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Species diversity of Odonata in Mimbilisan Protected Landscape, Misamis Oriental, Philippines

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ABSTRACT

The sensitivity of Odonata to changing ecological conditions makes this group an effective indicator of aquatic and terrestrial health. The present study aimed to determine the species diversity and endemism of Odonata in Mimbilisan Protected Landscape. Sampling activity was conducted on July 18 to 28, 2017, using sweep-netting and handpicking methods in two forested sites and one riparian site. One hundred seventy-six individuals comprising 27 species under 10 families and 18 genera of Odonata were documented. Overall, endemism was recorded at 62.96%, including five species exclusive to Mindanao Island. *Orthetrum pruinosum clelia* and *Risiocnemis appendiculata* were the most abundant dragonfly and damselfly species, respectively. Findings also revealed highest species richness (S=24) and diversity (H'=2.732) in the forest stream (riparian site). Even distribution of species was observed in all sampling sites. Human-made disturbances were observed in the area. High level of endemism and moderate diversity of Odonata indicate that Mimbilisan Protected Landscape is a healthy area and conservation measures need to be sustained.

Key words: Damselfly, Dragonfly, Endemic, Mindanao, Riparian

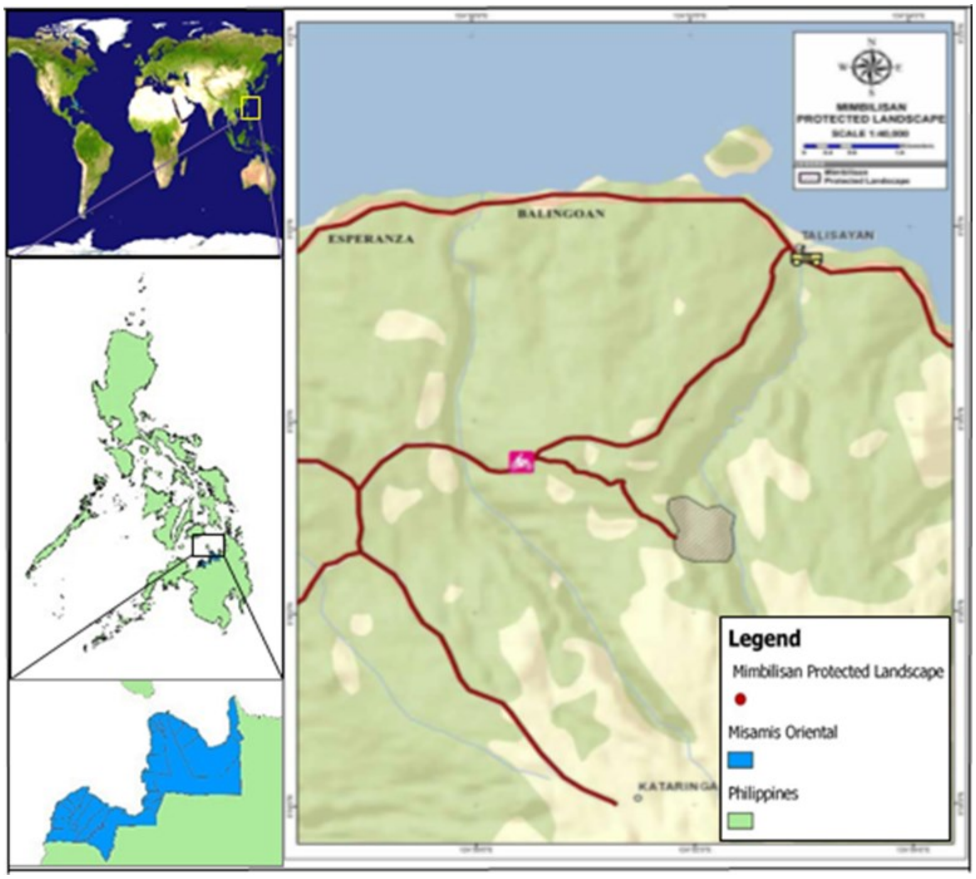

Figure 1. Map of the the world (Sokolowsky, 2004) showing the Philippines, province of Misamis Oriental (philgis.org, 2018), and location of the study area (Biodiversity Management Bureau, 2015).

Valley Province (Medina, et al., 2013), Siargao and Bucas Grande Islands (Villanueva, 2011b), Sultan Naga Dimaporo, Lanao del Norte (Yapac et al., 2016), Lanao del Sur (Malawani *et al*., 2014; Dimapinto *et al*., 2015), Talaingod, Davao del Norte (Villanueva and Cahilog, 2013) and Tawi-tawi, Sanga-sanga, and Jolo Islands (Villanueva and Cahilog, 2012).

