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Species diversity of Odonata in the urban ecosystem of Iligan City, Philippines

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Abstract. *Banaybanay DP, Amparado OA, Morilla LJG, Estaño LA. 2024. Species diversity of Odonata in the urban ecosystem of Iligan City, Philippines. Biodiversitas 25: 890-899.* Urbanization impacts ecosystem function and services, resulting in changes in ecological processes, increasing human population, and biodiversity loss. This threat may influence Odonata species' abundance, diversity, and distribution in freshwater habitats. The survey of Odonata in the urban ecosystem in Iligan City, Philippines was carried out from December 2022 to March 2023 to determine the species diversity, abundance, endemism, distribution, and their correlation to various environmental parameters in freshwater habitat in this area. Field sampling was conducted in six identified barangays: Barangay Tubod, Bagong Silang, Del Carmen, Villa Verde, Poblacion, and Ubaldo Laya. The study recorded 569 individuals consisting of two major Odonate families, the Family Libellulidae, comprising nine species: *Acisoma panorpoides, Brachydiplax chalybea, Crocothemis servilia, Diplacodes trivialis, Neurothemis terminata, Neurothemis ramburii, Orthetrum sabina, Rhodothemis rufa* and *Trithemis aurora*; and Family Coenagrionidae with four species: *Agriocnemis femina, Ceriagrion lieftincki, Ischnura senegalensis* and *Pseudagrion pilidorsum.* Among the recorded species, *I. senegalensis* (34.80%) was found to be the most abundant species, followed by *A. femina* (32.51%) and *O. sabina* (10.54%), which are encountered in all sampling sites. Meanwhile, the low diversity and low endemism (7.69%) were recorded in all sampling areas, with *C. lieftincki* as the only Philippine endemic recorded in Barangay Bagong Silang, Iligan City, Philippines. Canonical correspondence analysis reveals that environmental factors such as air temperature, water temperature, water pH, water turbidity, and relative humidity are crucial parameters in determining the assemblage of Odonata. Overall, urban ecosystems in Iligan City are dominated by oriental species, signifying that the areas are heavily disturbed. Therefore, urgent management of urban ecosystems is required to enhance the city's ecological health, sustainability, and insect biodiversity.

Keywords: Bioindicator, ecosystem health, endemic, freshwater, insect, urbanization

INTRODUCTION

Odonates are highly sensitive to habitat changes, which is why they are excellent biological indicators, particularly in riverine ecosystems. Their habitat specificity makes them a good bio-monitoring marker for assessing the health of freshwater ecosystems (Dimapinto et al. 2015). Odonates' sensitivity to the environment makes them helpful in evaluating aquatic ecosystems, as they rely on water quality and surrounding plants to thrive. They are also considered flagship species for freshwater conservation, as their essential role highlights their value within the ecosystem (Hart et al. 2014). Odonata assemblages can also be used as surrogates to determine aquatic areas for conservation prioritization (Vilenica et al. 2022). Approximately 300 species were recognized in the Philippines, and 90% are mostly Zygopterans and 40% Anisopterans (Hämäläinen 2004). Interestingly, Mindanao Island in the southern Philippines holds up to 140 species (Villanueva and Cahilog 2013).

Meanwhile, Iligan City is categorized as a highly urbanized city in the Philippines known for being the "Industrial City of the South" (DOTr 2020). This city houses industries like steel, tinplate, cement, and flour mills that contribute to the development and economic productivity (Britannica 2023). Based on topographic features, Iligan City also harbors important forest patches on its adjacent mountains that conjure with scenic clear water, and it is well known as the city of majestic waterfalls on its waterways that support the freshwater ecosystems in lowland areas (Medecilo-Guiang et al. 2022). However, the continuing development of industries, commercial buildings, various transportation improvements, emerging tourism popularity, and the growing population became factors of land degradation, pollution, and habitat destruction of the local inhabitant species. Any changes to these environments will significantly affect the assemblage of odonates and their diversity. The findings of Ishak et al. (2021) support evidence that anthropogenic activities resulted in pronounced changes in the taxonomical composition of the Odonata in waterways. Likewise, the findings of Adu et al. (2022) describe the health status of River Aponmu, Ipogun Southwest Nigeria, as a polluted freshwater habitat base of the Odonata community structure.

As urbanization expands, understanding how ecological processes function in cities has become increasingly important for conserving biodiversity (Lepczyk et al. 2017). The greatest threat to most dragonfly species in an urban ecosystem is the acceleration of modern urbanization, which contributes to biodiversity loss through habitat alteration, rapid ecological changes, and a growing population (Perez and Bautista 2020). Fortuitously, odonates can live in various freshwater habitats, including streams, lakes, marshes, swamps, marshes, pools, rivers, reservoirs, creeks, and ponds (Seidu et al. 2019). However, most odonates studies were conducted in protected landscapes, sanctuaries, or environments generally surrounded by vegetation and waterways. There is a dearth of information on Odonates diversity and distribution in urban associates. Therefore, there is a need to study the biodiversity and status of odonates in an area unrestricted from threats and disturbances. The results of this study will provide vital information on odonate assemblages in urban settings to recommend conservation measures for species and their urban freshwater ecosystems.

