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Seasonal dynamics of odonate (Insecta: Odonata) species diversity and abundance in West Bengal State University Campus, West Bengal, India

Dinámica estacional de la diversidad y abundancia de especies de odonatos (Insecta: Odonata) en el campus de la Universidad Estatal de Bengala Occidental, Bengala Occidental, India

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ABSTRACT

This field study aimed to investigate the seasonal variation, relative abundance, and biodiversity of odonates within the diverse habitats of the West Bengal State University (WBSU) campus, India, from January to December 2022. Using the 'belt-transect' method, a systematic survey was conducted to document the presence and distribution of odonate species across distinct habitats throughout the four seasons. In total 42 odonate species have been documented, with the highest number of species being recorded from the family Libellulidae (62%), followed by Coenagrionidae (26%), Platycnemididae (5%), Aeshnoidea (5%), and Gomphidae (2%), providing comprehensive insights into the richness and diversity of these ecologically significant insects within the WBSU campus. The results revealed distinct seasonal patterns in odonate abundance, with notable variations in species composition and relative abundance across the post-monsoon, and monsoon seasons. The findings underscore the importance of considering seasonal dynamics in understanding odonate populations and their responses to environmental changes. This study contributes to our understanding of odonate ecology within university settings and highlights the significance of sustained monitoring and conservation efforts to safeguard the diverse odonate communities present within the WBSU campus. The insights gained from this research have implications for biodiversity conservation and habitat management, emphasizing the relevance of university campuses as valuable ecological niches supporting a rich odonate diversity.

Keywords: Biodiversity; Conservation; Ecosystem; Libellulidae; Seasonality; Wetland ecology

RESUMEN

Este estudio de campo tuvo como objetivo investigar la variación estacional, la abundancia relativa y la biodiversidad de los odonatos dentro de los diversos hábitats del campus de la Universidad Estatal de Bengala Occidental (WBSU), India, desde enero hasta diciembre de 2022. Utilizando el método del "transecto de cinturón", se realizó una investigación sistemática para documentar la presencia y distribución de especies de odonatos en distintos hábitats a lo largo de las cuatro estaciones. En total, se han documentado 42 especies de odonatos, registrándose el mayor número de especies dentro de la familia Libellulidae (62%), seguida de Coenagrionidae (26%), Platycnemididae (5%), Aeshnoidea (5%) y Gomphidae (2 %), proporcionando información completa sobre la riqueza y diversidad de estos insectos ecológicamente significativos dentro del campus WBSU. Los resultados revelaron distintos patrones estacionales en la abundancia de odonatos, con variaciones notables en la composición de especies y la abundancia relativa a lo largo de las estaciones posmonzónica y monzónica. Los hallazgos subrayan la importancia de considerar la dinámica estacional para comprender las poblaciones de odonatos y sus respuestas a los cambios ambientales. Este estudio contribuye a nuestra comprensión de la ecología de los odonatos en entornos universitarios y destaca la importancia de los esfuerzos sostenidos de monitoreo y conservación para salvaguardar las diversas comunidades de odonatos presentes dentro del campus de la WBSU. Los conocimientos adquiridos a partir de esta investigación tienen implicaciones para la conservación de la biodiversidad y la gestión del hábitat, enfatizando la relevancia de los campus universitarios como nichos ecológicos valiosos que sustentan una rica diversidad de odonatos.

Palabras clave: Biodiversidad; Conservación; Ecosistema; Libellulidae; Estacionalidad; Ecología de humedales

INTRODUCTION

Odonates, comprising dragonflies (Anisoptera) and damselflies (Zygoptera), are captivating insects that inhabit a diverse range of ecosystems worldwide (Cannings, 2014). Out of 5000 odonate species reported globally, 500 species in 142 genera belonging to 18 families have been reported in India (Varshney, 1995; Kulkarni & Prasad, 2002; Subramanian, 2014; Mallick & Ghorai, 2024; Mallick & Mondal, 20023). Mitra (2005) recorded 499 and later on 463 species were confirmed by Subramanian (2009). Fraser mentioned 536 species of Odonates from British India in the three volumes of his book entitled 'Fauna of British India' (Fraser, 1933, 1934, 1936). These iconic insects are not only visually striking but also play significant ecological roles, functioning as predators of various small insects and serving as indicators of ecosystem health and water quality (Romanowski, 2013; Chandra & Gupta, 2022). Odonates have aquatic larval phases. Their presence as top predators in both adult and larval stages contribute significantly to aquatic food webs (Mishra *et al.*, 2019; Babosova *et al.*, 2019). Their widespread distribution and sensitivity to environmental changes make them excellent subjects for ecological studies, particularly in the context of biodiversity monitoring and conservation efforts (Hassall & Thompson, 2008; Cerini *et al.*, 2020). In this study, we investigate the seasonal dynamics of odonate species diversity and abundance within the West Bengal State University (WBSU) campus, India, spanning a period from January 2022 to December 2022.

