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Abstract: For gauging suitability of zygopteran odonates as bioindicators of ecosystems, an attempt was made to record the seasonal diversity of damselflies from seven different types of habitats in Paschim Medinipur District, West Bengal covering 14 land use sites. The study revealed existence of 19 species of damselflies belonging to 10 genera under two families. While the riparian zone had maximum number of species (15), paddy field had the lowest number (six). Ceriagrion coromandelianum and Agriocnemis pygmaea were the most common species. C. coromandelianum was eudominant in grassland and wetland-forest interface, whereas A. pygmaea was eudominant in fish pond and paddy field. Six species, viz., Paracercion calamorum, P. malayanum, Pseudagrion australis, P. decorum, P. spencei, and P. microcephalum were confined only to the riparian zone. Maximum abundance of damselflies was found in the riparian zone and minimum in the paddy field. Damselflies exhibited a distinct peak in March–April and a lesser peak in September–October. Most of the land use patterns exhibited similar zygopteran faunal composition. Species diversity index was moderate (1.4–2.5) and evenness index was on the higher side (0.76–0.94). Dominance Index ranged from 26.2 to 64.6. Riparian zone appeared to be the least stressed and most equitable habitat with highest diversity and evenness index and lowest dominance index. Paddy field seemed to be the harshest habitat for damselflies with least diversity and highest dominance index. The present study suggests that community analysis of damselflies can be quite useful in the assessment of the quality of any ecosystem.

Keywords: Bioindicator, damselfly, dominance index, evenness index, land use type, species diversity index, Zygoptera.

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Author contributions: PKJ conducted field work with regular data collection, identification and documentation along with interpretation of results and preparation of initial manuscript. PHM has designed and supervised the study with contribution in editing and reviewing the draft article and maintaining communications. TB has provided inputs in data analysis and interpretation, revision and write-up of final manuscript.

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COMMUNITY STRUCTURE OF DAMSELFIES

INTRODUCTION

Sensitivity of damselflies to structural habitat features and their amphibious habit makes them well suited as bioindicators of environmental changes (Subramanian et al. 2008; Doiný et al. 2011). In general, odonates have been popular for monitoring health of wetlands all over the world (Chovanec & Waringer 2001). The species assemblages of damselflies are influenced by the aquatic and terrestrial vegetation which act as one of the main cues for their habitat choice. Although considerable work has been done on the ecology and diversity of odonates in many parts of India, some of the latest ones are those of Baba et al. (2019), D’Souza & Pai (2019), Payra et al. (2020), Bedjanič et al. (2020), and Pavithran et al. (2020).

In West Bengal, Odonata fauna has been explored in recent years by Payra & Tiple (2019) & Pahari et al. (2019) from Purba Medinipur and Nayak (2020) from Asansol–Durgapur industrial area. Despite efforts of Jana et al. (2009), large parts of Paschim Medinipur have remained unexplored with respect to odonate distribution and ecology. In the aforementioned context, the present study was undertaken across different habitat structures and land use patterns comprising aquatic and semi-aquatic water bodies of Paschim Medinipur District.

METHODS

Study area

The present study was carried out in five blocks of Paschim Medinipur District of West Bengal, India namely Pingla, Debra, Kharagpur I, Kharagpur II and Midnapore, predominantly encompassing freshwater lentic wetlands (Figure 1). On the basis of the habitat heterogeneity, seven land use types, viz., fish pond (FP), eutrophic pond (EP), unmanaged wetland (UW), grassland (GL), paddy field (PF), wetland-forest interface (WFI), and riparian zone (RZ) were selected (Image 1a–g). The fish pond was a semi-natural water body used only for commercial fish culture and with little littoral and floating macrophytes. The man-made eutrophic pond, having high nutrient content, was severely infested with *Pistia* sp. (90 %), with smaller proportions of *Alternanthera philoxeroides* (8 %) and other hydrophytes (2 %). Unmanaged wetland was a natural water body with profuse macrophytes of varieties. The macrophytes were inventoried with reference to Mallick & Chakraborty (2014). Grassland included open fallow lands having stretches of herbaceous plants dominated by grasses. Paddy fields were lands under paddy cultivation. Wetland-forest interface were the confluence of homestead vegetation and water bodies. Riparian zone comprised of riverbank along Kangsabati River.