MATERIALS AND METHODS

Study area

The study was conducted in , Iligan City, Philippines, a highly urbanized city (Figure 1). It is nestled on the island of Mindanao at roughly 8° 14' North and 124° 14' East. The provinces of Bukidnon and Lanao del Sur in the east, Misamis Oriental in the North, and Lanao del Norte in the south border it. The elevation at these locations is 6.0 meters, or 19.8 feet, above mean sea level (PhilAtlas 2023). It comprises 44 barangays with a total land area of 813.37 km^2. According to the 2020 Census, its population was 363,115 people (Philippine Statistic Authority 2020). It is Mindanao's most major industrial city, as well as an important port at the mouth of the Iligan River. Its expansion has been fueled mostly by the Agus River's proximity, with its enormous hydroelectric potential harnessed at Maria Cristina Falls. This study identified six sampling sites where water systems served as Odonata's habitat in the Iligan City urban area (Table 1).

Table 1. Freshwater habitat of Odonata in urban ecosystem in Iligan City, Philippines

Sampling sites (Barangays)	Freshwater habitat description
Site 1 (Barangay Tubod)	River; characterize as lotic ecosystems with fast-moving water
Site 2 (Barangay Bagong Silang)	Wetpark; man-made ponds that were connected with small water pathways underneath a concrete walkway
Site 3 (Barangay Del Carmen)	Slow-moving ditch located along the roadside
Site 4 (Barangay Villaverde)	Creek; slow-flowing water and acts as a drainage system
Site 5 (Barangay Poblacion)	Creek; slow-flowing water acts as a basin of wastewater for the surrounding residential houses
Site 6 (Barangay Ubaldo Laya)	Pond; characterized by having a muddy soil type with very turbid water

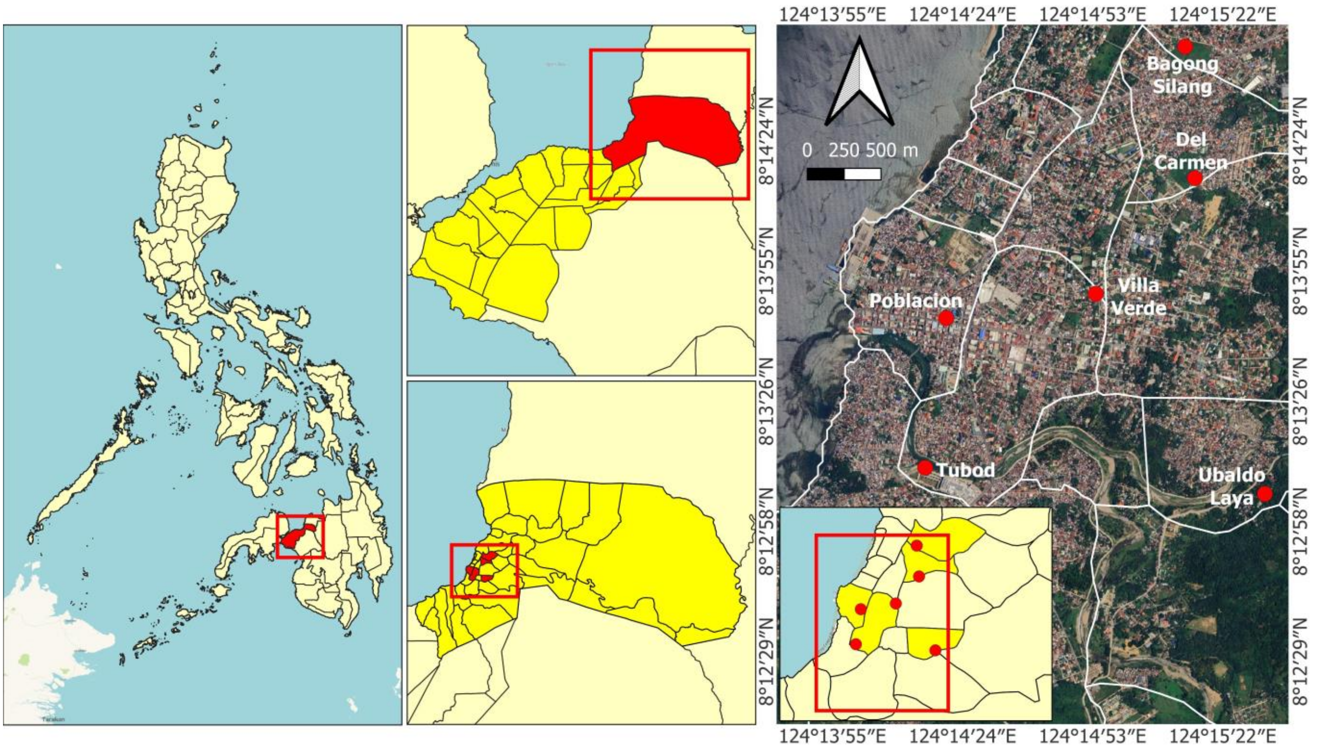

Figure 1. Map showing the sampling sites in Iligan City, Northern Mindanao, Philippines

Collection, processing, and identification of samples

Before field sampling, a permit was secured for each sampling site. The sampling activities were carried out between December 2022 and March 2023 in strategically identified habitats of odonates, such as creeks, ditches, rivers, and ponds across Iligan City. The sampling techniques for collecting samples were adapted from Mapi-ot et al. (2013), which included using sweep nets for capturing Odonata and hand-picking methods for collecting samples. Each site was sampled by four field insect collectors for two days between the hours of 07.00 and 15.00. Only adult Odonata were collected, and specimens were stored in white triangular envelopes labeled with the date, location, and capture time. Additionally, photo documentation was conducted in the field to represent the sampling sites and the representative species.

