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Species richness of Odonata in selected freshwater systems in Zamboanga del Sur, Philippines

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Abstract. The Odonata is important in identifying the habitat health of freshwater ecosystems. In this study, the species richness and relative abundance of Odonata were determined in 12 sampling sites in Zamboanga del Sur. Field work was conducted in August-December, 2012 using the random sampling method. Thirty-six species belonging to 10 families were documented of which 16 (44%) species are Philippine endemic. High species richness was recorded in Cabilinan Stream which is considered to be the most undisturbed site in the 12 sampling sites. Species richness was also considerably high in eight sampling sites despite habitat modification and water pollution from agricultural run-offs. The presence of Oriental species which are indicators of degraded environments suggests that the streams are disturbed. However, the presence of some endemic species indicates that these endemic fauna can thrive in disturbed habitats.
Key Words: endemic, freshwater, habitat, indicators, threats.

Introduction. Odonata which consists of two major groups: Anisoptera, the dragonflies and Zygoptera, the damselflies (Asaithambi & Manickavasagam 2002) is perhaps the most fascinating insects of freshwater habitats (Palot & Soniya 2000). Over 5,875 species worldwide have been described with 31 identified families (Paulson & Schorr 2012) where 2,739 of these species belong to the suborder Zygoptera and 2,941 species belong to the suborder Anisoptera (Kalkman et al 2008).

Although Odonata is common and diverse in lentic waters, there are species that occur in lotic waters such as rivers and streams (Bouchard 2004). This group has strong responses to habitat change such as increased erosion and thinning of forest (Clausnitzer et al 2009).

Patterns of distribution of Odonata primarily relate to the biogeographic zones where climates may vary. Based on the number of species per family in specific biogeographical region, Palaearctic has relatively 560 known species (75-100 species undescribed); Nearctic, 451 known species (5-10 undescribed); Neotropical, 1636 known species (400-500 undescribed); Afrotropical, 889 known species (100-125 undescribed); Oriental, 1665 known species (300-400 undescribed); Australasian, 870 known species (175-250 undescribed); Pacific, 168 known species (30-40 undescribed) and no species is known from Antarctica (Kalkman et al 2008). In the synopsis of the Philippine Odonata by Hämäläinen & Müller (1997), only 15 families, 91 genera and 309 species are named of which 203 species (65.7%) are endemic. Of these, Order Zygoptera consisting of 34 genera and 186 species has 85.5% endemism. Order Anisoptera contains 57 genera and 123 species where only 44 species (35.8%) are endemic (Gapud 2003).

Temperature plays a big role in the increase of diversity from the poles to the equator. The tropics hold higher diversity of Odonata where 12 of the 31 families are restricted mostly to lotic waters within tropical forest habitats. In tropical countries like the Philippines, diversity of Odonata is highly dependent on the types of aquatic habitats

in different forests. This is the reason why the Philippines is recognized for its high number of endemic Odonata (Kalkman et al 2008). Gapud (2003) reported that the very high endemism of Zygoptera is attributed to forested water bodies in high elevation which are favorable for Odonata. However, many species belong to red list due to habitat fragmentation (Villanueva & Mohagan 2010). Threats to the tropical island are more on the anthropogenic activities such as land conversion for agricultural and infrastructural development (Khrokalo & Prokopov 2009), illegal logging resulting to the disappearance of forest cover and hence altering the habitat of Odonata (Villanueva et al 2012).

Odonata is one of the groups of insects which experiences numerous shifts in distribution and abundance and consequently extinction risk and biodiversity loss (Thomas et al 2004). The deterioration of freshwater habitats across the globe prompted an increased concern on Odonata (Nelson et al 2011). Habitat loss due to deforestation is possibly the main threat to global Odonata diversity, which potentially leads to the extinction of several species (Dudgeon et al 2006). Unfortunately, these species are often poorly identified resulting to difficulty in assessing whether a species is genuinely rare or just overlooked. More taxonomic work is necessary to create accurate ranges of these species.

The Odonata in the Philippines is poorly characterized because only a few find interest in studying these species. Quisil et al (2013) surveyed the Odonata of Lanuza and San Agustin, Surigao del Sur and found two species which are new Mindanao record. Villanueva (2011 a,b) reported new records from his Odonata surveys in some parts of the Philippines like Diomabok Lake in Davao Oriental, Catanduanes Island, and Siargao and Bucas Grande islands. He stressed the need to conduct fieldworks in various areas in the archipelago since several parts of the archipelago's main islands like Mindanao are virtually unexplored. Mindanao, as one of the three large island groups, has a rich diversity of fauna and is considered to possess a high level of biodiversity due to high mountain ranges (Amoroso 2007). Zamboanga del Sur in Mindanao, Philippines is one of the places with poor odonatological record. The region is currently under significant human pressures such as mining activity, timber extraction, and other forms of landscape modifications which could lead to the dramatic decline of Odonata and thus in need of urgent faunal survey. Inadequate knowledge of these species encourages further zoological expedition in the region (Hämäläinen & Müller 1997)). Extensive research and fieldwork in the archipelago is highly required to establish species accounts on the Odonata to enable the government to determine the threat status and design concrete conservation efforts in particular areas (Oppel 2005; Villanueva 2011b).

In this study, selected freshwater systems in Zamboanga del Sur were assessed to determine species richness, abundance, endemism and biodiversity indices as well as observe the possible threats to the Odonata.

Materials and Methods

Study area. Three municipalities, namely, Aurora, Tukuran, and Lakewood in Zamboanga del Sur were selected as study areas (Figure 1) and 12 sampling sites were established.

Table 1 shows the 12 sampling sites with the coordinates. Six sampling sites were established in the municipality of Aurora, two in Lakewood, and four in Tukuran, Zamboanga del Sur.

Figure 1. Map of Mindanao showing the location of the three study areas: Aurora, Tukuran, and Lakewood (National Geospatial-Intelligence Agency 2010).