Despite the many surveys in different areas on Mindanao, some parts of this major island group are still poorly explored. For instance, there are no available data on Odonata in Mimbilisan Protected Landscape (MPL). Located in Balingoan, Misamis Oriental, the 66.515-hectare protected area is characterized by a forest and water retentive aquifers, thus functions as a watershed (Biodiversity Management Bureau, 2015). The present study provides a baseline record of Odonata species in the area and primarily aimed to determine the Odonata species diversity in Mimbilisan Protected Landscape.

MATERIALS AND METHODS

Study Area

This study was conducted in Mimbilisan Protected Landscape (MPL), which is situated in Barangay Mapua of Balingoan, Misamis Oriental, Philippines (Figure 1). Mimbilisan Protected Landscape is outlined like a gorge in between two mountainous forests with a freshwater body (Mindocdocan Creek) present at its base (Biodiversity Management Bureau, 2015).

Sampling Sites

Site 1, *Riparian Area (forest stream),* was established at 08°56.574' North; 124°52.059' East to 08°56.924' North; 124°52.062' East at an elevation of 350-450 meters above sea level (masl). Direct sunlight penetrated the area due to open canopy. The site was dry because the water flow was redirected for community use, thus revealing large rocks. Temporary water bodies and shallow slow-flowing or stagnant water pools were observed in the area. Various macrophytes including algae, were present in the aquatic bodies. Substrates were mainly covered with moss (*Bryophyta* sp.), especially near water pools.

Emergent tree taxa include 'magkuno' (*Xanthostemon verdugonianus*) and 'lauan' (*Shorea* sp.). Canopy tree taxa include *Dracontomelon dao*, *Bosscheria minahassae*, and "barobo" (*Diplodiscus paniculatus*). The canopy epiphytes present include moss, vines, and ferns. Understory plants include bamboo, "salin-ubod" (*Ficus benjamina*), "hanopol" (*Poikilospermum suaveolens*), *Clerodendrum paniculatum*, *Alocasia princeps, Aglaonema nitidum*, "gabi," *Pandanus yvanii,* and *Cheilocostus speciosus.* The ground cover plants include ferns, plants locally called "iskobia", "dagom-dagom" and "dalili" (*Schismatoglottis calyptrata*). Fruit-bearing tree taxa include *Artocarpus odoratissimus*, *Artocarpus heterophyllus*, *Lansium parasiticum,* and 'balingbing' (*Averrhoa carambola*). *Musa* sp. is the fruit-bearing plant observed. There was a rare density of grasses and sedges present along the stream trail. Natural tree fall was the only on-site disturbance observed.

Site 2, *Mixed Dipterocarp Forest,* was located 8°56.820' North and 124°52.042' East at an elevation of 415-465 masl. This forested site is characterized by secondary vegetation. Canopy cover density was thick enough allowing small amount of diffused sunlight to pass through. The emergent tree was 'lauan' (*Shorea* sp.). Canopy tree taxa include red lauan (*Shorea negrosensis*), white lauan (*Shorea contorta*), narra (*Pterocarpus indicus*), mahogany (*Swietenia mahogani*), "dao" (*Dracontomelon dao*), "tobog" (*Artocarpus sericarpus*), and "kayakaya" (*Ficus gul*). Understory plants include rattan (Family Arecaceae), "mantawasi" (*Costus igneus*), and "pugahan" (*Caryota mitis*). Canopy vines were present. Ground cover plants include "dalili" (*Schismatoglottis calyptrata*) and ferns. *Ficus* density was rarely observed. Fruit-bearing plants include *Musa* sp. and *Cocos nucifera*. Leaf litter cover was approximately 2cm thick. Soil type is clay. Fallen logs and dead twigs were observed. Presence of human-made trails indicates that the site can be utilized as an accessible path to reach the forest stream at the base of the gorge, thus contributes to disturbance. The distance from anthropogenic disturbance (location of camping site) was 400 meters away from the site.