During the sampling process, various environmental parameters were also recorded. Physicochemical water quality characteristics were measured on the same day of collection of Odanata sampling at each location. The Hanna Multimeter was used to measure temperature, water pH, turbidity, air and water temperature, and relative humidity. This device provides a direct reading for these physicochemical parameters (Ishak et al. 2021). While water flow was measured using a plastic ball and stopwatch, the type of vegetation and existing disturbances were also noted. These parameters were recorded to assess whether they may have influenced the assemblage and occurrence of Odonata. Initial identification was done using published photographs and pictorial keys. Important morphological characteristics, including the color pattern of the thorax, specifically the synthorax; patterns of wing venation; abdomen, specifically the segment ten and the epiproct; the sizes, shapes, and even their flight behaviors were used in species identification (Dubois 2009). Further verification was done by Odonata expert R.J.T. Villanueva, an Odonata expert in the Philippines.

Data analysis

Paleontological Statistics Software Package (PAST) version 4.12b was employed to determine the species diversity, relative abundance, total endemism, evenness value, and percentage composition. Shannon-Wiener index was used to determine species diversity and relative abundance in each sampling site. The chi-square test of independence was also used to determine the differences in Physicochemical parameters among habitats. Pearson's Correlation Analysis was also used to determine the association of abundance in pH physicochemical parameters in these areas and it was done using SPSS v.20.0 software. The Canonical Correspondence Analysis was employed to determine the association between environmental variables and Odonata species. Likewise, Bray-Curtis Analysis was also used to determine the clustering of Odonata community complexity and was done through PAST version 4.12b.

RESULTS AND DISCUSSION

Species composition and abundance

Five hundred sixty-nine (569) individuals of Odonata were collected and identified in sampling sites of the urban freshwater ecosystems in Iligan City. Thirteen (13) species were classified into two (2) suborders, two (2) families, and twelve (12) genera. The family Libellulidae comprised nine (9) species namely, *Acisoma panorpoides* 21 (3.69%), *Brachydiplax chalybea* 3 (0.53%), *Crocothemis servilia* 3 (0.53%), *Diplacodes trivialis* 47 (8.26%), *Neurothemis terminata* 13 (2.28%), *Neurothemis ramburii* 3 (0.53%), *Orthetrum sabina* 60 (10.54%), *Rhodothemis rufa* 6 (1.05%), and *Trithemis aurora* 6 (0.89%), while the family Coenagrionidae consisted of four (4) species namely, *Agriocnemis femina* 185 (32.51%), *Ceriagrion lieftincki* 19 (3.34%), *Ischnura senegalensis* 198 (34.80%), and *Pseudagrion pilidorsum* 6 (1.05%) (Table 2; Figure 2). The most abundant species observed was the *I. senegalensis*, an oriental damselfly species. It was observed in all sites and dominates the population in Sites 1, 2, and 6. Interestingly, *C. lieftincki* is the only Philippine endemic exclusively found in the vegetation near Site 2.

The family of Libellulidae had the highest number of species observed in the area. This finding is coherent with the studies of Perez and Bautista (2020) and Vitor et al. (2022) in assessing the diversity of Odonata in urban areas in the Philippines, specifically in Mindanao. Their observation shows that the family Libellulidae comprises the majority of the collected specimens, and it is evident, as Koneri et al. (2017) stated, that the Libellulids can be found in any habitat type, but with a preference for open and stagnant-water areas. Sites 1 and 2 are open areas, exhibiting both lotic and lentic waters and with an adequate amount of vegetation. Therefore, the area is viable for Odonata's survival, especially the Libellulidae family. Kiany and Minaei (2009) further explained that Libellulids breed predominantly in lentic habitats and thrive in waters with low dissolved oxygen levels, while some species can also occupy brackish water habitats.

Orthetrum sabina is the only member of Anisoptera with the highest number of individuals (10.54%) collected and present in all sampling sites. According to IUCN (2022), *O. sabina* is a species that is both common and widespread, even in Malaysia, occupying a broad range of slow-flowing and still-water habitats (e.g., ponds, lakes to wet rice fields, irrigation ditch, and marshes). Additionally, *O. sabina* tends to breed in artificial environments, making them abundant in many habitats. This species is very tolerant of high salt contents and habitat disturbance, making them known as eurytopic or habitat generalists (IUCN 2022). In the Philippines, the number of *O. sabina* is also notable in the study of Perez and Bautista (2020) as it holds the highest number of individuals (71.62%) recorded in the urban areas of Davao. Similarly, Quisil et al. (2013) found *O. sabina* to be the most abundant and widely distributed species in the surveyed areas of Surigao del Sur.

