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DIVERSITY AND SEASONAL OCCURRENCE OF ODONATES IN THE DRY DECIDUOUS ECOREGION OF PURULIA, WEST BENGAL, INDIA

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Abstract. A year-long study was conducted in the dry deciduous ecoregion of Purulia, West Bengal, India from March 2018 to February 2019 to document the diversity, species composition, and occurrence of odonata species in different seasons. Direct search and opportunistic sighting methods were used in combination at five selected sites, namely, the Sidho-Kanho-Birsha University campus, Saheb Bandh, the Surulia Deer Park (Mini Zoo), Ketika, and the Kansai river-side. A total of 11,471 individuals belonging to 8 families and 40 species were recorded during the study period. Anisoptera (dragonflies) were represented by 29 species belonging to 4 families, whereas Zygoptera (damselflies) were also found to be represented by 4 families but only 11 species. Libellulidae were found to be the largest family represented by 24 species, while the ground skimmer *Diplacodes trivialis* was the most dominant species. Species richness was the highest in the post-monsoon, whereas the Shannon diversity index was found to reach maximum values in winter. Overall, we conclude that the town of Purulia and its adjoining area with its patchy vegetation and extreme weather conditions have moderate odonate diversity.

INTRODUCTION

Dragonflies and damselflies (Insecta: Odonata) are insects which comprise the suborders Anisoptera (dragonflies) and Zygoptera (damselflies). The order Odonata comprises 6369 species worldwide (Paul et al. 2023), 503 species of which are recorded from India (Joshi et al. 2020) and 239 species from West Bengal (Dawn 2021). The Indian subcontinent, especially the regions of Sikkim, North Bengal, Khasi Hills, Western Ghats, and Nilgiris, harbours the greatest number of odonata species (Kalkman et al. 2008, 2020; Lahiri 1989). In this article, the term odonates will be used as an inclusive form that refers to both dragonflies and damselflies. Odonates spend their immature stages of life in water bodies such as lakes, ponds, rivers, and streams, where they need clean water to thrive, thus acting as an important indicator of different water quality parameters. As they are very sensitive to different environmental pollutants and temperature fluctuations, their diversity and abundance may be used to monitor both aquatic and terrestrial environments (Hassall and Thompson 2008; Ferreras-Romero et al. 2009). They act as efficient predators of many aquatic insects, while many birds, frogs, and other animals prey upon them. Thus, they act as an important link in different food chains. The "Dragonfly biotic index", which is useful for the identification of habitat characteristics and for the maintenance and conservation of other aquatic species, has been developed (Clark and Samways 1996; Smith et al. 2007; Simaika and Samways 2009). Research works involving the application of odonates in mosquito and other pest control are gaining importance, and there are several published works indicating that the appropriate use of odonates might perform a significant role in vector mosquito management (Sebastian et al. 1990; Fincke et al. 1997; Stav et al. 2000; Mandal et al. 2008; Faithpraise et al. 2014; Staats et al. 2016; Samanmali et al. 2018).

The biodiversity of the Purulia district is insufficiently explored to date (Samanta et al. 2017; Das 2018; Mahato et al. 2021), with no recent published reports about odonate diversity. The present study aims to prepare a checklist of odonates from the Purulia region and to assess their diversity and seasonal occurrence.

MATERIAL AND METHODS

Purulia, the westernmost district of West Bengal, India is topographically an undulated land that constitutes the

eastern part of the Chotanagpur plateau. The district has scattered vegetation with mostly dry deciduous plants, such as Sal *Shorea robusta*, Palash *Butea monosperma*, Mahua *Madhuca longifolia* and Neem *Azadirachta indica*, and plenty of water bodies. In the Purulia district, rainfall occurs mostly due to the Southwest monsoon. The average annual rainfall varies between 1100 and 1500 mm (Samanta et al. 2017). Temperature is very high in summer (52 degrees) and low in winter (2.8 degrees) (Samanta et al. 2017).

The present study was carried out from March 2018 to February 2019 in and around the town of Purulia (23.33°N; 86.36°E), Purulia, West Bengal, India to document the dragonfly and damselfly diversity in this area. Five study sites were selected within the region: the Sidho-Kanho-Birsha University campus, Saheb Bandh, the Surulia Deer Park (Mini Zoo), Ketika, and the Kansai river-side (Figure 1). The sites were selected based on the preliminary pilot study, which was conducted throughout the town. The places with open land, water bodies, plenty of vegetation and the visible presence of odonata species were selected for the present study.

The campus of Sidho-Kanho-Birsha University has a vast open land with scattered bushes and trees. Saheb Bandh is a large man-made lake with some vegetation surrounding it. The Surulia Deer Park is an urban forest with water bodies and a mini zoo inside it. Ketika, situated about 2 km from the Purulia railway station, is a well-wooded residential area with trees, bushes, open lands, intermittent small ponds, and ditches. The Kansai river-side is an area around the bank of the Kansai River, which flows along the southern boundary of the town, with bushes, shrubs and some large trees.

