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Species diversity of adult odonata in selected areas of Lanao Del Sur, Philippines

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Abstract

Odonata (dragonfly and damselfly) plays an important role in the ecosystem. It is considered an indicator group in determining fluvial habitat status. Field work in selected areas in Lanao del Sur was conducted to determine the Odonato fauna present in the area. Adult Odonata samples were collected using sweep netting and hand-picking methods from four sampling sites. Biodiversity indices, similarity index, and canonical correspondence analysis were determined using Paleontological Statistics Software Package (PAST) version 2.17c. Twenty-one species (10 damselflies and 11 dragonflies) were documented with relatively low endemism of 42.86%. High relative abundance of 37.28% was observed in site 4. Sites 1 and 3 were observed to have high species diversity while sites 2 and 4 had moderate species diversity. There was a more or less even species distribution in the areas sampled. Dominance of *Pseudagrion pilidorsum pilidorsum* was recorded in Marawi City. Canonical correspondence analysis showed that environmental factors such as elevation, air temperature and relative humidity affect the abundance of species. It appears that human-induced activities limit the occurrence and abundance of the Odonata, especially the endemic species.

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Introduction

Order Odonata (dragonflies and damselflies) is considered as one of the most successful and beautiful insects that ever roamed in the Earth (Sharma *et al*., 2007). These common freshwater-associated organisms (Suhling *et al*., 2003) are dominant invertebrate predators in any ecosystem (Sharma *et al*., 2007). According to Reece and McIntyre (2009), because of the amphibious life history, relatively short generation time, high trophic position, and diversity of Odonata, it is considered as a 'flagship' indicator group (Sharma *et al*., 2007). It has become one of the most used aquatic insect groups in ecological quality assessment (Gómez-Anaya and Novelo-Gutiérrez, 2010). Golfieri *et al.* (2012) believe that Odonata offers more complete evaluation of ecological quality of destruction of fluvial and terrestrial conditions due to its sensitivity to changes in the environment, atmospheric temperature, and the weather conditions (Quisil *et al*., 2013), a true "guardian of the watershed" as Clausnitzer and Jödicke (2004) tagged. Because of this, several studies were published on their diversity (Cleary *et al*., 2004; Sharma *et al*., 2007; Fulan *et al*., 2008; Das *et al*., 2012), distribution (Gómez-Anaya *et al*., 2011; Dalzochio *et al*., 2011; Mamat *et al*., 2012; Willigalla and Fartmann, 2012), and dispersal (McCauley, 2006).

Das *et al.* (2012) reported that there is a total of 5, 740 Odonata species known globally. Majority of these species occur in the tropics, of which, 12 of the 31 families are known to inhabit mainly in this region. Highest diversities in the Neotropical and Oriental regions were recorded, with about 1,650 species each (Kalkman *et al*., 2008).

Vedra *et al.* (2013) reported that the Philippines' inland waters like lakes and rivers have relatively high biodiversity. A high number of Odonata endemic species has been accounted (Hämäläinen, 2004). Kalkman *et al.* (2008) also stated that there are more than 60% named endemic species in the country. Series of fieldworks were conducted and most of the time, new species are being recorded (Villanueva, 2011; Villanueva and Gil, 2011; Villanueva *et al*., 2012). According to Jumawan *et al.* (2012), records of new species are usually from poorly explored regions in Mindanao. Recent surveys include the area of Davao Oriental (Villanueva and Mohagan, 2010) and Iligan City and Lanao del Norte where 26 species with 35% endemism were documented by Aspacio *et al.* (2013). Quisil *et al.* (2014), Jomoc *et al.* (2013), and Mapi-ot *et al.* (2013) also recorded relatively low endemism in Surigao del Sur; Cagayan and Bukidnon and Misamis Occidental, Philippines, respectively. Nevertheless, Quisil *et al.* (2013) noted a higher number of species (49) in Lanuza and Agustin, Surigao del Sur, Philippines of which two species are new records for the island. Despite many studies that had been conducted, some areas are still poorly surveyed and this includes the province of Lanao del Sur.