Sampling

Field sampling of adult zygopterans was done from March 2018 to February 2019. The sampling and quantitative measurements of adult damselfly species were carried out at each study site between 0800 h and 1400 h using line transect method. Transect routes, distances walked, and durations were kept constant across study sites throughout the survey. All sites were surveyed once per month preferably under reasonable weather conditions, barring a few instances. The prominent features of the study sites were also noted on the spot. Adult damselfly species were identified and photographed in the field; doubtful specimens were captured using an aerial insect net. Later they were identified by examining the morphological characteristics through a hand lens and were released after recording. For identification purpose, few damselflies were sacrificed by gently pressing their thorax and kept dry in paper envelope or in 70 % ethanol and were brought to the laboratory. The observed and collected species were identified to the lowest possible rank using taxonomic literature and field identification keys provided by Subramanian (2009), Mitra & Babu (2010), and by photographic guides from ‘Odonata of India’ website (Anonymous 2020). Updated species names were taken following the Subramanian & Babu (2017).

Data analysis

Important community parameters like abundance, relative abundance, Shannon–Wiener diversity index ($H'$) (Shannon & Wiener 1963), evenness index of Pielou (EI) (Pielou 1975), McNaughton & Wolf’s dominance index (DI) (McNaughton & Wolf 1970), and Sørensen’s similarity index (Sørensen 1948) were calculated using MS Excel.

RESULTS

During the course of study, 19 zygopteran species belonging to 10 genera under two families were recorded from the study sites. The family Coenagrionidae contained 17 species and family Platycnemididae contained two species.

Species richness exhibited spatial and temporal changes (Table 1). RZ had maximum numbers of species...
(15). This was followed by UW (13), FP (12), GL (10), EP (8), WFI (7) and PF (6).

Maximum number of individuals was recorded at RZ and minimum at PF. Like species richness, number of individuals also varied spatially and temporally (Table 1; Figure 2). Damselfly exhibited a more or less bimodal pattern of population fluctuation with two peaks, first one in the pre-monsoon period (March–April) and the second one in the post-monsoon period (September–October) which was not quite distinct in the WFI (Figure 2). From paddy fields no damselfly species were recorded in the month of June. WFI has highest abundance only in pre-monsoon period and there was little increase in number of individuals in post-monsoon period as compared to other land use types.

Dominance status of each species in a particular habitat was ascertained on the basis of its relative abundance according to scale of Engelmann (1973). Table 1 reveals that *Agriocnemis pygmaea* was eudominant species in FP and PF and dominant in remaining five habitats. Likewise, *Ceriagrion coromandelianum* was eudominant in GL and WFI and dominant species in the remaining habitats. No species was eudominant in EP, UW, and RZ. Other dominant species were *Ceriagrion cerinorubellum* & *Copera marginipes* in EP and WFI, *Agriocnemis lacteola* & *Ischnura rubilio* in PF, *Ischnura*
Table 1. Species richness (S), number (N), relative abundance (RA in %), and dominance status (DS) of zygopteran species in different land use types.

[RA <1= subrecedent (SR); 1–3.1= recedent (R); 3.2–10= subdominant (SD); 10.1–31.6= dominant (D); >31.7= eudominant (ED)] (Engelmann 1973).