On the other hand, *Ischnura senegalensis* (34.80%) and *Agriocnemis femina* (32.51%) had the highest number of collected individuals in the suborder Zygoptera. Both species were present in all sampling sites and are observed to have the highest relative abundance of all sampled areas. These two species of damselflies were also known to be among the most widespread species in the world that can tolerate pollution and disturbed habitats (IUCN 2022; Jiang et al. 2023). They can breed in various shallow weedy habitats, marshes, and margins of lakes, and even reported in water-filled wheel ruts, polluted drains, and ditches inside cities. Unlike the *O. sabina* and the other dragonfly species, the *I. senegalensis* and *A. femina* preferred shaded rather than open habitats. Additionally, *A. femina*, according to Janra and Herwina (2022), tends to perch more in densely bushed areas and shows abundance in polluted ditches.

Table 2. Odonata species recorded in urban freshwater ecosystems in Iligan City, Mindanao, Philippines

Species	Tubod	Bagong Silang	Del Carmen	Villa Verde	Poblacion	Ubaldo Laya	Total	RA(%)
Acisoma panorpoides (Rambur, 1842)	-	16	5	-	-	-	21	3.69
Brachydiplax chalybea (Brauer, 1868)	3	-	-	-	-	-	3	0.53
Crocothemis servilia (Drury, 1773)	2	1	-	-	-	-	3	0.53
Diplacodes trivialis (Rambur, 1842)	22	23	-	-	-	2	47	8.26
Neurothemis terminata (Ris, 1911)	6	6	1	-	-	-	13	2.28
Neurothemis ramburii (Kaup, 1866)	3	-	-	-	-	-	3	0.53
Orthetrum sabina (Drury, 1773)	14	10	23	5	7	1	60	10.54
Rhodothemis rufa (Rambur, 1842)	5	1	-	-	-	-	6	1.05
Trithemis aurora (Burmeister, 1839)	5	-	-	-	-	-	5	0.89
Agriocnemis femina (Brauer, 1868)	37	26	34	11	35	42	185	32.51
Ceriagrion lieftincki (Asahina, 1967)	-	19	-	-	-	-	19	3.34
Ischnura senegalensis (Rambur, 1842)	46	32	31	15	31	43	198	34.80
Pseudagrion pilidorsum (Brauer, 1868)	5	1	-	-	-	-	6	1.05

Note: *Relative Abundance (RA)

Figure 2. Recorded odonates in Iligan City, Northern Mindanao, Philippines in which: A. Male *A. panorpoides*, B. Male *B. chalybea*, C. Teneral male *C. servilia*, D. Male *D. trivialis*, E. Male *N. terminata*, F. *Neurothemis ramburii*, G. Male *O. sabina*, H. Male *R. rufa* and I. *Trithemis aurora*, J. Immature male *A. femina*, K. Pruinose mature male *A. femina*, L. Male *C. lieftincki*, M. Immature female *I. senegalensis*, N. Mature female *I. senegalensis*, O. Mature male *I. senegalensis*, P. Mature male *P. pilidorsum* and Q. Mature female *P. pilidorsum*

Table 3. Biodiversity indices of Odonata species in urban ecosystems in Iligan City, Mindanao, Philippines

Parameter	Tubod	Bagong Silang	Del Carmen	Villa Verde	Poblacion	Ubaldo Laya
Taxa_S	11	10	5	3	3	4
Individuals	145	135	94	31	73	88
Dominance_D	0.1979	0.1575	0.2949	0.3656	0.4113	0.4611
Shannon (H')	1.902	1.962	1.304	1.045	0.9547	0.8569
Evenness_e^H/S	0.6088	0.7115	0.7366	0.9482	0.8659	0.589

Species diversity and distribution

The Shannon-Wiener Diversity Index shows that Iligan City Wet Park of Barangay Bagong Silang (site 2) had the highest diversity index (H' = 1.962), followed by Brgy. Tubod (H' = 1.902), Del Carmen (H' = 1.304), Brgy. Villa Verde (H' = 1.045), and Brgy. Poblacion (H' = 0.9547), while the Barangay Ubaldo Laya (site 6) was the lowest (H' = 0.8569). Likewise, the number of individuals recorded was highest in Brgy. Tubod was followed by Bagong Silang, Del Carmen, Ubaldo Laya, and Poblacion, while Villa Verde recorded the least. In terms of Evenness value (e^H/S), Barangay Villa Verde (e^H/S = 0.9482) recorded the highest, followed by Poblacion (e^H/S = 0.8659), Del Carmen (e^H/S = 0.7366), Bagong Silang (e^H/S = 0.7115), and Tubod (e^H/S = 0.6088) while Ubaldo Laya (e^H/S = 0.589) harbored lowest. In contrast with the Dominance value (D), the Barangay Ubaldo Laya (D = 0.4611) recorded the highest, followed by Poblacion (D = 0.4113), Villa Verde (D = 0.3656), Del Carmen (D = 0.2949) and Tubod (D = 0.1979) while Bagong Silang (D = 0.1575) recorded least. In terms of the number of species harbors per site, Barangay Tubod recorded 11 species, Bagong Silang reported 10 species, Del Carmen recorded five species, and Ubaldo Laya recorded four, while both Villa Verde and Poblacion recorded three species, respectively (Table 3).