University campuses, often characterized by a mosaic of habitats, including manicured lawns, natural green spaces, wetlands, and urbanized areas, can provide crucial refuges for diverse flora and fauna, including odonates (Mallick, 2023a). Understanding the seasonal patterns of odonate diversity and abundance within the university campus is paramount for assessing the impacts of environmental changes, human activities, and land management practices on these ecologically important insects (Saha, 2017).

Recent studies have highlighted the fundamental importance of odonates in maintaining ecological balance and functioning as bio-indicators of environmental quality (Kietzka, 2019; Ilhamdi *et al.*, 2020; Das & Maity, 2021). The substantial anthropogenic pressures and natural fluctuations that impact ecosystems, it is imperative to assess the responses of odonate communities to these changes (Villalobos-Jimenez *et al.*, 2016; Dolny *et al.*, 2021; Silva *et al.*, 2021). By concentrating on a university campus, this study won't only contribute to our understanding of odonate ecology but also will offer insights into the potential role of academic institutions in sustaining and enhancing biodiversity within urban landscapes (Hassall & Thompson, 2008). Furthermore, the findings may inform conservation strategies and habitat management practices, contributing to the development of sustainable campus environments that support diverse odonate communities.

This research aspires to bridge the knowledge gaps regarding odonate ecology within university settings, ultimately serving as a stepping stone for integrating biodiversity conservation into educational and land management agendas. The study will emphasize the significance of long-term monitoring and conservation actions to safeguard odonate populations within the WBSU campus. By obtaining a deeper understanding of the factors that influence odonate diversity and abundance, the findings of this study can contribute to the formulation of conservation initiatives and the development of best practices for preserving these captivating insects within the campus and broader urban landscapes.

METHODOLOGY

Study Area

The present study was conducted in WBSU campus, Barasat, Kolkata, West Bengal, India. WBSU campus is located in between 88.434936° E longitude and 22.739327° N latitude in West Bengal, India (Figure 1). The campus encompasses an array

of habitats, including natural wetlands, wooded areas, manicured lawns, and urbanized zones, which collectively provide a mosaic of environments conducive to supporting diverse odonate communities (Mallick, 2023a). These varying habitats present an ideal setting for examining the ecological significance of odonates in response to seasonal fluctuations, human activities, and environmental changes within a university landscape.

Fieldwork methods

To comprehensively assess the seasonal dynamics of odonate species diversity and abundance, a systematic field study was conducted in the West Bengal State University campus from January to December 2022. The establishment of 500-meters and 200-meters routes for conducting 9-belt transect methods to sample odonates across different habitats and seasons, aiming to document the presence, distribution, and relative abundance of odonate species throughout the study period. The study encompassed four distinct seasons: winter (January to February), spring (March to May), summer (June to August), and autumn (September to December) (Mallick, 2023b). Each season was characterized by unique climatic and environmental conditions, providing an opportunity to investigate the responses of odonate populations to seasonal variations. The sampling effort was evenly distributed across the seasons, ensuring that the study captured the full spectrum of seasonal dynamics in odonate diversity and abundance. Belt transect surveys were employed as the primary method for sampling odonates across the diverse habitats present within the university campus. Transects were established to systematically cover representative areas within each habitat type, allowing for standardized sampling and reliable comparisons of odonate abundance and diversity across different habitats and seasons. The selection of transect locations aimed to encompass a variety of microhabitats, including riparian zones, open fields, wooded areas, and wetlands, reflecting the diversity of odonate habitats present within the campus. No specimens were collected or harmed during the study and identified to the species level using taxonomic keys. Dragonflies and Damselflies were identified using suitable keys from published literature (Subramanian, 2005; Nair, 2011; Fraser, 1933, 1934, 1936; Mitra, 2002; Subramanian & Babu, 2017).