Site 3, *Mixed Dipterocarp Forest with a water source,* was situated 08'56.913' North and 124'52.109' East at an elevation of 430-485 masl. The location is across Site 2 and characterized by secondary vegetation. Diffused sunlight can only pass through the forest canopy. Huge water pipes that extend to the community area for water sources were present. The ground was wet due to water seepages. The slightly-sloped ground causes the water to run down then accumulates at one point to form a mini waterfall. The emergent tree was "lauan" (*Shorea* sp.). Understory plants in the area include "barobo" (*Diplodiscus paniculatus*), rattan (Family Arecaceae), *Daemonorops ochrolepis*, *Calamus caryota,* and *Calamus mitis.* Canopy tree taxa include red lauan (*Shorea negrosensis*), white lauan (*Shorea contorta*), "tanguile" (*Shorea polysperma*), "lagaklak" (*Dipterocarpus valida*), and salin-ubod (*Ficus benjamina*). "Dalili" *Schismatoglottis calyptrata* was the dominant ground cover plant present. Leaf litter cover was about 1cm in depth. Moss was also common in the area. Fallen logs and dead twigs were observed. Soil type is clay. Exposed rocks were moderately present. The area can be utilized as a pathway trekked by some locals to reach the neighboring agroecosystem site. The agroecosystem site was planted with coconut (*Cocos nucifera*) and coffee (*Coffea* sp.).

Collection, Processing, and Identification of Samples

Field sampling was conducted from July 18 to July 27, 2017. Sampling activity commenced at 1000 hours and ended at 1500 hours for a total of 89 person-hours. Sweep netting (Subramanian, 2005) and hand-picking methods were utilized in collecting the specimens (Quisil *et al.*, 2013). Photographs of the sampling sites and specimens were taken during sampling. Distribution of Odonata in the study area and sex of specimens were also recorded.

Representative specimens were placed separately in an empty white paper triangular envelope with their wings folded over the back (Mapi-ot *et al*., 2013; Jomoc *et al*., 2013). However, pairs that were caught in tandem were placed in the same paper triangular envelope (Cayasan *et al*., 2013). A cotton ball soaked in ethyl acetate was used to kill the specimens and stop their metabolism (Jomoc *et al*., 2013). Suffocation takes around 5 to 10 minutes, depending on the size of the captured specimen (Nuñeza et al., 2015). Preservation was done by submerging the dragonflies in acetone for about 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 air-dried and placed in a new paper triangular envelope with a label (Mapi-ot *et al*., 2013; Quisil *et al*., 2013; Aspacio *et al*., 2013). Dried specimens were sorted according to the site of collection and kept in separate sturdy plastic containers without packing them tightly (Mapi-ot *et al*., 2013; Quisil *et al.*, 2013). Naphthalene balls were added to the container to prevent the entry of other insects that may cause deterioration to the samples (Cayasan *et al.*, 2013). The plastic containers were placed in a cool and dry place (Mapi-ot *et al*., 2013).

Samples were identified by the third author. The conservation status of each species was checked using the IUCN Red List of Threatened Species (IUCN, 2017).

Conservation status, distribution, and biodiversity indices

Distribution and conservation status of Odonata species was determined using published studies and IUCN Red List of Threatened Species (IUCN, 2017). Percent endemism was calculated. Biodiversity indices were computed using PAST version 2.17c software (Hammer, Harper, & Ryan, 2001).

RESULTS AND DISCUSSION

Species Composition, Relative Abundance, and Conservation Status

One hundred seventy-six individuals were documented comprising 27 species of Odonata, where 13 species belong to suborder Anisoptera (dragonflies) representing 10 genera in four families and 14 species belong to suborder Zygoptera (damselflies) representing eight genera in six families (Table 1). *Orthetrum pruinosum clelia* was the most abundant (11.36%) Anisoptera species recorded in all sampling sites. This species was also recorded to be abundant in the study of Malawani *et al.* (2014) in Lanao del Sur. The abundance of this species is associated with aquatic pools (Sharma, 2010), which are present in sampling site 1. On the other hand, *Risiocnemis appendiculata* was the most relatively abundant (16.48%) zygopteran, which was observed in all sampling sites. This species was also recorded abundant in San Agustin and Lanuza, Surigao del Sur (Quisil *et al.*, 2013), but least abundant in Bega Watershed, Agusan del Sur (Nuñeza *et al.*, 2015).

Furthermore, five species (*Anax panybeus*, *Macromidia samal*, *Diplacodes trivialis*, *Pseudagrion buenafei*, and *Euphaea amphicyana*) were represented by only a single individual, thus recorded with the lowest relative abundance. The low abundance of these species might be due to the sampling method employed in this study, which was opportunistic and active by the use of sweep-netting and hand-picking techniques. According to Dalzochio et al. (2011), active sampling of adult Odonata can lead to an increased probability of documenting vagrant species of low abundance such as rare species. In contrast to other studies, *Diplacodes trivialis* was found to be abundant in the deciduous forest of Thoothukudi District, Tamil Nadu, South India (Kannagi *et al.*, 2016). In Mindanao, *D. trivialis* was abundant in selected areas of Misamis Occidental (Mapi-ot *et al.*, 2013), Lanao del Sur (Dimapinto *et al.*, 2015), and Mt. Pinukis and Mt. Gimamaw, Zamboanga del Sur (Yuto *et al.*, 2015).

