

IMPACT OF TEMPORAL AND SPATIAL VARIATION ON ODONATA COMMUNITIES IN NORTHEASTERN TRANSBOUNDARY HILL STREAMS OF BANGLADESH, INCLUDING TWO NEWLY RECORDED ODONATA SPECIES IN THE COUNTRY



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ABSTRACT

Globally, dragonflies and damselflies (Odonata), are playing a significant ecological role as bioindicators of wetland health and as natural controller of pest and disease-vector populations. In Bangladesh, research focus on Odonata is not sufficient specially in the transboundary areas. In the hill streams and associated aquatic ecosystems support a rich diversity of Odonata species; however, comprehensive information on their diversity, distribution, ecology, and conservation status remains limited. A comprehensive scientific ecological study of Odonata was conducted in the transboundary forest of the northeastern region of Bangladesh from July 2023 to June 2024. The study documented a total of 67 Odonata species, comprising 44 species (68%) from the suborder Anisoptera and 23 species (32%) from Zygoptera. Within Anisoptera, the family Libellulidae was the most diverse, accounting for 35 species (53.84%), while Coenagrionidae was the dominant family among Zygoptera, represented by 12 species (18.46%). Of the two surveyed locations, Site B (Non-disturbed) exhibited the highest species richness (56 species, 83.58%) and abundance (n = 1276), along with the highest values for both the Shannon-Wiener diversity index (H = 3.20) and Simpson's index (Ds = 0.935). Seasonal analysis showed maximum species richness (63 species) and individual abundance (n = 1008) during the rainy season, while the winter season exhibited the highest evenness (E = 0.608). *Orthetrum pruinosum* emerged as the most dominant species overall (n = 289), especially in Site B, whereas *Rhyothemis variegata* was most frequently observed at Site A (n = 179). An Analysis of Similarities (ANOSIM) revealed a statistically significant variation (R = 0.551, $p < 0.0001$) in community composition between the two sites. One-way ANOVA indicated significant seasonal variation in species richness (F = 6.358, df = 2, $p = 0.0043$) and showed significant differences in abundance (F = 30.198, df = 2, $p < 0.0001$) between winter and the other two seasons (rainy and summer). Importantly, two Odonata species, *Phyllothemis eltoni* and *Elattoneura campioni*, were newly recorded in Bangladesh, marking the first national records for both genera, *Phyllothemis* and *Elattoneura*. These findings highlight hill stream of northeastern Bangladesh as a key Indo-Burma Odonata biodiversity landscape, requiring focused research and awareness for Odonata conservation.

KEYWORDS: Dragonfly, Damselfly, Seasonality, Hill Streams, Conservation, Transboundary

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Introduction

By serving as crucial routes for the movement of animals, transboundary areas contribute significantly to the resilience of animal populations and the maintenance of species diversity (Grainger, 2013). Species can disperse and adapt to changing environmental conditions when these cross-border habitats are effectively protected (Allan *et al.*, 2017). Joint initiatives, such as transboundary protected areas, biosphere reserves, and wildlife corridors, enable coordinated conservation efforts, knowledge sharing, and sustainable management (Lim, 2016). Bangladesh is a relatively small country in south Asia that has

long international boundaries with Myanmar (270 kilometers) and India (4,096 kilometers) (Jamwal, 2004). Its north-eastern and south-eastern mountainous forest regions border India and are rich in faunal diversity. These transboundary zones routinely provide new faunal records for Bangladesh, particularly among insects (Biswas *et al.*, 2021).

Wetland ecosystems within these forested regions, especially hill streams, locally referred to as 'Chora' are ecologically significant. They provide essential ecosystem services, including agricultural support, drinking water supply, breeding

habitats, and ecological regulation (Surachita and Palita, 2022). Among Bangladesh's diverse faunal groups, Odonata (dragonflies and damselflies) are particularly dependent on these hill stream habitats in the south-eastern and north-eastern regions (Khan, 2015). Past research has documented rare and newly recorded Odonata species from these streams (Khan, 2015; 2017; 2018; 2021).

Bangladesh's geographical setting and diverse freshwater wetlands create favorable conditions for Odonata (Shome *et al.*, 2019), with over 109 species currently documented and strong potential for more discoveries, particularly in the transboundary hill stream regions of the northeast and southeast (Shome *et al.*, 2021, Emrose, *et al.*, 2024). Odonates are paleopteran insects with aquatic larval stages that forage close to aquatic environments like ponds and temporary pools, making them conspicuous due to their relatively large size and vibrant coloration (Tiple, 2020). A significant portion of their lifecycle is spent in freshwater habitats (Silsby, 2001), extensively relying on water sources for mating and feeding (Crowley and Johnson, 1982; Butler, 2008; Silva *et al.*, 2010).

Due to their sensitivity to environmental changes, Odonates serve as reliable indices of wetland health (Kalkman *et al.*, 2008; Tuhin and Khan, 2018; Sganzerla *et al.*, 2021). As prey for birds and predators of smaller insects, such as mosquitoes and other pests, they also play a significant ecological function in food webs (Cheshire *et al.*, 2005). In this way, they contribute to the management of mosquito populations and help decrease the transmission of illnesses, including malaria, dengue, and filariasis (Mandal *et al.*, 2008; Saha *et al.*, 2012; Payra *et al.*, 2014). Due to habitat destruction, pollution, climate change, and other ecological pressures, Odonata species are becoming increasingly vulnerable worldwide (Sánchez-Bayo and Wyckhuys, 2019). Bangladesh is not exempt from this global trend, but unfortunately, comprehensive regional-scale documentation of Odonata diversity remains limited (Emrose, *et al.*, 2024).