Table 1

Coordinates of the sampling areas in Zamboanga del Sur freshwater systems

Site number	*Site name*	*Coordinates*	
1	Bemposa Stream, Aurora	07º56'59.23"N	123º35'02.10"E
2	Cabilinan Stream, Aurora	07º55'43.58"N	123º39'27.68"E
3	Lantungan Stream, Aurora	07º53'32.17"N	123º37'48.93"E
4	Masahan Stream, Aurora	07º54'36.40"N	123º37'26.90"E
5	Cebuneg Stream, Aurora	07º53'28.70"N	123º39'26.20"E
6	Inroad River, Aurora	07º54'51.60"N	123º39'08.40"E
7	Baclay Stream, Tukuran	07º53'43.80"N	123º36'36.60"E
8	Tabuan Stream, Tukuran	07º52'38.60"N	123º33'24.60"E
9	Tinotongan Stream, Tukuran	07º52'47.00"N	123º35'26.50"E
10	Alindahaw River, Tukuran	07º51'21.50"N	123º33'30.00"E
11	Lukuan Stream, Lakewood	07º49'32.82"N	123º09'16.99"E
12	Lake Lakewood, Lakewood	07º50'43.03"N	123º08'47.89"E

Sampling site 1. Bemposa Stream, Aurora is a permanent water system measuring 2.4 m to 4 m wide with depth of 0.2-0.4 m. Tree taxa include *Albizia falcata*, *Artocarpus blancoi*, *Ficus minahassae*, *Mallotus floribunda*, *Diplodiscus paniculatus*, *Ficus nota*, *Litsea plateafolia*, and *Gmelina arborea*. Bamboo thickets are the dominant bank-side vegetation of the stream. Agricultural plants present include: *Cocos nucifera*, *Musa* sp., *Zea mays*, and edible root crops. The height of emergent tree was approximately 15-20 m and the height of canopy trees was approximately 3-5 m. Understory plants identified in the area include *Lantana camara* while ground cover consisted of patches of *Imperata cylindrica* and *Chloromolaema odorata.* Fallen logs were not common. Ferns and vines were less abundant. Measurement of the A-horizon of the soil is 3 cm. The water is clear in areas shaded by trees specifically in the upstream and murky in the middle and lower streams. The stream is 100-150 meters away from the road. Agricultural expansion and timber cutting were the on-site disturbances.

Sampling site 2. Cabilinan Stream, Aurora is a permanent water system which originates from the two Barangays in Aurora: Cabilinan and Bag-Ong Maslog. The location is characterized by undulating steep slope. The stream has 1.8 -3.6 m width and 0.5-2 m depth. Tree taxa include *Panicum palmifolium*, *Endospermum peltatum, A. blancoi*, *Melanolepis multiglandulosa*, *Syzygium albayanse*, *Duabanga moluccana*, *Dipterocarpus grandiflorus*, *Neonauclea bartlingii, Syzygium gigantifolium*, and *Tarrietia javanica*. Agricultural plants include: *Z. mays, Musa* sp., *Abelimoschus esculentus, Solanum melongena*, and *C. nucifera*. The height of emergent tree was approximately 22-25 m and the height of canopy trees was approximately 5-8 m. Bamboo thickets were less common. Canopy vines and epiphytes were present in moderate amount. Ferns were abundant. Ground cover consisted of *Mimosa pudica.* The ground was mostly covered by leaf litter. Measurement of the A-horizon of the soil is 6 cm. The soil was classified as loam and clay. The water is clear running along slightly pristine forested area. Immediate vicinity contains considerable flora at the bank-side in the lower stream. Several natural spring waters from the ground were present. The stream is 100-200 meters from the road. Chemical run-off from agricultural land was observed.

Sampling site 3. Lantungan Stream, Aurora is a stream about 2m to 5m wide which originates from the mountain ridges named “Forestal”. The side of the stream is dominated by trees, bushes, grasses and other flora but highly modified due to timber extraction. Tree taxa include *Pentacme contorta, Shorea negrosensis, Garuga floribunda, Ficus callosa, Cinnamomum mercadoi*, *F. nota, Colona serratifolia, D. grandiflorus, Vitex parviflora, Pipturus arborescens*, *Ficus minahassae, Macaranga tanarius*, *Cleistanthus pilosus*, *Canarium luzonicum*, and *Trema orientalis*. Agricultural plants present were *C. nucifera*, *Musa* sp., *Z. mays*, *Momordica charantia, Vigna radiata, Lycopersicon esculentum*, and edible root crops. The height of emergent tree was approximately 25-30 m and the height of canopy trees was approximately 5-8 m. Bamboo thickets were abundant in upstream near Islaw falls and moderate in the lower stream. Canopy vines present were *Calamus maximus* and *Anamirta cocculus.* Ferns and *Ficus* density were moderate. Measurement of the A-horizon of the soil is 4 cm. Ground cover consisted of *I. cylindrica*, *Paspalum notatum*, and *P. conjugatum*. The bottom substrate of the stream is typically composed of sand, gravel and big stones. The clearance of vegetation, soil erosion and human disturbance are the possible threats to the habitats of the Odonata.

Sampling site 4. Masahan Stream, Aurora is an agricultural area with undulating slope. The stream is about 2 meters in diameter. The water is clear with sandy substrate. Exposed moderate-sized rocks and fallen logs were present. Plant taxa that were identified in the area include *Mangifera indica*, *Terminalia catappa*, *C. nucifera*, and *G. arborea*. Understory plants that were identified in the area were banana *Musa* sp., *Colocasia esculenta*, and *Gliricidia sepium*. Ground cover plants such as *P. conjugatum*, and *I. cylindrica* were found to cover 40% of the land. Bamboo was also observed. Various developments were observed such as road access and bridge with culverts.