Eleven dragonfly species and two damselfly species were evaluated to belong to the least concern status.

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

Taxon	Geographic Distribution	Conservation Status (IUCN, 2017)	Riparian Area	Forested Area		TOTAL	
			Forest Stream (Site 1)	Mixed Dipterocarp Forest (Site 2)	Mixed Dipterocarp Forest with water sources (Site 3)		
			F	F	F	F	RA
Suborder Anisoptera							
Anax panybeus (Hagen, 1867)	O	LC	1♂	0	0	1	0.57
Idionyx philippa (Ris, 1912)	PE	LC	2♀	0	1♀	3	1.70
Macromidia samal (Needham & Gyger, 1937)	PE	LC	0	T(1♀)	0	1	0.57
Heliogomphus bakeri (Laidlaw, 1925)	PE	LC	2♂	0	0	2	1.14
Agrionoptera insignis (Rambur, 1842)	O	LC	2♂	0	0	2	1.14
Diplacina bolivari **(Selys, 1882)**	PE	NE	1♂; 2♀	0	1♀	4	2.27
Diplacodes trivialis **(Rambur, 1842)**	O	LC	1♀	0	0	1	0.57
Neurothemis ramburii ramburii **(Brauer, 1868)**	O	LC	4♂	0	0	4	2.27
Neurothemis terminata terminata **(Ris, 1911)**	O	LC	1♂; 1♀	0	0	2	1.14
Orthetrum pruinosum clelia **(Selys, 1878)**	O	LC	19♂; 1♀	0	0	20	11.36
Trithemis adelpha **(Selys, 1878)**	O	NE	2♂	0	0	2	1.14
Trithemis aurora **(Burmeister, 1839)**	O	LC	2♂	0	0	2	1.14
Trithemis festiva **(Rambur, 1842)**	O	LC	6♂; 4♀	0	1♂	11	6.25
Suborder Zygoptera							
Rhinocypha colorata **(Hagen *in* Selys, 1869)**	PE	NE	13♂; 4♀	0	0	17	9.66
Rhinocypha turconii **(Selys, 1891)**	PE	NE	6♂	0	0	6	3.41
Pseudagrion buenafei **(Müller, 1996)**	MIE	NE	1♂	0	0	1	0.57
Pseudagrion pilidorsum pilidorsum **(Brauer, 1868)**	O	NE	8♂; 6♀	0	0	14	7.95
Teinobasis annamaijae **(Hämäläinen & Müller, 1989)**	PE	NE	9♂; 2♀	0	0	11	6.25
Euphaea amphicyana **(Ris, 1930)**	PE	LC	1♂	0	0	1	0.57
Coeliccia dinocerus **(Laidlaw, 1925)**	PE	NE	8♂; 3♀	0	0	11	6.25
Risiocnemis appendiculata **(Brauer, 1868)**	PE	NE	6♂	2♂; 2♀	13♂;6♀	29	16.48
Risiocnemis atripes **(Needham & Gyger, 1941)**	MIE	LC	1♂; 2♀	0	0	3	1.70
Risiocnemis flammea **(Selys, 1882)**	PE	NE	0	1♂	3♂	4	2.27
Risiocnemis fuligifrons **(Hämäläinen, 1991)**	PE	NE	0	0	6♂; 5♀	11	6.25
Risiocnemis tendipes **(Needham & Gyger, 1941)**	MIE	NE	1♂	1♂	3♂; 1♀	6	3.41
Drepanosticta clados **(van Tol, 2005)**	MIE	NE	1♂	0	2♂	3	1.70
Prodasineura integra **(Selys, 1882)**	PE	NE	3♂; 1♀	0	0	4	2.27
Total Number of Individuals			127	7	42	**176**	
Total Number of Species			24	4	8	**27**	
Relative Abundance			72.16	3.98	23.86		
Total Number of Endemics			14	4	7	**17**	
Endemism			82.35	23.53	41.18	**62.96**	

Legend- O: Oriental; PE: Philippine Endemic; MIE: Mindanao Island Endemic; LC: Least Concern; NE: Not evaluated; F: Frequency; RA: Relative Abundance; T: Teneral specimen; ♂: Male specimen; ♀: Female specimen.