Direct search (Sutherland 1996) and opportunistic sighting methods were used in combination to document the diversity and abundance of odonates. Field surveys were done during the morning and noon (10 am to 3 pm) when odonates are most active and the probability of sighting is the highest. Following visual observation, the presence of odonates was confirmed with the help of binoculars (Olympus 8 × 40 DPS1) and photographs were taken with digital cameras (Nikon Coolpix P520 and Canon 1200d, lense: 55–250 mm). The specimens were identified from the photographs using respective

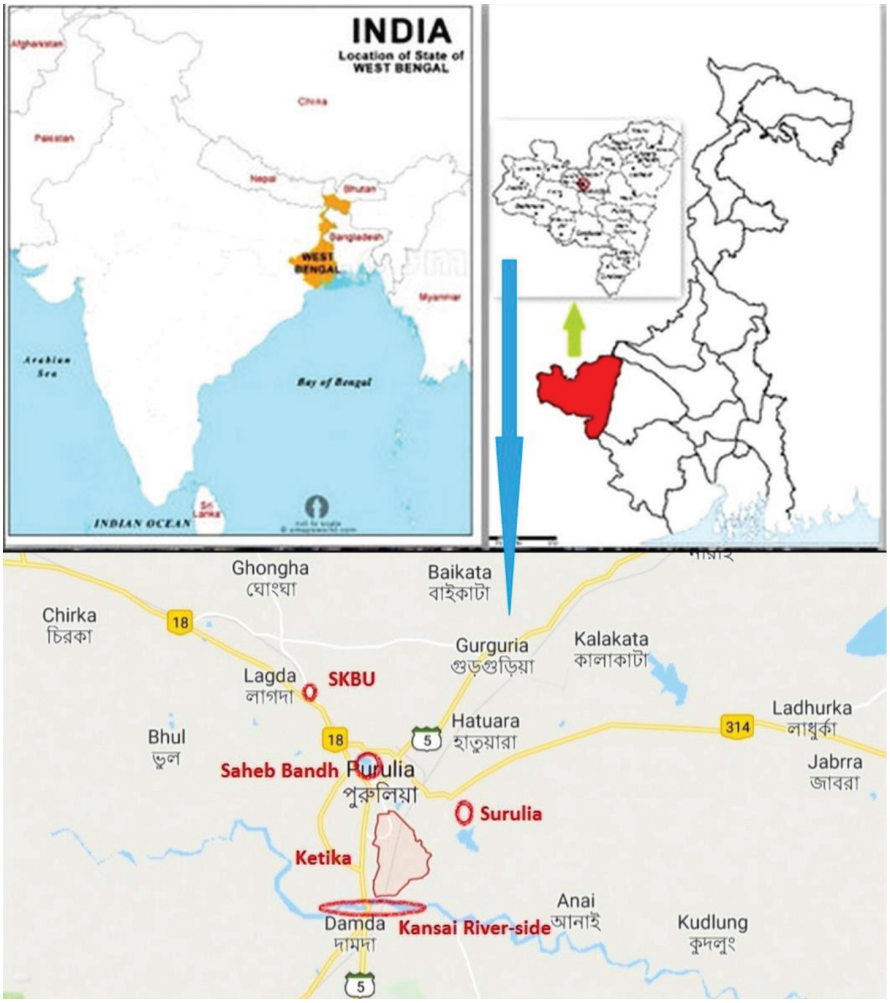

Figure 1. Location and google map image of five study sites selected for the present study (the Sidho-Kanho-Birsha University campus, Saheb Bandh, the Surulia Deer Park (Mini Zoo), Ketika and the Kansai river-side).

Table 1. Checklist of Odonates found in the selected habitats of the Purulia town with their relative abundance (p_i) and seasonal distribution.

