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Species diversity and distribution of Odonata in Brgy. Rogongon, Iligan City, Philippines

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Abstract. *Magsalay DD, Nuñeza OM, Villanueva RJT. 2024. Species diversity and distribution of Odonata in Brgy. Rogongon, Iligan City, Philippines. Biodiversitas 25: 4909-4919.* Odonata is an insect order often utilized as a bioindicator to help determine the health of an ecosystem. The Philippine Odonata is recognized to have high diversity and endemicity, especially the suborder Zygoptera, since its limited range and its habitat distribution are low. This study was conducted to provide baseline information on the species diversity and distribution of Odonata in Brgy. Rogongon, Iligan City, Philippines. The research employed an 'opportunistic method', a strategy that involves collecting data based on the availability of the species, using sweep nets as a collection tool. Therefore, 35 species belonging to 10 families under 25 genera were found. Results showed that the most abundant family is Libellulidae (S = 9), followed by the family Platycnemididae (S = 8). All the study sites showed moderate diversity (H' = 1.73 - 2.75). On the other hand, one endangered, three vulnerable, and two near-threatened Odonata species were recorded in this study. Moreover, the distribution trend of Odonata species along an elevational gradient in the study areas is that species richness and endemism increase until Site 2 (730 to 787 m asl.) and then decreases as the elevation increases. Factors such as habitat structure and level of disturbances could be the reason for such a trend. Environmental factors such as air temperature, relative humidity, water temperature, water pH, and streamflow affect the distribution and abundance of the Odonata based on the canonical correspondence analysis. Any alteration in the habitat in each study site would be a threat to the population of Odonata. Thus, there is a need to protect the remaining forest of Iligan City, especially since endangered and vulnerable species are present.

Keywords: Elevational gradient, endangered, endemic, vulnerability, Zygoptera

INTRODUCTION

Odonata is an insect order that comprises two suborders, namely, Anisoptera (dragonfly) and the Zygoptera (damselflies) (Asaithambi and Manickavasagam 2002; Corbet 2013). In 2008, Anisozygoptera was recognized as the third suborder of Odonata with extant species from Japan and the eastern Himalayas. Anisozygoptera is a combined feature of Anisoptera and Zygoptera, now under the new name Epiprocta (Kalkman 2007). Dijkstra et al. (2013) provided the updated classification and numbers of described genera and species up to the family level. Under the suborder Anisoptera, dragonflies are considered larger species. On the other hand, species under Zygoptera are generally smaller, more slender, and less active in the air. These two orders share the same special feature in the location and arrangement of their copulatory organs (Heckman 2008).

Odonata is the most vibrant and energetic among all of the insect fauna (Nelson et al. 2011). It is regarded as a good bioindicator that helps in determining the health of the ecosystem, especially in a fluvial environment because it is very responsive to habitat and landscape degradation (Asaithambi and Manickavasagam 2002; Cayasan et al. 2013; Yuto et al. 2015; Mangaoang and Mohagan 2016; Yapac et al. 2016). Aside from being a good bioindicator, Odonata species are also effective as biocontrol agents of agricultural pests and vector mosquitoes (Mangaoang and Mohagan 2016). With this, members of the order Odonata are regarded as captivating insects inhabiting freshwater environments (Palot and Soniya 2000).

Odonata can be found on all continents except in the continent of Antarctica. Anisoptera is a major family well-distributed all over the continents (Bybee 2005). Globally, there are 6,407 known species of Odonata, with 31 identified families (Bhatia and Kumari 2024). Of all the known species of Odonata, there are 3,217 belonging to the suborder Zygoptera and 3,092 to the suborder Anisoptera (WOL 2020). In 2024, in the latest revision, the updated number of known species of odonatan is 6,407 globally (WOL 2024).

Odonata has been recorded in American and Asian countries. In a tropical dry forest in Mexico, 50 species belonging to 26 genera and six families were obtained in the survey of González-Soriano et al. (2021). Pires et al. (2019) surveyed 49 species from 21 genera and six families in deciduous forest fragments in southern Brazil. There were 318 specimens of dragonflies first recorded belonging to 17 Cordulegasteridae, 18 Gomphidae, and 283 Libellulidae from the district Lower Dir (LD), Khyber Pakhtunkhwa, Pakistan (Perveen et al. 2014). In Davanagere District of Karnataka, India, 34 species of Odonata comprising 24 genera belonging to six families being reported; this comprises 25 species from the Anisoptera and nine from the sub-order Zygoptera (Harisha 2016).

In the Philippines, Odonata is characterized by a high percentage of endemic species, particularly in the suborder Zygoptera, which has the most limited range (Hämäläinen 2012). Odonata was found and recorded in the country's different mountains and forest ecosystems. On Mt. Makiling, 24 species are recorded, and 18 are endemic to the Philippines (Ramos and Gapud 2007). On Mindanao Island, there are 36 morphologically identified species, which represent 10 families and 19 genera (Casas et al. 2018). There are also 31 species recorded on Mt. Hamiguitan with 94% endemism for damselflies and 33.3% for dragonflies (Villanueva and Mohagan 2010). On Mt. Pinukis and Gimamaw, Zamboanga del Sur, there are 35 species recorded belonging to 25 genera and 10 families (Yuto et al. 2015). Moreover, 36 species were recorded in selected areas of Zamboanga del Sur belonging to 10 families (Cayasan et al. 2013). In Southern Mindanao, specifically in Kabacan, Cotabato, 13 species of Odonata were recorded, belonging to three families (Mangaoang and Mohagan 2016). In the study of Jomoc et al. (2013) in Cagayan De Oro and Bukidnon, 38 species were recorded under 28 genera and 12 families.

Despite the numerous literature on the distribution of Odonata in the country, there are still a lot of forest covers that have not been surveyed, especially on Mindanao island, which is poorly explored (Villanueva and Mohagan 2010; Villanueva 2011). Due to anthropogenic activities, Odonata and their microhabitats are under threat (Harisha 2016). In addition, Odonata is one of the least studied taxa of insects, with most species lacking information on both ecological and biogeography (Bried et al. 2020; Alves-Martins et al. 2024). Thus, assessment of species diversity and distribution of Odonata in the remaining forest ecosystem of Brgy. Rogongon, Iligan City, Lanao Del Norte was conducted. Moreover, anthropogenic threats were also documented.