Among the six sites, site 2 gained the highest species diversity because of an open habitat with stagnant water and adequate vegetation; however, Brgy. Villa Verde recorded the lowest number of individuals, primarily because of the few vegetative areas, unlike Brgy, Tubod, and Bagong Silang, where an adequate amount of vegetation was observed. According to May (2017), open habitats with still water and vegetation are crucial for adult dragonflies because they require warmth for thermoregulation, bodies of water for oviposition, and vegetation for protection. On the contrary, site 6 exhibits more of a vegetative environment—a favorable environment for damselflies. Although Barangay Ubaldo Laya acquired the lowest diversity, it gained the highest dominance of damselflies, especially the *I. senegalensis* and *A. femina*. Nicolla et al. (2021) confirm this observation as *I. senegalensis* acquired the highest relative abundance in a canopied area compared to a non-canopied area in Gumuk Pasir Parangkusumo, Indonesia.

Moreover, Ball-Damerow et al. (2014), Kietzka et al. (2018), and Rocha-Ortega et al. (2019) emphasize that odonate communities in urbanized environments tend to have similar species richness and are more homogeneous than those found in non-urban sites. This is due to the prevalence of habitat generalist species, which have expanded their range, and the decline of specialist species. *Agriocnemis femina* also showed dominance in the study of Janra and Herwina (2022), in which a polluted ditch is the most favorable habitat of *A. femina* rather than a clean pond site. This is because of a possible trade-off of *A. femina* by choosing a habitat with minimum predators rather than ideal conditions yet prone to predation. The dispersal abilities of these damselflies might also influence their dominance as damselflies have limited dispersal ability that restricts them from spreading (Seidu et al. 2019).

Furthermore, rainfall patterns contributed to the low diversity yet high abundance and dominance of Odonata in Brgy. Ubaldo Laya. This is because the sampling period was conducted in March. Due to the passage of the rainy seasons in which odonata reproduce, Luke et al. (2020) reported that higher levels of Odonata abundance were seen in March. This means the rainy season can provide suitable habitats for larval dragonflies. When the dry season comes, they flourish and appear to be slightly more homogenous than those caught during the rainy season. Villanueva and Cahilog (2013) also noted that weather conditions such as excessive rain could affect the survey, and expected species might be absent despite assessing during the "dry" season since dragonflies hide in vegetation when the weather is too cold or wet. Consequently, this affected the Odonata assemblage in the dry season.

All the sampling sites acquired low diversity, which indicates that all sites are disturbed. The results coincide with other urban diversity studies, implying that urban areas generate low diversity because of many Oriental species and on-site disturbances (Mapi-ot and Enguito 2014). This study is also consistent with Adu et al. (2022), in which the Idi stream in Ipogun, Southwest Nigeria, presented a poor species diversity attributed to the human disturbance in this habitat. Likewise, Yuto et al. (2015) agree that human-induced disturbances limit the occurrence and abundance of the Odonata, especially the endemic species. Moreover, the recorded Odonata in urban and degraded areas near human settlements recorded lower diversity (Mapi-ot et al. 2013; Mapi-ot and Enguito 2014; Perez and Bautista 2020). The current study recorded low diversity in all sampling sites since the area is near human settlements in urban areas and frequently exposed to other disturbances. In contrast, the study of Guadalquiver et al. (2022), reported a high endemicity and moderate to high diversity of Odonata in pristine and protected landscapes in the Philippines, which connotes a healthy and excellent habitat for Odonata.

The family Libellulidae is one of the largest families dominating standing water and tolerating anthropogenic disturbances. Therefore, their presence is associated with the adverse effects of various habitat modifications like human settlement and forest clearing for agricultural use (Dejadena et al. 2015). The similarity of Odonata species distribution in the urban ecosystem of Iligan City was examined (Figure 3). From the thirteen species presented, two significant clusters are formed. The first cluster shows that *O. sabina, A. femina,* and *I. senegalensis* showed similarities in distribution. These species were present in all sampling sites and not limited to specific habitats. However, *A. femina* and *I. senegalensis* have shown greater resemblance since both species had the highest abundance. Meanwhile, *D. trivialis* is closely related to *C. lieftincki* and *A. panorpoides*, as both species were found in the same habitat. But *D. trivialis* exhibits greater abundance than the two species.

In the second major cluster, *N. terminata* was slightly associated with the previous cluster and the current cluster primarily because *N. terminata* can be found in some habitats where the species of the previous cluster were observed and habitats in the current cluster. *R. rufa, P. pilidorsum, T. aurora, B. chalybea, N. ramburii*, and *C. servilia* were only found in 2 sampling sites, the Barangay Tubod and Barangay Bagong Silang. *Trithemis aurora,* on the other hand, was found exclusively in Barangay Tubod, while *R. rufa* and *P. pilidorsum* were observed in both sites which had the same abundance. Furthermore, *B. chalybea, N. ramburii* and *C. servilia* were closely associated in terms of abundance but differed in their distribution as *C. servilia* was found inhabiting both lotic and lentic ecosystems of Barangay Tubod and Bagong Silang with moderate vegetation, open habitat, and tolerable disturbances.