Odonata documentation in Bangladesh, specifically studies with community composition, habitability, spatial and temporal

variation explicitly in transboundary hill-stream ecosystems remain scarce. Understanding how community composition responds to habitat disturbance and seasonal changes is essential for biodiversity monitoring and conservation planning in these ecologically sensitive landscapes and habitat relationships in the transboundary hill stream ecosystems of northeastern Bangladesh. This research provides the initial thorough evaluation of temporal and spatial fluctuations in Odonata communities within these distinctive hill stream ecosystems, incorporating species diversity, community structure, and environmental changes. Additionally, the documentation of two newly identified Odonata species for Bangladesh enhances the recognized national biodiversity inventory and underscores the untapped conservation significance of these ecosystems. This study offers fresh perspectives on freshwater biodiversity patterns by filling in current knowledge gaps and creates a scientific foundation for ongoing monitoring and conservation efforts regarding Odonata and hill stream ecosystems in a transboundart part of Indo-Burma biodiversity area.

Materials and Methods

Study Area

This research was conducted in the hill streams of the Rajkandi Forest Range, located in Kamalganj, Moulvibazar district, a transboundary semi-evergreen forest region in the northeastern part of Bangladesh (24.226952°N, 91.903176°E). The forest covers an area of approximately 5,295 hectares (Fig. 1, Table 1), experiencing a tropical monsoon climate characterized by high rainfall during the monsoon season (June-October), a relatively dry winter (November-February), and a warm pre-monsoon summer (March-May). For the study, the area was categorized into two primary sites based on the degree of anthropogenic disturbances. Each of these sites was further subdivided into 10 distinct sampling units.

Table 1. Details of study sites and habitat features with threats.

Survey sites	Area Name	Habitat features	Threats
Site A	Hill stream associated areas with anthropogenic disturbance	Hill-streams, forest, trail, bush	Presence of anthropogenic disturbance, frequent movement of local people.
Site B	Hill stream areas without anthropogenic disturbance	Hill-streams, dense forest, layers of vegetation, ditch, bush,	No anthropogenic activities, characterized by intact natural habitat.

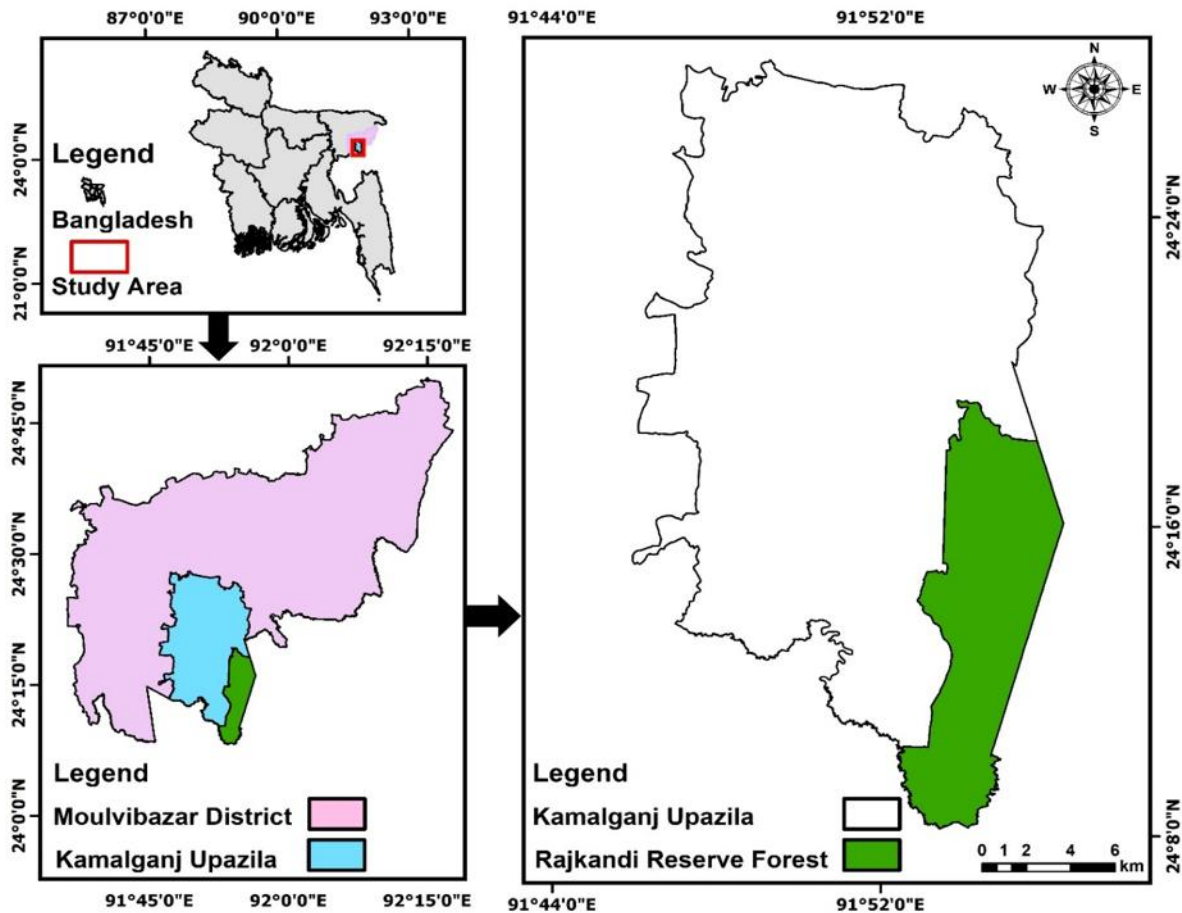


Figure 1. Map of the study area

Data Collection

This study used systematic field observations to assess adult Odonata assemblages from July 2023 to June 2024. At each specified site, the seasonal survey consisted of two sampling events, with an emphasis on peak activity times between 10:00 AM and 3:00 PM (Payra and Tiple, 2019) as Odonates exhibit maximum flight activity during mid-day under optimal sunlight conditions. Both transect-based and opportunistic survey techniques were used. At each location, two transects were developed based on the occurrence of appropriate Odonata habitats. Each transect covered an area of 500 square meters, with measurements of 50 meters in length and 10 meters in width. Observations were conducted over three specified seasons: summer (March-June), monsoon (July-October), and winter (November-February). For proper sampling and properly know about the temporal variation as well as the ecological status two field visit in each sampling site was conducted in a particular season.

