Vol. 12 January 2021
Print ISSN 2094-5019 • Online ISSN 2244-0461
doi: http://dx.doi.org/10.7828/ajob.v12i1.1397

Asian Journal of Biodiversity
This Journal is in the Science
Master Journal List of Clarivate
Zoological Record

Structure of Odonate Assemblage in K'laja Karst Ecotourism Park, General Santos City, Philippines

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ABSTRACT

Odonates are sensitive to disturbances and changes in habitat quality and integrity. However, our understanding of odonates as environmental bioindicators remains limited. This concern arises primarily from the significant data gaps in the local and global structure and distribution pattern of odonate fauna, especially in terrestrial landscapes. This study determined the assemblage and diversity attributes of odonate species in K'laja Karst Ecotourism Park, one of the few remaining natural reserves in General Santos City, Southern Mindanao. Data showed a rich and highly diverse odonate fauna with 22 species belonging to 19 genera within nine families. More than 45% of the documented odonate species were endemic to the Philippines, 89% of which were Zygopterans (damselflies). Anisopterans (dragonflies) were more abundant and species-rich, comprising 56% and 59% of the total collection, respectively, with the libellulids dominating in both respects. Several Anisopteran species thrived abundantly in open, cultivated fields, while most Zygopteran species recorded higher numbers and diversity indices in shaded habitats adjacent to the river. Findings reveal that while odonate composition and diversity remain robust, the relative distribution and proportion of Zygopteran and Anisopteran species indicate habitat alteration and degradation. Together, these data provide a basis for identifying priority areas for protection and conservation in the karst landscape.

Keywords: biodiversity, K'laja Karst, odonate assemblage, Zygoptera-Anisoptera ratio

INTRODUCTION

Insects of the Order Odonata, commonly known as damselflies (Suborder Zygoptera) and dragonflies (Suborder Anisoptera), are brightly colored predatory invertebrates (May, 2019). While adult odonates are terrestrial, they depend on freshwater ecosystems such as rivers, ponds, and springs for reproduction (Sha & Khan, 2020). Odonates have specific habitat preferences and requirements (Oliveira-Junior & Juen, 2019b), making them suitable in evaluating changes and disturbances in the environment (Dolny et al., 2011; Dolny et al., 2012). Indeed, earlier studies have reported that adult odonates are good, versatile environmental indicators (Dolny et al., 2012; Seidu et al., 2018; Adu et al., 2019). The sensitivity of odonate fauna to habitat quality also suggests their far-reaching implication in the fields of water pollution studies, conservation biology, and sustainable development endeavors (Kalkman et al., 2010; Seidu et al., 2019).

Around 6300 odonate species within 600 genera have been discovered and described worldwide (Paulson & Schorr, 2020). Many of these species are highly diverse and occurring abundantly in the tropics (Kalkman et al., 2008). However, the adverse impacts of climate change and anthropogenic influences threaten odonate populations worldwide (Hassall & Thompson, 2008). Recently, a widespread decline in insect populations, including odonates, has been reported (Aguilar & Ortega, 2019; Nakanishi et al., 2020).

The Philippines is home to at least 300 odonate species (Hamalainen, 2004). This number grows as more species have been discovered and described throughout the archipelago (Villanueva & Schorr, 2011; Villanueva & Dow, 2014). Remarkably, over 60% of the odonate species documented so far in the country are endemic to the area (Hamalainen & Muller, 1997; Hamalainen, 2004). However, the data on local odonate fauna remain sparse and fragmented. This problem remains a significant gap in our understanding of local odonate assemblages, especially in Mindanao. The same becomes a grave concern when anthropogenic disturbances threaten odonate habitats (Dolny et al., 2011), such as the case for natural reserves and landscapes opened for recreation and tourism purposes (Finnessey, 2012; Angulo et al., 2016).

OBJECTIVES OF THE STUDY

This study assessed the structure and biodiversity attributes of adult odonate assemblage in K'laja Karst Ecotourism Park (KKEP) in General Santos City, Southern Mindanao. Specifically, this study (a) documented the extant odonate species and their abundance and diversity and (b) evaluated karst habitat conditions. This study is the first odonate record in the KKEP.