| Land use Types | FP | EP | UW | GL | PF | WFI | RZ |
|---------------|----|----|-----|-----|----|-----|----|
|               | N  | RA | DS | N  | RA | DS | N  | RA | DS | N  | RA | DS | N  | RA | DS | N  | RA | DS | N  | RA | DS |
| Scientific Names |     |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Family Coenagrionidae |
| 1 | Agriocnemis kalirno Nair & Subramanian, 2015 | 1 | 0.2 | SR | - | - | - | 32 | 5.4 | SD | 4 | 1.2 | R | - | - | - | - | - | 62 | 6.1 | SD |
| 2 | Agriocnemis bicosta Selys, 1877 | - | - | - | - | - | 28 | 4.7 | SD | 33 | 9.8 | SD | 23 | 11.8 | D | - | - | - | - | - |
| 3 | Agriocnemis pygmaea (Rambur, 1842) | 200 | 34.0 | ED | 98 | 21.4 | D | 159 | 26.9 | D | 98 | 29.2 | D | 75 | 38.5 | ED | 43 | 15.9 | D | 123 | 12.1 | D |
| 4 | Anphiallagma parvum (Selys, 1876) | 16 | 2.7 | R | 77 | 16.8 | D | 48 | 8.1 | SD | 24 | 7.1 | SD | 4 | 2.1 | R | 32 | 11.8 | D | 34 | 3.3 | SD |
| 5 | Centrogonia cerinorubellum (Brauer, 1865) | 16 | 11.5 | D | 102 | 22.3 | D | 67 | 11.3 | D | 115 | 34.2 | ED | 38 | 19.5 | D | 105 | 38.7 | ED | 124 | 12.2 | D |
| 6 | Ischnura rubilla Selys, 1876 | 39 | 6.6 | SD | 6 | 1.3 | R | 13 | 2.2 | R | 15 | 4.5 | SD | 51 | 26.2 | D | - | - | - | 38 | 3.7 | SD |
| 7 | Ischnura senegalensis (Rambur, 1842) | 77 | 13.1 | D | - | - | - | 42 | 7.1 | SD | 13 | 3.9 | SD | 4 | 2.1 | R | - | - | - | 123 | 12.1 | D |
| 8 | Mortona grusonii (Laidlaw, 1914) | 22 | 3.7 | SD | 26 | 5.7 | SD | 30 | 5.1 | SD | - | - | - | - | - | - | - | 33 | 12.2 | D | - | - |
| 9 | Onychogryllus atricosta (Selys, 1865) | 4 | 0.7 | SR | 45 | 9.8 | SD | 36 | 6.1 | SD | 8 | 2.4 | R | - | - | - | 12 | 4.4 | SD | - | - |
| 10 | Paracercion californium (Ris, 1916) | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 26 | 2.6 | R |
| 11 | Paracercion malayanum (Selys, 1876) | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 43 | 4.2 | SD |
| 12 | Pseudagrion australasiae Selys, 1876 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 26 | 2.6 | R |
| 13 | Pseudagrion decorum (Rambur, 1842) | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 142 | 14.0 | D |
| 14 | Pseudagrion microcephalum (Rambur, 1842) | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 51 | 5.0 | SD |
| 15 | Pseudagrion rubriceps Selys, 1876 | 46 | 7.8 | SD | - | - | - | 16 | 2.7 | R | - | - | - | - | - | - | - | - | - | 64 | 6.3 | SD |
| 16 | Pseudagrion sanguineum (Selys, 1863) | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 27 | 2.7 | R |
| Family Platycentridae |
| 17 | Copera marginipes (Rambur, 1842) | 39 | 6.6 | SD | 72 | 15.7 | D | 52 | 8.8 | SD | 13 | 3.9 | SD | - | - | - | 41 | 15.1 | D | - | - |
| 18 | Pseudocoptera ciliata (Selys, 1863) | 52 | 8.8 | SD | 32 | 7.0 | SD | 29 | 4.9 | SD | 13 | 3.9 | SD | - | - | - | 5 | 1.8 | R | 35 | 3.4 | SD |
| Total number of Species (S) | 12 | 8 | 13 | 10 | 6 | 7 | 15 |
| Total number of Individuals (N) | 589 | 458 | 591 | 336 | 195 | 271 | 1017 |
Community structure of damselflies

Paracercion calamorum, Pseudagrion australasiae either subdominant or recedent. Three species, viz., Mortonagrion aborense in WFI. Rest of the species were senegalensis & Pseudagrion decorum in RZ, and Mortonagrion aborense in WFI. Rest of the species were either subdominant or recedent. Three species, viz., Paracercion calamorum, Pseudagrion australasiae, and Pseudagrion spencei were recedent in the riparian zone. In FP, two species (Agriocnemis kalinga and Onychargia atrocyana) were subrecedent.

Interestingly, no representative of family Platycnemididae was found in PF during the entire period of investigation. Turning to the analysis of species composition based on Sørensen's index (Table 2), it is seen that WFI was moderately dissimilar in zygopteran faunal composition with RZ and slightly dissimilar with PF. Likewise, RZ was slightly dissimilar with PF and EP. All other habitats were similar in species composition. Maximum similarity was seen between FP and UW.

Analysis of diversity and evenness indices (Table 3) revealed that species diversity indices were relatively low ranging from 1.4 in the PF to 2.5 in the RZ. Evenness index, on the contrary, was on the higher side ranging between 0.76 in the GL to 0.94 in the RZ. Simultaneously, dominance index ranged from 26.2 (RZ) to 64.6 (PF).

### Table 2. Sørensen’s index of similarity between land use types.

| Land use types | EP   | UW  | GL   | PF   | WFI  | RZ   |
|----------------|------|-----|------|------|------|------|
| FP             | 0.80 | 0.96| 0.82 | 0.56 | 0.74 | 0.67 |
| EP             | 0.76 | 0.78| 0.57 | 0.93 | 0.43 |      |
| UW             | 0.78 | 0.63| 0.70 | 0.57 |      |      |
| GL             | 0.75 | 0.71| 0.56 |      |      |      |
| PF             |      | 0.46| 0.48 |      |      |      |
| WFI            |      | 0.36|      |      |      |      |

[0.5–0.6= slightly similar; 0.6–0.7= moderately similar; >0.7= strongly similar; 0.5–0.4= slightly dissimilar; 0.4–0.3= moderately dissimilar; <0.3= strongly dissimilar.]