For accurate taxonomic identification, specimens were gathered using a standard entomological sweep net. Collected specimens were identified using standard taxonomic keys (Fraser, 1933; Subramanian, 2009), and species nomenclature follows Kalkman *et al.*, (2020). Simultaneously, high-resolution photos of the observed individuals were captured using a DSLR camera (Nikon 500D with a 200-500 mm zoom lens) for photographic documentation and verification. Specimen collection was conducted in compliance with local forest department regulations and after taking photo species was released in the nature according to the regulations.

Data analysis

Statistical analyses were performed using Microsoft Excel, PAST software, and R (R Core Team, 2020) to fulfill the objectives of the study. Species richness within the study area was estimated using four non-parametric estimators: first-order Jackknife, second-order Jackknife, Bootstrap, and Chao 2, as implemented in PAST (Chao and Shen, 2003). These estimators were derived through a resampling procedure involving 1,000 randomized iterations with replacement, enabling the calculation of standard deviations and richness estimates based on the observed data. The mean value of the four richness estimators was used as an overall approximation of estimated species richness. The frequency of Odonata sightings was classified following the method outlined by Khan (2015), which categorizes species based on their proportion of total observations across survey efforts. Specifically, species representing 10-19% of total sightings were classified as rare (F), 20-49% as uncommon (UC), 50-79% as common (C), and 80-100% as very common (VC).

Relative abundance for each Odonate species was measured following the formula below:

$$\text{Relative abundance} = \frac{\text{Number of individuals of a species}}{\text{Total number of individuals of all}} \times 100$$

To effectively illustrate species dominance patterns, a rank-abundance plot was constructed following the method proposed by Whittaker (1965). Additionally, a non-metric

multidimensional scaling (NMDS) analysis based on the Bray-Curtis dissimilarity index (Bray *et al.*, 1957) was performed to assess community composition across the two study sites. To identify the species contributing to significant differences in community structure between sites, an Analysis of Similarities (ANOSIM) analysis were conducted using the "anosim" functions from the *vegan* package in R (Oksanen *et al.*, 2019). Biodiversity was further assessed using the Shannon-Wiener Index (Shannon and Wiener, 1949) and Simpson's Index (Simpson, 1949). Pielou's Evenness was calculated by dividing the Shannon-Wiener index by the natural logarithm of species richness. One-way Analysis of Variance (ANOVA) was employed to determine whether species richness and abundance significantly varied across different study sites and seasonal periods.

Results

Species recorded

Throughout this year-long study, 67 Odonata species were recorded across the study sites. Of these, 44 species (68%) belonged to the suborder Anisoptera, while the remaining 23 species (32%) were classified under the suborder Zygoptera. The documented species were distributed across eight families, with the family Libellulidae representing the highest diversity, comprising 35 species (53.84%). Coenagrionidae followed this with 12 species (18.46%) and Platycnemididae with six species (9.23%). The Macromiidae family had the lowest representation, with only a single species observed (1.53%).

Table 2. Odonata species recorded during the study period in the study area:

Sub-order	Family	SN	EN	Se	RA-A	RA-B
Anisoptera	Aeshnidae	<i>Anaciaeschna jaspidea</i> (Burmeister, 1839)	Rusty Darner	R, S	0.179	0.705
		<i>Anax guttatus</i> (Burmeister, 1839)	Lesser Green Emperor	R, S	0	0.548
		<i>Anax indicus</i> (Lieftinck, 1942)	Elephant Emperor	R, S	0.179	0.705
		<i>Gynacantha khasiaca</i> (McLachlan, 1896)	Green Darner	R	0	0.156
		<i>Gynacantha subinterrupta</i> (Rambur, 1842)	Dingy Dusk Hawker	A	0.626	0.94
	Gomphidae	<i>Ictinogomphus rapax</i> (Rambur, 1842)	Common Clubtail	A	2.148	5.485
		<i>Macrogomphus</i> sp.	Clubtail dragonfly	R	0	0.078
		<i>Paragomphus lineatus</i> (Selys, 1850)	Lined Hooktail	R	0	0.156
	Libellulidae	<i>Acisoma panorpoides</i> (Rambur, 1842)	Trumpet tail	R	0.447	0
		<i>Acthriamanta brevipennis</i> (Rambur, 1842)	Scarlet Marsh Hawk	A	0.805	0.94
		<i>Barchydiplax chalybea</i> (Brauer, 1868)	Rufous-Backed Marsh Hawk	A	0	1.018
		<i>Barchydiplax farinosa</i> (Kruger, 1902)	Black Tailed Dasher	A	0.268	0.705
		<i>Barchydiplax sobrina</i> (Rambur, 1842)	Little Blue Marsh Hawk	A	0.358	0.313
		<i>Brachythemis contaminata</i> (Fabricius, 1798)	Ditch Jewel	A	0.716	0.313
		<i>Bradynophya geminata</i> (Rambur, 1842)	The Granit Ghost	R	0.179	0.078
		<i>Camacinia gigantea</i> (Brauer, 1867)	Giant Forest Skimmer	R	0	0.235
		<i>Crocothemis servilia</i> (Drury, 1770)	Ruddy Marsh Skimmer	A	6.624	6.739
		<i>Diplacodes nebulosa</i> (Fabricius, 1798)	The Black-Tipped Ground Skimmer	R, W	0.626	0.47
		<i>Diplacodes trivialis</i> (Rambur, 1842)	Ground Skimmer	A	1.79	0.94
		<i>Elattonaura campioni</i> Fraser, 1922	-	R	0	0.156
		<i>Hydrobasileus croceus</i> (Brauer, 1867)	Amber-Winged Glider	R	0	0.235

