Distribution and Species Richness of Adult Odonata in Urban Wetlands in Tagum City, Mindanao, Philippines

Karyn Chrislene A. Vitor1*, Ella C. Pagarigan4, Marian Dana T. Tagoon2, Melanie M. Garcia3, and Majella G. Bautista4

1Department of Arts and Sciences Education, University of Mindanao Tagum College, Tagum City, Davao del Norte 8100 Philippines
2Department of Biology, College of Medicine, Davao Medical School Foundation Inc., Davao City, Davao del Sur 8000 Philippines
3Department of Biology, College of Arts and Science, Mapua Malayan Colleges Mindanao, Gen. Douglas McArthur Highway, Matina, Davao City 8000 Philippines
4Natural Science Department, University of Southeastern Philippines, Barrio Obrero, Davao City 8000 Philippines

Several studies on Philippine Odonata have focused mainly on the protected landscapes and forest reserves; however, little ecological research has been done in an urban setting. Species distribution, abundance, and diversity of Odonata in Tagum were conducted, where no previous records were available. Field sampling was conducted from July–October 2018 among various locations in Tagum City, Davao del Norte. Results showed a total of 1,239 individuals of identified Odonata composing nine species of Family Libellulidae and three species of Family Coenagrionidae. The dominant and most abundant species were *Pantala flavescens*, Diplacodes trivialis, and *Orthetrum sabina*. A relatively high Margalef's Index of species richness (R = 2.148) and moderate species diversity (H' = 1.935) were recorded in Botanical Park and a less even distribution was observed in all sites. Canonical correspondence analysis indicated that both temperature and humidity can affect the abundance of certain species within the community.

Keywords: Anisoptera, biodiversity, Coenagrionidae, Odonata, Tagum City

INTRODUCTION

The Philippines is home to around 300 species of Odonata, the majority of which are endemic in the country, and most are confined in island groups (Hämäläinen 2012). However, human-induced activities (Sala et al. 2000) leading to habitat loss and modification have led to the unprecedented rate of decline of odonates, and this may lead to the eventual loss of potential novel species that are still left largely unexplored. Although odonates do not provide direct economic importance (May 2012), they play role in ecosystem services as they are utilized as prey items by other larger organisms (Kalkman et al. 2008), as well as provide a valuable role in the natural control of harmful insect populations such as rice pests (Thipaksorn et al. 2003; Shukla et al. 2016). Moreover, they also serve as good biological indicators in fluvial ecosystems (Kalkman et al. 2008). Thus, odonate inventory is crucial for habitat monitoring and conservation purposes in aquatic habitats (Malawani et al. 2014). As odonates are found in many bodies of water such as rivers, lakes, ditches, and even temporary man-made ponds, their community structure may reflect the anthropogenic impacts on their immediate environment (Renner et al. 2018; Sganzerla et al. 2021). For instance, representatives...
of the Suborder Zygoptera were found to be more sensitive to disturbance compared with the generalist Anisopteran species (Perez and Bautista 2020; Sganzerla et al. 2021).

Published data on odonates in Mindanao have been presented in various localities in Davao region such as in Talaingod, Davao del Norte (Villanueva and Cahilog 2013); Compostela Valley Province (Medina et al. 2015b); and Mt. Hamiguitan (Medina et al. 2018). Odonate inventories in areas that do not have too many anthropogenic activities have observed higher endemism, particularly in undisturbed sites characterized by intact forests and good water quality (Gapud 2005; Medina et al. 2018).

In an urban ecosystem, there are many threats that may affect odonate assemblage (Perez and Bautista 2020). Studies on odonate inventories in aquatic environs within highly urbanized areas in Mindanao were conducted in Davao City (Medina et al. 2015a; Caparoso et al. 2016; Perez and Bautista 2020), whereas another study was conducted in the fringes of Cagayan de Oro City (Jomoc et al. 2013). Inventories of odonates in urban areas are, therefore, lacking and studies in other urban localities can contribute to a larger body of knowledge on odonate diversity. This study reported the Odonata diversity in select sites within Tagum City, Davao del Norte, Mindanao, Philippines.

MATERIALS AND METHODS

Six (6) sampling sites were established in Tagum City, Davao del Norte, Mindanao, Philippines (Figure 1) and represented different habitat types that included two rivers, two residential areas, an agricultural land, and a botanical park. The geographic coordinates were taken using the mobile application GeoCam Pro. Sampling was conducted from July–October 2018. Each site was characterized in terms of vegetation type, type of body of water, and weather conditions during sampling.