MATERIALS AND METHODS

Study area

The study sites were established in Sitio Libandayan, Brgy. Rogongon, Iligan City, Philippines. In Iligan City, Brgy. Rogongon is one of the 44 barangays located in the northeastern part of the city at 1,010 meters above sea level (m asl.) and has a land area of 38,000 hectares. Brgy. Rogongon consists of predominantly residual and dipterocarp forest patches. There are 23 sitios or puroks in this barangay inhabited by the Higaonons, Maranaos, a blend of Higaonon-Maranao, and Christians. The only remaining forest in Iligan City is in Rogongon situated at approximately 08°12 to 8°17 latitude and 124°22.20 to 124°33.30 longitude (Figure 1). Four sampling sites with different elevations were established in the area described below.

Sampling sites

Sampling Site 1

Site 1 is a mixed secondary dipterocarp forest adjacent to an abaca (*Musa textilis* Née) agroecosystem. This site is located at 619-680 m asl. and has coordinates of 08°13.514 N, 124°28.275 E. It has a fast-moving stream with small to large pebbles, a stream flow of around 0.59 m/s, and a stream length of about 6.7 meters. *Araceae* "gabi-gabi" plant, *Fabaceae* "ipil-ipil" plant, and ferns are among the understory plants found along and near streams. Near the streams, epiphytes and other vines were also seen. In addition, a few large trees, such as "lauan" and "kaliyaan" were in the area. The ground is covered with thin leaf litter of about 0.5 inches.

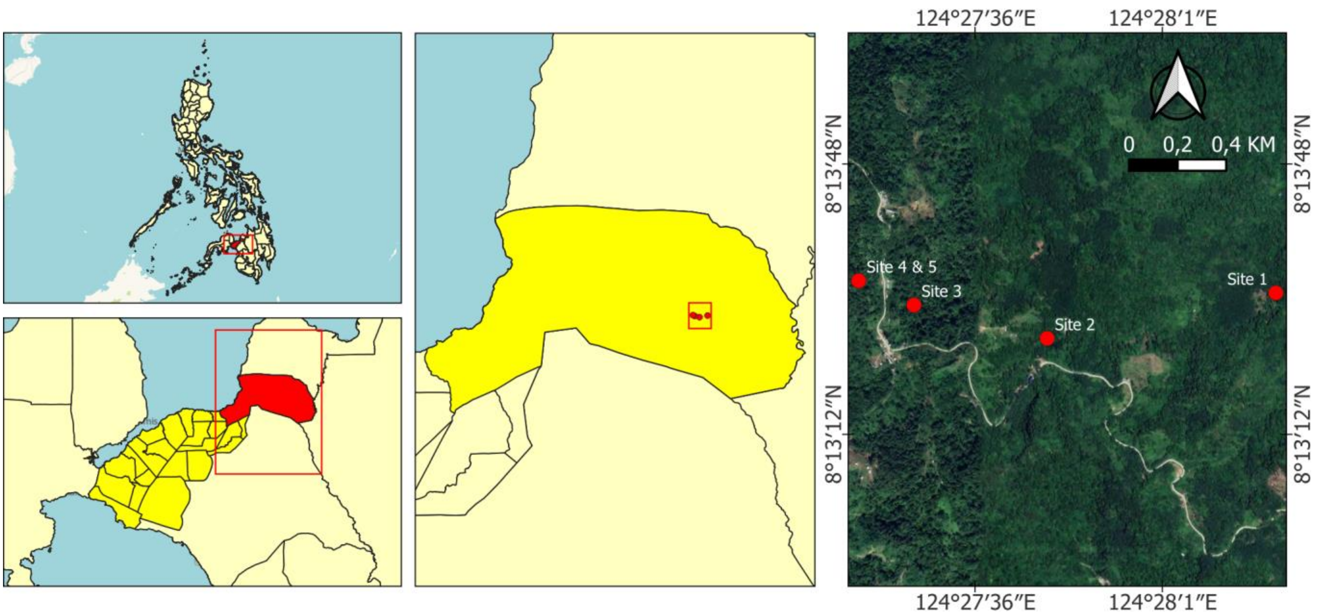

Figure 1. Map showing the established sampling sites in Sitio Libandayan, Brgy. Rogongon, Iligan City, Philippines

Sampling Site 2

Site 2 has coordinates of 08°13.413 N, 124°27.762 E and is located at 730 to 787 m asl.. This site is a secondary dipterocarp forest with a moderately flowing stream of around 0.61 m/s and several pebbles and rocks that block the water's flow. The stream's width fluctuates from 4.9 to 6 meters. In several parts of the area, there were also ponds. The area has dense understory vegetation, including the Araceae "*gabi-gabi*" plant, Fabaceae "*ipil-ipil*" plant, ferns, grasses, palm trees, and various plants. *Magnolia pubescens* (Merr.) Figlar & Noot., *Shorea* sp., *Lithocarpus sulitii* Soepadmo, *Paulownia elongata* S.Y.Hu, and *Ficus minahassae* (Teijsm. & de Vriese) Miq. are large trees that contribute to the canopy in the area. Other plants found in the area were abaca, rattan, and *Falcataria falcata* (L.) Greuter & R.Rankin. On the other hand, the ground was covered witha layer of leaf litter ranging from 0.5 to 1 inch deep, with some fallen and decaying logs.

Sampling Site 3

Site 3 is located at 830 to 899 m asl. with coordinates 08°13.487 N, 124°27.463 E. Site 3 is a mixed secondary dipterocarp forest with dipterocarp trees such as *Shorea* sp., *P. elongata*, Suluan, and *Neonauclea formicaria* (Elmer) Merr. The area has several understory flora including the *Araceae* "*gabi-gabi*" plant, ferns, grasses, palm palms, bamboo, and other bushes. There are also epiphytes and vines, and wild and planted *M. textilis*. Rotten, fallen, and chain-sawed trees were discovered in several areas of the sampling site. The riparian habitat is characterized by a slow-flowing stream of roughly 0.38 m/s with tiny to medium-sized stones. The stream's width fluctuates from 1 to 3 meters. A tiny pond can also be found in another section of the area. The ground is covered in 0.5 to 1.5 inches of fine leaf litter.