Species under the least concern (LC) category include widespread and abundant taxa and do not qualify for Critically Endangered, Endangered, Vulnerable, or Near Threatened categories (IUCN Standards and Petitions Subcommittee, 2010). The remaining Odonata species shown in the table are labeled 'Not Evaluated' (N.E), which means that they have not yet been assessed by the IUCN Red List.

Libellulidae was the most dominant and diverse family of dragonflies in this study (Figure 2). Libellulidae is one of the largest and most diverse families in order Odonata with 143 genera and 1,012 species (Kalkman *et al.*, 2008). Species belonging to this family are characterized often by colored or patterned wings (Ware et al., 2007). They exist in almost every type of habitat and dominate the unshaded habitats with stagnant water (Koneri *et al.*, 2017). Furthermore, the dominance of Libellulidae was exemplified in the study of Neog and Rajkhowa (2016), where all species recorded only belong to Family Libellulidae.

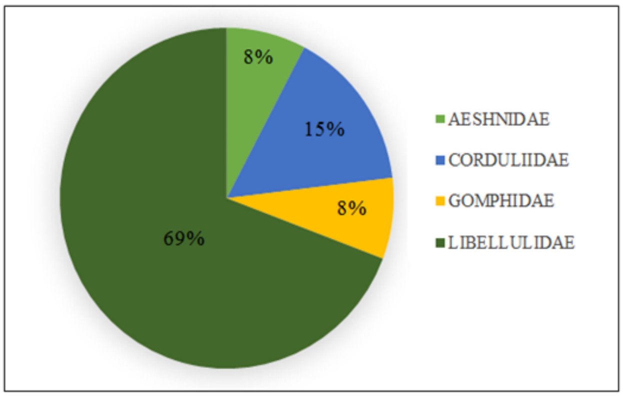

Figure 2. Percentage composition of Dragonfly (Anisoptera) families in Mimbilisan Protected Landscape

Family Platycnemididae was the most represented damselfly family in this study (Figure 3). According to Kalkman *et al.* (2008), there are 130 species in the Oriental biogeographic region and 210 species in the entire world that belong to family Platycnemididae. Species belonging to this family are often observed in streams with slow water flow (Dudgeon, 1999).

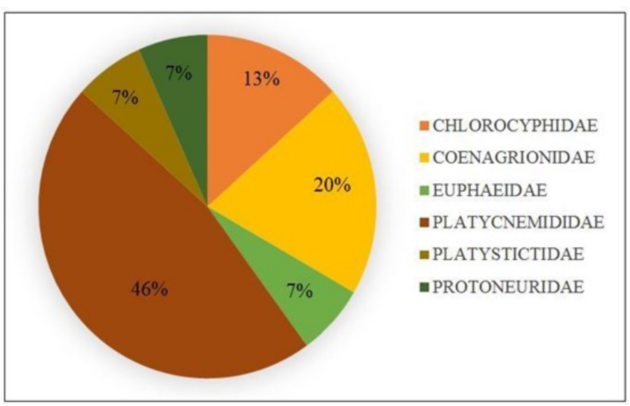

Figure 3. Percentage composition of Damselfly (Zygoptera) families in Mimbilisan Protected Landscape.

Species Endemism

Seventeen species (62.96%) were recorded as Philippine endemic, including five species (*Pseudagrion buenafei*, *Risiocnemis atripes, Risiocnemis fuligifrons, Risiocnemis tendipes*, and *Drepanosticta clados*) that are only found on Mindanao Island. This proportion of recorded endemic species is similar to the previous findings of Nuñeza *et al*. (2015) conducted in Bega Watershed, Agusan del Sur. Figure 4 shows the endemism of odonata across sampling sites. The highest endemism was recorded in Site 1, with 14 endemics and 10 Oriental species. Most of the endemic species (n=11) in the forest stream (Site 1) belong to Order Zygoptera. According to Harisha and Hosetti (2017), the presence of damselflies could be due to the presence of shade provided by trees around the aquatic bodies, which covers their habitat and also to the existence of aquatic vegetation. Most of the Oriental species (n=9) observed in this study were dragonflies found in Site 1, which has an open canopy providing high light intensity. Seidu *et al.* (2017) noted that Anisoptera species, especially belonging to Family Aeshnidae and Libellulidae need more open areas or habitats for thermoregulation.