Site 1 is a 2-ha privately owned rice field (Oryza sativa) located in Barangay Pagsabangan (7°29’21.2136”N 125°45’13.5144”E) that is 157.3 m away from the provincial road. Vegetations in this site included banana (Musa sapientum var.), coconut (Cocos nucifera L.), cacao (Theobroma cacao), wire grass (Eleusine indica), and gabi-gabi (Colocasia esculenta) were present. Irrigation provided by the NIA (National Irrigation Administration) supplied water to the rice paddies. A few settlements approximately 20 households were observed 20 m from the site.

Site 2 is a riverbank near the confluence of Pagsabangan River (7°28’44.1048”N 125°45’10.5084”E) with slow-flowing water and muddy type of soil. The river is free.
from aquatic vegetation but is surrounded by coconut (Cocos nucifera), banana (Musa spp.), and bamboo (Bambusa spinoza). Weeds and grasses like makahiyas (Mimosa pudica), wire grasses (Eleusine indica), carabao grass (Paspalum conjugatum), and gabi-gabi (Colocasia esculenta) were found along the banks. It is approximately 5 m from the provincial road.

Site 3 is a riverbank of the Hijo River located in Barangay Apokon (7°26'23.5"N 125°49'42.4"E). Several plants were observed in the sampled area such as gabi-gabi (Colocasia esculenta), banana (Musa spp.), carabao grass (Paspalum conjugatum), and wire grass (Eleusine indica). The river is characterized by slow-flowing water and a muddy type of soil. Rocks and stones were observed but lack aquatic vegetation. On the opposite side of the river is an agricultural field planted with agricultural crops.

Site 4 is the San Agustin Botanical Park, a 31-ha park in Barangay San Agustin (7°29'07.6"N 125°50'10.6"E). Vegetations found in this park mostly included fruit trees and ornamentals such as lantzones (Lansium domesticum), pomelo (Citrus grandis Linn.), marang (Artocarpus odoratissimus Blanco), guava (Psidium guajava), santol (Spondoricum koetjape), durian (Durio zibethinus), katurai (Seszenia grandiflora Linn.), large-leafed mahogany (Swietenia macrophylla King), forest oak (Casuarina junghuhniana), molave (Vitex parviflora Juss.), river red gum (Eucalyptus camaldulensis Dehn.), and falcata (Albizia falcatoria). A small ditch near a marang tree (Artocarpus odoratissimus) with a muddy type of soil was observed.

Site 5 is a residential area located in Barangay Visayan Village (7°25'28.7"N 125°47'34.2"E) characterized by several stagnant waterways with abundant growth of kangkong (Ipomea aquatica).

Site 6 is a residential area located in Barangay San Miguel (7°26’ 37.827”N, 125° 46’ 28.149” E) is characterized by heavy traffic and road construction. The area is vegetated with tall grasses and crops like mango (Mangifera indica), maize (Zea mays), cogon grass (Imperata cylindrica), makahiyas (Mimosa pudica), coconut tree (Cocos nucifera), lemonsito (Citrifortunella sp.), carabao grass (Paspalum conjugatum), guava (Psidium guajava), banana (Musa sp.), Bermuda grass (Cynodon dactylon), and jackfruit (Artocarpus heterophylla). There were no drainage canals in the area, but some ditches were observed along the road.

In each study site, a prior informed clearance was accomplished, and a wildlife gratuitous permit (No. XI-2018-30) was secured from the Department of Environment and Natural Resources (DENR) Region 13 Office, Davao City. The opportunistic sampling method was employed using sweep nets and hand-picking for the collection of Odonata specimens (Nuñez et al. 2015; Yapac et al. 2016) using a black catching net made of nylon measuring 25 cm x 60 cm, following the specifications indicated in the paper of Villanueva and Mohagan (2010). Sampling was conducted for five non-consecutive days per site from 0800–1100 hours (Mapi-ot et al. 2013). Captured individuals were released after recording, except for those used for diagnostic characterization and as a voucher. Voucher specimens were placed in an empty white triangular envelope with their wings folded and labeled according to the time, place, and day it was collected. Voucher specimens were culled in a killing jar (Villanueva and Mohagan 2010) and were kept in a dry plastic container. Initial identification of the collected samples was based on pictorial keys using available field guides (see Theischinger and Hawking 2006), Nair (2011), Yapac et al. 2016, and Medina et al. 2018). Verification of the identified specimen was done by consultation with odonate experts.