Sampling site 5. Cebuneg Stream, Aurora is an agricultural area with undulating slope. The stream is about 3 meters in diameter. The water is clear with sandy substrate. Exposed moderate and big-sized rocks and fallen logs were present. Plant taxa that were identified in the area include *C. nucifera*, *G. arborea*, *Livistona rotundifolia*, *Tectona*

grandis, *Leucaena leucocephala*, and *M. indica*. Understory plants that were identified are *Musa* sp., *Annona muricata*, *Psidium guajava*, *Gliricidia sepium*, and *C. odorata*. Ground cover plants such as *P. conjugatum*, and *I. cylindrica* were found to cover 60% of the land. Bamboo was also observed. Various activities in the stream like cow and pig wallowing in the river and women doing laundry were observed. Pig manure disposal along the stream was noted.

Sampling site 6. Inroad River, Aurora has mountainous slope with disturbed secondary vegetation. The water is cloudy with sandy substrate. The river is about 5 meters in diameter. Fallen logs and small to medium-sized rocks were present. Plant taxa that were identified in the area were *C. nucifera*, *Tectona grandis*, *Plumeria acuminata*, *Livistona rotundifolia*, *L. leucocephala*, and *M. indica*. Understory plants that were identified were *Gliricidia sepium*, *Musa* sp., and *C. odorata*. Ground cover plants such as *P. conjugatum*, and *I. cylindrica* were found to cover 80% of the land. Bamboo was also observed. Numerous activities such as washing of clothes, bathing, swimming, carabao wallowing in the shallow portion of the river and bamboo cutting were noted in the river.

Sampling site 7. Baclay Stream, Tukuran is about 3 meters wide and inhabited by variety of organisms such as dragonflies, damselflies, water spiders, and butterflies. Some of the plant taxa present were *M. indica, C. nucifera, Chrysophyllum cainito, Shorea negrosensis, Sandoricum koetjape*, *Psidium* sp., and *M. charantia.* Grasses such as *P. conjugatum* and *I. cylindrica* were common. The substrates of the stream are sand, mud, and stones. Human sewage and waste and fallen tree branches were present. Agricultural ecosystems such as rice fields were abundant in the area.

Sampling Site 8. Tabuan Stream, Tukuran is an agricultural ecosystem and ponds are just right beside the stream and residential houses are about 15 meters away. The width of the stream is about 3 meters. Some of the plants recorded were *Musa* sp., *V. radiata, C. nucifera, P. conjugatum*, *I. cylindrica*, and *Bambusa blumeana*. Moderate density of ferns and moss was observed. Butterflies and birds like crows were noticed. The stream is half a kilometer from the main highway from which buses and jeepneys pass by. This is a small stream that intersects with a river located in the same barangay.

Sampling Site 9. Tinotongan Stream, Tukuran is about one kilometer from the stream located in Barangay Baclay. Most of the tree taxa found in the area were *Syzygium cumini*, *S. negrosensis*, and *M. indica*. *Musa* sp. and *C. nucifera* were also abundant. The stream has a substrate combination of sand, gravel, stones and mud. Human wastes and habitat modification such as agricultural area expansion were observed. The residents benefit from the water for personal usage and agricultural purposes.

Sampling Site 10. Alindahaw River, Tukuran has width of approximately 10 meters. The water was mud-covered due to heavy rain. Among the plants noted were *Pandanus* sp., *Musa* sp., *G. arborea*, *Terminalia* sp., *Lantara camara*, *L. leucocephala, Z. mays, M. pudica*, grasses such as *P. conjugatum*, and *I. cylindrica*. *C. nucifera* which lined both sides of the river were numerous. Turbidity of the water brought by heavy rain or flood was observed. Aside from agricultural areas and fish ponds, the local residents benefit from the river as source of income and livelihood.

Sampling Site 11. Lukuan Stream, Lakewood is approximately 1 km from the main entrance of Lake Lakewood. It is undulating to mountainous. From the anthropogenic clearing, it is approximately 20 meters. Exposed rocks were present along the water. Other noted organisms were butterflies, ants and bees. Water buffalo (*Bubalus bubalis* Linn.) was seen wallowing in the stream.

Sampling Site 12. Lake Lakewood, Lakewood is a lake located in Barangay Biswangan. It has an area of approximately 800 ha. The lake is the largest lake in Zamboanga del Sur and Zamboanga Peninsula. It is approximately 55 km from Pagadian City, the capital city of the province. Private vehicles or vans are the transportation used to reach the lake. The major ethnic group living around the lake is the Subanen people. Other organisms observed along with dragonflies and damselflies were butterflies, ants, beetles, wild ducks and mosquitoes.

Sampling methods and collection of samples. Field sampling was conducted at 09:00-16:00 hours for a total of 26 days or 333 man-hours between the months of August-December, 2012. Specimens were collected in the 12 freshwater systems (nine streams, two rivers, and a lake) in Zamboanga del Sur using random sampling method. This Odonata inventory was based principally on adult specimens by manually netting the adult flying individuals during hot sunny days. Adults were caught by hand picking or using a catching net with an opening of 18 inches and a length of two meters.

Processing of samples. The live Odonata samples were stored in small brown envelopes with the wings folded over the back. Only one specimen was kept in each envelope to avoid damage. However, pairs caught in tandem were placed in the same envelope. Because the color of adults fade or change after preservation, photographs were taken in the field or right after the samples were caught.

The specimens inside the box were treated with ethyl acetate to kill them. After killing, specimens of the same species were arranged in a plastic container and soaked in acetone for 24 hours. Specimens were air-dried. Dried specimens were placed in paper triangles. The paper triangles containing the specimens were put in a sealed container. Naphthalene balls were added to the container to prevent entry of other insects that can damage the preserved samples.

Samples collected were identified using pictorial keys and verified by the fourth author.