Sub-order	Family	SN	EN	Se	RA-A	RA-B
		<i>Lathrecista asiatica</i> (Fabricius, 1798)	Asiatic Blood Tail	R, S	0	0.313
		<i>Neurothemis fulvia</i> (Drury, 1770)	Fulvous Forest Skimmer	A	6.982	5.564
		<i>Neurothemis intermedia</i> (Rambur, 1842)	Ruddy Meadow Skimmer	A	0.716	1.41
		<i>Neurothemis tullia</i> (Drury, 1770)	Pied Paddy Skimmer	A	1.163	0
		<i>Orthetrum glaucum</i> (Brauer, 1865)	Blue Marsh Hawk	A	1.969	3.056
		<i>Orthetrum pruinosum</i> (Rambur, 1842)	Crimson Tailed Marsh Hawk	A	9.847	14.028
		<i>Orthetrum sabina</i> (Drury, 1770)	Green Marsh Hawk	A	9.937	13.166
		<i>Orthetrum testaceum</i> (Burmeister, 1839)	Orange Skimmer	R	0	0.078
		<i>Palpopleura sexmaculata</i> (Fabricius, 1787)	Asian Widow	A	0	2.037
		<i>Pantala flavescens</i> (Fabricius, 1798)	Wandering Glider	R	10.205	0
		<i>Phyllothemis eltoni</i> Fraser, 1935	-	R	0	0.235
		<i>Potamarcha congener</i> (Rambur, 1842)	Yellow-tailed Ashy Skimmer	A	5.998	8.385
		<i>Rhodothemis rufa</i> (Rambur, 1842)	Rufous Marsh Glider	A	2.864	3.605
		<i>Rhyothemis variegata</i> (Linnaeus, 1763)	Common Picture Wing	A	12.354	4.231
		<i>Tetrathemis platyptera</i> (Selys, 1878)	Pigmy Skimmer	A	0.358	4.388
		<i>Tholymis tillarga</i> (Fabricius, 1798)	Coral Tailed Cloudwing	A	4.118	3.84
		<i>Tramea basilaris</i> (Kirby, 1889)	Red Marsh Trotter	R	0.179	0
		<i>Tramea limbata</i> (Desjardins, 1832)	Ferruginous Glider	R	0.268	0.156
		<i>Trithemis aurora</i> (Burmeister, 1839)	Crimson Marsh Glider	R	0	0.391
		<i>Trithemis pallidinervis</i> (Kirby, 1889)	Long Legged Marsh Glider	A	4.028	0.783
		<i>Urothemis signata</i> (Rambur, 1842)	Greater Crimson Glider	A	4.386	2.194
		<i>Zygomma petiolatum</i> (Rambur, 1842)	Brown Dusk Hawk	A	1.253	0.94
	Macromiidae	<i>Epophthalmia vittata</i> (Burmeister, 1839)	Common Torrent Hawk	A	0.179	0.235
Zygoptera	Calopterygidae	<i>Matrona nigripectus</i> (Selys, 1879)	-	R	0	0.078
		<i>Neurobasis chinensis</i> (Linnaeus, 1758)	Stream Glory	A	0	1.097
		<i>Vestalis gracilis</i> (Rambur, 1842)	The Clear-Winged Forest Glory	A	0	1.41
		<i>Agriocnemis femina</i> (Brauer, 1868)	Pruinosed Dartlet	R, W	0	1.018
		<i>Libellago lineata</i> (Burmeister, 1839)	River Heliodor	A	0	0.94

Sub-order	Family	SN	EN	Se	RA-A	RA-B
	Coenagrionid ae	<i>Agriocnemis kalinga</i> (Nair and Subramanian, 2015)	-	R	0	0.078
		<i>Agriocnemis pieris</i> (Laidlaw, 1919)	White Dartlet	R	0.268	0
		<i>Agriocnemis pygmaea</i> (Rambur, 1842)	Pygmy Dartlet	A	1.7	1.018
		<i>Calicnemia pulverulans</i> (Selys, 1886)	-	W	0	0.156
		<i>Ceriagrion cerinorubellum</i> (Brauer, 1865)	The Orange- Tailed Marsh Dart	A	1.88	1.489
		<i>Ceriagrion coromandelianum</i> (Fabricius, 1798)	Coromandel Marsh Dart	A	2.148	1.332
		<i>Ceriagrion olivaceum</i> (Laidlaw, 1914)	Rusty Marsh Dart	R	0	0.156
		<i>Ischnura rubilio</i> (Selys, 1876)	Western Golden Dartlet	R	0.179	0.548
		<i>Ischnura senegalensis</i> (Rambur, 1842)	Senegal Golden Dartlet	A	0.358	0.235
		<i>Paracercion calamorum</i> (Ris, 1916)	Dusky Lilysquatter	S	0.089	0
		<i>Pseudagrion microcephalum</i> (Rambur, 1842)	The Blue River Damsel	R	0.179	0
		<i>Pseudagrion rubriceps</i> (Selys, 1876)	Saffron-Faced Blue Dart	R, S	0.537	0
	Platycnemidid ae	<i>Coeliccia didyma</i> (Selys, 1863)	-	W	0	0.156
		<i>Copera marginipes</i> (Rambur, 1842)	Yellow Bush Dart	W	0	0.156
		<i>Copera vittata</i> (Selys, 1863)	Blue Bush Dart	R	0	0.156
		<i>Onychargia atrocyana</i> (Selys, 1865)	The Marsh Dancer	R	0.179	0
		<i>Onychargia atrocyana</i> (Selys, 1865)	The Marsh Dancer	R	0.447	0
		<i>Pseudocopera ciliata</i> (Selys, 1863)	Pied Bush Dart	R	0.268	0