Sl. No.	Common Name	Scientific Name	p_i	Seasons**	Species Code
	Infraorder: Anisoptera				
	Family: Aeshnidae				
1	Blue-Tailed Green Darner	*Anax guttatus* (Burmeister, 1839)	0.00105	1, 2	AGU
2	Brown Darner	*Gynacantha dravida* (Lieftinck, 1960)	0.00009	3	GDR
3	Rusty darner	*Anaciaeschna jaspidea* (Burmeister, 1839)	0.00009	3	AJA
	Family: Gomphidae				
4	Common clubtail	*Ictinogomphus rapax* (Rambur, 1842)	0.00253	1, 2, 3,4	IRA
	Family: Libellulidae				
5	Blue marsh hawk	*Orthetrum glaucum* (Brauer, 1865)	0.00174	4	OGL
6	Blue-tailed Black Marsh Skimmer	*Orthetrum cancellatum* (Linnaeus, 1758)	0.00026	1	OCA
7	Common picture wing	*Rhyothemis variegate* (Linnaeus, 1763)	0.03627	1, 2, 3, 4	RVA
8	Coral-tailed Cloud Wing	*Tholymis tillarga* (Fabricius, 1798)	0.00078	3, 4	TTI
9	Crimson-tailed Marsh Hawk	*Orthetrum pruinosum* (Burmeister, 1839)	0.02589	1, 2, 3, 4	OPR
10	Ditch jewel	*Brachythemis contaminate* (Fabricius, 1793)	0.27757	1, 2, 3, 4	BCO
11	Fulvous forest skimmer	*Neurothemis fulvia* (Drury, 1773)	0.01465	1, 3, 4	NFU
12	Granite Ghost	*Bradinopyga geminate* (Rambur, 1842)	0.00288	1, 2, 3, 4	BGE
13	Greater Crimson Glider	*Urothemis signata* (Rambur, 1842)	0.00113	1, 2, 4	USI
14	Green Marsh Hawk	*Orthetrum Sabina* (Drury, 1770)	0.00924	1, 2, 3, 4	OSA
15	Ground skimmer	*Diplacodes trivialis* (Rambur, 1842)	0.28141	1, 2, 3, 4	DTR
16	Little blue marsh hawk	*Brachydiplax sobrina* (Rambur, 1842)	0.00131	1, 2, 4	BSO
17	Long legged marsh glider	*Trithemis pallidinervis* (Kirby, 1889)	0.00218	1, 2, 3, 4	TPA
18	Ruddy marsh skimmer/ Scarlet skimmer	*Crocothemis servilia* (Drury, 1770)	0.17113	1, 2, 3, 4	CSE
19	Ruddy Meadow Skimmer	*Neurothemis intermedia* (Rambur, 1842)	0.00009	1	NIN
20	Rufous Marsh Glider	*Rhodothemis rufa* (Rambur, 1842)	0.00192	1, 2	RRU
21	Rufous-backed Marsh Hawk	*Brachydiplax chalybea* (Brauer, 1868)	0.00052	1, 4	BCH
22	Small skimmer	*Orthetrum taeniolatum* (Schneider, 1845)	0.00044	1	OTA
23	Trumpet tail/ Asian pintail	*Acisoma panorpoides* Rambur, 1842)	0.00262	1, 4	APA
24	Wandering Glider	*Pantala flavescens* (Fabricius, 1798)	0.07253	1, 2, 3, 4	PFL
25	Yellow-tailed Ashy Skimmer	*Potamarcha congener* (Rambur, 1842)	0.00427	3, 4	PCO
26	Brown Dusk Hawk	*Zyxomma petiolatum* Rambur, 1842)	0.00009	3	ZPE
27	Red marsh trotter	*Tramea basilaris* (Palisot de Beauvois, 1817)	0.00026	3	TBA
28	Black marsh trotter	*Tramea limbata* (Desjardins, 1832)	0.00009	3	TLI
	Family: Macromiidae				
29	Common torrent hawk	*Epophthalmia vittata* (Burmeister, 1839)	0.00009	3	EVI
	Infraorder: Zygoptera				
	Family: Calopterygidae				
30	Clear winged forest glory	*Vestalis gracilis* (Rambur, 1842)	0.00479	1, 2, 3	VGR
	Family: Coenagrionidae				
31	Coromandel Marsh Dart	*Ceriagrion coromandelianum* (Fabricius, 1798)	0.0326	1, 2, 3, 4	CCO
32	Dusky lilly squatter	*Paracercion calamorum* (Ris, 1916)	0.00924	1, 2, 3, 4	PCA
33	Golden dartlet	*Ischnura rubilio* (Selys, 1876)	0.01194	1, 2, 3, 4	IRU
34	Orange tailed marsh dart	*Ceriagrion cerinorubellum* (Brauer, 1865)	0.00357	1, 2, 4	CCE
35	Pygmy dartlet	*Agriocnemis pygmaea* (Rambur, 1842)	0.01142	1, 2, 3, 4	APY
36	Senegal golden dartlet	*Ischnura senegalensis* (Rambur, 1842)	0.0088	1, 2, 3, 4	ISE
	Family: Lestidae				
37	Emerald-striped Spreadwing	*Lestes viridulus* (Rambur, 1842)	0.00078	2, 3, 4	LVI
	Family: Platycnemididae				
38	Black marsh dart	*Onychargia atrocyana* (Selys, 1865)	0.00209	1, 2, 3	OAT
39	Black winged bamboo tail	*Disparoneura quadrimaculata* (Rambur, 1842)	0.00052	1, 3	DQU
40	Pied bush dart	*Pseudocopera ciliate* (Selys, 1863)	0.00113	1, 2, 3	PCI

*Seasons: 1 = Summer, 2 = Monsoon, 3 = Post monsoon, 4 = Winter; p_i = relative abundance.

keys (Fraser 1933, 1934, 1936; Mitra 2006; Subramanian 2005, 2009, 2014; Nair 2011). No specimen was collected or harmed during the study. Each study site was visited twice a month. The data obtained from the five study sites were pooled month-wise. The monthly data obtained from the one-year study were divided into four seasons: summer (March to May); monsoon (June to August); post-monsoon (September to November) and winter (December to February) to compare seasonal variations in odonate species richness and abundance.