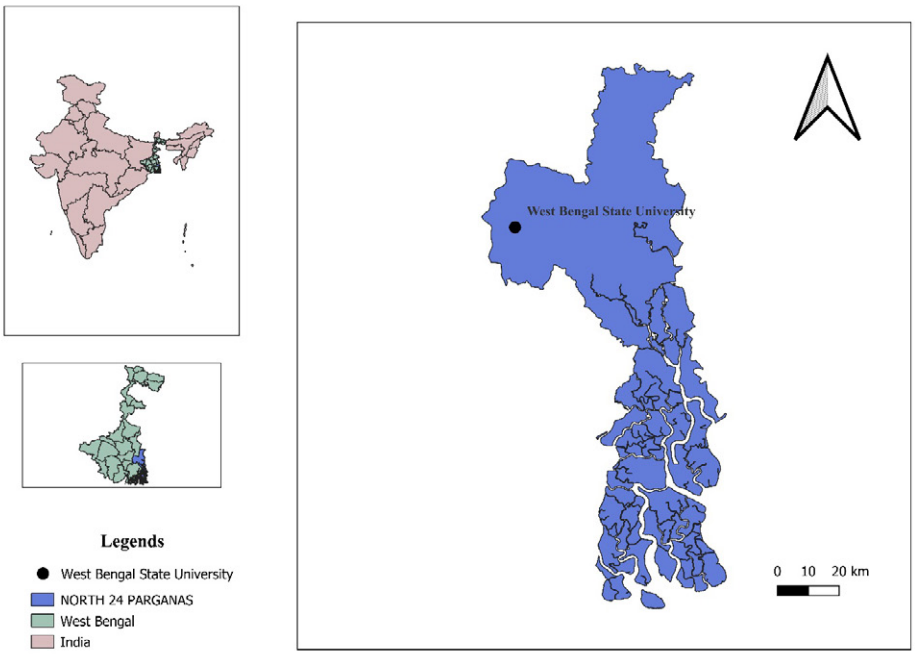

Figure 1. Map of study area in North 24 Parganas district, West Bengal, India. The software QGIS was used to produce these maps.

Analytical methods

Data were arranged to obtain the following parameters:

I) Relative abundance = n/N, where n is the total number of a particular species and N is the total number of all species (MacArthur, 1960). The diversity indices were calculated using Simpson's diversity index (Simpson, 1949), Shannon Wiener diversity index (Shannon, 1948; Shannon, 1949), Margalef's Richness index (Margalef, 1994) and Evenness index (Magurran, 1949; Pielou, 1969; Mallick, 2023b). The input for the data analysis was a relative abundance matrix of family, genera, and species across season.

II) Measurement of Diversity. The type of diversity used here is an alpha diversity which is the diversity of species within a community or habitat that diversity index was calculated by using the Shannon Wiener diversity index (Moreno *et al.*, 2017).

Shannon Wiener diversity index (H')
H' = {-∑pi (ln)pi}
[pi=n/N]
S = number of individuals of species,
N = total number of all individuals in the sample,
ln = logarithm to base e

Measurement of species richness
Margalef's Richness index = [(S-1) /ln(n)]
S = total number of species,
N = total number of all individuals in the sample,
Ln = Natural logarithm,

Dominance and Simpson index
(1-D) = ∑n*(n-1)/N*(N-1)
Where N is the number of individuals of taxon I
Dominance 1 - Simpson index ranges from 0 to 1
Simpson Index 1-D. Measures evenness of the community from 0 to 1 dominance and Simpson indices are often interchangeably.

Pielou Evenness Index (J)
J = H' /Log (S)

Microsoft Excel 2013 was used for data analysis, and the software PAST was employed for calculating diversity indices and performing biodiversity analyses (Hammer *et al.*, 2001). Raw data are available in an Excel file as Supplementary material.

RESULTS

The investigation revealed substantial seasonal variation in odonate species diversity within the WBSU campus. Across the four distinct seasons, the study documented shifts in species composition, with certain species being more prevalent during specific seasons while others exhibited a more consistent presence throughout the year. Species richness, as a measure of the number of distinct odonate species observed within the study area, varied significantly across seasons, reflecting the dynamic nature of odonate communities within the campus.