Ecological indices such as Margalef’s index (R), evenness (E’), and Shannon-Wiener index of diversity (H’) were calculated using the PAST (Paleontological Statistics) software package v. 3.21 (Hammer et al. 2001). Canonical correspondence was also calculated to determine the effects of relative humidity, temperature, and rainfall on odonate distribution.

RESULTS AND DISCUSSION

A total of 1,239 identified Odonata were captured from all six sites. Two suborders were identified. Suborder Anisoptera was represented with nine species belonging to Family Libellulidae (Figure 2), whereas Suborder Zygoptera was represented with three species belonging to the Family Coenagrionidae (Figure 3). All odonate species collected have widespread distribution according to the latest IUCN (International Union for Conservation of Nature) Red List of Threatened Species (2021) with stable population trends – except for Potamarcha congener, Tholymis tillarga, and Tetrathemis irregularis being data deficient, thus warranting further investigations (Table 1).

Family Libellulidae comprised the majority of the collected species in all five sites except for the San Agustin Botanical Park (Site 4), where there was only a small ditch that served as a habitat for the odonates. The same observation was made in the study of Mapi-ot et al. (2013) and Jomoc et al. (2013). This odonate group usually dominates standing water and they can occupy different aquatic habitats including temporary ponds (May and Matthews 2008).
The circumtropical *P. flavescens* was the most dominant species among the Anisoptera and is widely distributed throughout many countries in the tropics and temperature regions (Vieira and Cordero-Rivera 2015). The study of Vieira and Cordero-Rivera (2015) noted that the invasive nature of *P. flavescens* allows it to successfully adapt when introduced to new fluvial habitats. In the Philippines, it is found in highly disturbed sites in urban areas (Perez and Bautista 2020), agroecosystems (Jomoc et al. 2013), and within low elevation forests (Medina et al. 2018) characterized by standing water and lentic habitats. Its generalist feeding habit allows it to consume a wide variety of insect prey. *P. flavescens* is considered an invasive species (Medina et al. 2018). Although invasive, *P. flavescens* consume a high number of insect pests (Rathod and Parasharya 2015). Other Anisopterans that are abundant across all sites included *Diplacodes trivialis* and *Orthetrum sabina*. Similar observations were made in


**Figure 3.** Dragonflies of Suborder Zygoptera from the six study sites: [A] *Pseudagrion pilidorsum pilidorsum*, [B] *Ischnura senegalensis*, and [C] *Agriocnemis femina femina*. Photos by J.G. Molano.
For the Zygoptera, *A. f. femina* dominated most sites except for Site 6. The study of Jomoc et al. (2013) also observed this species in their study sites. They were found highest in fluvial habitats with vegetation. The results of this study corroborated the study of Villanueva (2011), wherein they were frequently encountered in grassy and weedy areas adjacent to forest streams. The low number of representatives for Zygoptera may be due to their narrow geographic range as they prefer good vegetation cover and are sensitive to anthropogenic disturbances (Medina et al. 2018). All three species from Suborder Zygoptera were found near human habitats, open ecosystems, and relatively disturbed areas (Jomoc et al. 2013; Caparoso et al. 2016; Ramos et al. 2020).

The highest species richness (R = 2.148) and diversity (H’ = 1.935) were observed for the Botanical Garden (Site 4), although there is only a small ditch that served as a habitat for odonates (Table 2).

This was attributed to the capture of *L. asiatica*, *N. fluctuans*, and *T. irregularis* that were not found in other sites. All three species were able to tolerate disturbance and are found in wide habitat types, including swamp forests and forest streams with adequate shade (IUCN 2018). The high number of dragonflies in this site is possible due to the diverse vegetation that provides shade and the area. Moreover, another attributing factor to the high diversity in this site was the diverse vegetation in the area. The paper of Yapac and colleagues (2016) reported that *Neurothemis* spp. is found in sites with fewer disturbances. Similar to the urban project created in South Africa, the provision of