Statistical analyses were done using the Biodiversity Pro Software (McAleece et al. 1997). The Shannon Wiener diversity index [$H' = \sum p_i \ln p_i$] and the Shannon maximum diversity [$H_{max} = Log_{10}(S)$] were used to calculate odonate species diversity, and Shannon's evenness index was calculated using the formula $J = H' / H_{max}$ (Pi = proportion of total sample belonging to i^{th} species, S = total number of species in habitats (species richness) (Magurran 2004).

RESULTS

The present study recorded 40 species of odonates, 29 of which were Anisoptera (dragonflies) and 11 were

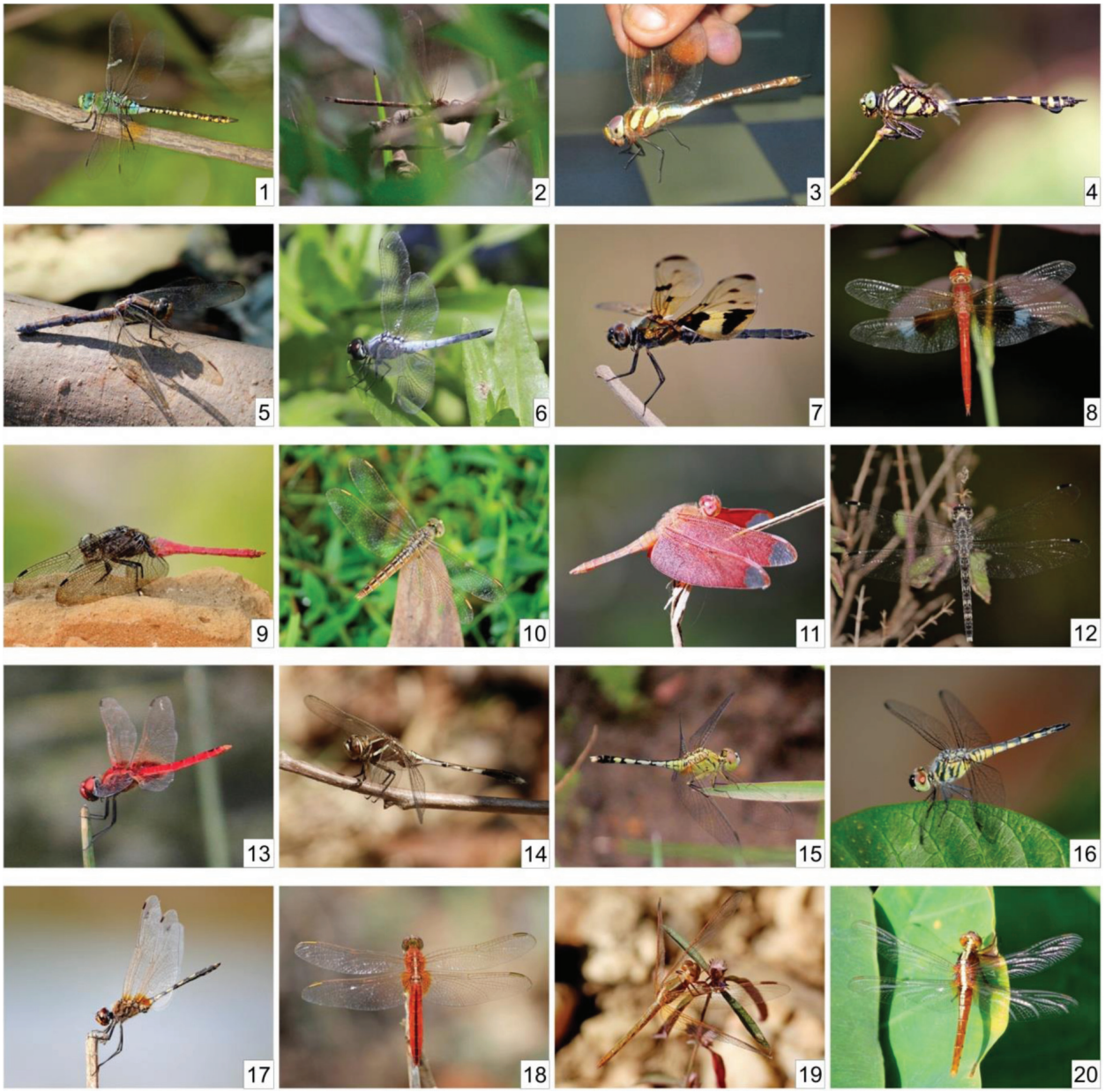

Figure 2A. Photographs of the odonata species taken during the study. 1 – *Anax guttatus*, 2 – *Gynacantha dravida*, 3 – *Anaciaeschna jaspidea*, 4 – *Ictinogomphus rapax*, 5 – *Orthetrum glaucum*, 6 – *Orthetrum cancellatum*, 7 – *Rhyothemis variegata*, 8 – *Tholymis tillarga*, 9 – *Orthetrum pruinosum*, 10 – *Brachythemis contaminata*, 11 – *Neurothemis fulvia*, 12 – *Bradinopyga geminata*, 13 – *Urothemis signata*, 14 – *Orthetrum sabina*, 15 – *Diplacodes trivialis*, 16 – *Brachydiplax sobrina*, 17 – *Trithemis pallidinervis*, 18 – *Crocothemis servilia*, 19 – *Neurothemis intermedia*, 20 – *Rhodothemis rufa*.

Zygoptera (damselflies) (Table 1; Figure 2A and 2B). Anisoptera included 4 families, namely, Aeshnidae, Gomphidae, Libellulidae, and Macromiidae. The number of the recorded Zygoptera families was the same (4), i.e.: Calopterygidae, Coenagrionidae, Lestidae, and Platycnemididae (Table 1). Libellulidae had the highest species richness (24 species, 60%) followed by Coenagrionidae (6 species, 15%), Aeshnidae (3 species, 7.5%) and Platycnemididae (3 species, 7.5%). Four families, i.e., Gomphidae, Calopterygidae, Lestidae, and Macromiidae, were represented by only one species (2.5%) (Figure 3). Among the identified odonates, 14 species were found throughout the year (Table 1). The relative abundance of individual odonate species clearly indicates that *Diplacodes trivialis* (ground skimmer) was the most dominant species followed by *Brachythemis contaminate* (ditch jewel) and *Crocothemis servilia* (ruddy marsh skimmer), respectively (Table 1, Figure 4). The total number of the observed odonates was the highest in monsoon (2886) followed by winter (2765), post-monsoon (2754), and summer (2509). The highest species richness was recorded in post-monsoon (29) followed by winter (27), summer (26), and monsoon (24) (Figure 5). Accordingly, the highest Shannon diversity values were