In this study, two suborders were identified, Anisoptera and Zygoptera. Within Anisoptera, 29 species of the family Libellulidae (26 species) were recorded and we recorded two species of the family Aeshnidae and recorded one species of the family Gomphidae. The other suborder, Zygoptera, was represented by 11 species of the family Coanagrinoidae and two species of the family Platycnenimidae (Figure 2). The study area has a diverse range of odonate species, including 12 rare, 4 not-rare, 19 common, and 7 very-common species, indicating a healthy and complex ecosystem. In total we recorded 3359 individuals representing 42 species of Odonata in each season (Table 1, Figure 3). Different diversity indices, such as Shannon-Wiener index, Simpson's index, and species richness, were calculated for the odonate species from the study area (Table 2).

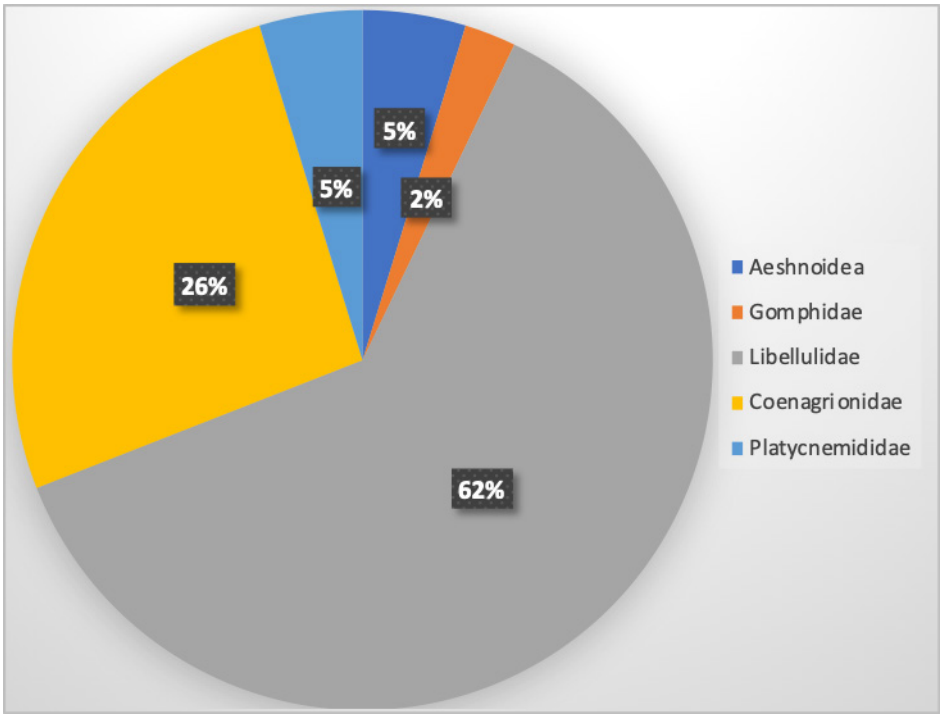

Figure 2. Family-wise abundance of odonate species in the West Bengal State University campus, India.

The study found that the monsoon and post-monsoon seasons have the highest diversity of odonate species (55-59% of total species), indicating that these periods are most favorable for odonate populations due to abundant water and food resources. Summer had a moderate diversity (32%), while winter had the lowest diversity (29%). The diversity of odonates was significantly lower during the winter season, with only 19 species recorded, and a decreased number of species observed in all sampled habitats. The cold temperatures and decreased insect activity characteristic of the winter months likely contributed to the lower species richness during this season. However, certain cold-tolerant species, such as the winter damselfly [*Brachythemis contaminata* (Fabricius, 1793)] and winter skimmer [*Orthetrum sabina* (Drury, 1770)], were observed, indicating the resilience of specific species to winter conditions. As the summer season (March to May) transitioned in, the odonate diversity exhibited a notable increase, with the emergence of new species and heightened activity within the campus. The warmer temperatures and favorable environmental conditions during spring provided optimal breeding and foraging opportunities for odonates, resulting in a surge in species richness. Species that are characteristic of this season, such as the Senegal golden dartlet [*Ischnura senegalensis* (Rambur, 1842)] and pied paddy skimmer [*Neurothemis tullia* (Drury, 1773)], contributed to the seasonal upswing in odonate diversity.