Lanao del Sur, houses Lake Lanao, the second largest lake in the Philippines, located in high altitude in Mindanao and an ideal area for several fauna to breed and prosper especially Odonata. However, due to the peace and order situation, surveys for Odonata and other fauna are rarely conducted and at times, poorly established. The first Odonato fauna record of Lanao del Sur was documented by Malawani *et al.* (2014) which are limited to two municipalities. Results displayed more or less relatively low endemism (50%) with 46 species. The present paper is designed to provide additional record of Odonata in Lanao del Sur. This study would provide initial records of selected areas in the province. The present study aimed to determine the species composition, endemism, abundance and diversity of Odonata in selected areas in Lanao del Sur, as well as to determine the effect of selected physical parameters on the abundance of the species.

Materials and methods

Study area

The province of Lanao del Sur (Fig. 1) has an elevation of 702 meters above sea level (masl) and bounded on the east by Bukidnon, on the south by

Maguindanao and North Cotabato, on the west by Illana Bay and on the northwest, by the Province of Lanao del Norte. Four sampling sites were established. Sites visited were: (1) Barit Stream, Balindong, Lanao del Sur; (2) upstream of Calanogas waterfall, Calanogas, Lanao del Sur; (3) Mataling Spring, Malabang, Lanao del Sur; and (4) Upstream of Bliss River, Marawi City, Lanao del Sur.