Species endemism and conservation status

The majority of documented species are Oriental, with only *C. lieftincki* being listed as a Philippine endemic. All species are categorized by the International Union for Conservation of Nature (IUCN) as least concern. High endemicity and moderate diversity stipulate that an area is a healthy and suitable habitat for Odonata (Guadalquiver et al. 2022). However, low endemism indicates that the sites sampled were already disturbed (Mapi-ot and Enguito 2014). Low endemism (7.69%) was found in all the sampling sites. From all the species collected, only one (1) species of Odonata is considered to be Philippine endemic, while the rest were Oriental species.

A small population of *C. lieftincki* was found exclusively in Site 2, perching on the bushes near the man-made ponds. *Ceriagrion lieftincki* needs to be better recorded in terms of the habitats and ecology of this species. Still, it occurs in shady ponds and lakes, marshes, and sometimes streams with some degree of disturbance tolerance (IUCN 2022). Moreover, *C. lieftincki* is mostly widespread, but certain groups have incredible cryptic diversity that remains understudied, especially in Asia (Joshi and Sawant 2019). Generally, endemic species are restricted to a particular geographical area (May 2017) and are vulnerable to environmental changes. Because of their sensitivity, most endemic species are habitat specialists that reflect their adaptability to specific environmental regimes (Behroozian et al. 2020). Yuto et al. (2015), articulated that human-induced disturbances also limit the occurrence and abundance of the endemic Odonata. This means that urbanized areas are unsuitable habitats for endemic species, as extensive disturbance exists. As such, Odonata species that are habitat generalists will predominate degraded areas because they show broad environmental tolerances (Székely and Langenheder 2014). However, all of them are least concerned, and no reports have been made that constitute their decline since disturbance-tolerant and widespread species are not likely to be globally threatened (IUCN 2022). The International Union for Conservation of Nature Red List of Threatened Species (2022) reported that most Odonata species collected are widespread and have a stable population trend except *Acisoma panorpoides, Rhodothemis rufa, Trithemis aurora, A. femina, C. lieftincki* and *Pseudagrion pilidorsum* which were unknown, and *Crocothemis servilia* which population is increasing. The most abundant odonata species recorded in this study, *I. senegalensis*, has been introduced to various parts of the world beyond its native habitat and has the potential to establish invasive populations in suitable environments (Adriaens and De Knijf 2015). The occurrence of this generalist damselfly has been documented outside its natural range, including instances in Germany (Lambertz and Schmied 2011), the Canary Islands (Peels 2014), and Austria (Laister et al. 2014).

Physico-chemical parameters

Barangay Bagong Silang had the highest temperature in air and water, while Tubod reported the lowest. Regarding water pH, Barangay Bagong Silang reported the highest, followed by Tubod, Ubaldo Laya, Villa Verde, and Del Carmen, while Poblacion recorded the lowest. Barangay Ubaldo Laya recorded the highest water turbidity, followed by Villa Verde and Bagong Silang, Tubod, and Del Carmen, while Poblacion recorded the lowest. Both Ubaldo Laya and Bagong Silang are lotic types of water habitats. With regard to relative humidity, Ubaldo Laya recorded the highest, followed by Poblacion and Villa Verde, while Tubod and Del Carmen recorded the lowest (Table 4).

Various environmental conditions are among the factors that affect the presence of Odonata. These are significant parameters that determine species' abundance, diversity, and distribution. According to Calvão et al. (2020), abiotic factors are one of the critical elements in the structuring of natural communities of Odonata. Brgy. Bagong Silang had the highest temperature (29.83°C), followed by Brgy. Del Carmen (29.67°C) and Brgy. Villa Verde (29.17°C). While Brgy. Tubod had the lowest temperature at 27°C. The air temperature of all sites varies, but there is no significant difference between them as odonates thrive between 18 and 45°C in shade (Castillo-Pérez et al. 2022). The Chi-square statistic results also confirm that no significant difference in air temperature among sites at the p-value equals 0.115. However, in terms of water temperature, Brgy Bagong Silang had the highest water temperature at 28.67°C. The probable reason why Brgy. Bagong Silang gained the highest ambient and water temperature because of the open habitat that Brgy. Bagong Silang exhibits. Disturbances such as infrastructures and loss of plant cover increases ambient temperature, according to Castillo-Perez et al. (2022). Results from the Chi-square statistic confirm that water temperature among sites reveals significance at a p-value equal to 0.011.

Table 4. Recorded environmental parameters in the urban ecosystems in Iligan City, Mindanao, Philippines

Environmental parameters	Tubod	Bagong Silang	Del Carmen	Villa Verde	Poblacion	Ubaldo Laya	Chi-Square	p-value
Air temperature (°C)	27	29.83	29.67	29.17	28.33	28.30	6.63	0.155
Water temperature (°C)	25	28.67	27.17	27	27	27.67	13.10	0.011
Water pH	8.24	8.76	7.60	7.87	6.73	8.13	10.57	0.032
Water turbidity	4	5	4	5	3	8	14.00	0.009
Water flow rate (m/s)	0.65	0	0.33	0.12	0.24	0	13.62	0.007
Relative humidity (%)	85	79	85	86	86	93	14.00	0.008