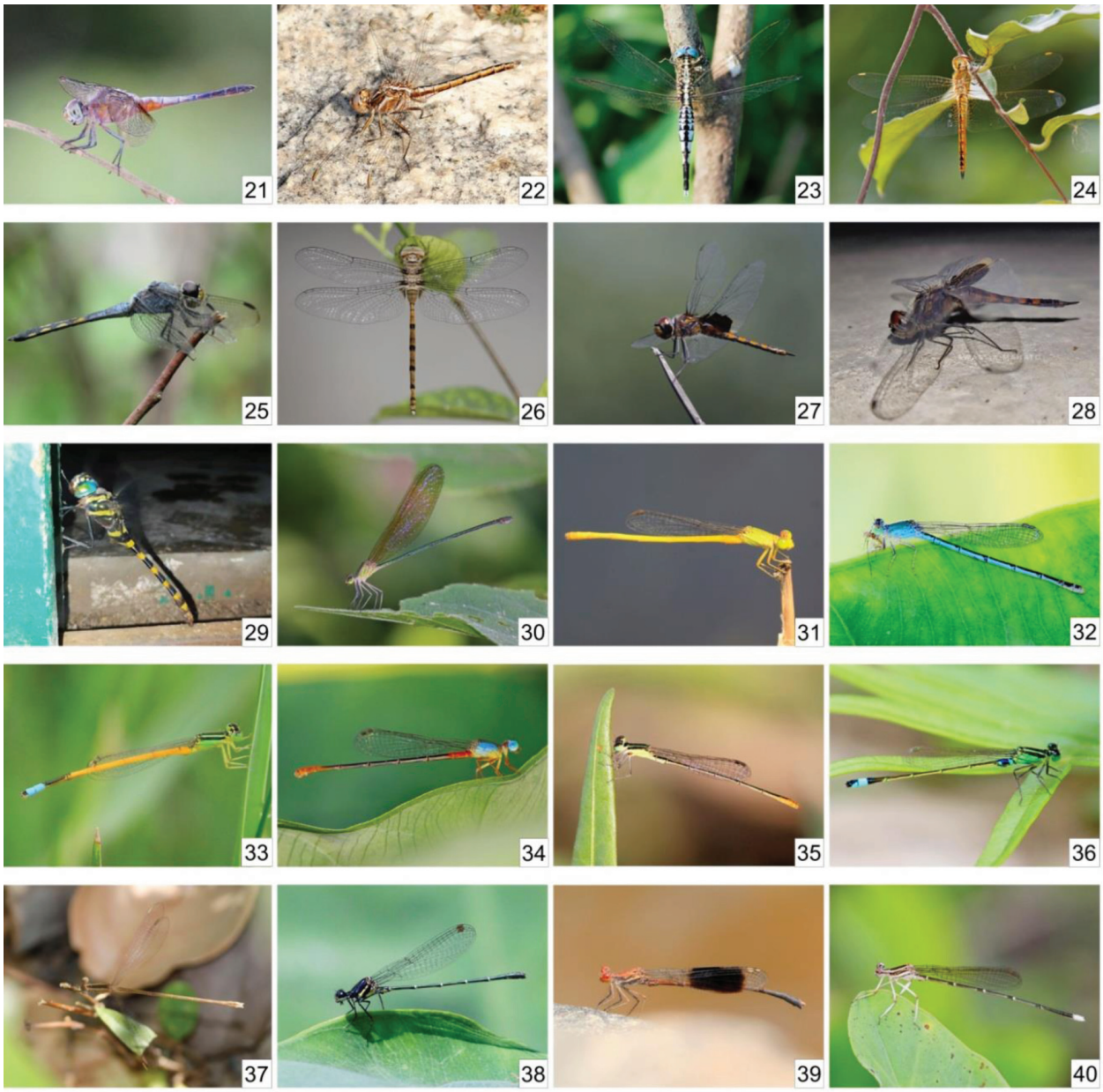

Figure 2B. Photographs of the odonata species taken during the study. 21 – *Brachydiplax chalybea*, 22 – *Orthetrum taeniolatum*, 23 – *Acisoma panorpoides*, 24 – *Pantala flavescens*, 25 – *Potamarcha congener*, 26 – *Zyxomma petiolatum*, 27 – *Tramea basilaris*, 28 – *Tramea limbata*, 29 – *Epophthalmia vittata*, 30 – *Vestalis gracilis*, 31 – *Ceriagrion coromandelianum*, 32 – *Paracercion calamorum*, 33 – *Ischnura rubilio*, 34 – *Ceriagrion cerinorubellum*, 35 – *Agriocnemis pygmaea*, 36 – *Ischnura senegalensis*, 37 – *Lestes viridulus*, 38– *Onychargia atrocyana*, 39 – *Disparoneura quadrimaculata*, 40 – *Pseudocopera ciliate.*