The monsoon season was characterized by a significant increase in odonate diversity, with 36 species observed, and a concentrated presence of species across the campus's varied habitats, underscoring the significance of this period for odonates population. The diverse array of odonate species, including the Greater crimson glider (*Urothemis signata* (Rambur, 1842)] and Crimson-tailed marsh hawk [*Orthetrum pruinosum* (Burmeister, 1839)]. The summer season's warm temperatures and plentiful resources enabled 21 odonate species to thrive, as they capitalized on the favorable conditions to proliferate and dominate the habitat. The period following the monsoon season saw a significant surge in odonate diversity, with 39 species observed, highlighting the importance of this season for odonate populations. The high species richness observed during this period underscored the importance of seasonally favorable conditions in shaping odonate community dynamics. As winter (September to

December) unfolded, the odonate diversity gradually transitioned, reflecting a decline in species richness compared to the peak diversity observed during the summer months. The changing environmental conditions, including decreasing temperatures and alterations in habitat structure, likely contributed to the seasonal turnover in odonate species. However, certain autumn-affiliated species, such as the Pygmy dartlet [*Agriocnemis pygmaea* (Rambur, 1842)] and ruddy marsh skimmer [*Crocothemis servilia* (Drury, 1773)], continued to contribute to the odonate community during this transitional period. The study elucidated the intricate seasonal dynamics of odonate species diversity and abundance within the West Bengal State University campus (Figure 3). Percentile of seasonal variation of odonate species in study area (Figure 4).