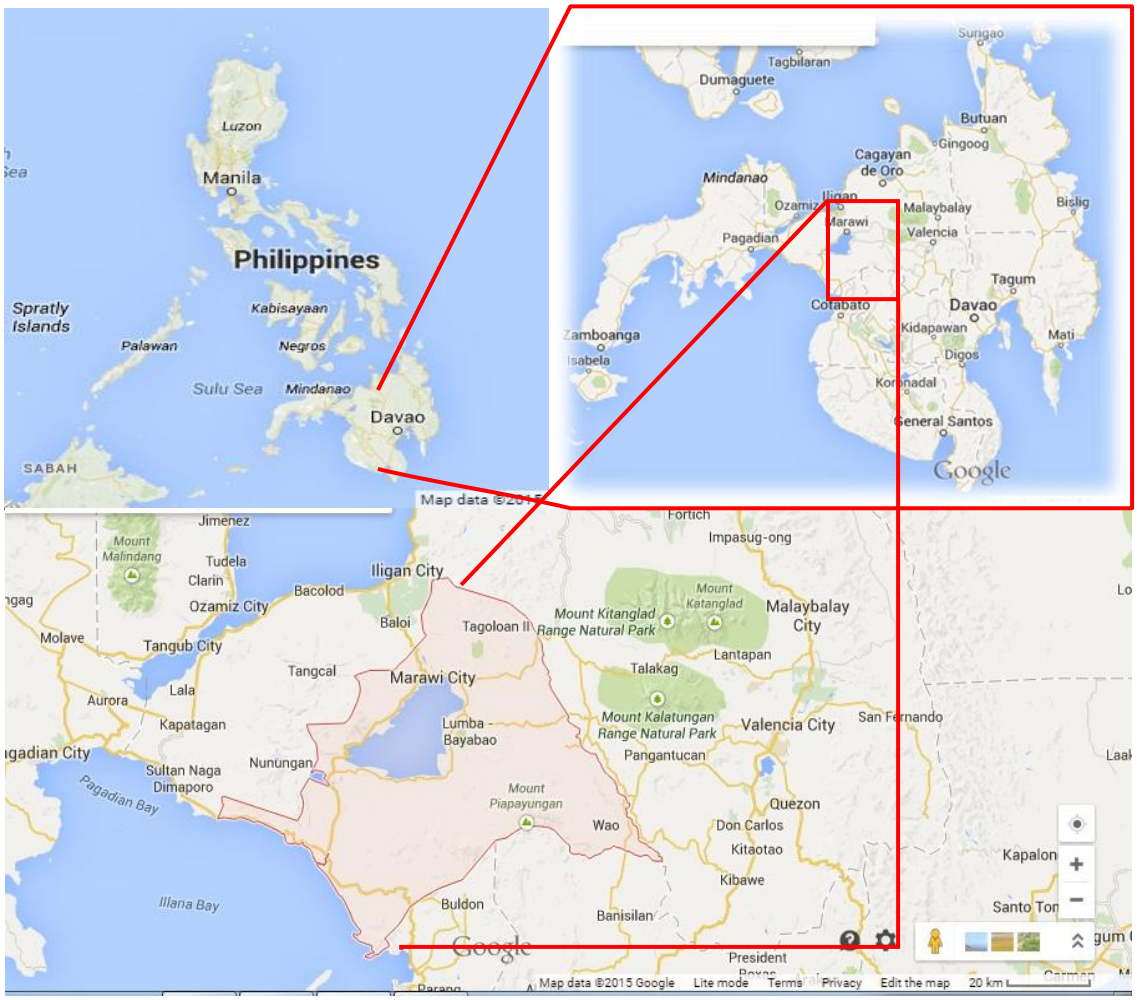

Fig. 1. Map of the Philippines showing the province of Lanao del Sur [Highlighted in red] (https://www.google.com.ph/maps, 2015).

Sampling sites

Sampling site 1 is a stream located in Barangay Barit, Balindong, Lanao del Sur (7°90'7885" N and 124°19'7137" E) with an undulating slope and disturbed vegetation. Narra (*Pterocarpus* sp.), coconut (*Cocos nucifera*), bamboo (*Bambusa spinosa*), banana (*Musa* sp.), ferns, and sun flowers were observed in this site. "Gabi-gabi" (*Colocasia esculenta*) was moderately present. Soil was moderately covered with leaf litter and carabao grass (*Paspalum conjugatum*) was abundant in the area. The water is clear and it serves as the only water source that each household uses. The stream is a permanent water system which originates from the upper part of the mountain and situated 40-60 meters away from the farm lands.

Sampling site 2 is the upstream of Calanogas waterfall (7°72'58" N and 124°07'66" E). This site has an undulating slope with secondary vegetation type. Bamboo (*Bambusa spinosa*) and grasses were observed to be abundant. The stream is approximately 2-3 m wide and has 1-1.5 m depth. It has a moderate current flow. Exposed big-sized rocks

were moderately present. The stream is 6-10 m from the road and 30 m away from the agricultural lands of the residents.

Sampling site 3 is a spring located at Spencer Tree Park and Wildlife Sanctuary in Barangay Mataling, Malabang, Lanao del Sur (7°63'80" N and 124°04'18" E). It is a secondary forest with flat slope. "Gabi-gabi" (*Colocasia esculenta*), ferns, and wild berries were found moderately covering the land. Bamboo (*Bambusa spinosa*) and fallen logs were moderately present. Soil was covered with 2 cm depth of humus and 10 cm depth of leaf litter. Water flowing in the spring naturally rises from the ground. The spring is 20-30 meters away from a factory and is a laundry site for the nearby residents.

Sampling site 4 is a part of Agus River and serves as a boundary of two barangays, Barangay Lilod and Barangay Bliss in Marawi City, Lanao del Sur (08°01'509" N and 124°29'718" E). The site is a secondary forest with mountainous slope. Mango (*Mangifera indica)*, coconut (*Cocos nucifera*) and banana (*Musa* sp.) as well as bamboo (*Bambusa spinosa*) were observed at the sides of the river. Big-sized rocks were observed exposed in this 8-15 wide river. The river serves as the laundry and swimming site for the residents. Water buffaloes were observed wallowing in the shallow portion of the river.

Collection, processing of samples, and data analysis

Adult Odonata were collected using sweep netting and hand-picking methods. Samples were stored in a white triangle paper with its wings folded over the back (Mapi-ot *et al.*, 2013) and placed in a closed plastic container. Photo-documentation was also done in the field as well as habitat assessment. Air temperature and relative humidity were recorded.

Odonata samples were suffocated using ethyl acetate immersed in cotton for five minutes. Specimens were submerged in acetone for preservation, 12 hours for damselflies and 24 hours for dragonflies (Quisil *et al.*, 2014). Acetone was used to extract fat and water from the specimens (Mapi-ot *et al.*, 2013). Preserved specimens were placed in another triangle paper and put in a plastic container with naphthalene balls to prevent the entry of other insects (Quisil *et al.*, 2014). Identification of species was done by the third author.

Biodiversity indices, cluster analysis, and the canonical correspondence analysis (CCA) were obtained using Paleontological Statistics Software Package (PAST) version 2.17c while relative abundance was calculated manually.