recorded in winter (0.896) and the lowest in monsoon (0.807). Similar values were obtained for summer and post-monsoon (0.85). The evenness values derived from the Shannon diversity index were almost equal for all the seasons (Figure 6). From the output of SHE analysis (Figure 7), the association among S (species richness), H (information – Shannon-Weiner diversity index), and E (evenness) can be inferred in 12 samples. Species richness (S) and odonata community diversity (H) remained almost the same throughout the year.

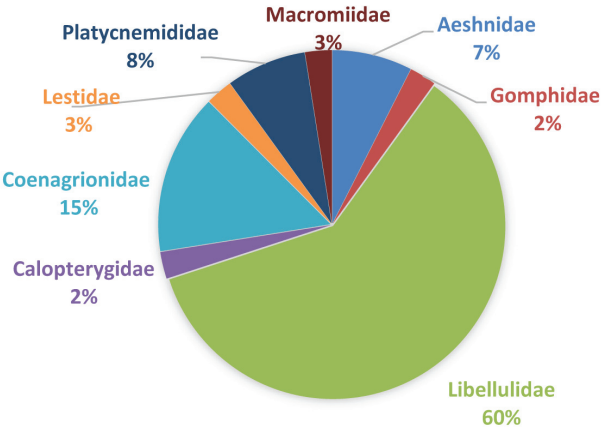

Figure 3. Family-wise abundance of the Odonates recorded in the present study.

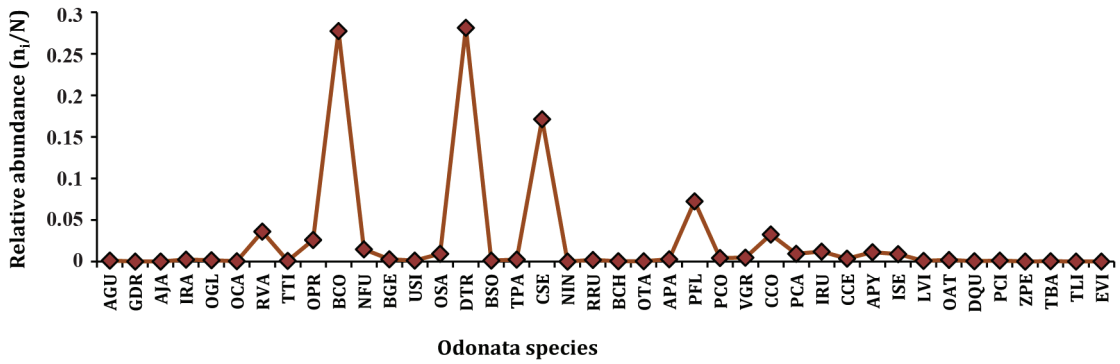

Figure 4. Relative abundance of different odonate species recorded during the present study.