Sampling Site 4

Site 4 is located at 908 to 973 m asl. and has coordinates of 08°13.541 N, 124°27.339 E. It is a mixed dipterocarp forest with dipterocarp trees dominated by *Shorea* sp., *P. elongata*, and *Vitex parviflora* A.Juss. The understory vegetation is slightly dense, especially near the stream, with ferns, aerial and ground orchids, grasses, palm trees, bamboo, and other shrubs and Araceae, the "*gabi-gabi*" plant. There are also epiphytes and vines. Slow-moving streams with a velocity of 0.27 m/s feature fewer rocks and stones and are more common in small falls (0.5 to 1 m height).The stream's width fluctuates from 0.8 to 1.5 m. Moreover, the ground is coated with a 1 to 1.5-inch thick layer of leaf litter. The fog was frequently seen in the area, especially before or after rain.

Sampling Site 5

Site 5 is between 1,007 and 1,039 m asl, with coordinates of 08°13.541 N and 124°27.339 E. This location is a secondary dipterocarp forest with fairly dense dipterocarp trees dominated by "ulayan", *Shorea* sp., *P. elongata*, and *Shorea polysperma* (Blanco) Merr. Aerial orchids are attached to some tree branches, which are coated in mosses. Since the land was originally part of the local government's eco-farm project for the Indigenous People (IPs), understory vegetation such as ferns, aroid plants, and grasses is limited. Abaca, rattan, and coffee were also found on the property. Although no streams were seen, temporary ponds were formed due to the rain. The groundis coated in 2 to 3 inches of dense leaf litter. The site is frequently fogged over, especially before or after rain.

Sampling methods and collection of samples

Field sampling was conducted last 21 June to 5 July 2021, 7-10 August 2021, and 12-24 March 2022 from 0900 to 1600 with a total of 462 person-hours. Favorable climatic conditions fell on the dates mentioned, which were the best to collect odonata's in the wild. An opportunistic method was employed for collection, and a sweep net of 15 inches in diameter with 2 meters of wooden stick was the best tool employed. Environmental parameters such as air temperature and humidity were measured using a thermometer and a psychrometer. Soil temperature and pH meter (Extech pH 110) were used to get the soil temperature and pH. At the same time, a water temperature and pH meter device was used to measure the water temperature and pH. Elevation per site was obtained using the handheld Global Positioning System device (GPS-Garmin).

Processing and identification of samples

Collected Odonata from the net was carefully placed into an envelope of glassine paper. The cotton balls were soaked in acetone and placed in an envelope containing the samples to suffocate and stop the Odonata's metabolism (Jomoc et al. 2013). Suffocation of the Odonata usually takes 5 to 10 mins, depending on the size of the Odonata (Nuñeza et al. 2015). After the suffocation process, the specimen was soaked into a container with acetone for preservation. The preservation period for dragonflies was 24 hours, and 12 hours for damselflies using an air-tight container (Aspacio et al. 2013; Mapi-ot et al. 2013). After preservation, specimens were dried and placed in a clear envelope with a label. Photos for each of the dried specimens were taken after the preservation process. After labeling and taking photos, the specimens were placed in a container with naphthalene balls to keep them from ants. Pictorial keys were used to identify specimens and later verified by the third author. International Union for Conservation of Nature (IUCN) (2009-2021) Red List, the Philippine Red List of Threatened Fauna (2019), and the studies of Jomoc et al. (2013), Dimapinto et al. (2025), and Yuto et al. (2015) were the references used for the conservation and geographical distribution of the observed Odonata.

Data analysis

The species richness, evenness, and diversity indices were calculated using the Paleontological Statistics (PAST), whereas the similarity index was obtained using BioDiversity Pro software version 2.0 (Hammer et al. 2001; McAleece et al. 1997). QGIS (Geographic Information Systems) Map version 3.22.5 created map representations. This computer software integrates geographic and descriptive information to aid map production for more accessible and effective data analytics. The responses of Odonata species to various environmental conditions were visualized using Canonical Correspondence Analysis (CCA), a multivariate computational method. In addition, statistical analysis was calculated using the Paleontological Statistics (PAST) software version 2.19c (Hammer et al. 2001).

RESULTS AND DISCUSSION

Species composition, relative abundance, conservation, and distribution status

A total of 455 individuals, of which 35 species of Odonata belonging to 10 families, were recorded. The Odonata families are Aeshnidae, Corduliidae, Gomphidae, Libellulidae, Amphipterygidae, Calopterygidae, Coenagrionidae, Chlorocyphidae, Platystictidae, and Platycnemididae. Of the recorded 35 species, 14 are from suborder Anisoptera, whereas 21 are from suborder Zygoptera (Table 1). Of the established sampling sites, Site 2 had the highest relative abundance (40.88%), and species richness (26 species). Site 1 had the lowest relative abundance and species richness with 13.41% and nine species, respectively. In terms of distribution status, 20 (57%) are Philippine endemics, namely: *Ceriagrion lieftincki* Asahina, 1967, *Cyrano angustior* Hämäläinen, 1989, *Coeliccia exoleta* Lieftinck, 1961, *Devadatta basilanensis* Laidlaw, 1934, *Diplacina bolivari* Selys, 1882, *Diplacina braueri* Selys, 1882, *Drepanosticta lestoides* (Brauer, 1868), *Igneocnemis fuligifrons* (Hämäläinen, 1991), *Rhinocypha turconii* Selys, 1891, *Risiocnemis appendiculata* (Brauer, 1868), *Risiocnemis atripes, Risiocnemis flammea, Risiocnemis moroensis* Hämäläinen, 1991, *Teinobasis samaritis* Ris, 1915, *Vestalis melania* Selys, 1873, *Heteronaias heterodoxa* (Selys, 1878), *Idionyx philippa* Ris, 1912, *Heliogomphus bakeri* Laidlaw, 1925, and two are Mindanao island endemic, namely *Drepanosticta aries* Needham & Gyger, 1941 and *Igneocnemis tendipes* (Needham & Gyger, 1941). Based on IUCN 2020, three vulnerable species, two near-threatened species, and one endangered species were observed in this study. The vulnerable species are *C. exoleta*, *D. aries*, and *D. lestoides*, which were observed in Sites 2, 3, and 4. Near-threatened species were observed in all four established sites whereas the endangered species, *R. moroensis* was recorded in Site 4 only.