Cluster Analysis based on Ward's Method was performed to compare the faunal similarities (Gómez-Anaya *et al.*, 2011) among the sites. This approach does not combine the two most similar objects successively. Instead, those objects whose merger increases the overall within-cluster variance to the smallest possible degree are combined (Mooi and Sarstedt, 2011). Canonical correspondence analysis (CCA) was used to relate transformed species abundance to environmental variables (Gómez-Anaya *et al.*, 2011). Environmental variables used were elevation, temperature, and relative humidity.

Results and discussion

Species Composition, Endemism, Abundance

Twenty-one species of Odonata belonging to six families with a total of 218 individuals were recorded of which 11 species were under sub-order Anisoptera (Dragonfly) and 10 species were under sub-order Zygoptera (Damselfly) (Table 1). The six families identified were Families Libellulidae, Calopterygidae, Chlorocyphidae, Coenagrionidae, Platycnemididae, Protoneuridae

Family Libellulidae and family Coenagrionidae appeared to have the most number of species identified. Studies by Jomoc *et al.* (2013), Mapi-ot *et al.* (2013) and Quisil *et al.* (2013) also found similar results. Kalkman *et al.* (2008) reported that both families Coenagrionidae and Libellulidae belong to the four largest families of Order Odonata. According to Mamat *et al.* (2012), these two families are

dominants of unshaded habitats in stagnant waters. Of the 1084 species of family Coenagrionidae and 1012 species of family Libellulidae identified worldwide, 185 species of family Coenagrionidae and 190 of family Libellulidae are oriental species. According to Mapi-ot *et al.* (2013), oriental species are most likely found in disturbed areas. Site 1 (Balindong) had the highest recorded species richness of 14 of which 10 are oriental species. High number of oriental species can be attributed to the presence of agro-ecosystem in the area. Villanueva and Mohagan (2010) reported that agro-system has the highest disturbance of 83% and that utilization of water resources for agricultural production implies that this habitat is disturbed or modified for human use. The higher species richness in the dipterocarp forest than in modified habitats and agro-ecosystem indicates that the Odonata prefers forested and undisturbed areas (Malawani *et al.*, 2014). Despite being relatively disturbed, site 1 still hosts 44.44% of the endemic species recorded.

The present study serves as the first record of Odonatofauna for Calanogas (Site 2), Malabang (Site 3) and Marawi City (Site 4), but second in the province of Lanao del Sur. All 21 species identified are present in the previous Odonata record of Lanao del Sur done by Malawani *et al.* (2014). Overall endemism (42.86%) is relatively lower compared to the first record of Lanao del Sur. The sites explored in this study are no longer pristine, which explains the lower endemism. However, the endemism is relatively higher than that of Aspacio *et al.* (2013) in Iligan City and Lanao del Norte which are more disturbed areas.

The highest endemism (55.55%) was recorded in Site 2. Despite their wide range, the endemic species, *Vestalis melania*, *Rhinocypha turconii, Risiocnemis tendipes*, and *Diplacina bolivari* were only recorded in this site. Highest percentage of endemism may be due to shading, vegetation-type, and natural spring waters (Schridde and Suhling, 1994) of the site. Moreover, anthropogenic activities were less observed due to the undulating slope.

Lowest relative abundance (11.84%) and species richness were observed in site 3 even if the site is situated in a shaded secondary forest, a good habitat for Odonata. The presence of a factory in the area and the water system which is used as bathing and laundry site may be responsible for this low record. Siregar *et al.* (2006) stated that the richness of the community is generally limited to those groups of species which could adapt to the habitat.

Table 1. Species richness, relative abundance, and distribution of Odonata in four sampling sites.