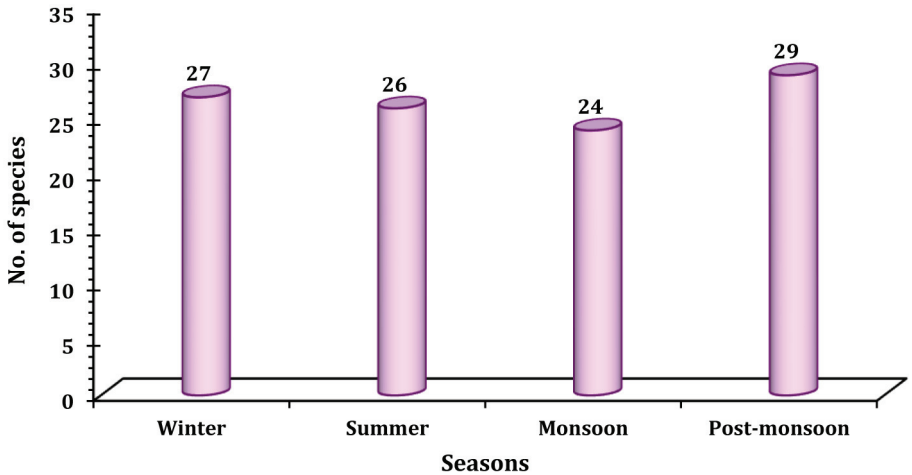

Figure 5. Season-wise species richness of the Odonates recorded during the present study.

DISCUSSION

The present study recorded 40 species of Odonates in Purulia, an arid district of West Bengal, India. This observation is comparable to the results obtained from the studies in other arid areas of India such as Jabalpur (22 species in Jabalpur, 37 in Narmada basin), Maharashtra (22 species) and Nagpur (21 species) (Shukla et al. 2016; Painkra et al. 2016; Manwar et al. 2012; Tijare and Patil 2012) and Durgapur, W.B. (51 species) (Nayak and Roy 2016; Nayak 2020), and in each place, the family Libellulidae was found to be dominant. The highest numbers of odonates were recorded in the monsoon season as rainfall influences the abundance of plants, which, in turn, augments the density of herbivorous insects as well as the thriving of the insect population depending upon herbivores (Nayak and Roy 2016).

Odonates are ideal organisms for assessing the state of urban ecosystems as they are sensitive to environmental pollutants and thermal changes (Castella 1987). Odonates serve as bioindicators in both aquatic and terrestrial habitats as they are aquatic in the larval stage and terrestrial when they become adults. Thus, they may act as a potent tool to evaluate the environmental health of

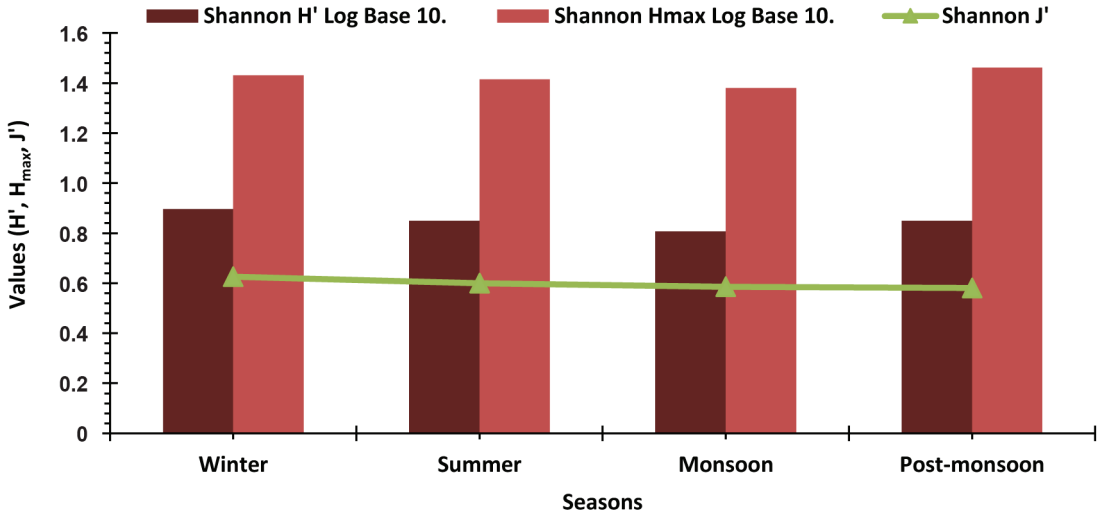

Figure 6. Shannon diversity indices in different seasons for the Odonates recorded during the present study.