Results and Discussion

Species composition, abundance, and endemism. Thirty-six species of Odonata in 10 families with a total of 809 individuals were documented in the 12 sampling sites. The Odonata recorded comprised of 18 Zygoptera species belonging to seven families (Amphipterygidae, Calopterygidae, Chlorocyphidae, Coenagrionidae, Platycnemididae, Platystictidae, and Protoneuridae) and 18 Anisoptera species belonging to three families: Corduliidae, Gomphidae, and Libellulidae (Table 2).

In site 1 (Bemposa Stream), 15 species of Odonata were recorded with 11 Oriental species and only four endemic. Twenty-two species, which are considered to be the highest in the 12 sampling sites, were found in site 2 (Cabilinan Stream) with 11 endemic species. Nineteen species of which eight are endemic were documented in site 3 (Lantungan Stream). Out of the eight species collected in site 4 (Masahan Stream), only one endemic species was found and seven species were Oriental. Other sites had the following record: site 5 (Cebuneg Stream) – 10 species (8 Oriental, 2 endemic); site 6 (Inroad River) – 13 species (10 Oriental, 3 endemic); site 7 (Baclay Stream) – 13 species (8 Oriental, 5 endemic). No endemic species was recorded in sites 8, 9, and 10. Ten species were documented in site 7 (Lukuan Stream) with five endemic species. Site 12 (Lake Lakewood) has 14 recorded species with 10 endemic species. High number of Oriental species was observed in site 1 which is an open and disturbed habitat. However, most endemic species reside in clean and forested streams like sites 2 (Cabilinan Stream) and 12 (Lake Lakewood) where clear water systems are available.

Table 2

Species distribution and abundance of Odonata in selected freshwater systems in Zamboanga del Sur

Species name	*Distribution in selected freshwater systems in Zamboanga del Sur*													
	Site 1	Site2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11	Site 12	TOTAL	
	F	F	F	F	F	F	F	F	F	F	F	F	F	%RA
Suborder ANISOPTERA														
Family Corduliidae														
*Heteronaias heterodoxa****	0	0	0	0	0	0	0	0	0	0	0	2	2	0.25
Family Gomphidae														
*Gomphidia kirschii****	0	0	0	0	0	0	0	0	0	0	0	2	2	0.25
Family Libellulidae														
Acisoma p. panorpoides	0	0	0	0	0	0	0	0	0	0	0	2	2	0.25
Agrionoptera insignis	5	4	2	0	0	0	0	0	0	0	0	0	11	1.36
*Diplacina bolivari**	2	4	1	0	0	2	2	0	0	0	0	0	11	1.36
Diplacodes trivialis	0	0	0	0	5	0	2	7	13	15	0	0	42	5.19
Neurothemis r. ramburii	8	2	5	5	8	12	3	3	3	2	2	0	53	6.55
Neurothemis t. terminata	0	0	0	0	1	4	5	3	10	3	3	0	29	3.58
Orthetrum sabina sabina	7	2	4	2	9	12	3	3	9	3	0	0	54	6.67
Orthetrum pruinosum clelia	5	3	5	0	0	0	0	0	0	0	0	2	15	1.85
Orthetrum t. testaceum	2	1	4	0	0	0	0	0	0	0	0	0	7	0.87
Pantala flavescens	6	3	3	1	0	3	0	4	4	3	0	0	27	3.34
Potamarcha congener	1	1	3	1	0	1	0	3	3	3	0	0	16	1.98
Rhyothemis phyllis subphyllis	0	0	0	0	0	2	0	0	0	0	0	0	2	0.25
Tholymis tillarga	5	3	7	0	0	2	0	0	1	4	0	0	22	2.72
Trithemis aurora	10	5	7	2	13	30	0	2	0	0	0	0	69	8.53
Zyxomma obtusum	2	2	3	0	0	0	0	0	0	0	0	0	7	0.87
Zyxomma petiolatum	0	0	0	0	1	0	0	0	0	0	0	0	1	0.12
Suborder ZYGOPTERA														
Family Amphipterygidae														
*Devadatta podolestoides basilanensis**	0	0	0	0	0	0	0	0	0	0	0	3	3	0.37
Family Calopterygidae														
*Vestalis melania**	0	6	0	0	0	0	0	0	0	0	3	1	10	1.24
Family Chlorocyphidae														
*Cyrano angustior**	0	0	0	0	0	0	0	0	0	0	0	2	2	0.25
*Rhinocypha colorata**	18	9	12	0	0	21	2	0	0	0	4	3	69	8.53

Family Coenagrionidae														
Agriocnemis femina femina	0	0	0	1	4	0	7	8	0	0	0	0	20	2.47
Agriocnemis rubescens intermedia	0	0	0	0	0	0	1	0	0	0	0	0	1	0.12
Ischnura senegalensis	0	0	0	0	0	0	12	0	0	0	3	2	17	2.10
Pseudagrion microcephalum	0	0	0	0	0	1	0	0	0	0	1	0	2	0.25
Pseudagrion p. pilidorsum	21	7	19	6	17	17	16	3	1	0	1	1	109	13.47
*Teinobasis annamaijae**	0	4	0	0	0	0	0	0	0	0	0	0	4	0.49
Family Platycnemididae														
*Coeliccia dinocerus**	0	7	2	0	0	0	2	0	0	0	0	1	12	1.48
*Risiocnemis appendiculata**	0	4	7	0	0	0	0	0	0	0	0	0	11	1.36
*Risiocnemis flammea**	0	3	0	0	0	0	0	0	0	0	0	0	3	0.37
*Risiocnemis fuligifrons**	3	16	13	0	0	0	0	0	0	0	0	0	32	3.96
*Risiocnemis tendipes**	0	0	0	0	0	0	1	0	0	0	2	1	4	0.49
Family Platystictidae														
*Drepanosticta flavomaculata**	0	8	12	0	0	0	0	0	0	0	0	0	20	2.47
*Drepanosticta krios**	0	3	5	0	0	0	0	0	0	0	1	2	11	1.36
Family Protoneuronidae														
*Prodasineura integra**	13	8	15	7	31	20	8	0	0	0	3	2	107	13.23
Total Number of Individuals	108	105	129	25	89	127	64	36	44	33	23	26	809	100
Total Number of Species	15	22	19	8	10	13	13	9	8	7	10	14		
Philippine Endemic	4 (27%)	11 (50%)	8 (42%)	1 (13%)	2 (20%)	3 (23%)	5 (38%)	0	0	0	5 (50%)	10 (71%)		

LEGEND: * - Philippine endemic; F- Frequency.