Species Name	Distrib-ution Status	Distribution in Selected Areas in Lanao del Sur				Total
		Site 1 (Balindong)	Site 2 (Calanogas)	Site 3 (Malabang)	Site 4 (Marawi)	
SUB-ORDER ANISOPTERA						
Family Libellulidae						
Crocothemis servilia servilia	OS	1 (1.43)	-	-	-	1
Diplacina bolivari	PES	-	5 (10.87)	-	-	5
Diplacina braueri	PES	1 (1.43)	-	4 (14.81)	5 (5.88)	10
Diplacodes trivialis	OS	21 (30)	-	-	-	21
Neurothemis r.ramburii	OS	17 (24.29)	1 (2.17)	2 (7.41)	9 (10.59)	29
Orthetrum pruinosum clelia	OS	5 (7.14)	1 (2.17)	4 (14.81)	2 (2.35)	12
Orthetrum sabina sabina	OS	11 (15.71)	-	-	2 (2.35)	13
Orthetrum t. testaceum	OS	3 (4.29)	-	-	-	3
Pantala flavescens	C	1 (1.43)	-	-	-	1
Tholymis tillarga	OS	1 (1.43)	-	-	-	1

Species Name	Distrib-ution Status	Distribution in Selected Areas in Lanao del Sur				Total
		Site 1 (Balindong)	Site 2 (Calanogas)	Site 3 (Malabang)	Site 4 (Marawi)	
Trithemis aurora	OS	-	1 (2.17)	4 (14.81)	1 (1.18)	6
SUB-ORDER ZYGOPTERA						
Family Calopterygidae						
Vestalis melania	PES	-	10 (21.73)	-	-	10
Family Chlorocyphidae						
Rhinocypha colorata	PES	1 (1.43)	7 (15.21)	5 (18.52)	7 (8.24)	20
Rhinocypha turconii	PES	-	4 (8.69)	-	-	4
Family Coenagrionidae						
Agriocnemis femina femina	OS	-	-	-	9 (10.59)	9
Agriocnemis rubescens	OS	1 (1.43)	-	3 (11.11)	-	4
Ceriagrion lieftincki	PES	4 (5.71)	-	-	-	4
Pseudagrion p. pilidorsum	OS	2 (2.86)	16 (34.78)	4 (14.81)	50 (58.82)	72
Teinobasis annamaijie	PES	1 (1.43)	-	-	-	1
Family Platycnemididae						
Risiocnemis tendipes	PES	-	1 (2.17)	-	-	1
Famiy Protoneuridae						
Prodasineura integra	PES	-	-	1 (3.70)	-	1
Total number of individual species		**70 (30.70)**	**46 (20.18)**	**27 (11.84)**	**85 (37.28)**	**228**
Total number of species		**14**	**9**	**8**	**8**	**21**
Total number of endemic species		**4**	**5**	**3**	**2**	**9**

Legend: ( ) Relative Abundance in percentage, CS -Circumtropical Species, PES–Philippine Endemic Species, and OS–Oriental Species.

Despite low species richness and endemism, site 4 had the highest relative abundance (37.28%) with 85 individuals of which only two species, *Diplacina braueri and Rhinocypha colorata*, are endemic (25%). Relatively low endemism could be associated with the warm air temperature (average: 28°C) and high humidity (average: 93%) since insects are very sensitive to the variation of these two abiotic factors. Fazal *et al.* (2012) stated that temperature and humidity, limit the reproduction and development of insects. *Pseudagrion pilidorsum pilidorsum* was observed abundant in this site with 50 individuals. Villanueva (2009) also found this species abundant in eight sites in Babuyan and Batanes group of Islands. The species' unique breeding characteristic was observed by Drozd *et al.* (2011) and reported to breed in strong acidic water rather than in more neutral water. Thus, this characteristic significantly benefits the richness and survival of this species.

Biodiversity indices

The Shannon's Diversity index classifies the area to have low diversity if the index value is below 1, moderate if between 1 and 2, and high diversity if the value is greater than 2. High species diversity (Table 2) was observed in sampling sites 1 and 3 while moderate species diversity was recorded in sites 2 and 4.

Highest species diversity (H' = 2.009) was recorded in Site 1. High number of Oriental species was present in this site. This suggests that the area is relatively disturbed. Malawani *et al.* (2014) stated that species diversity is affected by the type of environment and the characteristics of freshwater systems the organism inhabits.

Site 3 had the most even distribution. Evenness value is influenced mainly by the competition of species for food and territory within an area (Malawani *et al*., 2014). Hence, competition of species in this site is less compared to other sites. Low evenness value (E = 0.5012) and high dominance value (D = 0.3799) in Site 4 are due to the high abundance of *Pseudagrion p. pilidorsum*.

Table 2. Biodiversity indices in four sampling sites.