<p>| Table 1. Odonata species identified from Urban Wetlands in Tagum City, Mindanao, Philippines (codes: 1 = Barangay Pagsabangan, 2 = Pagsabangan River, 3 = Hijo River, Barangay Apokon, 4 = San Agustin Botanical Park, Barangay Magdum, 5 = Barangay Visayan Village, and 6 = Barangay San Miguel). |</p>
<table>
<thead>
<tr>
<th>Species name</th>
<th>Sites</th>
<th>Total</th>
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<td></td>
</tr>
<tr>
<td><strong>Family Libellulidae</strong></td>
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</tr>
<tr>
<td><em>Pantala flavescens</em></td>
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<td>154</td>
</tr>
<tr>
<td><em>Diplacodes trivialis</em></td>
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<td>87</td>
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<td><em>Potamarcha congener</em></td>
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<tr>
<td><em>Orthetrum sabina</em></td>
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<tr>
<td><em>Tholymis tillarga</em></td>
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</tr>
<tr>
<td><em>Neurothemis terminata terminata</em></td>
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<td>2</td>
</tr>
<tr>
<td><em>Neurothemis fluctuans</em></td>
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<td>–</td>
</tr>
<tr>
<td><em>Lathrecista asiatica</em></td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td><em>Tetrathemis irregularis</em></td>
<td>–</td>
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<tr>
<td><strong>Suborder Zygoptera</strong></td>
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<tr>
<td><strong>Family Coenagrionidae</strong></td>
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<tr>
<td><em>Pseudagrion pilidorsum pilidorsum</em></td>
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<tr>
<td><em>Ischnura senegalensis</em></td>
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<td>1</td>
</tr>
<tr>
<td><em>Agriocnemis femina femina</em></td>
<td>30</td>
<td>1</td>
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<td><strong>Table 2. Biodiversity Indices of Odonata in Urban Wetlands of Tagum City, Mindanao, Philippines (codes: 1 = Barangay Pagsabangan, 2 = Pagsabangan River, 3 = Hijo River, Barangay Apokon, 4 = San Agustin Botanical Park, Barangay Magdum, 5 = Barangay Visayan Village, and 6 = Barangay San Miguel).</strong></td>
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<td>Margalef’s (R)</td>
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<td>Shannon-Weiner (H’)</td>
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<tr>
<td>Evenness (E’)</td>
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<td>0.3885</td>
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</table>
appropriate biotopes increased species richness by two-fold (Samways and Steytler 1996). Thus, habitat integrity and macrophyte cover are two important factors for the Odonata community (Pereira et al. 2019).

High species richness of Anisoptera was observed in intermediate habitats, which are ecologically characterized as intermediate between built-up and well-preserved areas, while Zygoptera showed specificity for preserved habitats (Junior et al. 2015). They have a higher richness in preserved areas than in degraded habitats (de Carvalho et al. 2013). Similarly, the recent finding showed high species richness among Zygoptera in Mt. Hamiguitan, Davao Oriental (Medina et al. 2018), primarily because the area is a protected landscape and, hence, an undisturbed habitat. High species richness was recorded in undisturbed areas of Cagayan de Oro, Bukidnon (Jomoc et al. 2013) Buru-un, Iligan City, and Tubod, Lanao del Norte (Aspacio et al. 2013).

Canonical correspondence analysis (CCA) generated results that showed the association of species between sites with ambient temperature during the study period (Figure 4). Axis 1 was negatively weighed on the population of P. congener, I. senegalensis, P. flavescens, A. femina, N. terminate, and A. femina but was positively related to O. sabina, N. fluctuans, L. asiatica, and T. irregularis. These species were mostly found in shaded areas (Site 4) – as described by Orr and Kalkman (2015), in which the shade provided by the vegetation contributes to a reduction in the ambient temperature (Monteiro-Júnior et al. 2014). Site 4 is shaded by a dense canopy, limiting the penetration of light. The richness and abundance of Anisopterans are correlated positively with high ambient temperatures (Monteiro-Júnior et al. 2014). Moreover, the correlation between species richness and the temperature was statistically significant in the study by Laltanpuii and colleagues (2017). This result could be attributed to their ability to thermoregulate. As cited by Fulan and colleagues (2008), adult dragonflies are independent of the environmental temperature to maintain active flight via thermoregulation.

To avoid overheating, some species may seek shade and ensure means of postural adjustments (May 1976; Mazzacano et al. 2014) such as at higher temperatures; they then point their abdomen towards the sun, which results in an obelisk-like posture. Perchers settled at the hottest sites near the ground. But at lower temperatures, they show a preference for bare soil, rock, or colored surfaces. Some species are less dependent on ambient temperature, but the pattern of daily activity is greatly influenced by temperature; moreover, the responses of adult dragonflies to temperature depend upon their age and sex (Corbet 1962). This pattern was observed by Mason (2017), noting that the perch orientation of damselfly decreased as the ambient temperature increased, as well as the perching strategies along varied abiotic conditions.

Several Anisoptera maintains their body temperature more constant than ambient temperature. Some are endothermic regulators during flight by controlling metabolic heat...
production (gliding or powered flight) and controlling heat loss (altering circulation between thorax and abdomen). Body size is an important factor among heliothermic dragonflies. Small fliers are unable to thermoregulate because they are subjected to high rates of convective heat loss (May 1976).