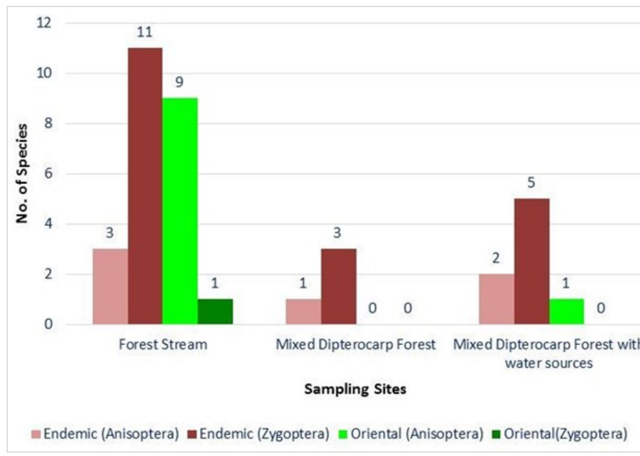

Figure 4. Endemism of Odonata species across sampling sites.

Site 2 had four species which are all endemic. Seven out of eight species in Site 3 are all endemic. Endemic species observed in this study inhabit both forested (Sites 2 and 3) and riparian (Site 1) sites. Studies suggest that endemic species of Odonata occur largely limited to forested and less disturbed habitats (Mapi-ot and Enguito, 2014; Yapac *et al.*, 2016; Luke *et al.*, 2017). Furthermore, Caparoso *et al.* (2016) noted that endemic species are found in tributaries and water sources with adequate vegetation and pristine waters.

The number of endemic species recorded was higher in suborder Zygoptera (92.86%) compared to suborder Anisoptera (30.77%). Higher endemism of damselflies compared to dragonflies was also observed in the studies of Villanueva and Mohagan (2010), Cayasan *et al.* (2013), Medina *et al.* (2013), Malawani *et al.* (2014), and Nuñeza *et al.* (2015). Numerous species of Zygoptera require shaded and pristine forest environment (Oppel, 2005) since they have small, delicate, and thin bodies, which probably make them susceptible to overheating and dehydration (De Oliveira-Junior *et al.*, 2015). In contrast, the shaded environment is not suitable for most species of Anisoptera because they need to

Table 2. Species distribution of Odonata in Mimbilisan Protected Landscape.

Taxon	Riparian Area	Forested Area	
	S1	S2	S3
Anax panybeus (Hagen, 1867)	■		
Idionyx Philippa (Ris, 1912)	■		■
Macromidia samal (Needham & Gyger, 1937)		■	
Heliogomphus bakeri (Laidlaw, 1925)	■		
Agrionoptera insignis (Rambur, 1842)	■		
Diplacina bolivari (Selys, 1882)	■		■
Diplacodes trivialis (Rambur, 1842)	■		
Neurothemis ramburii ramburii (Brauer, 1868)	■		
Neurothemis terminata terminata (Ris, 1911)	■		
Orthetrum pruinosum clelia (Selys, 1878)	■		
Trithemis adelpha (Selys, 1878)	■		
Trithemis aurora (Burmeister, 1839)	■		
Trithemis festiva (Rambur, 1842)	■		■
Rhinocypha colorata (Hagen *in* Selys, 1869)	■		
Rhinocypha turconii (Selys, 1891)	■		
Pseudagrion buenafei (Müller, 1996)	■		
Pseudagrion pilidorsum pilidorsum (Brauer, 1868)	■		
Teinobasis annamaijae (Hämäläinen & Müller, 1989)	■		
Euphaea amphicyana (Ris, 1930)	■		
Coeliccia dinocerus (Laidlaw, 1925)	■		
Risiocnemis appendiculata (Brauer, 1868)	■	■	■
Risiocnemis atripes (Needham & Gyger, 1941)	■		
Risiocnemis flammea (Selys, 1882)		■	■
Risiocnemis fuligifrons (Hämäläinen, 1991)			■
Risiocnemis tendipes (Needham & Gyger, 1941)	■	■	■
Drepanosticta clados (van Tol, 2005)	■		■
Prodasineura integra (Selys, 1882)	■		

*S- sampling site

thermoregulate under direct sunlight exposure (Oppel, 2005). Also, zygopterans have greater habitat specialization compared to anisopterans (Corbet, 1999; Corbet and May, 2008) because Anisoptera is more tolerant of diverse environmental conditions and has greater dispersal ability (Tscharntke *et al*., 2002; Mendes *et al*., 2015).