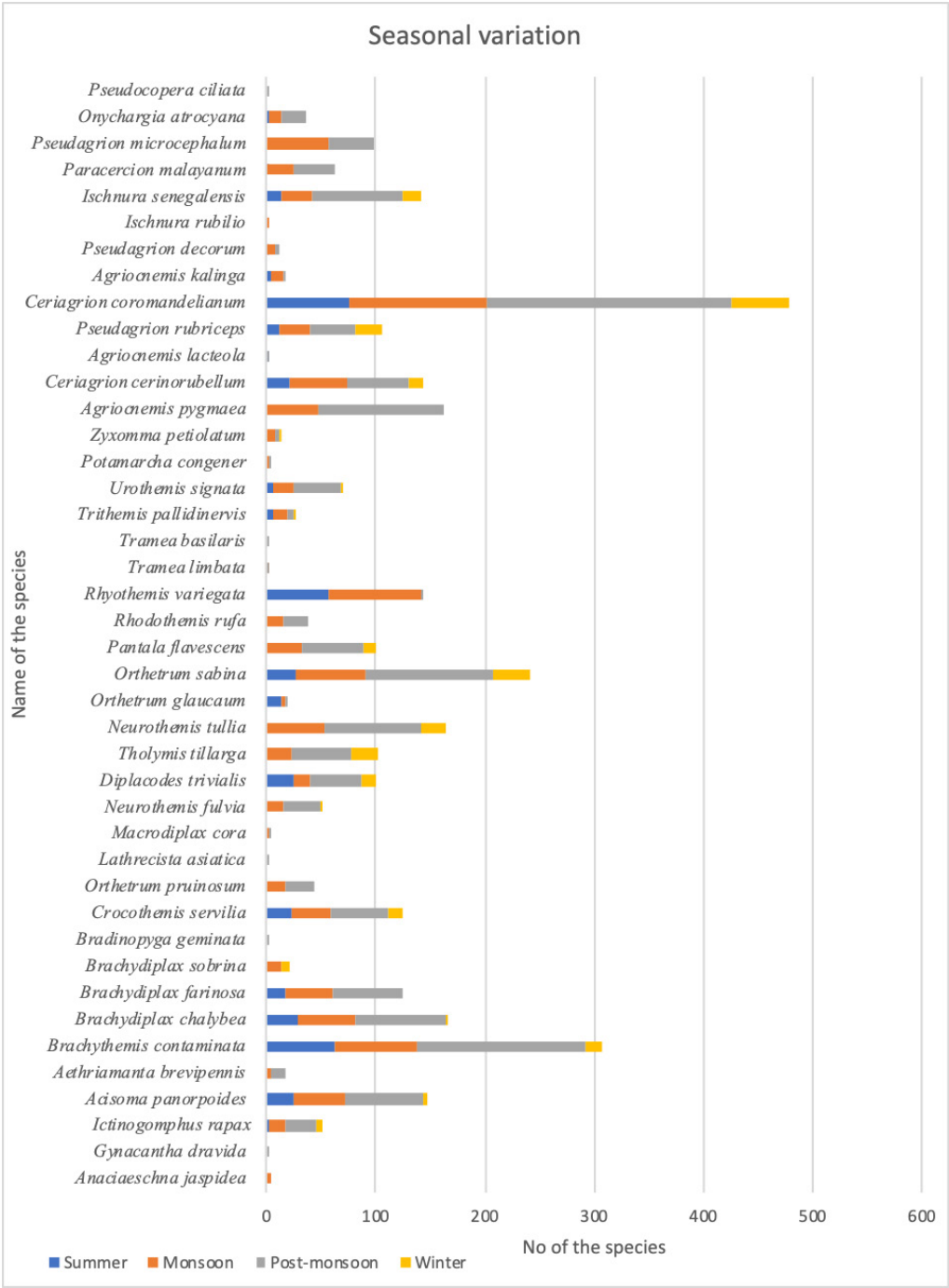

Figure 3. Seasonal variation of different odonate species in West Bengal State University campus, India.

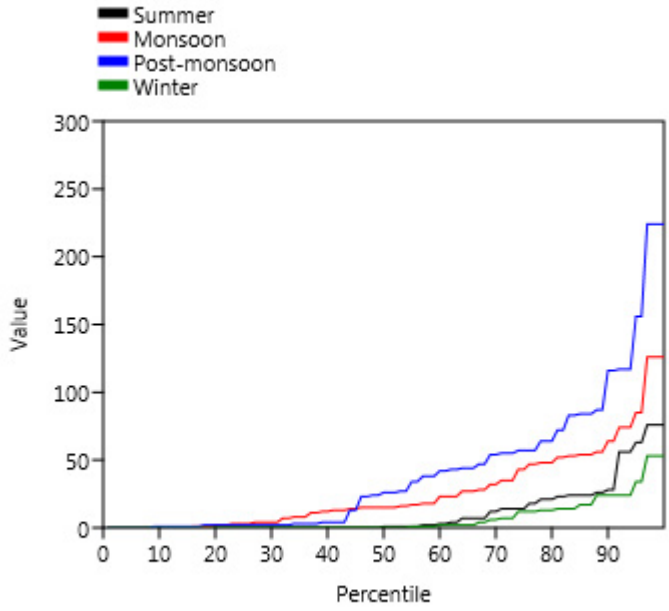

Figure 4. Percentile of seasonal variation of odonate species in West Bengal State University campus, India.

Table 1. List of odonate species (Anisoptera, dragonflies; Zygoptera, Damselflies) in the West Bengal State University campus, India. Survey took place from January to December 2022.

Family	Common Name	*Scientific Name*	Abundance	Local Status
Suborder Anisoptera				
Aeshnidae	Rusty darner	*Anaciaeschna jaspidea* (Burmeister, 1839)	4	Rare
Aeshnidae	Brown darner	*Gynacantha dravida* Lieftinck, 1960	2	Rare
Gomphidae	Indian common clubtail	*Ictinogomphus rapax* (Rambur, 1842)	51	Common
Libellulidae	Trumpet-tail	*Acisoma panorpoides* Rambur, 1842	148	Very Common
Libellulidae	Scarlet marsh hawk	*Aethriamanta brevipennis* (Rambur, 1842)	17	Not Rare
Libellulidae	Ditch jewel	*Brachythemis contaminata* (Fabricius, 1793)	307	Very Common
Libellulidae	Rufous-backed marsh hawk	*Brachydiplax chalybea* (Brauer, 1868)	166	Very Common
Libellulidae	Black-tailed dasher	*Brachydiplax farinosa* Krüger, 1902	125	Common
Libellulidae	Little blue marsh hawk	*Brachydiplax sobrina* (Rambur, 1842)	21	Not Rare
Libellulidae	Granite ghost	*Bradinopyga geminata* (Rambur, 1842)	2	Rare
Libellulidae	Ruddy marsh skimmer	*Crocothemis servilia* (Drury, 1770)	124	Common
Libellulidae	Crimson-tailed marsh hawk	*Orthetrum pruinosum* (Burmeister, 1839)	43	Common
Libellulidae	Asiatic blood-tail	*Lathrecista asiatica* (Fabricius, 1798)	1	Rare
Libellulidae	Estuarine skimmer	*Macrodiplax cora* Brauer, 1867	4	Rare
Libellulidae	Fulvous forest skimmer	*Neurothemis fulvia* (Drury, 1773)	51	Common
Libellulidae	Blue ground skimmer	*Diplacodes trivialis* (Rambur, 1842)	100	Common