Of the 36 species recorded in all sampling sites, 16 of these are Philippine endemic (*H. heterodoxa*, *G. kirschii*, *D. bolivari, D. p. basilanensis, V. melania, C. angustior, R. colorata, T. annamaijae, C. dinocerus, D. flavomaculata, D. krios, R. appendiculata, R. flammea, R. fuligifrons, R. tendipes,* and *P. integra*). Endemic species were mostly under suborder Zygoptera (damselfly) and only three endemic species (*H. heterodoxa, G. kirschii, and D. bolivari*) were under suborder Anisoptera (dragonfly). Endemic Zygopterans are commonly restricted to Greater Mindanao subregion but other endemic species are widespread in the country like *D. bolivari, V. melania, R. colorata,* and *P. integra.* The low endemism (44%) indicates that the sites are predominated by Oriental species due to anthropogenic pressures on the streams.

Majority of the species collected belong to suborder Anisoptera under family Libellulidae. Family Libellulidae is extensively distributed worldwide and in local areas (Norma-Rashid et al 2001) as it is the largest dragonfly family in the world (Last & Whitman 1999-2000). Highest relative abundance of Anisoptera was observed in site 1 which is an open and disturbed habitat. These species often inhabit open and sunny environments like sites 1, 6, 8, 9 and 10. Remsburg et al (2008) reported that partial blocking of sunlight in an area directly reduces dragonfly habitat selection. It is typical in most Odonata studies that more Anisoptera species are recorded compared to Zygoptera. Families Libellulidae and Coenagrionidae are most represented. Based on the results, although dragonflies and damselflies are equal in species number, family Libellulidae of Suborder Anisoptera and family Coenagrionidae of Suborder Zygoptera represented both by nine species were the most dominant. For instance, Costa et al (2000) reported that in São Paulo State, around 50% of the species collected belong to family Libellulidae. Sharma et al (2007) have affirmed that family Libellulidae is the most dominant consisting of 15 genera during their Odonata study in Southern India. In the Philippines, the recent study of Quisil et al (2013) showed that 41% of the species collected belong to family Libellulidae. Villanueva (2010 and 2011a) found that in Polilo Island and Diomabok Lake (Davao Oriental), Family Libellulidae comprises most of the Odonata species surveyed followed by family Coenagrionidae. The next abundant family is Coengarionidae with about 1,100 species, constituting 57% of all damselfly species (Dijkstra & Kalkman 2012). One reason for this pattern is associated with the body size of the species of family Libellulidae which is commonly large and bulky which increases alertness and contributes to wide range distribution (Dalzochio et al 2011). The rest of Odonata families represented by one or two species in this study constitute some of the rare species. Shelton & Edwards (1983) stated that more individuals are composed by common species than rare species.

In this study, Site 1 (Bemposa Stream) had the highest relative abundance of Oriental species (68.51%) among the 12 sites suggesting that the sampling site is highly disturbed. Most of these Oriental species are anisopterans. Site 1 had only four (27%) endemic species (*D. bolivari, R. colorata, R. fuligifrons,* and *P. integra*). This very low endemism could be attributed to many sunny patches on the streams since the bank-side vegetation is dominated by bamboo thickets. The stream is more open and warmer because of the disappearance of overhanging branches (Dijkstra & Lempert 2003).

Site 2 (Cabilinan Stream) had the highest species richness and endemism (50%). Evergreen canopy cover is enough to support endemic species (Subramanian et al 2008). The site had also the least relative abundance of Oriental species (35.33%). This could be due to the shading, vegetation-type, and natural spring waters (Schridde & Suhling 1994). This is also the smallest stream among the three sampling sites where bank-side is loaded with detritus. It is concluded in the study of Dijkstra & Lempert (2003) that sunlight in small streams only reaches the water in a few sunspots making the water system cooler which is favorable to Odonata. These diversely structured microhabitats facilitate the existence of endemic species (Dijkstra & Vick 2004). This is also in consonance with the view of Mac Arthur (1965) who stated that the adjustment in species abundance is more in diversified ecosystem.

Site 3 (Lantungan Stream) had the highest relative abundance (15.95%) with 129 individuals of which eight species are endemic (42%). This relatively low endemism may be due to open and warmer watercourses caused by extensive elimination of trees in the

area. The least abundant species was *D. bolivari* with 0.78% relative abundance (1 individual). This species is considered to be Philippine endemic but it has wide distribution range throughout Philippines. The most abundant species in this site was *P. p. pilidorsum* with 19 individuals. The abundance of this species is attributed to its adaptive behavior to open, disturbed habitats. This species is often found breeding in strongly acidic water rather than in more neutral water (Dolny et al 2011).

Sites 6 (Inroad Stream), 8 (Tabuan Stream), 9 (Tinotongan Stream) and 10 (Alindahaw Stream) had also considerably high number of Anisopterans. Clausnitzer (2003) reported that with increasing freshwater width and more light penetrating tree canopy, the number of dragonfly species rapidly increases. The presence of more dragonflies might be due to less shade cover. Anisopterans are naturally much stronger fliers than damselflies (Sanchez-Herrera & Ware 2012). Remsburg et al (2008) observed that compared to sites with no shade, dragonfly abundance is lower at sites with high or moderate shade cover. The presence of shade cover and aquatic vegetation favors Zygopteran population more than Anisoptera (Arulprakash & Gunathilagaraj 2010). This contributes to the high number of dragonflies than damselflies in the areas.