Most species encountered that are not affected by temperature are found in open spaces with high light penetration, as in Sites 1, 2, 3, and 5. Monteiro-Júnior and colleagues (2014) support this observation, wherein richness and abundance of anisopterans are correlated positively with increased incidence of sunlight.

The mean annual temperature in the Philippines is 26.6 °C based on the average of all-weather stations (excluding Baguio City) since altitude showed greater contrast in temperature. There is no difference in the mean annual temperature in Luzon, Visayas, and Mindanao measured at or near sea level (PAGASA 2018).

Results indicated in the CCA showed a significant association of some species with relative humidity. Axis 2 was strongly related to the presence of N. terminata, N. fluctuans, L. asiatica, and T. irregularis and was negatively weighed on the population of P. congeners and P. pilidorsum.

This could mean that relative humidity is a favorable factor and may influence the distribution of Odonata. This finding is similar to the result of Laltanpuii and colleagues (2017), wherein a correlation of species richness and humidity was statistically significant. O. sabina also occurred in areas with higher relative humidity conditions such as in Site 4. The nature of this species could tolerate a wide range of habitats but prefers standing and temporary water body, as described by Theischinger and Hawking (2006).

This relationship could be accounted for by the canopy cover and the physical integrity of the environment in Site 4. The relatively higher mean relative humidity of Site 4 compared to other sites and the absence of an optimum water source in the area might be contributory to this result. Site 4 is a natural park with several domesticated trees and natural vegetation. The influence of forests on the environment forms part of a vast and complex relationship between environments. Vegetation and forest raise the relative humidity of the air through evaporation (Ansari 2003).

The Philippines has high relative humidity due to high temperatures and surrounding bodies of water. The average monthly relative humidity varies between 71% in March 2018 and 85% in September 2018. The high sensible temperature is the result of the combination of warm temperature and high relative plus absolute humidity throughout the archipelago (PAGASA 2018).

Results in CCA showed no significant relationship between species abundance and relative rainfall. This is similar to the findings of Laltanpuii and colleagues (2017), wherein no significant correlation between species richness and rainfall was noted. Axis 3 was positively weighed on the population of N. fluctuans, L. asiatica, and T. irregularis and to a smaller extent with P. flavescens. The population of O. sabina, P. pilidorsum, and A. femina weighed negatively and – to a smaller extent – with D. trivialis.

Even though they revealed a low eigenvalue and percentage, the marginal insignificance of the correlation was due to the low amount of rainfall recorded during the study. On average, the amount of rainfall observed was 5.526 mm (Site 4), and almost little to no rainfall was observed during the site visits. Similar in nature to this observation, the absence of rainfall resulted in very few nymphs successfully emerging, which showed that rainfall characteristics such as intensity, duration, and frequency of rainfalls might exert strong effects on insect population growth (Pan et al. 2014).

With the given CCA results, this may not be directly related to the Odonata assemblage since other factors such as migration, competition, predation, and water resources availability may play an important role in determining the abundance of adult Odonata. Nevertheless, these results provide an indication of Odonata assemblage and environmental conditions across several habitat types in the locality of Tagum City.

CONCLUSION

The Odonata in the urban wetlands of Tagum City is composed of common species tolerant of anthropogenic pressures that belong to Families Libellulidae and Coenagrionidae. The most frequent and dominant species are P. flavescens, O. sabina, D. trivialis, and A. femina (ricefield damselfly). Shannon's diversity index showed that most sites have a relatively moderate species diversity and are less evenly distributed. CCA indicated that relative humidity and ambient temperature could affect the abundance of certain species in the community. The importance of vegetation and fluvial habitat is critical in enhancing the population of odonates in highly urbanized areas, such as what we have observed in Tagum Botanical Park.
ACKNOWLEDGMENTS

We thank the local government unit of Tagum City for allowing us to do fieldwork. We are also thankful to the DENR Region 11 Office for granting us a gratuitous permit for collecting our specimens. Special thanks are given to the following experts for assisting us in the verification of the odonate species: Andre Nel, Ph.D. (L’ Institut de Systématique, Évolution, Biodiversité, France); Dennis Paulson, Ph.D. (Slater Museum of Natural History); Vincent Kalkman, Ph.D. (Naturalis Biodiversity Center Holland); Reagan Joseph Villanueva, M.D. (Southern Philippines Medical Center); and Matti Hääläinen, Ph.D. (Taxonomy and Systematics Naturalis Biodiversity Center Holland). We also thank Jeaneth G. Molano and her team for the field assistance and for the photo.

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