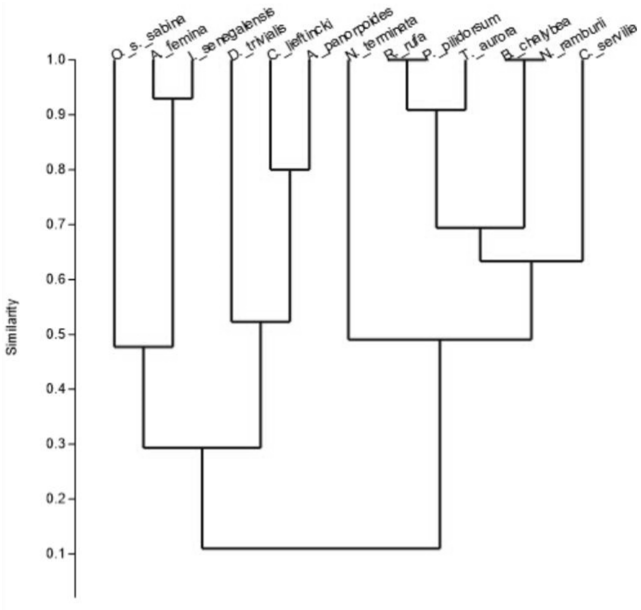

Figure 3. Cluster analysis of the distribution of Odonata in Iligan City, Northern Mindanao, Philippines

Moreover, Brgy. Bagong Silang also obtained the highest pH from all the sampling sites, while Brgy. Poblacion gained the lowest pH—the acidity level of Brgy. Poblacion occurred because of an ongoing bridge reconstruction and household wastewater that could contribute to the lower pH level of the site. Results from Chi-square statistic reveal a significant pH difference among sites at a p-value equal to 0.032. According to Ali et al. (2014), cement dust harms aquatic communities, and high soil pH levels have been found in studies of cement dust and dust pollution—however, the alkalinity of Brgy. Bagong Silang is evident as algal growth was observed as a product of the high temperature of the site.

As for water turbidity, Brgy. Ubaldo Laya acquired the highest turbidity, while Brgy. Poblacion had the lowest. Turbid waters are caused mainly by algae growth, clouding the aquatic habitat. Water turbidity among sites also shows a significant difference at a p-value of 0.008. In the flow rate of water, Brgy. Tubod had the highest rate of flow. However, it also exhibits a lentic ecosystem along with Brgy. Bagong Silang and Ubaldo Laya. Results from the Chi-square statistic test reveal a significant difference in water flow at a p-value of 0.009. At the same time, the rest of the site has slow-flowing water. However, Odonata occurs in almost all types of freshwater habitats, and there is no difference in species richness between temporal and permanent water bodies (Suhling et al. 2015; Renner et al. 2020). On the other hand, Brgy. Ubaldo Laya had the highest relative humidity (93%), while Brgy. Bagong Silang gained the lowest. Differences in relative humidity among sites were significant at a p-value equal to 0.007. According to the National Weather Service, warm air can possess more water vapor than cold air. Hence, warmer air has a lower relative humidity, while cooler air has a higher relative humidity.

Environmental factors have substantial effects on the occurrence of Odonata species. For example, *C. lieftincki* and *A. panorpoides* are closely associated with a higher level of ambient temperature and water temperature (Figure 4). This implies that certain species tend to increase more in a hotter environment. Meanwhile, *D. trivialis* and *N. terminata* are adapted to lower pH levels, which means they may survive and even thrive in acidic habitats. On the other hand, *A. femina, I. senegalensis,* and *O. sabina* indicate that turbid water is also suitable for their growth. They can tolerate the effect of turbidity and can thrive despite having no pristine water, as Odonata typically prefer. The rest of the environmental factors appeared to be less impactful to these species, indicating that they are more of a habitat generalist than a specialist. *Agriocnemis femina, I. senegalensis,* and *O. sabina* are known to be widespread species. *Agriocnemis femina* was recorded to proliferate more in a polluted area than in a clean water body (Janra and Herwina 2022). Meanwhile, *O. sabina* was recorded in a brackish lake on Flores Island, Lesser Sunda Archipelago (Potapov et al. 2020).

Canonical Correspondence Analysis (CCA) shows the implication of pH level on the abundance of odonata. It appears that most of the Odonata species collected can tolerate a pH level of 6 to 9 (Figure 5). The results imply that a pH level of 6 to 9 is the optimum pH level at which odonata can thrive and reproduce. According to (Ishak et al. 2021), some Odonata remains unaffected by exposure to soft water at pH 5.1 and 3.5. With their tolerance to low pH, widespread distribution of Odonata would likely occur in acid-stressed ecosystems.