Odonata is characterized as a semi-aquatic insect that highly depends on water bodies. Thus, areas with many water bodies tend to have a very high diversity (Suhonen et al. 2010; Siregar and Bakti 2016; Medina-Espinoza 2022). The collected dragonflies and damselflies were all observed near water bodies, such as streams and stagnant water. In this study, Site 2 had the greatest number of water bodies, such as streams, artificial (human-made ponds), and natural ponds. This was immediately followed by Site 3, with streams and natural ponds, and Site 4, with a small-sized stream and an artificial (man-made) pond. This could probably be the reason for the high species richness and abundance in these study areas, given that these are the preferred microhabitats of the Odonata species (Suhonen et al. 2010; Juen and De Marco 2011; Siregar and Bakti 2016; Oliveira et al. 2019). On the other hand, despite having a medium-sized stream in Site 1, the low species richness and abundance could probably be attributed to the sampling effort of the team. This site was less visited, given the security and safety of the team due to the presence of armed conflict. Moreover, Site 1 is highly disturbed, considering it is converted to agricultural land, whereas Sites 2, 3, and 4 are slightly disturbed. Accordingly, dragonflies can thrive in disturbed and undisturbed areas, whereas damselflies can thrive mostly in slightly undisturbed areas (Jordan et al. 2003; Subramanian 2005; Kalkman et al. 2007).

Most of the species observed in this study are damselflies, which were mostly observed in the slightly disturbed Sites 2, 3, and 4, resulting in a high number of species richness and abundance compared to Site 1 (S = 9). Lastly, numerous species in the suborder Zygoptera (damselfly) are shade-seeking specialists (Jordan et al. 2003). Given that understory cover is high in Sites 2, 3, and 4, it could also be one of the reasons for its high species richness and abundance. Moreover, the low species richness in Site 1 may also be due to the lower number of days of sampling in this site since this site is a conflicted area where rebel groups are active, and the safety of the researchers must be prioritized.

All species of suborder Anisoptera (dragonfly) were found in open fields and disturbed areas. The family Libellulidae is the most abundant in the sampling sites, with nine species documented. It is one of the largest families of Odonata that can thrive in disturbed and pristine habitats (Subramanian 2005; Kalkman et al. 2007). This result is consistent with the previous surveys of Odonata, where family Libellulidae was also the most abundant (Jomoc et al. 2013; Mapi-ot et al. 2013; Quisil et al. 2014; Yuto et al. 2015; Serigar and Bakti 2016; Ilhamdi 2018).

The presence of red-listed species labeled as vulnerable, near threatened, and endangered in the study areas could be attributed to the level of disturbances. Sites 2, 3, and 4 are slightly disturbed areas with less human intervention compared to site 1, which is mostly visited by Indigenous People (IPs) for their agriculture. Thus, the endangered, vulnerable, and threatened species were mostly observed only in Sites 2, 3, and 4.

Biodiversity indices

The value of Shannon's diversity index determines the species diversity of the area. If the index value is below 1, the diversity is low. On the other hand, if the index value is between 1 and 3, then diversity is moderate. Lastly, the diversity is high if the index value exceeds 3 (Colwell 2009; Morris et al. 2014).

The Evenness index (E) represents the distribution of individuals between species (Bengen 2000; Bahri et al. 2015). Its value ranges from 0-1. A value of 0-0.5 indicates a depressed community (some species dominate the area). Values from 0.5-0.75 mean an unstable community and 0.75-1 are stable (Krebs 1989). The lower the evenness index, the lower the population uniformity. It was revealed that the number of members of each species per site in this study is not evenly distributed, indicating that one species is likely to dominate. The dominant species observed in each sampling site are *R. turconii* (S1), *V. melania* (S1), *O. pruinosum* subsp. *clelia* (S2), *C. angustior* (S3), and *D. basilanensis* (S4).

Table 1. Species composition, relative abundance, distribution, and conservation status of Odonata

Species name	Conservation status	Distribution in the sampling sites				
		Site 1 (riparian)	Site 2 (riparian & terrestrial)	Site 3 (riparian & terrestrial)	Site 4 (riparian & terrestrial)	Total
Suborder Anisoptera						
Family Aeshnidae						
Anax panybeus Hagen, 1861*	LC		1 (0.54)			1
Indaeschna grubaueri Förster, 1904*	LC		1 (0.54)			1
Family Corduliidae						
Heteronaias heterodoxa Selys, 1878**	LC			3 (2.78)	6 (6.06)	9
Idionyx philippa Ris, 1912**	LC			1 (0.93)		1
Family Gomphidae						
Heliogomphus bakeri Laidlaw, 1922**	LC			2 (1.85)	1 (1.01)	3
Family Libellulidae						
Diplacina bolivari Selys, 1882**	LC	5 (8.20)	21(11.30)	6 (5.56)	3 (3.03)	35
Diplacina braueri Selys, 1882**	LC		2 (1.075)	1 (0.93)		3
Neurothemis ramburri Brauer, 1867*	LC		9 (4.84)	2 (1.85)	1 (1.01)	12
Orthetrum pruinosum subsp. *clelia* Selys, 1878*	LC	4 (6.56	31(16.67)	7 (6.48)	4 (4.04)	46
Orthetrum sabina subsp. *sabina* Drury, 1773*	LC				1 (1.01)	1
Orthetrum testaceum Burmeister, 1839*	LC		5 (2.69)	2 (1.85)	2 (2.02)	9
Pantala flavescens Fabricius, 1798*	LC		3 (1.61)		2 (2.02)	5
Potamarcha congener Rambur, 1842*	LC			1 (0.93)		1
Trithemis festiva Rambur, 1842*	LC		2 (1.08)		2 (2.02)	4
Suborder Zygoptera						
Family Amphipterygidae						
Devadatta basilanensis Laidlaw, 1934**	LC	4 (6.56)	11 (5.91)	6 (5.56)	24(24.24)	45
Family Calopterygidae						
Vestalis melania Selys, 1873**	LC	20 (32.79)	27(14.52)	13(12.04)	2 (2.02)	62
Family Coenagrionidae						
Agriocnemis rubescens intermedia Selys, 1877*	LC			3 (2.78)		3
Ceriagrion lieftincki Asahina, 1967**	LC		1 (0.54)			1
Pericnemis sp.	-	3 (4.92)	3 (1.61)	2 (1.85)	2 (2.02)	10
Pseudagrion pilidorsum pilidorsum Brauer, 1868*	LC			1 (0.54)	1 (0.93)	2
Teinobasis samaritis Ris, 1915**	LC		3 (1.61)			3
Teinobasis sp.	LC			5 (4.63)		5
Family Chlorocyphidae						
Cyrano angustior Hämäläinen, 1989**	NT	2 (3.28)	7 (3.76)	17(15.74)	7 (7.07)	33
Rhinocypha turconii Selys, 1891**	LC	20 (32.79)	11 (5.91)	16(14.81)		47
Family Plastystictidae						
Drepanosticta lestoides Brauer, 1868**	VU		1 (0.54)	1 (0.93)		2
Drepanosticta aries Needhan & Gyger, 1941***	VU		4 (2.15)	1 (0.93)	1 (1.01)	6
Drepanosticta sp.	-		8 (4.30)	4 (3.70)	3 (3.03)	15
Family Platycnemididae						
Coeliccia exoleta Lieftinck, 1961**	VU		3 (1.61)		2 (2.02)	5
Igneocnemis fuligifrons Hämäläinen, 1991**	NT		1 (0.54)			1
Igneocnemis tendipes Needhan & Gyger, 1941***	NE		7 (3.76)	4 (3.70)	16(16.16)	27
Risiocnemis appendiculata Brauer, 1868**	LC		1 (0.54)		3 (3.03)	4
Risiocnemis atripes Needhan & Gyger, 1941**	LC		16 (8.60)	8 (7.41)	7 (7.07)	31
Risiocnemis flammea Selys, 1882**	LC	2 (3.28)	6 (3.23)	2 (1.85)	9 (9.09)	19
Risiocnemis moroensis Hämäläinen, 1991**	EN				1 (1.01)	1
Risiocnemis sp.	-	1 (1.63)			1 (1.01)	2
Total number of individuals		61(13.41)	185(40.88)	108(23.74)	101(21.98)	455
Total number of species		9	26	23	22	35
Total number of endemic species		6	16	14	13	20
Total number of vulnerable species		0	3	2	3	3
Total number of near threatened species		1	2	1	1	2
Total number of endangered species		0	0	0	1	1