### Table 3. Shannon-Wiener diversity index, evenness index, and dominance index of different land use types.

| Land use types | S-W Diversity index (H’) | Evenness index (E) | Dominance index (D) |
|----------------|---------------------------|--------------------|---------------------|
| FP             | 2.1                       | 0.83               | 47.0                |
| EP             | 1.9                       | 0.91               | 43.7                |
| UW             | 2.3                       | 0.91               | 38.2                |
| GL             | 1.7                       | 0.76               | 63.4                |
| PF             | 1.4                       | 0.81               | 64.6                |
| WFI            | 1.7                       | 0.86               | 54.6                |
| RZ             | 2.5                       | 0.94               | 26.2                |

DISCUSSION

Spatial heterogeneity is often regarded as a key factor that shapes diversity (Tews et al. 2004). Structurally complex habitats provide more niches and diverse ways of exploiting the environmental resources thereby increasing species diversity (Bazzaz 1975). In the present study, 19 species of Zygoptera were recorded which is comparable to the findings of Pahari et al. (2019) who found 20 species from Purba Medinipur District. Lower species richness recorded by them in all probability is because of urbanization. Most of the study sites in the present investigation exhibited similar species composition which might be attributed to the spatial proximity of sites but differences in land use types made some habitats dissimilar in species composition.

Increased richness and abundance of damselflies during pre-monsoon period, as observed in the present study, is in accordance with the findings of Corbet (2004) and Hassall & Thompson (2008), who observed higher richness and abundance during pre-monsoon period which they assigned to increased temperature and precipitation. Documentation of zygopteran diversity is important for the assessment of the health of agroecosystem. The odonate diversity in the present study was reported to be lower in agricultural landscapes than in other ecosystems, which corroborates with the findings of Kulkarni & Subramanian (2013) and it has been suggested that the lower diversity was due to the water quality, insecticide usage and vegetation structure in the paddy fields which significantly affects the zygopteran community (Baba et al. 2019; Giuliano & Bogliani 2019).

Ceriagrion coromandelianum and Agriocnemis pygmaea were the most common species encountered during the present study being eudominant and dominant species, respectively, wherever these were distributed. Relatively low species diversity index is suggestive of a relatively harsh, stressed and disturbed habitat. According to Wilhm & Dorris (1968) general diversity index ranging 1–3, suggests a moderate disturbance or stress operating in the habitat. Of the seven land use types, the riparian zone appears to be relatively less stressed whereas paddy field appears to be the most stressed. These human-altered ecosystems can be essential in serving as alternative habitats for biodiversity, especially water reliant species such as odonates. Species diversity and evenness indices in the present study are comparable with those of a study by Pahari et al. (2019) in Purba Medinipur District. Higher evenness indices (>0.8) in majority of the habitat types...
Figure 2. Temporal fluctuation in Number of Individuals (N) of damselflies during 2018–2019 across land use types. [FP= fish pond, EP= eutrophic pond, UW= unmanaged wetland, GL= grassland, PF= paddy field, WFI= wetland-forest interface, RZ= riparian zone].

indicate a structural heterogeneity of the habitats. Grassland with the least evenness index appears to be the most homogeneous habitat.

Findings pertaining to the dominance index also substantiate the relation between species diversity and habitat structure and quality. McNaughton & Wolf (1970) asserted that the dominance index can be correlated with the harshness of the environment, which increases with the increase in harshness and decreases with the equitability of the habitat. Karr (1971) and Ghosh & Bhattacharya (2018) though found that dominance index for avifauna declined with vegetational development. Pahari et al. (2019) opined that dominance index of odonates is an indicator of the quality of environment. Harsh environment favours dominance of one or two species making them eudominant or dominant by eliminating some other species. In the present study, dominance index was high in paddy field and grassland which are structurally simple with little vegetational diversity subjected to greater anthropogenic interferences, experience more fluctuation of climatic and edaphic factors and as such are less equitable and harsh as compared to other habitats. On the contrary, riparian zone and unmanaged...
Image 1. Study sites in selected blocks: (a) fish pond in Pingla | (b) eutrophic pond in Pingla | (c) unmanaged wetland in Kharagpur II | (d) grassland in Kharagpur I | (e) paddy field in Debra | (f) wetland–forest interface in Pingla | (g) riparian zone in Midnapore. © Pathik Kumar Jana. EP—eutrophic pond | FP—fish pond | GL—grassland | PF—paddy field | RZ—riparian zone | UW—unmanaged wetland | WFI—wetland–forest interface.
wetland had low dominance index and hence may offer better and equitable habitat resulting into relatively high zygopteran species diversity as compared to other land use types. It may thus be concluded that the damselflies have potentiality to be used as good indicators of the condition and health of land use types and habitat quality.

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