Note: SN- Scientific name, EN- English Name, Se- Season, S- Summer, R- Rainy, W-Winter; RA- Relative abundance

Spatial variation

Site B exhibited the highest species richness, with 56 species accounting for 83.58% of the total recorded diversity, and the highest abundance ($n = 1,276$). Diversity indices were also highest at Site B, with a Shannon-Wiener index (H) of 3.20 and a Simpson's diversity index (Ds) of 0.935, while Pielou's Evenness ($E = 0.485$) reached its maximum at Site A. The mean number of Odonata species observed was significantly greater at Site B (mean = 34.60 ± 3.577), compared to Site A (mean =

26.08 ± 4.176) (Fig. 2A). A similar trend was observed in terms of Odonata abundance at both sites (Fig. 2B). The average Shannon-Wiener diversity index (H) confirmed higher species diversity at Site B ($H = 3.110 \pm 0.099$), whereas Site A recorded the lowest value ($H = 2.928 \pm 0.182$) (Fig. 2C). However, this variation in Shannon-Wiener index between the sites was not statistically significant ($F = 3.903$, $p = 0.099$). Pielou's Evenness indicated a more uniform species distribution at Site A ($E = 0.708 \pm 0.046$) compared to Site B (Fig. 2D)

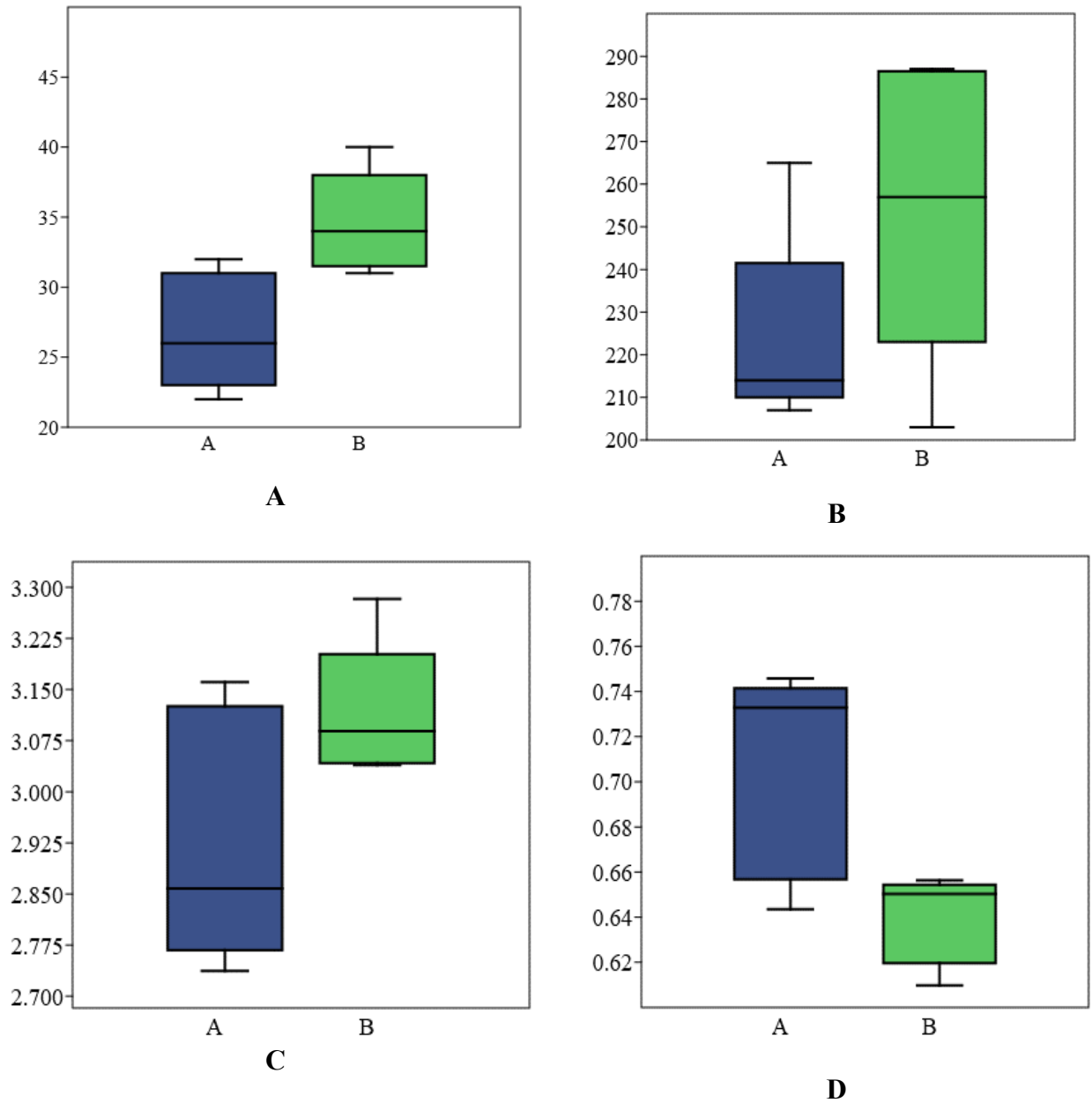


Figure 2. Boxplots of Odonata **A.** species richness. **B.** abundance. **C.** Shannon diversity index. **D.** Evenness by study sites per season.