Note: *: Oriental species; **: Philippine endemic species; ***: Mindanao island species. EN: Endangered species; LC: Least concern; NE: Not evaluated; NT: Near Threatened; VU: Vulnerable species

Site 2 recorded the highest species diversity (H' = 2.75), followed by Sites 3 and 4, with H' = 2.73 and H' = 2.58, respectively (Table 2). Site 1 recorded the lowest species diversity value (H' = 1.733). In general, all of the sampling sites have moderate species diversity. This pattern of diversity could be attributed to the presence of water bodies, the level of disturbances, and the habitat structure per site. As mentioned, Sites 2, 3, and 4 are slightly disturbed habitats with high canopy cover and numerous bodies of water, such as streams, stagnant water, and artificial and natural ponds, which are preferred habitats of Odonata. However, Site 1 is a highly disturbed area of agricultural land. Moreover, since this is a conflicted area (rebels are active), the sampling effort is also limited, which could lead to low species richness and abundance and, therefore, low species diversity relative to the other sites.

Similarity index

Using Biodiversity Pro Software version 2, a cluster analysis of the site was generated. Based on the composition of Odonata species at the four designated sampling locations, this powerful tool revealed significant similarities between locations (Figure 2). The results showed that Site 1 (riparian) and Site 3 (riparian and terrestrial) were similar, while Site 4 (riparian and terrestrial) was slightly different from the other sites. According to Dimapinto et al. (2015), the formation of Odonata structures could be caused by geographical distance. Site 4 presents a unique case with its higher elevation and location far from S1 and about two kilometers from Site 3. Species habitat specificity was classified based on niche breadth (Harabiš and Dolný 2010).

Based on Figure 2, S1 and S3 showed greater percentage numbers and had the most similarity percentage (57%). This means that these two established sampling sites shared almost the same species. The highest number of species, namely *Cyrano anguistor* Hämäläinen, 1989, *Rinocypha turconii* Selys, 1891, and *Vestalis melania* Selys, 1873, were found in these two sites. These sites are riparian and secondary dipterocarp forests where these species are observed. According to Villanueva and Mohagan (2010), optimum temperature and the presence of aquatic habitat contribute to the abundance of Odonata, which can be observed in these two sites. For S2, the number of percentages is not significantly different from S1 and S3; this means species in S1 and S3 can be found in S2.

Site 4 had the lowest percentage of similarity. The low similarity of S4 to the other sites could be due to its small-sized stream. Streams are important for Odonata species. Low species richness and abundance were observed since this has only a small stream compared to the other sites. On Site 4, on the left side of its stream, the construction of a church is ongoing. Despite such, the stream is pristine as it is the water source for the community in the lower elevation. Thus, the endangered species *R. moroensis* was recorded. In addition, the species richness of the species belonging to Zygoptera is high in a preserved environment (Carvalho et al. 2013). Numerous species of Zygoptera require shaded and pristine forest environments due to their small, delicate, and thin bodies, which likely increase their vulnerability to overheating and dehydration, emphasizing the critical role of habitat quality in their survival and population health (Oppel 2005; De Oliveira-Junior et al. 2015). In contrast, the species under Anisoptera requires sunlight exposure for thermoregulation (Oppel 2005).

Species distribution of Odonata

The most represented Family under Suborder Anisoptera is Family Libellulidae with nine species, Ashnidae and Corduliidae with two species, and Gomphidae with only one. On the other hand, the most represented family under suborder Zygoptera is family Platycnemididae with eight species, followed by family Coenagrionidae with six species and family Plastystictidae with three species. The lowest represented family of suborder Zygoptera is family Chlorocyphidae, with only two species, and Amphipterygidae and Calopterygidae, with only one species each. The abundance of the family Libellulidae in this study is similar to the result of Bora et al. (2014), Quisil et al. 2014, Saha and Gaikwad (2014), Anital et al. (2016), Patil et al. (2018), and Vitor et al. (2022)

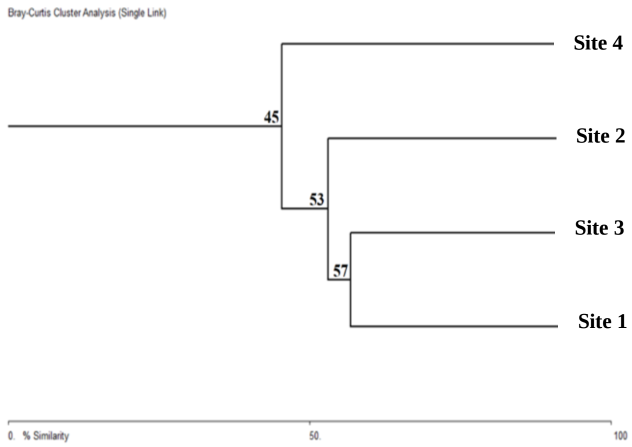

Figure 2. Cluster analysis showing the similarity of four established-sites on the Bray-Curtis method (Bootstrap N = 999)

