIOSIS Previews, CAB Abstracts, EBSCO, Google Scholar, Index Copernicus, Index Fungorum, JournalSeek, National Academy of Agricultural Sciences, NewJour, OCLC WorldCat, SCOPUS, Stanford University Libraries, Virtual Library of Biology, Zoological Records.

NAAS rating (India) 5.64

Print copies of the Journal are available at cost. Write to:
The Managing Editor, JoTT,
c/o Wildlife Information Liaison Development Society,
43/2 Varadarajulu Nagar, 5th Street West, Ganapathy, Coimbatore,
Tamil Nadu 641006, India
ravi@threatenedtaxa.org

Journal of Threatened Taxa

www.threatenedtaxa.org

ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

February 2024 | Vol. 16 | No. 2 | Pages: 24615–24818
Date of Publication: 26 February 2024 (Online & Print)
DOI: 10.11609/jott.2024.16.2.24615-24818

Articles

Communications

Short Communications

Note

Publisher & Host

WILD zoo reach
Zoo Outreach Organisation

Threatened Taxa