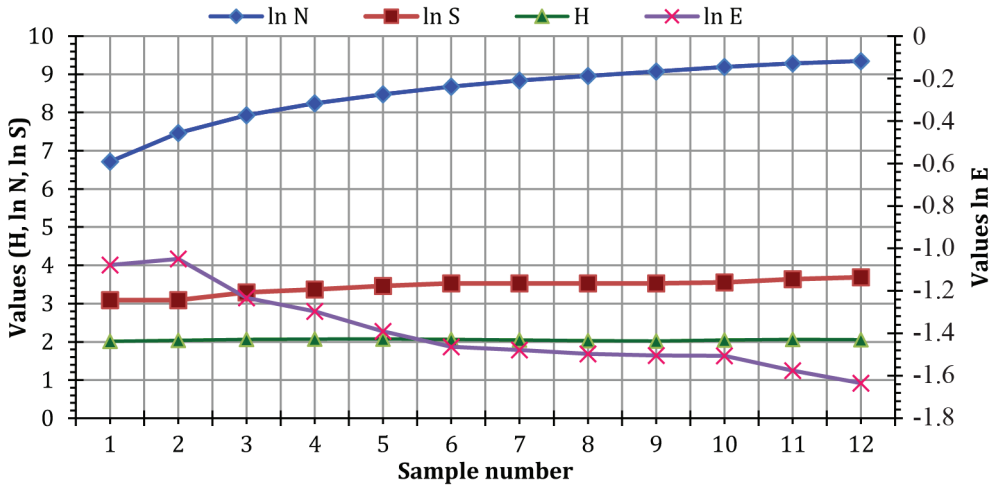

Figure 7. Plot of SHE analysis calculated based on one-year data for 12 samples recorded during the study. Each point on X-axis represents the sample number.

a city. It has been pointed out in numerous studies that two principal parameters of biodiversity, i.e., species richness and species evenness, of butterflies and ground arthropods in particular, decrease with the increase of urbanization (McKinney 2002, 2008; Ruszczyk 1987; Ruszczyk and De Araujo 1992; Blair and Launer 1997; McIntyre et al. 2001; Villalobos-Jiménez et al. 2016). It has been found that urban pollution helps to increase the abundance and dominance of the odonate family Libellulidae, but decreases the abundance of the family Gomphidae, because most of the species of Libellulidae are tolerant to urban pollution, while members of the family Gomphidae are sensitive to it (Ferreras-Romero et al. 2009; Malherbe et al. 2010). According to a study conducted in Kerala, India (Jacob and Manju 2016), *Neurothemis fulvia, Bradinopyga geminata, Ceriagrion cerinorubellum, Ceriagrion coromandelianum* are the common species at the sites with superior water quality, whereas *Brachythemis contaminate* and *Orthetrum sabina* are the most common species at the sites with the inferior quality of water. Each of these Odonates was recorded in the town of Purulia, which may be due to the presence of some well-maintained aquatic bodies, ditches and stagnant ponds.

In the present study, the family Libellulidae was found to be the most abundant, and *Diplacodes trivialis*, *Brachythemis contaminata* and *Crocothemis servilia* were found to be the three dominant species in the town. *Brachythemis contaminata* is a recognized bioindicator species (Ferreras-Romero et al. 2009) clearly indicating the presence of polluted drains and ponds in the town. *Orthetrum cancellatum* is another pollution-tolerant Libellulidae present at the study site, which indicates deforestation and water pollution (Ferreras-Romero et al. 2009).

Urbanization leads to deforestation and fragmentation of landscapes, and due to the presence of fewer water bodies, odonate connectivity becomes limited (Chovanec et al. 2000; Watts et al. 2004; Sato et al. 2008).

In Japan, the fragmentation of landscape in urban areas resulted in the disappearance of some species such as *Paracercion calamorum*, *Ischnura senegalensis* and *I. asiatica* (Villalobos-Jiménez et al. 2016). However, the presence of *Ischnura senegalensis,* recorded in the present study, signifies that the natural habitat in the town of Purulia has not been totally fragmented and there are still some opportunities to protect wild vegetation as well as biodiversity.

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Ethical Approval and consent to participate

Not applicable.

Consent for publication

All authors agree to publish the article in the present form

Contribution of the authors

The idea was conceived by Dipanwita Das, Sudipta Mandal and Swastik Mahato. Swastik Mahato carried out the field work including observations and data recording. Data analysis was performed by Dipanwita Das and Sudipta Mandal, drafting and compilation by Dipanwita Das, Sudipta Mandal and Swastik Mahato.

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Competing Interests

As authors of this article we declare no competing interest.

Availability of data and materials

The data concerning observations of the present study can be shared upon authentic and rational request.

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