MATERIALS AND METHODS

Study Site

The KKEP is among the few remaining natural reserves located at the northeastern border of General Santos City. The hilly landscape covers a total land area of 9,147 hectares. It receives an annual average rainfall of 250 mm and records a mean daily temperature of 25°C. Many floral and faunal species thrive in the karst, some of which remain undocumented. It is adjacent to the Mount Matutum Protected Landscape, a local key biodiversity area in the SOCSKSARGEN region, and serves as an ecological corridor for several wildlife species. The KKEP is a source of food and water for the surrounding communities. The declining forest cover and increasing anthropogenic activities, however, threaten the ecological balance in the karst. Small patches of secondary forest remain spread across the karstic landscape, particularly at ravines and higher altitudes, but much of the lower stretches are now agricultural or residential zones. The karst is famous for its natural caves, waterfalls, and springs. Recently, it has attracted many tourists, mountaineers, and outdoor enthusiasts.

Four sites were sampled in the KKEP, namely, Bunga, Malakong, Amsikong, and Sansapan (Figure 1). These sites are adjacent to river systems. The Bunga site is at 6°13'39.85" N 125°10'13.14" E, 281 meters above sea level (masl). It has agricultural lands planted with corn, coconut, and other cash crops. Plant species such as bamboos, native trees, and the invasive Piper aduncum also grow in the area. The Bunga river crosses the landscape with waters coming from upstream tributaries located in Amsikong and Malakong. The Malakong site is at 6°14’26.88” N 125°9’49.38” E, 216 masl. The Malakong river is stony and flows within the gulley. Patches of secondary forest provide shade in some segments of the river. The Amsikong site is at 6°15’44.76” N 125°9’57.66” E, 308 masl. The site has patches of secondary forest and agricultural areas. Similar to Malakong, the Amsikong river flows through the gulley. The riverbanks have open and closed canopy areas with riverbeds laid with gravel and sand. The Sansapan site is at 6°16’7.63” N 125°11’17.99” E, 398 masl. Cobbles and boulders cover the riverbed, while lithophytes and trees form much of the riparian vegetation. Waters in the Sansapan river come from a source different from the ones feeding the other sites. All the rivers have slow-moving alkaline waters within the normal turbidity range.

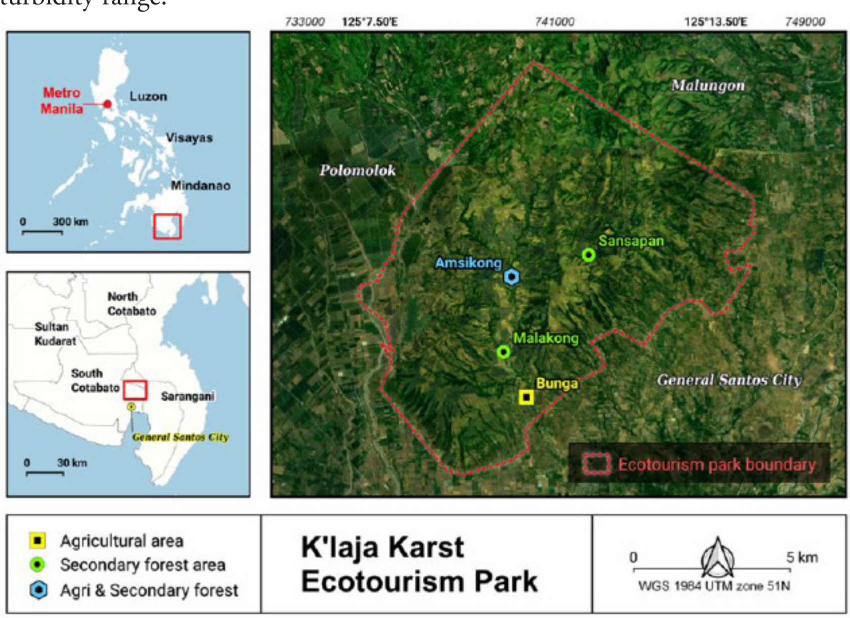

Figure 1. The KKEP showing the location of sampling sites.