Species Distribution

Table 2 shows that all Anisoptera species appeared in the riparian site (Site 1) except for an immature adult (teneral) of *Macromidia samal,* which was found in Site 2. According to Villanueva (2009d), *Macromidia samal* is known from Luzon, Negros, Mindoro, Mindanao, and Dinagat Islands. It is associated with well-forested habitats (Villanueva, 2009d). *Idionyx philippa*, *Diplacina bolivari*, and *Trithemis festiva* were seen not only in Site 1 but also in Site 3. *I. philippa* can be encountered in shaded montane forests near or at some distance of aquatic bodies (Villanueva, 2009a). *Diplacina* species, including *D. bolivari* thrive in forested areas (Villanueva, 2009b) or near water sources with few vegetated parts (Medina *et al*., 2015) and less disturbed habitat (Yapac *et al*., 2016). *T. festiva* was found in riparian and forested habitats in the study of Nuñeza *et al*. (2015).

Despite the preference of most zygopteran species to shaded habitats, some damselfly species were observed to occur only in open habitat. *Rhinocypha colorata*, *Rhinocypha turconii*, *Pseudagrion pilidorsum pilidorsum*, *Pseudagrion buenafei*, *Teinobasis annamaijae*, *Euphaea amphicyana*, *Coeliccia dinocerus*, *Risiocnemis atripes,* and *Prodasineura integra* were observed only in Site 1. According to Villanueva (2009b, 2009c), *Rhinocypha colorata* and *Euphaea amphicyana* prefer forested streams, creeks, and rivers with open spaces. Also, *Pseudagrion pilidorsum pilidorsum* can also be found in open ecosystems (Caparoso *et al*., 2016).

Risiocnemis appendiculata and *Risiocnemis tendipes* were found in all sites. *R. appendiculata* was observed to be the most widely distributed member of its genus in the Greater Mindanao bio-geographic region (Villanueva, 2011a). Moreover, *R. appendiculata* is found in pristine sites (Caparoso *et al*., 2016). *Risiocnemis tendipes* is widespread on Mindanao Island (Gassmann and Hämäläinen, 2002). It was observed that *Risiocnemis* species (*R. appendiculata, R. flammea, R. fuligifrons,* and *R. tendipes*) recorded in this study dominated Site 3. *Risiocnemis* species has an affinity to small flowing waters (Hämäläinen, 1991) and shady forest environment (Gassmann and Hämäläinen, 2002) which characterized Site 3.

Sex Composition of Odonata in Mimbilisan Protected Landscape

Figure 5 shows the sex composition of Odonata individuals in Mimbilisan Protected Landscape. The number of male individuals was observed to be higher compared to female individuals in all sampling sites.

The numerical prevalence of males in adult Odonata compared to females was observed in various studies. Stoks (2001) formulated several hypotheses on male-biased sex ratio of mature damselfly population based on *Lestes sponsa* species. Male-biased sex ratio may be due to: (1) male-biased sex ratio at emergence; (2) male and females may not emerge synchronously; (3) females have longer maturation period; (4) immature females have higher foraging rates than immature males

Table 3. Biodiversity indices of the three sampling sites in Mimbilisan Protected Landscape.

	Riparian Area	Forested Area	
	Forest Stream	Mixed Dipterocarp Forest	Mixed Dipterocarp Forest with water sources
Species Richness (S)	24	5	9
Shannon-Weiner (H')	2.732	1.475	1.776
Evenness (E)	0.6399	0.8743	0.6565

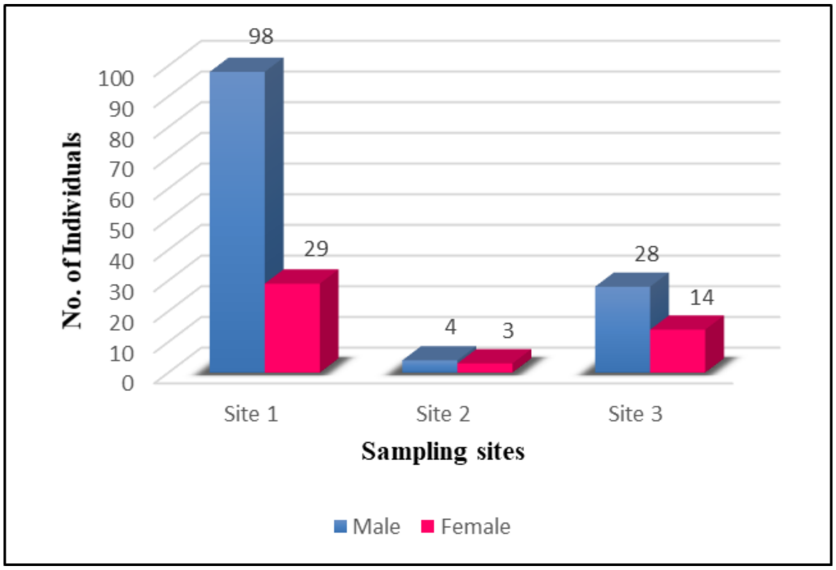

Figure 5. Sex composition of Odonata species in Mimbilisan Protected Landscape.