Table 2. Biodiversity indices in the four sampling sites

Biodiversity indices	Established sampling sites			
	Site 1	Site 2	Site 3	Site 4
Species richness	9	26	23	22
Shannon's diversity (H')	1.733	2.75	2.735	2.582
Dominance	0.235	0.087	0.086	0.113
Evenness (E)	0.6288	0.6018	0.67	0.6012

Figure 3 shows the distribution of Odonata species in the study sites using a GIS map. In comparison, Figure 4 shows the schematic diagram of the distribution of Odonata along an elevational gradient in the study sites. It is shown that the site with the highest number of species was Site 2 (730 to 787 m asl.), with 26 species, followed by Site 3 (830 to 899 m asl.), and Site 4 (908 to 973 m asl.), with 23 and 22 species, respectively. Only nine species were observed in Site 1 (619 to 680 m asl.), while no species was recorded in Site 5 (1,007 to 1,039 m asl.). Therefore, the distributional trend of the Odonata species along an elevational gradient in the study sites shows that species richness increased and peaked at Site 2 and then decreased as the elevation increased. Like species richness, species endemism also increased until Site 2 and decreased as the elevation increased. This distributional trend is similar to the study of Villanueva and Mohagan (2010) on the distributional trend along an elevation gradient in Mt. Hamiguitan Wildlife Sanctuary in Davao Oriental. It was revealed in their study that species richness and endemism were low in the agroecosystem site (400 m asl.), then high and increasing in the dipterocarp (900 m asl.) to montane (1,200) and then decreased as the elevation further increased (1,400 m asl.).

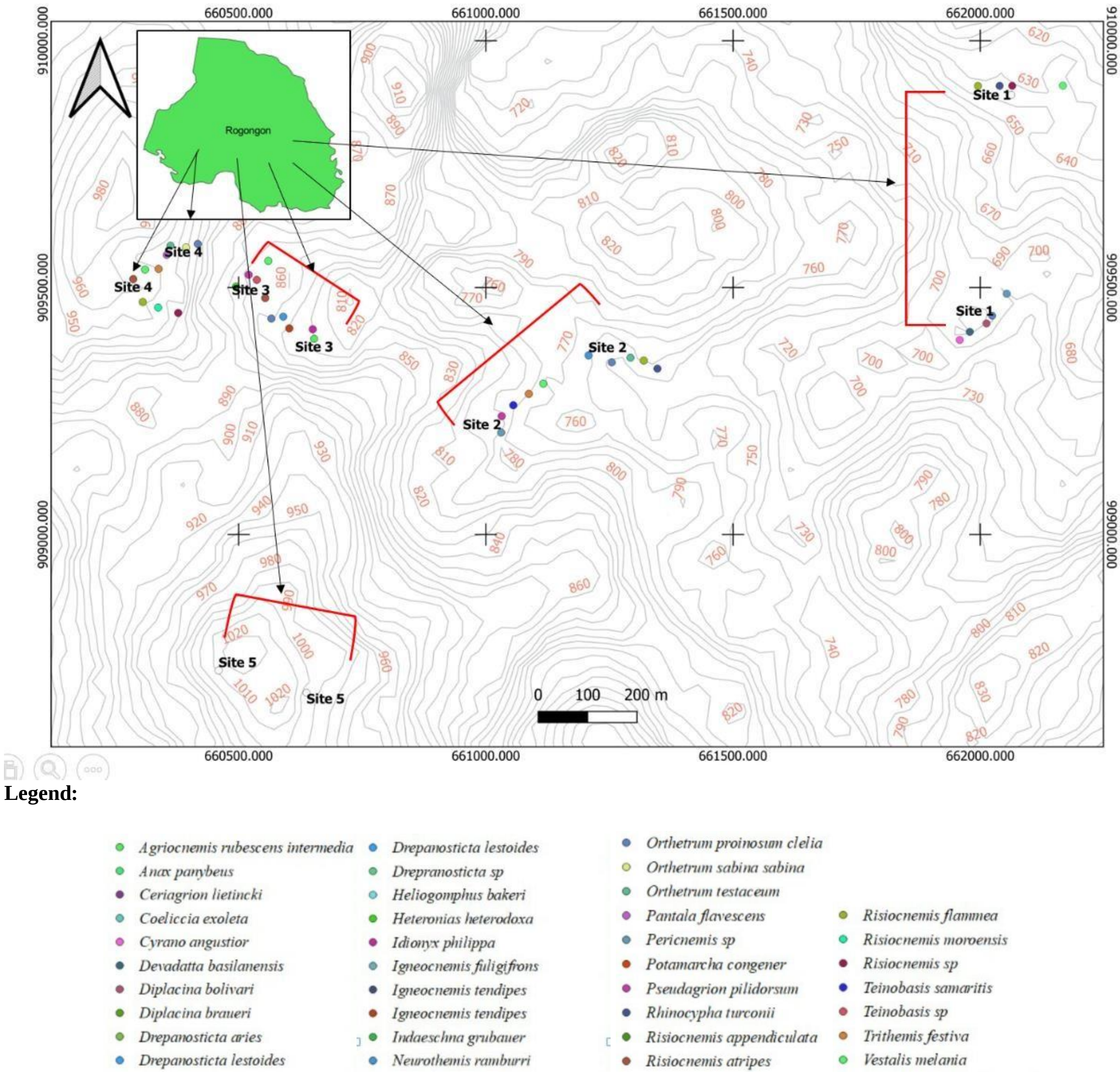

Figure 3. GIS map showing the distribution of the species of Odonata in the five established sampling sites