Collection and Identification of Species

Following an opportunistic approach, odonates were collected using a sweep net with approximately 15.0 cm diameter, 1.0 cm2 mesh size, and a 1.5 m handle. Photographs and body measurements of individual samples were taken and recorded. A voucher specimen for each species was secured and preserved in separate paper triangles dipped in pure acetone. Sampling was done from June to November 2017 at 7:00-11:00 in the morning and 1:00-5:00 in the afternoon. The weather was fair during sampling hours. The collected odonates were initially identified and classified using available identification and taxonomic guides. Dr. Reagan T. Villanueva, an odonate specialist, confirmed the species ID.

Data Analysis

The conservation status and endemism of odonates were classified based on available data in the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (IUCN, 2020). The distribution, diversity, and similarity indices were determined using PAST 4.03 (Hammer et al., 2001).

RESULTS AND DISCUSSION

Species Richness and Abundance

A total of 22 odonate species representing 19 genera and nine taxonomic families were documented (Table 1). There were nine Zygopteran species distributed in eight genera within seven families and 13 Anisopteran species belonging to 11 genera within two families. Remarkably, eight (89%) of the Zygopteran species were endemic to the Philippines. *Risiocnemis atripes* and *Risiocnemis appendiculata*, in particular, are confined in the Mindanao or Greater Mindanao area (IUCN, 2020). Meanwhile, only two (15%) of the Anisopteran species were Philippine endemic. These values translate to an overall 45% endemicity for odonate species found in the KKEP. This proportion is lower than the 60% country-wide odonate endemicity estimate (Hamalainen & Muller, 1997; Hamalainen, 2004). However, it is comparable to reported odonate endemicity values for various terrestrial habitats in Mindanao (Mapi-ot et al., 2013; Quisil et al., 2013). The observed higher Zygopteran endemicity agrees with several local odonate surveys (Kalkman et al., 2008; Malawani et al., 2014; Nuñeza et al., 2015). On the other hand, while most of the species recorded were of the least-concern status, a near-threatened (i.e., *Drepanosticta krios*) and a vulnerable (i.e., *Rhinagrion reinhardi*) Zygopteran species were documented in the Malakong and Sansapan sites, respectively.

The Sansapan and Amsikong sites had the highest odonate endemicity at 36% and 32%, respectively. While Sansapan harbored most of the endemic Zygopteran species, only Amsikong hosted all the endemic Anisopteran species recorded. Bunga and Malakong recorded similar endemicity at 18%. Sansapan was the most species-rich among the sites harboring 18 of the 22 species documented, but Amsikong had the greatest odonate count covering about 40% of the total collection. Overall, *Pantala flavescens*, *Euphaea amphicyana*, and *Diplacina bolivari* were the three most abundant species found in the karst comprising more than 26% of the total collection. *Pseudagrion pilidorsum pilidorsum, R. appendiculata*, and *Orthetrum pruinosum clelia* were the most common species recorded in all sampling sites, while *R. reinhardi* and *D. krios*, both Zygopteran species, were the rarest occurring only in Sansapan and Malakong, respectively. Libellulidae was the most speciose odonate family with ten species and comprised over 55% of the total collection in terms of abundance. Platycnemididae followed in richness and abundance with three species comprising 15% of all the odonates collected. Aeshnidae (0.47%) and Megapodagrionidae (1.13%) were the least abundant families with only one member species documented.

Table 1

List of odonate species and their relative abundance in KKEP. Species endemic to the Philippines are marked with an asterisk (*). En dash (–) indicates that the species is absent or not encountered during sampling. Conservation Status: VU – Vulnerable; NT – Near Threatened; LC – Least Concern; NE – Not Evaluated

Species	Conservation Status	Relative Abundance (%)				
		Bunga	Malakong	Amsikong	Sansapan	Overall
ZYGOPTERA						
Calopterygidae						
*Vestalis melania**	LC	–	–	9.86	6.73	6.04
Chlorocyphidae						
*Rhinocypha colorata**	LC	–	–	7.51	13.46	7.18
Coenagrionidae						
Pseudagrion pilidorsum pilidorsum	NE	1.92	4.35	3.99	6.73	4.34
Euphaeidae						
*Euphaea amphicyana**	LC	–	–	12.44	11.93	8.69
Megapodagrionidae						
*Rhinagrion reinhardi**	VU	–	–	–	3.67	1.13
Platycnemididae						
*Risiocnemis appendiculata**	LC	4.62	–	7.75	5.20	5.85
*Risiocnemis atripes**	LC	5.00	13.04	4.93	3.06	4.72
*Prodasineura integra**	LC	5.77	19.57	–	8.26	4.82

Table 1 continued.