Argiocnemis r. intermedia and *P. microcephalum* were encountered in singleton (represented by 1 individual). The occurrence of one individual of *P. microcephalum* is surprising since this is a common and dominant species (Ngiam 2009) and favors areas with enough shade cover. *P. microcephalum* was found in Sites 6 and 11 where vegetation was healthy and far from any human stress disturbance. Canopy trees were also abundant. *A. r. intermedia* was collectively rare and found only in Site 7 (Baclay Stream). Villanueva (2010) surveyed Odonata in four undisturbed and suitable habitats in Polilo Island, Philippines and observed *A. rubescens intermedia* in three sampling sites with good vegetation.

Several surveys of Odonata were done in various parts of the Philippines. The most recent is that of Quisil (2013) who documented 49 species which include 23 Philippines endemic species in Lanuza and San Agustin, Surigao del Sur. Villanueva (2011b) found 42 new records of Odonata from Catanduanes Island and three of these are new species, raising the total of the known species of the island to 60. These species were sampled from 26 sites in Catanduanes Island. The total of 60 species with new species records and species that are new to science is significantly higher compared to species collected in this study. In the recent survey conducted by Villanueva & Cahilog (2012) in Tawi-Tawi, Sanga-Sanga and Jolo islands, 10 new species were found in Tawi-Tawi raising the total number of Odonata to 54. Three new species records were made for Sanga-Sanga raising the known number on that island to 34. Three species were recorded for the first time in Jolo raising the total number to 18. Villanueva & Mohagan (2010) recorded 31 species of Odonata with three new species in Mt. Hamiguitan Wildlife Sanctuary, Davao Oriental. High endemism of damselfly (94%) and low endemism of dragonfly (33.3%) were significantly noted. This percent endemism was based on five surveyed vegetation types in Davao Oriental and is higher compared to percent endemism of Odonata in the present study. However, more interesting species could be recorded in Zamboanga del Sur when more areas are explored.

Villanueva (2011a) also visited Siargao and Bucas Grande islands, northeastern part of Mindanao. Fifty-one species of Odonata were recorded for both islands: 47 species in Siargao and 24 species in Bucas Grande. Thirty seven species are new island records for Siargao Island while the 24 species recorded in Bucas Grande represent the first island records. Three species are new to science. The present record in Aurora, Tukuran and Lakewood, Zamboanga del Sur is lower compared to the survey results in Siargao and Bucas Grande islands. However, despite the limited sampled areas in Zamboanga del Sur, ten endemic species (*H. heterodoxa, G. kirschii, D. p. basilanensis, C. angustior, C. dinocerus, D. flavomaculata, D. krios, T. annamaijie, R. tendipes*, and *V. melania*) were found to be absent in Siargao and Bucas Grande islands.

Biodiversity indices. Moderate species diversity (Table 3) was recorded in all freshwater systems. A more or less even distribution was noted. The moderate species diversity is attributed to clean waterways and shady environments in some parts of

sampling sites. Branching permanent spring waters from the ground like in Cabilinan Stream also favors the existence of endemic Odonata (Djikstra & Vick 2004). The presence of spring waters creates diversified microhabitats for many species to inhabit (Sharma et al 2007) which generally yields higher species diversity (Sethy & Siddiqi 2007). Villanueva & Mohagan (2010) reported that the Odonata as a group has preference for dense forest, undisturbed vegetation, optimum temperature and presence of aquatic habitat.

Table 3

Species richness, diversity, and evenness of Odonata in the 12 sampling sites

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11	Site 12
Species Richness	15	22	19	8	10	13	13	9	8	7	10	14
Shannon-Weiner(H')	2.140	2.880	2.702	1.811	1.858	2.114	2.212	2.093	1.778	1.856	2.201	2.578
Evenness (E')	0.892	0.932	0.918	0.871	0.806	0.824	0.862	0.953	0.855	0.851	0.956	0.977

Species richness is greatly affected by the characteristics of freshwater system and its surroundings as it indicates what kind of species an area would inhabit. Species-rich environments may be possibly due to the number of microhabitats like sand, rocks and leaf litter permitting the establishment of a greater number of species that leads to a greater diversity (Dalzochio et al 2011). Besides, the size of the temporary water bodies determines the species richness and diversity of Odonata (Schindler et al 2003). Dolny et al (2011) reported that the type of habitats is a factor essential for the composition and assemblage of dragonfly and the range of species changed with the condition of habitats.

Similarity index. Table 4 shows species similarity in the 12 sampling sites. Sampling sites 1 and 2 have similarity index of 81%. Sites 1 and 3 have 88% similarity; sites 2 and 3 have 93% similarity. Sites 8 and 9 are also related in terms of distribution and abundance having similarity index of 82%. Sites 9 and 10 are closely related (93.3%) due to the disturbance and vegetation-type shared by the two since both streams are located adjacent to each other. Similar species are commonly Oriental. The presence of Oriental species mostly under Family Libellulidae in the 12 sampling sites could be due to their high adaptive ability to different habitats specifically open and degraded habitats. Shelton & Edward (1983) stated that common species have more individuals than rare species and have the ability to survive in existing environmental conditions.