Libellulidae	Coral-tailed cloudwing	*Tholymis tillarga* (Fabricius, 1798)	102	Common
Libellulidae	Pied paddy skimmer	*Neurothemis tullia* (Drury, 1773)	165	Common
Libellulidae	Blue marsh hawk	*Orthetrum glaucaum* (Brauer, 1865)	19	Common
Libellulidae	Green marsh hawk	*Orthetrum sabina* (Drury, 1770)	241	Very Common
Libellulidae	Wandering glider	*Pantala flavescens* (Fabricius, 1798)	101	Common
Libellulidae	Rufous marsh glider	*Rhodothemis rufa* (Rambur, 1842)	39	Common
Libellulidae	Common picture wing	*Rhyothemis variegata* (Linnaeus, 1763)	143	Common
Libellulidae	Black marsh trotter	*Tramea limbata* (Desjardins, 1832)	3	Rare
Libellulidae	Red marsh trotter	*Tramea basilaris* (Palisot de Beauvois, 1805)	1	Rare
Libellulidae	Long-legged marsh glider	*Trithemis pallidinervis* (Kirby, 1889)	25	Not Rare
Libellulidae	Greater crimson glider	*Urothemis signata* (Rambur, 1842)	70	Common
Libellulidae	Yellow-tailed ashy skimmer	*Potamarcha congener* (Rambur, 1842)	5	Rare
Libellulidae	Brown dusk hawk	*Zyxomma petiolatum* Rambur, 1842	13	Rare
Suborder: Zygoptera				
Coenagrionidae	Pygmy dartlet	*Agriocnemis pygmaea* (Rambur, 1842)	163	Very Common
Coenagrionidae	Orange-tailed marsh dart	*Ceriagrion cerinorubellum* (Brauer, 1865)	144	Common
Coenagrionidae	Milky dartlet	*Agriocnemis lacteola* Selys, 1877	2	Rare
Coenagrionidae	Saffron-faced blue dart	*Pseudagrion rubriceps* Selys, 1876	106	Common
Coenagrionidae	Coromandel marsh dart	*Ceriagrion coromandelianum* (Fabricius, 1798)	479	Very Common
Coenagrionidae	Indian hooded dartlet	*Agriocnemis kalinga* Nair & Subramanian 2015	18	Common
Coenagrionidae	Three lined dart	*Pseudagrion decorum* (Rambur, 1842)	12	Not Rare
Coenagrionidae	Western golden dartlet	*Ischnura rubilio* Selys, 1876	1	Rare
Coenagrionidae	Senegal golden dartlet	*Ischnura senegalensis* (Rambur, 1842)	142	Very Common
Coenagrionidae	Malayan lily-squatter	*Paracercion malayanum* (Selys, 1876)	62	Common
Coenagrionidae	Blue grass dart	*Pseudagrion microcephalum* (Rambur, 1842)	99	Common
Platycnemididae	Black marsh dart	*Onychargia atrocyana* Selys, 1865	36	Common
Platycnemididae	Pied bush dart	*Pseudocopera ciliata* Selys, 1863	2	Rare

Table 2. Diversity indices of odonate species in the West Bengal State University campus, India.