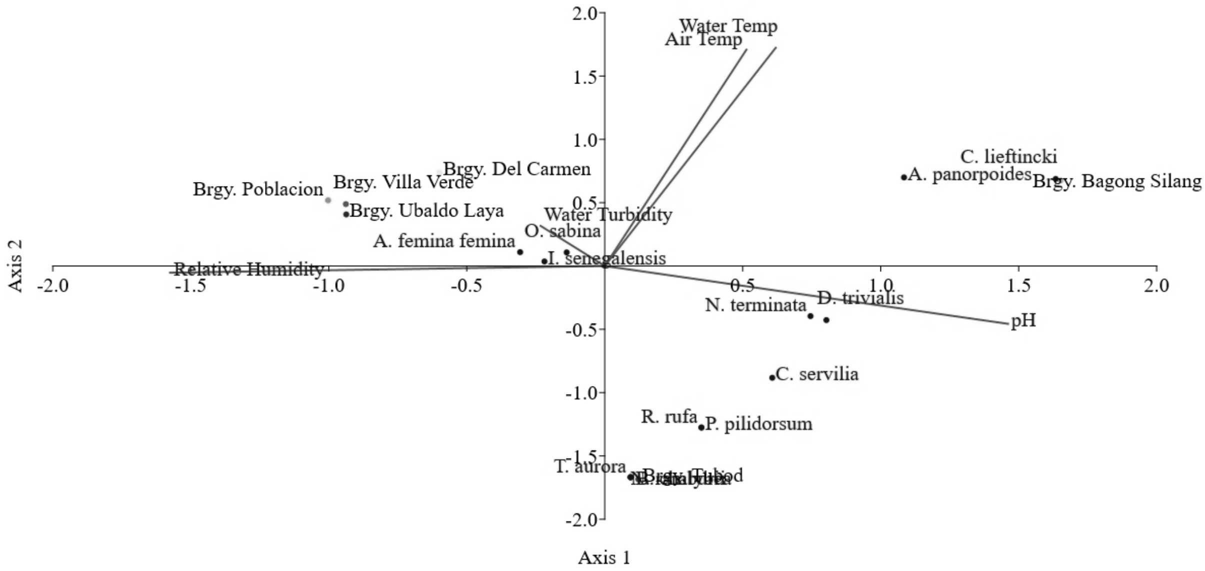

Figure 4. Canonical Correspondence Analysis of Odonata species and its associated environmental factors in Iligan City, Northern Mindanao, Philippines

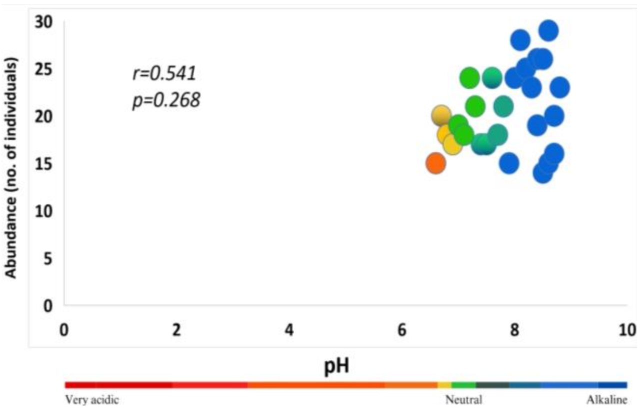

Figure 5. Correlation between pH level and abundance of Odonata in Iligan City, Northern Mindanao, Philippines

The current survey elucidates the community of Odonates in urban settings, as in the case of Iligan City, which harbors a bang-up freshwater ecosystem. The anthropogenic disturbances and improper disposal of waste in freshwater are considered factors that may have posed threats to the diversity of Odonata species in urban settings in Iligan City. Further habitat destruction, modification, and fragmentation, together with polluted water domains, could be primarily brought about by the apparent presence and impact of human settlements, human-made trails, gravel mining activities, deforestation due to slash and burn (kaingin) activities, and agricultural land expansion. Ultimately, habitat modification is an alarming biodiversity threat to highly diverse tropical ecosystems, which could result in the extinction and alteration of the abundance of persisting species. The stated land-use change, particularly agricultural development, industrialization, and urbanization, is a significant danger to the biological richness of terrestrial biomes and their related freshwater habitats.

The assessment of Odonata's diversity in the Iligan City's urban ecosystem determined that some species of Odonata could thrive and tolerate degraded habitats with different levels of environmental conditions. Although it has gained low diversity and endemism, some species have shown great dominance and abundance in polluted sites. Odonata can also indicate heavily disturbed habitats rather than only healthy ecosystems. Environmental parameters such as air temperature, water temperature, water pH, water turbidity, and relative humidity were also vital factors in the assemblage of Odonata. Vegetation is also crucial since most of the sites are converted to a modernized environment, limiting the existence of both aquatic and terrestrial vegetation. With the continuing urbanization, maintaining the quality of the urban ecosystem is difficult to attain. It requires enormous attention, budget, and participation of the community. To reinforce action that will limit gravel dredging in the Tubod River. Aside from increasing the flood risk, erosion, and sedimentation, dredging also affects the larvae of Odonata. By limiting this, we can improve their survival and help the community reduce the risk of disasters. This study also recommends further exploring other areas in the urban ecosystem, including tempo-spatial variations in assessing the Odonata community, to provide more comprehensive information. In conclusion, the diversity of Odonata in the Iligan City's urban ecosystem was recorded as low since the area indicates a heavily disturbed habitat. Environmental parameters and vegetation status in the area limit the occurrence and distribution of endemic species as the sampling sites are dominated by oriental species, signifying that anthropogenic activities massively affect the areas. Thus, immediate management of urban ecosystems is essential to improve the city's ecosystem health, long-term sustainability, and insect biodiversity.

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