Table 4

Similarity index values between sampling sites

Study areas	*Site 1*	*Site 2*	*Site 3*	*Site 4*	*Site 5*	*Site 6*	*Site 7*	*Site 8*	*Site 9*	*Site 10*	*Site 11*	*Site 12*
Site 1	---	81%	82%	52%	40%	71%	43%	50%	52%	36%	32%	28%
Site 2	81%	---	93%	47%	31%	57%	40%	39%	40%	28%	38%	39%
Site 3	82%	93%	---	52%	34%	63%	44%	43%	44%	38%	28%	30%
Site 4	52%	47%	52%	---	67%	57%	48%	71%	75%	53%	22%	18%
Site 5	40%	31%	34%	67%	---	52%	61%	74%	56%	47%	40%	17%
Site 6	71%	57%	63%	57%	52%	---	38%	64%	67%	60%	52%	22%
Site 7	43%	40%	44%	48%	61%	38%	---	71%	48%	40%	52%	37%
Site 8	50%	39%	43%	71%	74%	64%	71%	---	82%	75%	32%	9%
Site 9	52%	40%	44%	75%	56%	67%	48%	82%	---	93%	33%	9%
Site 10	36%	28%	38%	53%	47%	60%	40%	75%	93%	---	24%	0%
Site 11	32%	38%	28%	22%	40%	52%	52%	32%	33%	24%	---	25%
Site 12	28%	39%	30%	18%	17%	22%	37%	9%	9%	0%	25%	---

The sampling sites which are not similar with each other or are not related in terms of distribution and abundance were Site 12 (Lake Lakewood) and Site 10 (Alindahaw River) with similarity value of 0 suggesting unique species of Odonata in each site. These two sites have very different vegetation. Villanueva (2011b) reported that the weather and flood may affect the number of species. During the sampling in Alindahaw River, heavy rain was experienced and the water was very muddy indicating that the river experienced recent flood which resulted to a poor number of collected species. The 0 similarity value indicates that no species was shared by the two sites. This is because Site 10 has all the common species that are tolerant to disturbed habitats with no endemic species while Site 12 has 10 endemic species. Figures 2 and 3 are endemic species under suborder Anisoptera while figures 4-7 are endemic species under suborder Zygoptera.

Figure 2. *H. heterodoxa* Needham & Gyger, 1937 under Family Corduliidae.

Figure 3. *G. kirschii* Selys, 1878 under family Gomphidae.

Figure 4. *D. p. basilanensis* Laidlaw, 1934 under Family Amphipterygidae.

Figure 5. *C. angustior* Hämäläinen, 1989 under family Chlorocyphidae.

Figure 6. *R. tendipes* (Needham & Gyger, 1941) under Family Platycnemididae.

Figure 7. *D. flavomaculata* van Tol, 2005 under family Platystictidae.

Conclusions. High species richness (S = 22) was recorded in Cabilinan Stream while highest abundance was documented in Lantungan Stream (15.95%). Moderate diversity and a more or less even distribution in the 12 sampling sites were recorded. Low endemism (44%) in the sites sampled indicates that the sites are already disturbed and predominated by Oriental species. It is recommended that more field research and taxonomic work be conducted in other freshwater habitats in Zamboanga del Sur to build a complete database and to assess the conservation status of Odonata in the province.

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References

Amoroso V. B., 2007 Long-term biodiversity research programme for Mindanao, Philippines. Central Mindanao University, Musuan, Bukidnon, Philippines. Retrieved August 9, 2012 from www.klter.org/EVENTS/Conference99/doc/ Victor.htm.

Arulprakash R., Gunathilagaraj K., 2010 Abundance and diversity of Odonata in temporary water bodies of Coimbatore and Salem districts in Tamil Nadu. Journal of Threatened Taxa 2(8):1099-1102.

Asaithambi M., Manickavasagam S., 2002 Odonata of Annamalai University, Annamalainagar, Tamil Nadu, India. Zoos' Print Journal 17(2):704-706.

Bouchard R. W. Jr., 2004 Guide to aquatic invertebrates of the upper Midwest. Chapter 5, Odonata (Dragonflies and Damselflies). Water Resources Center, University of Minnesota, St. Paul, MN, pp. 65.

Clausnitzer V., 2003 Dragonfly communities in coastal habitats of Kenya: indication of biotope quality and the need of conservation measures. Biodiversity and Conservation 12:333–356.

Clausnitzer V., Kalkman V. J., Ram M., Collen B., Baillie J. E. M., Bedjanic M., Darwall W. R. T., Dijkstra K. D. B., Dow R., Hawking J., Karube H., Malikova E., Paulson D., Schütte K., Suhling F., Villanueva R. J., von Ellenrieder N., Wilson K., 2009 Odonata enter the biodiversity crisis debate: the first global assessment of an insect group. Biological Conservation 142(8):1864–1869.

Costa J. M., Machado A. B. M., Lencioni F. A. A., Santos T. C., 2000 [Diversity and Distribution of Odonata (Insecta) in the State of São Paulo, Brazil]. Publ Avul Mus Nac, Rio de Janeiro 80:3-28 [in Portuguese].

Dalzochio M. S., Costa J. M., Uchôa M. A., 2011 Diversity of Odonata (Insecta) in lotic systems from Serra da Bodoquena, Mato Grosso do Sul State, Brazil. Revista Brasileira de Entomologia 55:88–94.

Dijkstra K. D. B., Lempert J., 2003 Odonate assemblages of running waters in the Upper Guinean forest. Archiv für Hydrobiologie 157:397–412.

Dijkstra K. D. B., Kalkman V. J., 2012 Phylogeny, classification and taxonomy of European dragonflies and damselflies (Odonata): a review. Organisms Diversity and Evolution 12:209-227.

Dijkstra K. D. B., Vick G., 2004 Critical species of Odonata in western Africa. International Journal of Odonatology 7(2):229-238.

Dolny A., Bárta D., Lhota S., Rusdianto Drozd P., 2011 Dragonflies (Odonata) in the Bornean rain forest as indicators of changes in biodiversity resulting from forest modification and destruction. Tropical Zoology 24(1):63-86.

Dudgeon D., Arthington A. H., Gessner M. O., Kawabata Z. I. Knowler D. J., Lévêque C., Naiman R. J., Prieur-Richard A. H., Soto D., Stiassny M. L. J., Sullivan C. A., 2006 Freshwater biodiversity: importance, threats, status and conservation challenges. Biological Review 81(2):163–182.