Site B harbored the highest number of unique Odonata species, with 24 species found exclusively at this site, while 32 species were common in both Site A and Site B (Figure 3A). Community composition analysis revealed a statistically significant difference between the Odonata assemblages of the two sites, as indicated by the Analysis of Similarities

(ANOSIM) test ($R = 0.551$, $p < 0.0001$). This distinction was further supported by the non-metric multidimensional scaling (NMDS) analysis, which yielded a stress value of 0.152 well within the acceptable range (<0.2), indicating a reliable representation of the ordination (Fig. 3B).

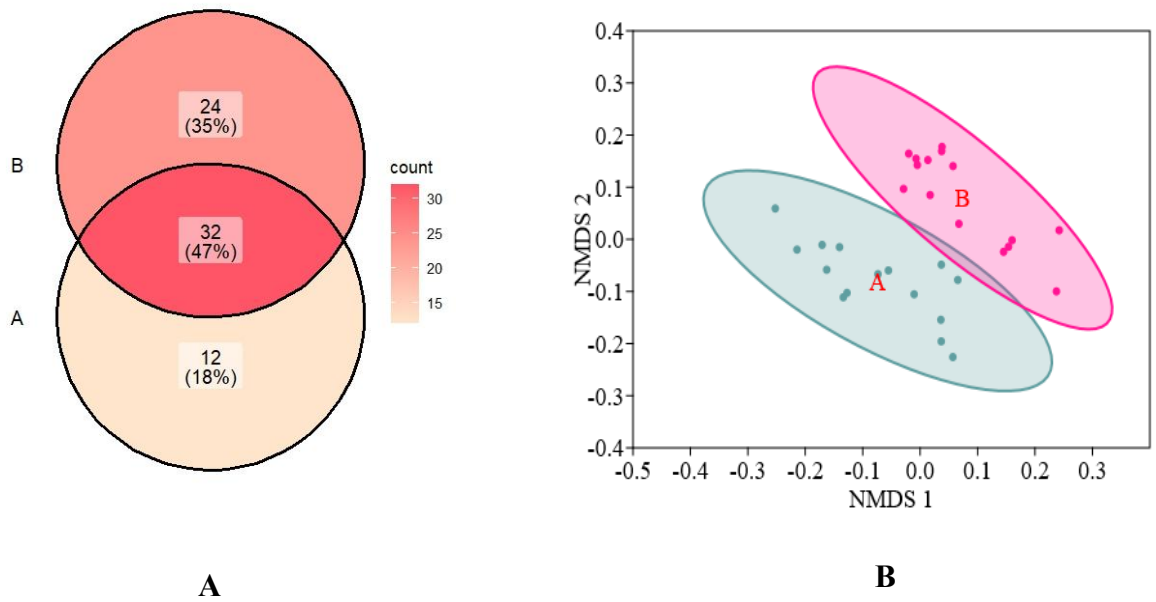


Figure 3. A. Venn diagram showing the number of shared and unique species between two study sites. B. Separation of Odonata communities between the two study sites is shown in a non-metric multidimensional plot. Pink circles and dots indicate Site A, and green circles indicate Site B.

Based on the observation status across the entire study area, 28.57% of the species (n = 10) were classified as very common, 14.28% (n = 5) as common, 26.20% (n = 12) as uncommon, and 30.95% (n = 20) as rare (Fig. 4A). Site A exhibited a higher number of rare species compared to Site B. *Orthetrum pruinosum* emerged as the most abundant species, accounting for the highest population and relative abundance within the study area (289 individuals, 12.08%) (Fig. 4B). Other highly abundant species included *Orthetrum sabina*, *Rhyothemis variegata*, *Potamarcha congener*, and *Crocothemis servilia*.

Collectively, the five most dominant species represented 45.72% of the total individuals recorded, while the 20 least abundant species comprised only 1.63% of the community. The rank-abundance curve showed a steep slope, indicating dominance by a few species and low abundance of many species (Fig. 4B). At the site level, *Rhyothemis variegata* was the most abundant species at Site A (138 individuals, 12.35%), whereas *Orthetrum pruinosum* dominated at Site B (179 individuals, 14.03%).