Biodiversity Indices	Sampling sites in Lanao del Sur			
	Site 1 (Balindong)	Site 2 (Calanogas)	Site 3 (Malabang)	Site 4 (Marawi)
Species Richness	14	9	8	8
Shannon's Diversity (H')	2.009	1.889	2.003	1.389
Dominance (D)	0.1861	0.1775	0.1413	0.3799
Evenness (E)	0.5327	0.735	0.9263	0.5012

Similarity index

Fig. 2 shows the dendrogram of cluster analysis using Ward's Method in PAST: Paleontological Statistics Software Package bootstrapped 1000 times for robustness (Jomoc *et al*., 2013). The results revealed that the Odonatofauna of Malabang was similar to that of Calanogas while Marawi City appears to have distant community structure. Geographical distance could be responsible for shaping the community structure of Odonata. Malabang and Calanogas are situated close to each other while Marawi City is situated farther away. According to Harabiš and Dolný (2010), the habitat specificity of each species is classified according to its niche breadth.

Calanogas and Malabang, Lanao del Sur had the most similarities (75%). This means that these areas share almost the same species. These species appear to prefer shaded secondary forest. Hence, the nature of the microhabitat is a possible reason for this assemblage. According to Schwéger and Galle (2014), shading is important because it affects microclimatic conditions of the forest floor. Villanueva and Mohagan (2010) reported that abundance of Odonata is affected by dense forest, undisturbed vegetation, optimum temperature, and presence of aquatic habitat.

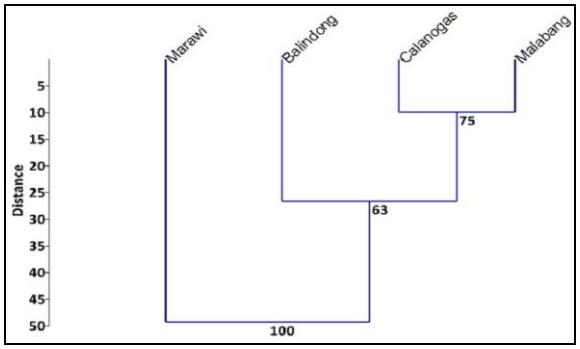

Fig. 2. Cluster analysis showing the similarity of four sites based on Ward's Method (Bootsrap N = 1000).

The low site similarity of Marawi City (site 4) from other sites could be due to disturbance present in the area. Marawi City is the capital and the only city found in Lanao del Sur. It serves as the center of trade in the province. Thus, it is highly urbanized. According to Willigalla and Fartmann (2012), urbanization has a harmful effect on the species diversity of Odonata. In consequence, species richness from the center of a city is significantly low compared to rural areas.

Canonical correspondence analysis

Table 3 shows the altitude, air temperature, and relative humidity values recorded from the four sampling sites. The sites are all located at low elevation with the lowest elevation of 74.786 masl (site 3). Lowest air temperature recorded was 25°C in site 2 and the highest air temperature was 28.83°C in

site 3. High relative humidity was observed in all sites but highest relative humidity was recorded in sites 4 and 2 (93%). Khaliq *et al.* (2014) reported that the insects' life cycle greatly depends on temperature as it can affect the insects' internal metabolic activities.

Table 3. Altitude, mean air temperature, and relative humidity in four sampling sites in Lanao del Sur.

Sampling Sites	Altitude (masl)	Air Temperature (°C)	Relative Humidity (%)
Site 1 (Balindong)	600	26	83
Site 2 (Calanogas)	684.139	25	93
Site 3 (Malabang)	74.786	28.83	59
Site 4 (Marawi)	800	28	93

Fig. 3 shows the effect of air temperature, relative humidity and elevation on the abundance of species in different sampling sites. Gómez-Anaya *et al.* (2011) proved through CCA that environmental factors are correlated to the abundance of Odonata species. It can be seen that the abundance of five species, *P. integra*, *A. rubescens*, *T. aurora*, *D. braueri* and *O. p. clelia* in site 3 are positively affected by air temperature but negatively affected by elevation and humidity. Highest air temperature (28.83°) was recorded in site 3. This means that these species have high tolerance to high temperature. However, species richness of these species is limited by elevation and humidity as it showed negative relationship. Harabiš and Dolný (2010) reported that Odonata species that occur in a wide range of habitats prefer low altitudes and therefore never occupy all of the potentially suitable freshwater habitats which are according to their habitat specificity. In contrast to this, abundance of species in site 2 is positively affected by humidity and elevation. Species positively affected by these factors include: *C. s. servilia, D. bolivari, D. trivialis, N. r. ramburii, O. s. Sabina, O. t. tescaceum, P. flavescens, T. tillarga, V. melania, R. colorata, R. turconii, T. annamaijie* and *R. tendipes* but, negatively affected by air temperature. Average temperatures close to or below the developmental threshold retard development and in many cases increase mortality (Savopoulou-Soultani *et al.*, 2012).