Gapud V. P., 2003 Biodiversity and biogeography of Philippine Odonata and waterbugs (Hemiptera). Department of Entomology. Univ. of the Philippines, Los Baños. Animal Taxonomy and Geography. Retrieved from http://agris.fao.org/agris-search/search/display.do?f=2005%2FPH%2FPH0503.xml%3BPH2005000178.

Hämäläinen M., Müller R. A., 1997 Synopsis of the Philippine Odonata, with lists of species recorded from forty islands. Odonatologica 26(3):249–315.

Kalkman V. J., Clausnitzer V., Dijkstra K. D. B., Orr A. G., Paulson D., van Tol J., 2008 Global diversity of dragonflies (Odonata) in freshwater. Hydrobiologia 595:351–363.

Khrokalo L., Prokopov G., 2009 Review of the Odonata of Crimea (Ukraine). IDF-Report 20:1-32.

Last L. L., Whitman R., 1999-2000 Aquatic macroinvertebrates of the Grand Calumet River. Proceedings of the Indiana Academy of Science 108-109:45–81.

Mac Artur R. H., 1965 Pattern of species diversity. Biological Reviews 40:510-533.

Nelson B., Ronayne C., Thompson R., 2011 Ireland Red List No. 6: Damselflies & Dragonflies (Odonata). National Parks and Wildlife Service, Department of the Environment, Heritage and Local Government, Dublin, Ireland. pp. 4.

Ngiam R. W. J, 2009 The biology and distribution of *Pseudagrion rubriceps rubriceps* Selys, 1876 (Odonata: Zygoptera: Coenagrionidae) in Singapore. Nature in Singapore 2:209–214.
Norma-Rashid Y., Mohd-Sofian A., Zakaria-Ismail M., 2001 Diversity and distribution of Odonata (dragonflies and damselflies) in the fresh water swamp lake Tasek Bera, Malaysia. Hydrobiologia 459:135–146.
Oppel S., 2005 Odonata of the Crater Mountain Wildlife Management Area, Papua New Guinea. IDF-Report 7:1-28.
Palot M. J., Soniya V. P., 2000 Odonata of Keoladeo National Park, Bharathpur, Rajasthan, India. Zoos' Print Journal 15(8):317-320.
Paulson D., Schorr M., 2012 University of Puget Sound: World Odonata List. Word Excel. Retrieved from http://www.pugetsound.edu/academics/academic-resources/slater museum/biodiversity-resources/dragonflies/world-odonata-list/.
Remsburg A. J., Olson A. C., Samways M. J., 2008 Shade alone reduces adult dragonfly (Odonata: Libellulidae) abundance. J Insect Behav 21:460–468.
Sanchez-Herrera M., Ware J. L., 2012 Biogeography of dragonflies and damselflies: highly mobile predators. In: Global Advances in Biogeography. Stevens L. (ed), ISBN: 978-953-51-0454-4, InTech, DOI: 10.5772/33750. Retrieved March 19, 2013 from www.intechopen.com/books/global-advances-in biogeography/biogeography of-dragonflies-and-damselflies-the-highly-mobile-predators.
Schindler M., Fesl C., Chovanec A., 2003 Dragonfly associations (Insecta: Odonata) in relation to habitat variables: a multivariate approach. Hydrobiologica 497:169-180.
Schridde P., Suhling F., 1994 Larval dragonfly communities in different habitats of a Mediterranean running water system. Advances in Odonatology 6:89–100.
Sethy P. G. S., Siddiqi S. Z., 2007 Observations on Odonates in Similipal Biosphere Reserve, Mayurbhanj, North Orissa. Zoos' Print Journal 22(11):2893-2894.
Sharma G., Sundararaj R., Karibasvaraja L. R., 2007 Species diversity of Odonata in the selected provenances of Sandal in southern India. Zoos' Print Journal 22(7):2765-2767.
Shelton M. D., Edwards C. R., 1983 Effects of weeds on the diversity and abundance of insects in soybeans. Environmental Entomology 12(2):296-298.
Subramanian K. A., Ali S., Ramachandra T. V., 2008 Odonata as indicators of riparian ecosystem health a case study from South Western Karnataka, India. Fraseria 7:83-95.
Thomas C. D., Cameron A., Green R. A., Bakkenes M., Beaumont L. J., Collingham Y. C., Erasmus B. F. N., de Siqueira M. F., Grainger A., Hannah L., Hughes L., Huntley B., van Jaarsveld A. S., Midgley G. F., Miles L., Ortega-Huerta M. A., Peterson A. T., Phillips O. L., Williams S. E., 2004 Extinction risk from climate change. Nature 427:145-148.
Villanueva R. J., 2010 Dragonflies of Polillo Island, Philippines. International Dragonfly Fund-Report 23:1-24.
Villanueva R. J., 2011a Odonata of Siargao and Bucas Grande Islands, The Philippines. International Dragonfly Fund-Report 34:1-25.
Villanueva R. J., 2011b Odonata fauna of Diomabok Lake and its surroundings, Davao Oriental, Mindanao Island, Philippines. International Dragonfly Fund–Report 38:1-29.
Villanueva R. J., Mohagan A. B., 2010 Diversity and status of Odonata across vegetation types in Mt. Hamiguitan Wildlife Sanctuary, Davao Oriental. Asian Journal of Biodiversity 1(1):25-35.
Villanueva R. J., Cahilog H., 2012 Notes on a small Odonata collection from Tawi-Tawi, Sanga-Sanga and Jolo islands, Philippines. International Dragonfly Fund-Report 55:1-32.
Villanueva R. J., Weerd M. V., Cahilog H., 2012 Odonata recorded in February 2012 in Isabela and Aurora Provinces, Luzon Island and Polillo Island, Philippines. International Dragonfly Fund-Report 49:1-42.

*** National Geospatial-Intelligence Agency, 2010 Tukuran River: Philippines. Retrieved from www.geographic.org/geographic_names/name.php?uni=-3385323&fid=4962&c= Philippines.

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