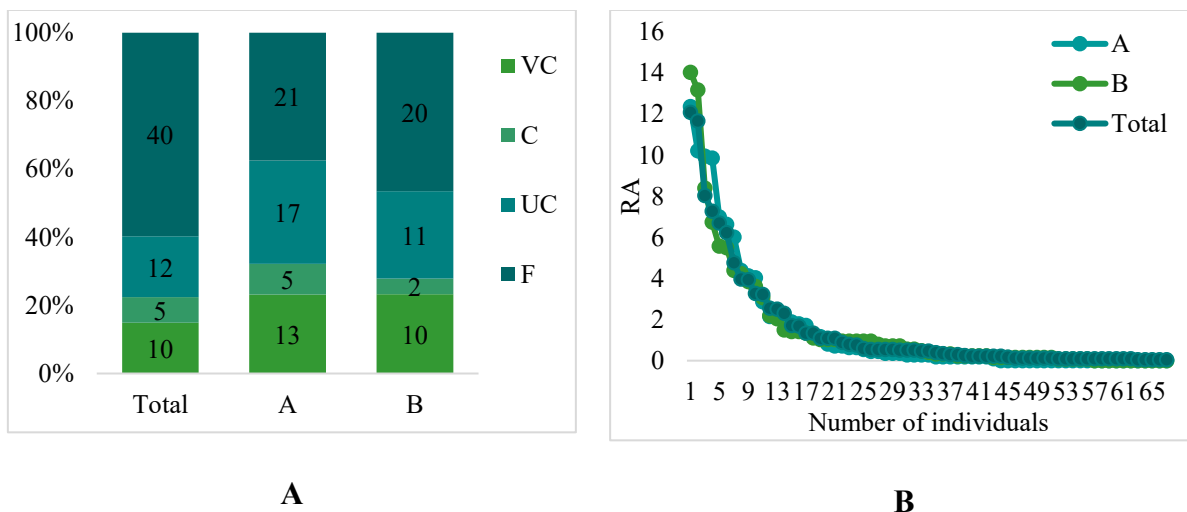


Figure 4. A. Observation status of species. B. Rank abundance plot for species recorded from the study area.

Temporal variation

This study revealed that seasonal (temporal) variation had a significant influence on the composition of Odonata communities within the study area. The rainy season recorded the highest species richness, with 63 species, and the greatest population abundance ($n = 1,008$). Biodiversity metrics indicated that the rainy season also exhibited the highest species diversity (Shannon-Wiener Index $H = 3.277$; Simpson's Index $D_s = 0.941$), while species were most evenly distributed during the winter season (Evenness, $E = 0.608$). Comparative analysis across seasons showed statistically significant differences in both species richness ($F = 6.358$, $df = 2$, $p = 0.0043$) and abundance ($F = 30.198$, $df = 2$, $p < 0.0001$). Post-hoc pairwise one-way ANOVA revealed that species richness differed significantly between the winter-rainy and winter-summer seasons, while Odonata abundance varied significantly across all three seasons.

New species record

Photographic documentation and morphological study confirmed the first record of two Odonata species from the study area within Bangladesh.

Phyllothemis eltoni Fraser, 1935

This species was recorded for the first time in Bangladesh on December 1, 2023, from a hill stream located in the Rajkandi Forest Range, Kamalganj, Moulvibazar District (24.226952°N, 91.903176°E). Three mature individuals were observed exhibiting mating behavior within the stream habitat. The

female was engaged in oviposition while being guarded by the territorial male, which actively repelled rival males. Following this, the male perched on a leaf to rest. High-resolution photographs were captured using a Nikon D500 camera equipped with a 200-500 mm zoom lens. Detailed morphological observations were also conducted in the field to support accurate identification.

The specimen exhibited a metallic midnight blue head adorned with subtle yellowish-green markings. The eyes were bright azure in living individuals, turning brown post-mortem. The labrum featured paired spots along its upper edge, while the clypeus and area above the frons vesicle were distinctly visible. The prothorax displayed yellow coloration dorsally on both the anterior and posterior lobes. The synthorax was predominantly black with distinctive yellow markings, including two broad lateral stripes, two short dorsal stripes at the anterior margin, and three pairs of yellow spots positioned near the wing bases. Additional yellow spots were present at the wing bases and on the metascutum. The wings were hyaline (transparent). The abdomen was black, marked with greenish-yellow patterns, and bore dorsally paired, elongated spots on segments S2-S7. Lateral spots were present on segments S2-S5, diminishing in size posteriorly. The superior anal appendages and caudal cerci were black, with the cerci measuring approximately twice the length of the 10th abdominal segment. The cerci were strongly curved and tapered to sharp apices (Fig. 5).



Figure 5. An adult male individual of *Phyllothemis eltoni* captured from the natural habitat of the study area.

Elatoneura campioni Fraser, 1922

This species was also documented on the same date from the hill stream within the designated study area. While surveying the stream, two male individuals of *Elatoneura campioni* were observed at rest. The individuals exhibited a predominantly black body with prominent azure blue longitudinal stripes. The eyes were black dorsally, transitioning to blue on the lower side. A transverse azure blue band extended across the head, from

eye to eye at the level of the anterior ocellus, linking the matte black vertex with the occiput. The thoracic dorsum was entirely black, with black markings along the postero-lateral suture and pale sky-blue coloration on the lateral sides. Wings were hyaline with black pterostigmata, and the anal bridge was complete. Multiple antenodal crossveins were present in both fore and hindwings. The abdomen was primarily black, adorned with azure blue markings, including large triangular spots on

segments 8 to 10. Segment 10 and the anal appendages were of similar length. The superior anal appendages were azure blue dorsally with a black apex and bore a small, imbricated black hook that was sharply curved; the inferior appendages were blue at the base and black distally. The legs were predominantly

black, with blue spotting on the coxae and trochanters (Figure 6). The morphological features observed are consistent with the species description of *Elattonneura campioni* as provided by Fraser (1933).



Figure 6. An adult male individual of *Elattonneura campioni* captured from the natural habitat of the study area

Discussion

Bangladesh, situated in South Asia, comprises a wide range of wetland ecosystems, including hill streams, ponds, marshes, freshwater lakes, rivers, and extensive swamps that provide diverse microhabitats conducive to supporting a rich assemblage of Odonata species (Khan, 2018; Chowdhury and Mohiuddin, 1994). Numerous studies conducted in the north-eastern region of the country have documented a substantial diversity of Odonates, with several species being reported for the first time from this area (Chowdhury and Mohiuddin, 2011; Bashar et al., 2014; Khan, 2015, 2018; Shome et al., 2019; 2022; Emrose et al., 2024). This suggests that the northeastern region represents an important center of Odonate diversity within Bangladesh and a more biologically enriched zone compared to other parts of the country. Consequently, this region warrants heightened conservation focus and prioritization.