Species	Conservation Status	Relative Abundance (%)				
		Bunga	Malakong	Amsikong	Sansapan	Overall
Platystictidae						
*Drepanosticta krios**	NT	–	39.13	–	–	1.70
ANISOPTERA						
Aeshnidae						
Anax panybeus	LC	–	–	0.70	0.61	0.47
Libellulidae						
Crocothemis servilia	LC	–	–	8.22	3.67	4.44
*Diplacina bolivari**	LC	5.38	–	9.86	8.56	7.93
Diplacodes triviales	LC	1.92	–	2.35	7.03	3.59
*Idionyx philippa**	LC	–	4.35	1.88	–	0.94
Lathrecista asiatica	LC	8.46	–	3.52	3.06	4.44
Neurothemis ramburii	LC	6.92	–	2.82	2.75	3.68
Neurothemis terminata	LC	8.46	–	6.57	7.65	7.08
Orthetrum pruinosum clelia	NE	8.08	6.52	5.34	4.89	6.33
Orthetrum sabina	LC	0.38	–	–	1.53	0.57
Pantala flavescens	LC	37.31	4.35	–	–	9.35
Potamarcha congener	LC	1.15	–	3.76	1.22	2.17
Trithemis aurora	LC	4.62	8.70	7.51	–	4.53
Total No. of Species		**14**	**8**	**17**	**18**	**22**
Total No. of Endemic Species		**4**	**4**	**7**	**8**	**10**

The differences in the structure and distribution of odonate assemblage in each sampling site demonstrate their habitat preference and sensitivity to environmental changes. Most of the Zygopteran species occurred at or near riparian environments associated with forest patches, while many of the Anisopteran species were abundant across all sites, even in cultivated fields. This distribution pattern agrees with the reported behavior, home range, and habitat requirements of the odonate groups. Zygopterans have a smaller body size, a limited range of tolerance, and reduced dispersal capacities (Narender et al., 2016; Oliveira-Junior & Juen, 2019b). They are speciose and thriving abundantly in riparian habitats with dense vegetation cover that provides them shade and substrate for thermoregulation and reproduction (Seidu et al., 2018; Seidu et al., 2019). The occurrence of P. *pilidorsum pilidorsum, R. atripes, R. appendiculata,* and *Prodasineura integra* in cultivated fields, however, may indicate that these species can tolerate a certain degree of habitat alteration. In contrast, Anisopterans are more adaptive and tolerant to environmental changes (Oliveira-Junior & Juen, 2019b). They are larger, more mobile, and have better dispersal capacities (Kalkman et al., 2010). Libellulidae, in particular, is among the widely distributed Anisopteran family worldwide (Seidu et al., 2019). Libellulids are highly dispersed and thrive in disturbed and degraded habitats such as cultivated fields and urbanized areas (Yapac et al., 2016; Cano-Mangaoang & Mohagan, 2016; Dwari & Mondal, 2017). Indeed, libellulids dominated our collection in terms of species richness, abundance, and dispersal range.

Species Diversity

Each sampling site had a moderate to high odonate species diversity and evenness (Table 2). In terms of species diversity, the sampling sites followed the order: Amsikong > Sansapan > Bunga > Malakong. Interestingly, while Malakong was the least diverse (H=1.75; 1-D=0.77) among the sites, odonate species in Bunga were the least evenly distributed (E=0.62), indicating a case of species dominance. Based on the ENS values, the Bunga site is equivalent to a community with nine (64%) equally abundant species. This value is relatively low compared to the 15 equally abundant species comprising 88% and 83% of the documented species in Amsikong and Sansapan, respectively.