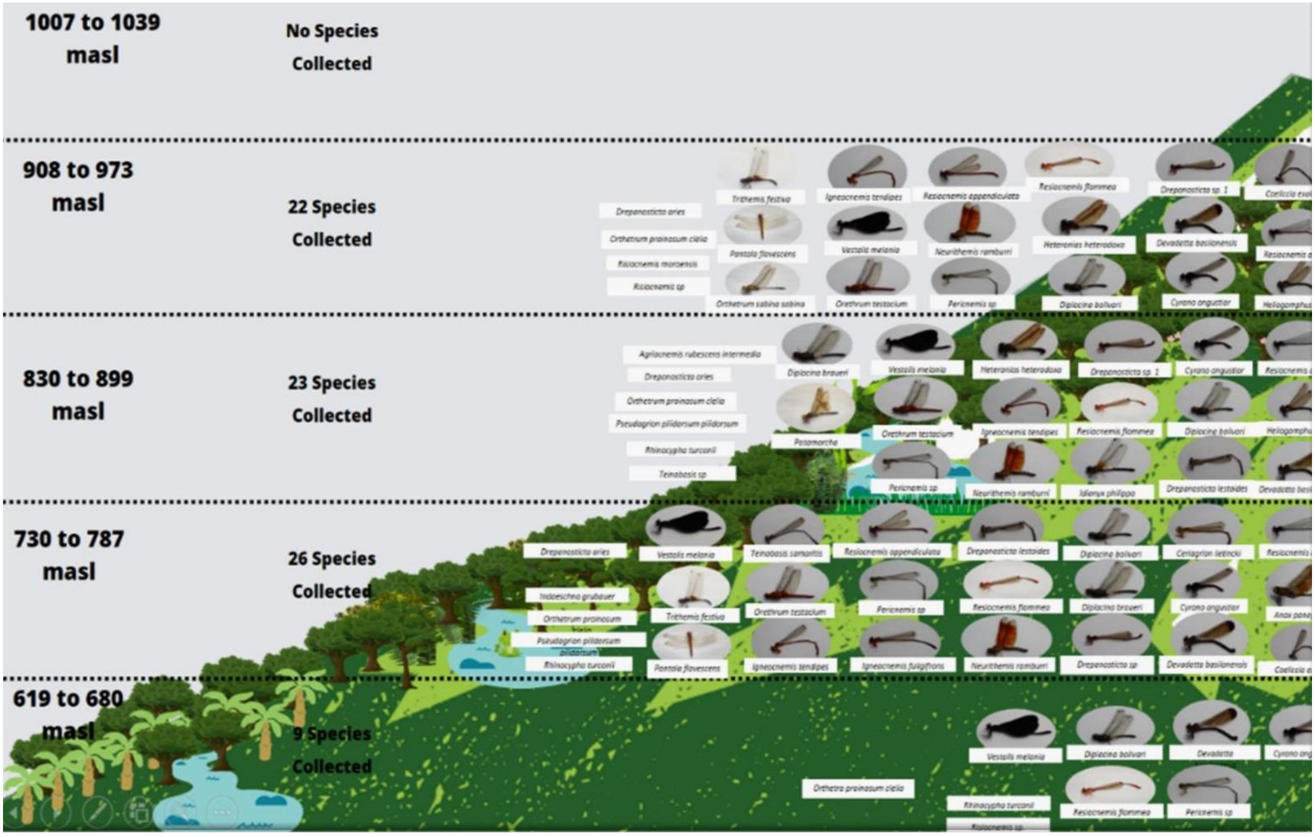

Figure 4. Schematic diagram showing the distribution of Odonata along an elevational gradient of the established fivesampling sites

Several factors have been identified in this study that could significantly influence the distributional pattern of Odonata species along an elevational gradient. This research, which includes the unique structure of the habitat per site, the level of disturbance, and the environmental factors associated with each study area, presents a novel approach to understanding Odonata species distribution. The preference of Odonata species for riparian habitats, such as forest streams and ponds, for their larval forms, mating, and reproduction, as documented by Kannagi et al. (2016) and Ramos et al. (2020), is a key finding. The absence of Odonata species in the highest elevation (1,007 to 1,039 m asl.) in this study could be attributed to the absence of riparian habitats such as streams and ponds. According to Kumar et al. (2018), the waterbodies provide habitat to both Odonata orders and could support a healthy breeding ground. In Sites 1, 2, 3, and 4, forest streams and ponds were observed in the area, resulting in varied species of Odonata. However, low species richness was recorded in Site 1 (619 to 680 m asl.). This could be attributed to the level of disturbance in the area since this is an agroecosystem site where abaca and coffee were planted.

Villanueva and Mohagan (2010) also reported that low Odonata species richness and abundance were observed in the agroecosystem site, which has a tremendous impact on this fauna. Compared to Site 1, sites 2, 3, and 4 are less disturbed, with denser dipterocarp trees and understory vegetation that could protect the Odonata species from high temperatures. Moreover, Site 1 was less visited than other sites, given the team's security suggestion (a conflicted area where the rebel group is mostly found).

Aside from the distributional trend of Odonata species in this study, it was also revealed that *Orthetrum sabina* subsp. *sabina* and the endangered *R. moroensis* were only observed at the higher elevation (930 m asl.). The endangered *R. moroensis* was recorded only on Mt Kalatungan and Mt. Kitanglad, Mindanao observed in higher undisturbed elevational areas (1,400 m asl.) (Dow 2020). In this study in Rogongon, Site 4 (930 m asl.), where the endangered species was found, was the least disturbed area relative to other sites, given that the stream in this area is the source of drinking water for the IPs living in the lower elevation. Thus, people have limited access to this area. On the other hand, other habitat-specific Odonata species include: *A. paneybeus, I. grubaueri,* and *I. fuligifrons* which were observed in site 2 (700 m asl.) only, and *I. philippa, P. congener, Teinobasis* sp., and the near threatened *A. rubescens intermedia* which were only recorded in Site 3 (800 m asl.). Given the specificity of the occurrence of these species in the study sites, with each having endangered and near threatened Odonata species, protection on this remaining forest habitat should be done to prevent the decrease or even extinction of this population in Sitio Libandayan, Rogongon, Iligan City, Philipines. Effective Environmental Impact Analysis (EIA/AMDAL) depends not only on implementing mitigation measures and monitoring but also on active community involvement (Momtaz and Kabir 2018).