The Rajkandi forest likely functions as part of a broader ecological corridor facilitating species dispersal across political boundaries. The present investigation in Rajkandi Reserve Forest documented a total of 67 Odonata species distributed across 8 families, representing approximately 65% of the known Odonata fauna of Bangladesh (Kalkman et al., 2020). Species richness estimators predicted a range between 68 to 74 species, which closely aligns with the number observed during field sampling. This concordance, along with a sample completeness rate of 92%, indicates that the sampling effort was robust and effectively captured the majority of species present in the study area.

This study also confirmed the presence of two previously unrecorded Odonata species in Bangladesh *Phyllothemis eltoni* (family: Libellulidae) and *Elattonneura campioni* (family: Coenagrionidae). Both genera are newly documented for the country, highlighting the incompleteness of the current national Odonata inventory. These findings emphasize the need for continued exploration and taxonomic research. Considering the ecological similarities and known Odonata diversity in neighboring Indian states such as Assam, Meghalaya, and Tripura, it is likely that additional undocumented species exist in Bangladesh. Regional faunal assessments provide critical insights into species richness, distribution patterns, and potential population fragmentation. Hence, regular surveys of regional Odonata communities are essential for informed biodiversity conservation and management strategies.

The higher abundance of *Orthetrum pruinatum*, *Orthetrum sabina*, *Rhyothemis variegata*, *Potamarcha congener*, and *Crocothemis servilia*, along with the presence of several unique species such as *Agriocnemis kalinga*, *Matrona nigripes*, *Macrogomphus* sp., *Orthetrum testaceum*, and *Paracercion calamorum*, contributed to the significant differences observed in Odonata communities between the two study sites (Fig. 3). Site B, characterized by a more pristine natural habitat with minimal anthropogenic disturbance, exhibited greater species richness (56 species) compared to site A, which was more impacted by human activities and supported 43 species (Fig. 2). The dominance of Libellulidae across both sites may be attributed to their ecological plasticity and ability to exploit a wide range of freshwater habitats. Many libellulids have high dispersal capacity and adaptability to habitats, allowing them to persist even under moderate disturbance. In contrast, several

Zygopteran taxa recorded exclusively at Site B are typically associated with shaded, forested stream environments, indicating higher habitat specificity and sensitivity to disturbance. Both newly recorded species, *Phyllothemis eltoni* and *Elatoneura campioni*, were found in site B. The significantly lower richness observed at Site A supports the hypothesis that anthropogenic disturbance influences odonate community structure. Additionally, *Gynacantha* species (*G. subinterrupta* and *G. khasiaca*) were predominantly found in shaded, bushy areas, while *Anax guttatus*, *Anax indicus*, and *Epophthalmia vittata* exhibited strong flight capabilities and were primarily located in the dense forest canopy near stream habitats.

Climate factors such as temperature, rainfall, and sunlight intensity significantly influence the distribution, flight activity, and movement of Odonata species (May, 1991). Additionally, freshwater availability, water flow, environmental conditions, and the quality of aquatic habitats play a crucial role in shaping the community composition of Odonates (Wahizatul-Afzan et al., 2006). In confirmation of that, the highest species richness and abundance were recorded during the rainy season, as increased rainfall during the monsoon season improves stream flow and creates more habitats for larvae, which helps with successful emergence and adult recruitment. Also, higher humidity and temperature during this time may boost adult flight activity and visibility, leading to higher recorded numbers.

Anthropogenic disturbance can alter vegetation structure, reduce canopy cover, modify microclimatic conditions, and influence water quality parameters. These factors directly impact oviposition sites and larval survival in Odonata. The decrease in species richness seen at Site A likely shows the combined effects of these habitat changes. These findings indicate that the region still supports a high diversity and abundance of Odonates. However, ongoing habitat degradation and anthropogenic disturbances pose potential threats to this biodiversity. Given the sensitivity of many stream-related dragonflies to habitat changes, ongoing human activity in reserve forest areas may cause local declines, especially among species that rely on specific habitats. Effective conservation strategies should focus on protecting riparian plants, managing human access in sensitive stream areas, and monitoring biodiversity over the long term.

Conclusion

Although the study areas were located within a reserve forest, certain sections are experiencing anthropogenic disturbances due to rapidly growing pressure for the forest dependent people. This year-long study documented 67 Odonata species across two contrasting hill-stream habitats, revealing significant spatial and seasonal variation in community structure of the transboundary forests in northeastern Bangladesh. Both study sites exhibited favorable conditions for Odonates; however, Site A provides extensive proof of undergoing anthropogenic disturbances, which may potentially worsen over time. Temporal variations also significantly influence the community structure of Odonates in the region, underscoring the strong influence of climatic factors on odonate dynamics in hill-stream ecosystems. This research contributes valuable information to the conservation of Odonates and hill-stream biodiversity in Bangladesh. The addition of *Elatoneura campioni* and

Phyllothemis eltoni to the list of new national records broadens Bangladesh's known odonate fauna and draws attention to the unexplored nature of transboundary forest ecosystems. Additionally, it highlights the transboundary regions and hill-stream habitats as vital sources of biodiversity and unique fauna, warranting increased conservation attention. These findings reinforce the role of northeastern Bangladesh as an ecologically significant extension of the Indo-Burma biodiversity landscape. Comprehensive research and public awareness campaigns are crucial for the protection of Odonate species in the hill stream areas of the north-eastern and south eastern Bangladesh. Molecular confirmation for species identification was absent in this study due to lack of specimen collection permission from forest department under wildlife conservation and protection regulations. In future more extensive studies on Odonata in the hill stream areas can discover more new Odonata species. Parallely conservation of Odonates can conserve more biodiversity in the hilly areas of Bangladesh.

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