Table 2

Overall diversity of odonate species. Indices for each sampling site were also provided

Site	Simpson's (1-D)	Shannon-Weiner (H')	Evenness (E)	Effective No. of Species (ENS)
Overall	0.94	2.91	0.83	18.32
Bunga	0.82	2.15	0.62	8.62
Malakong	0.77	1.75	0.72	5.76
Amsikong	0.92	2.68	0.86	14.56
Sansapan	0.92	2.69	0.82	14.75

On the one hand, the overall karst odonate diversity (H'=2.91 and 1-D=0.94) and evenness (E=0.83) were relatively high. These indices indicate that the KKEP is equally diverse and comparable to a community with 18 equally abundant species. Moreover, hierarchical clustering using Bray-Curtis Index revealed that Amsikong and Sansapan were comparable in terms of odonate species composition as indicated by the 67% similarity index (Figure 2a). Malakong was the least similar of the four, a trend that was reflected as well by its Anisopteran assemblage (Figure 2a,c). Interestingly, the Zygopteran assemblage in Malakong was also more similar (42% similarity index) to Bunga (Figure 2b).

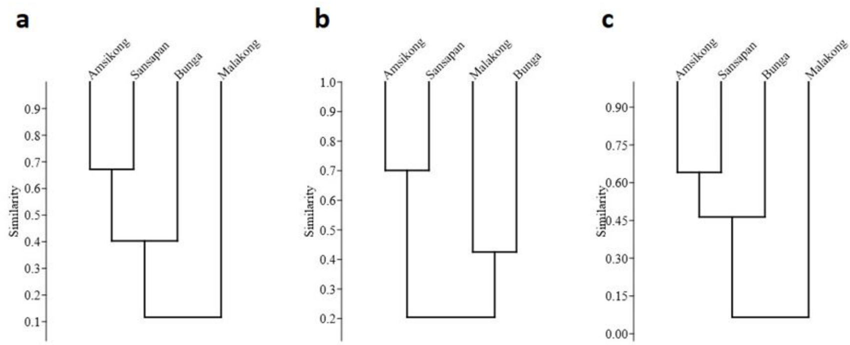

Figure 2. Similarity among sampling sites in terms of (a) overall odonate assemblage, (b) Zygopteran species, and (c) Anisopteran species.

Tropical conditions can influence species diversity and similarity (Nagy et al., 2019). Climatic factors in the tropics favorably support odonate reproduction and survival (Kalkman et al., 2008). Moreover, local variations in the karst microenvironment and landscape characteristics shape assemblages of Zygopteran and Anisopteran species. Odonates respond differently to environmental conditions because of limitations in their ecophysiological requirements (Narender et al., 2016). For instance, freshwater habitats with stones, rocks, and gravel provide favorable conditions that attract and support large numbers of odonates (Pesic et al., 2017). In tropical environments, forest cover and shading may encourage Zygopteran assemblage, while open vegetation might limit their effective dispersal (Oliveira-Junior & Juen, 2019b). The physical conditions (i.e., water temperature, flow rate, turbidity) of the freshwater habitat and surrounding vegetation help shape odonate structure by influencing their behavior, metabolism, and survival (Lee et al., 2018; Adu et al., 2019). Human-induced factors such as deforestation, land conversion, and urbanization can further alter odonate assemblage. These activities can adversely affect species richness and evenness or modify the spatial distribution of odonate individuals (Angulo et al., 2016; Aguilar & Ortega, 2019). Local anthropogenic influences can also change the species dominance structure in a community (Dolny et al., 2012; Cuevas-Yañez et al., 2017).

Zygoptera-Anisoptera Ratio

The overall proportion of Zygoptera was lower than that of Anisoptera in terms of species richness (Figure 3a) and abundance (Figure 3b). Site-wise, the relative proportions of Zygopterans over Anisopterans in terms of species richness and abundance were highest in the riparian habitats of Malakong. The Anisopterans, on the one hand, had the highest relative proportion values for the same parameters in the cultivated fields of Bunga. It is worth noting that despite the relatively higher Zygoptera-Anisoptera ratio, Malakong had the lowest abundance and species richness values among the sites, whether overall or in terms of Zygopteran and Anisopteran assemblages. Amsikong showed similar trends to Bunga; that is, Anisopterans had the highest species richness and abundance. In contrast, the riparian habitat in Sansapan had more Anisopteran species but more abundant Zygopteran species. Overall, our data suggest habitat alteration in some of the sites.