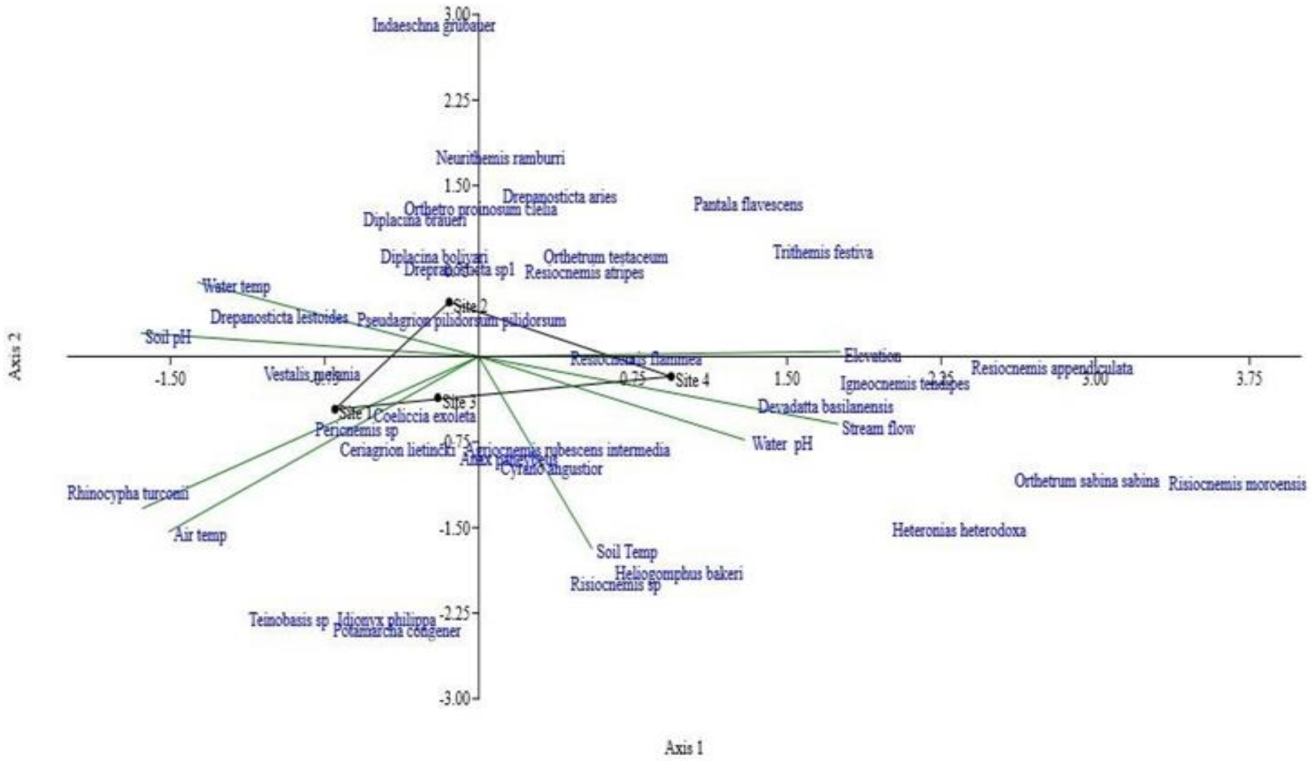

Figure 5. Ordination diagram showing the eight abiotic factors: soil pH, soil temperature, air temperature, relative humidity, water temperature,water pH, elevation, and stream flow using CCA analysis

In this study, species under Zygoptera were observed in slightly disturbed areas and pristine water. However, habitat destruction where the forest is being converted to infrastructure for tourism is rampant in the area. Moreover, vegetation characteristics could directly affect the abundance and distribution of the odonata species (Feriwibisono et al. 2016). Thus, the results of this research are good input for policymakers to create monitoring and mitigation methods for regional biodiversity conservation in Rogongon, Iligan City, with the active participation of the community.

Canonical correspondence analysis

Figure 5 shows the analysis of the influence of environmental factors such as soil pH, soil temperature, air temperature, relative humidity, water temperature, water pH, elevation, and stream velocity on the abundance and distribution of Odonata species in the sampling sites using the Canonical Correspondence Analysis (CCA). Geological and environmental factors influence Odonata's distribution (Kalkman et al. 2007; Feriwibisono et al. 2016; Abdul et al. 2017). Through CCA, the influence of abiotic factors on the abundance of the species could be determined (Gómez-Anaya et al. 2011).

Here, species from different families can survive at high air temperatures, namely *I. philippa*, *P. congener*, and *Teinobasis* sp. Moreover, the vulnerable species *C. exoleta* was observed in Sites 2 and 4. Together with *C. exoleta*, *Pericnemis* sp., and *C. lieftincki* are the species that can survive and prefer low air temperatures. *R. turconii* was affected by relative humidity. The highest relative humidity was recorded in Site 1 (83.55%). Thus, *R. turconii* appears to prefer high relative humidity.

Regarding soil temperature, *H. bakeri*, and *Risiocnemis* sp. are the species that can survive at high soil temperature. On the other hand, *A. rubescens intermedia*, *Anax panybeus Hagen, 1867*, and *C. angustior* are the species that can survive and prefer to live in low soil temperatures. Only *H. heterodoxa* is affected by water pH, where it prefers high water pH. It can be seen that *D. basilanensis*, *O. sabina* subsp. *sabina*, and even the endangered species *R. moroensis* prefer high-velocity streams. Regarding elevation, it can be seen that *R. flammea*, *D. aries*, *R. atripes*, and *O. testaceum* are the species that prefer low elevation. Meanwhile, *P. flavescens*, *T. festiva*, and *R. appendiculata* prefer to inhabit high elevations. Only *Vestalis melania* Selys, 1873 is affected by the change in soil pH; this species prefers low soil pH levels. *Drepanosticta lestoides*, *D. braueri*, and *D.bolivari* are the species affected by the change in water pH, and these three species prefer to live at low water pH levels. Lastly, the generalist species, such as *P. pilidorsum pilidorsum*, *Drepanosticta* sp., *O. pruinosum* subsp. *clelia*, *N. ramburii*, and *I. grubaueri*, were not affected by any changes in the eight abiotic factors mentioned.

In conclusion, the four sampling sites in Brgy. Rogongon has moderate species diversity. Of all the species found, 57% are endemic to the country. On the other hand, one endangered, three vulnerable, and two near-threatened Odonata species were recorded. Regarding distribution trends along the altitudinal gradient, species richness, and endemism increase up to Site 2 (730 to 787 m asl.), decreasing with increasing altitude. Factors such as habitat and level of disturbance in each study site could be the reason for this trend. Meanwhile, environmental factors such as air temperature, relative humidity, water temperature, water pH, and stream flow could also affect the distribution and abundance of odonata. Moreover, the species richness of the Zygoptera species is high in areas with less disturbance. This study identified habitat destruction due to forest conversion for infrastructure, agriculture, and tourism as the main threat to Odonata. The presence of endemic and red-listed species indicates the need to protect Iligan City's remaining forests.

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