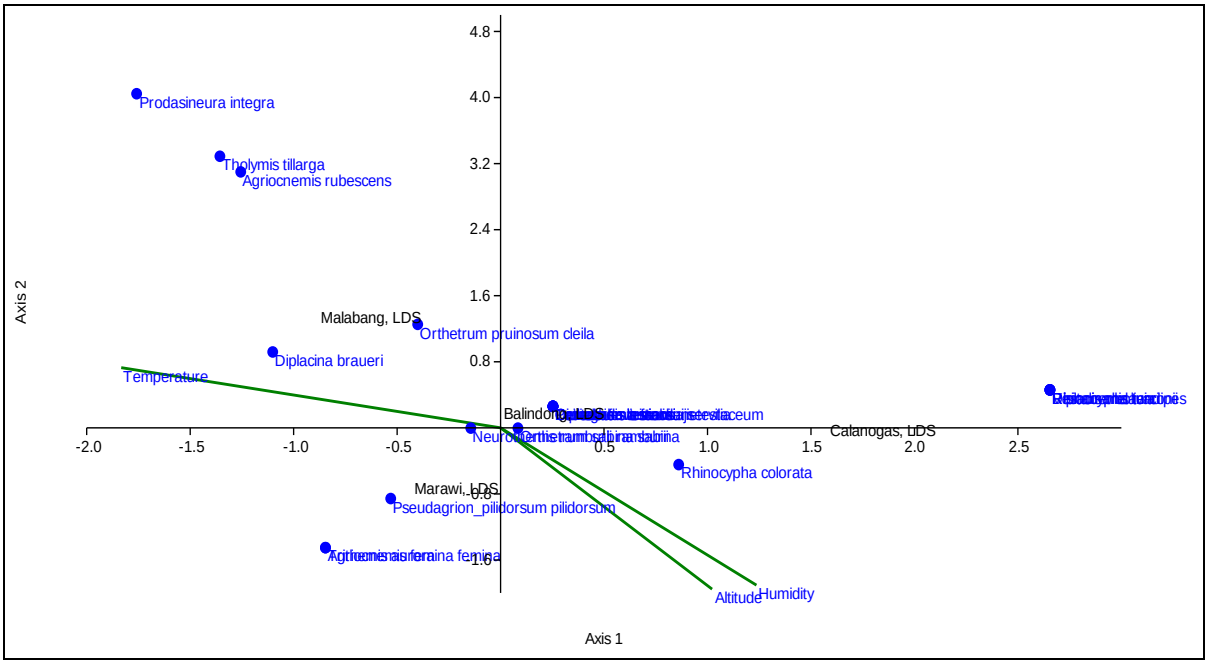

Fig. 3. Ordination diagram showing three environmental factors: temperature, relative humidity and elevation (Eigen values of axis 1 = 0.50809; axis 2 = 0.2876; axis 3 = 1.0888E- 06).

Furthermore, it can be seen in the fig. that two oriental species, *A. f. femina and P. p. pilidorsum,* are not directly affected by these environmental factors. These two species are known to be one of those highly adapted species in any environmental changes. High relative abundance of this species was observed in Marawi City (site 4) which is an urbanized area.

Conclusion

Low species richness (21 species) and low endemism (42.86%) in the selected areas in Lanao del Sur indicate that the sampling sites are already disturbed areas. Sites 1 and 3 have high species diversity while sites 2 and 4 have moderate species diversity. All sites have a more or less even distribution of species. Malabang (site 3) and Calanogas (site 2) appear to have similar community structure. Environmental factors such as air temperature, relative humidity and altitude ranges more or less affect the distribution and abundance of Odonata.

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