	Summer	Monsoon	Post-monsoon	Winter
Taxa_S	21	36	39	19
Individuals	425	1049	1619	266
Dominance_D	0.09663	0.05249	0.06028	0.09817
Simpson_1-D	0.9034	0.9475	0.9397	0.9018
Shannon_H	2.581	3.18	3.057	2.545
Evenness_e^H/S	0.6288	0.6677	0.5454	0.6707
Brillouin	2.485	3.104	3.005	2.417
Menhinick	1.019	1.112	0.9693	1.165
Margalef	3.305	5.032	5.142	3.224
Equitability_J	0.8476	0.8873	0.8345	0.8643
Fisher_alpha	4.637	7.221	7.195	4.683
Berger-Parker	0.1788	0.1201	0.1384	0.1992
Chao-1	22.5	36.5	39.75	19.25

DISCUSSION

The seasonal variation in odonate species diversity observed in this study highlights the importance of monsoon and post-monsoon seasons for these insects in the study area. The significant increase in species richness during these periods suggests that the abundance of water and food resources creates a favorable environment for odonates. This is likely due to the creation of temporary water bodies and the proliferation of aquatic vegetation during the monsoon season, which provides ideal breeding and foraging habitats for many odonate species.

The moderate diversity observed during the summer season may be attributed to the presence of residual water bodies and the persistence of some aquatic vegetation (Keinath *et al.*, 2023). In contrast, the lower diversity during the winter season may be due to the security of water and food resources, making it a less favorable period for odonates (Mallick & Mondal, 2023).

The seasonal dynamics of odonate species diversity and abundance within the West Bengal State University campus in India represent a compelling area of research, with wide-reaching implications for biodiversity monitoring, ecological conservation, and environmental management. The study's comprehensive investigation aimed to shed light on the presence and relative abundance of odonate species across different habitats within the university campus, providing valuable insights into the intricate patterns and processes governing odonate populations. Such varied environmental conditions offer a rich tapestry of ecological niches potentially supporting a wide array of odonate species. Understanding the distribution and seasonal dynamics of odonates in this complex landscape is paramount for devising effective conservation strategies and elucidating the broader ecological significance of odonates within university landscapes.

The study's emphasis on seasonal dynamics holds particular significance, as it acknowledges the dynamic nature of odonate populations and the underlying environmental factors governing their fluctuations. By conducting surveys across distinct seasons, the research endeavors to capture the temporal variations in odonate diversity and abundance, recognizing the unique ecological dynamics that unfold throughout the year. This temporally comprehensive approach holds immense value, as

it allows for the identification of seasonal peaks in odonate activity, the assessment of species turnover across seasons, and the recognition of potential ecological triggers driving these seasonal shifts in odonate populations.

Furthermore, the study's focus on the campus environment adds an additional layer of relevance and practicality, as it underscores the importance of understanding and conserving biodiversity within human-altered landscapes. University campuses often serve as microcosms of diverse ecological habitats, where human activities intersect with natural ecosystems. Investigating odonate diversity and abundance within this context lends valuable insights into the potential impacts of anthropogenic disturbances and habitat modifications on odonate populations, thereby informing conservation strategies tailored to such human-influenced landscapes.

The ecological implications of the study are far-reaching, extending beyond the confines of the university campus (Corbet *et al.*, 2006). Odonates, as prominent members of aquatic and terrestrial ecosystems, play pivotal roles in regulating insect populations, serving as food sources for various predators, and contributing to nutrient cycling within ecosystems (McPeek, 2008; Wesner, 2010; Stoks & Cordoba-Aguilar, 2012; Breviglieri & Romero, 2017). Understanding the seasonal dynamics of odonate populations not only enriches our knowledge of these charismatic insects but also provides essential information for ecosystem management and conservation (Woods & McGarvey, 2023; Mallick & Mondal, 2023). Moreover, odonates are often considered bio-indicators of environmental quality, and their population trends can reflect broader changes in ecosystem health and functioning (Bredenhand, 2005; Nasirian & Irvine, 2017). These findings have important implications for the conservation and management of odonate populations in the study area. The monsoon and post-monsoon seasons should be considered critical periods for habitat preservation and restoration efforts, while the summer and winter seasons may require targeted interventions to enhance water and food availability. Further research is needed to elucidate the specific habitat requirements and ecological adaptions of odonate species in the study area.

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Author Contributions. Md. Abu Imran Mallick: Conceptualization; data curation; formal analysis; map making; investigation; field survey; visualization; supervision; writing- original draft; writing- review and editing; methodology; software; validation Narayan Ghorai: Supervision; writing-review and editing. The authors read and approved the final version of the manuscript.

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