due to increasing mass during maturation, thus increasing their vulnerability to predators; and (5) mature females have lower survival probabilities. Kéry and Juillerat (2004), using the capture-recapture method on an Anisoptera species, *Orthetrum coerulescens*, observed that there were more males compared to females only when the temperature was increasing, and recapture rates were done on a 5-days interval.

Biodiversity Indices

As shown in Table 3, the highest species richness (S=24) was recorded in the forest stream (Site 1) while lowest in Site 2 (S=4). Species richness of Odonata is affected by several factors. The study of Ball-Damerow *et al.* (2014) reported that sites with high canopy cover have a low richness of Odonata species. Low species richness in Sites 2 and 3 could be attributed to disturbances such as the presence of human-made trails in both sites. In the study of De Oliveira-Junior *et al.* (2017), species richness of Odonata in aquatic systems is more likely to increase in environments that are less disturbed and more heterogeneous. This is due to a greater number of resources and habitat availability these kinds of environments have to offer (Dias-Silva *et al.*, 2010). For instance, species richness and local abundance of odonata increase with large variety of natural habitats compared to homogenous habitats such as tree monoculture (Samways and Steytler, 1996). Disturbances to the environment lead to loss or fragmentation of a specific resource which heavily affects specialists (e.g., endemic or rare species) than species adapted to a wide range of environmental conditions (generalists) (Korkeamäki and Suhonen, 2002; Miller *et al.*, 2015), thus decreasing species richness. For instance, disturbances in the forest might result in the disappearance of forest-dwelling Odonata species; hence, only generalist and tolerant species persist (Clausnitzer, 2003). Species belonging to Families Platystictidae, Platycnemididae, and Protoneuridae are considered habitat specialists, which thrive in forested habitat, especially mixed dipterocarp and swamp forests (Chovanec and Raab, 1997). The abovementioned specialist species are all endemic, as observed in this study, and mostly found in sampling sites associated with mixed dipterocarp and riparian vegetation.

Shannon-Wiener values of >3.0 are considered high diversity, moderate diversity for values 1.0<3.0, and low diversity for values<1.0 (Richardson, 1977). Moderate diversity was recorded in all sites. Moderate diversity is associated with primary-secondary forests and clean aquatic systems (Cayasan *et al*., 2013; Nuñeza *et al*., 2015). Determining Odonata diversity and distribution is mainly influenced by microhabitats with high heterogeneity of vegetation (Watanabe et al., 2004). The type and structure of vegetation may correspond to specific requirements of a certain life stage of Odonata species (Remsburg and Turner, 2009). Together with vegetation, the presence of macrophytes in aquatic bodies also influences Odonata diversity since it affects larval assemblages (Remsburg and Turner, 2009). Furthermore, water quality is another crucial factor that affects diversity such that good water quality results in high diversity (Koneri *et al.*, 2017).

All sampling sites in Mimbilisan Protected Landscape had a high evenness of Odonata species. Each site had no dominant species.

CONCLUSION

Odonata documented in Mimbilisan Protected Landscape (MPL) comprised 27 species belonging to 10 families and 18 genera. *Orthetrum pruinosum clelia* and *Risiocnemis appendiculata* were the most abundant dragonfly and damselfly species recorded across sampling sites, respectively. *Risiocnemis appendiculata* and *Risiocnemis tendipes* were distributed in all sampling sites. Most species are of the least concern status. High endemism of 17 species (62.96%) and richness (S=27) of Odonata in the area was associated with high heterogeneity of habitats and minimal disturbance. More male specimens were documented in all sites. All sites had moderate diversity with the forest stream (Site 1) showing the highest diversity (H'=2.732) due to Odonata's direct exposure to sunlight and the presence of diverse vegetation and aquatic bodies that meet the requirements of most dragonfly and damselfly species alike. All sampling sites revealed even distribution of Odonata. High endemism and moderate diversity of Odonata species present in the sampling sites serve as an indicator that Mimbilisan Protected Landscape is a healthy site despite the occurrence of some disturbances.

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