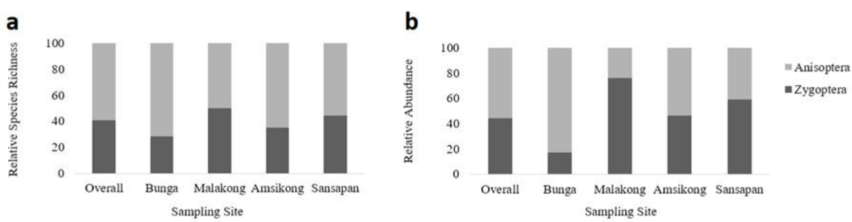

Figure 3. Proportion of Zygoptera and Anisoptera in terms of (a) species richness and (b) abundance. The overall ratio and site-specific values were presented for each case.

The Zygoptera-Anisoptera ratio relates the proportion of Zygopteran and Anisopteran species in the odonate collection to habitat quality and integrity (Oliveira-Junior & Juen, 2019a). This index considers the different responses of Zygopteran and Anisopteran species to changes in their surrounding environment. Zygopterans tend to thrive more in pristine environments, while Anisopterans tolerate altered habitats (Dolny et al., 2011; Seidu et al., 2018). Accordingly, a higher value for the Zygoptera-Anisoptera ratio in terms of species richness and abundance indicates a preserved habitat, while the contrary would mean a degraded or altered ecosystem. Based on the index, our sites followed the order Bunga > Amsikong > Sansapan > Malakong in a decreasing degree of disturbance. While alteration is strongly apparent in Bunga as indicated by the extremely low species richness and abundance of Zygoptera relative to Anisoptera, the case of Amsikong might suggest early-point and small-scale disturbances considering the relatively comparable abundance value of Zygopteran species. Moreover, while Sansapan and Malakong appear to be relatively preserved and still retain a greater abundance of Zygopterans, the low Zygoptera proportion in terms of species richness could indicate a localized change in environmental conditions.

The habitat alteration observed in Bunga and Amsikong could be driven by a range of human activities, including land conversion, human intrusion, small-scale mining, guano collection, sand quarry, and unsustainable agricultural practices. Anthropogenic activities are a primary contributor to habitat degradation and environmental disturbances that significantly change floral and faunal distribution and diversity (Dolny et al., 2012; Angulo et al., 2016; Cuevas-Yañez et al., 2017). The Bunga and Amsikong sites have a wide area of cultivated fields adjacent to the river. Farming in these areas uses fertilizers and pesticides to ensure a good harvest. In higher altitudes, crops are grown in steep terrains. This practice promotes soil erosion and contributes to siltation along the riverine area. The uncontrolled crowding and regular stream of visitors either on foot or using vehicles to the karst could also have contributed to habitat change and decline in the overall health and integrity of KKEP (Velos, 2016). Unregulated and poorly managed tourism and recreational activities in natural parks often result in pollution, decreasing ground cover, and accelerated soil erosion (Finnessey, 2012; Angulo et al., 2016).

CONCLUSIONS

The KKEP hosts a rich and highly diverse odonate species, several of which were endemic to the Philippines. While the overall odonate assemblage remains robust, the species distribution and proportion across sites indicate disturbed and altered habitats. Efforts to keep the integrity and overall health of the KKEP should consider the protection and conservation of karst resources.

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ACKNOWLEDGEMENTS

We thank the Department of Environment and Natural Resources Regional Office XII for the wildlife gratuitous permit (RXII-2017 No. 14) to conduct the study at the KKEP. We are grateful to Dr. Reagan T. Villanueva for his assistance in confirming the odonate species ID. Our gratitude also to Shahida Nor for helping in the fieldwork.