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Records of Odonata in the Riparian System of Andanan Watershed Forest Reserve, Philippines

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A B S T R A C T

The Odonata fauna is a good biological indicator of freshwater ecosystems. This research aims to provide a record inventory of both dragonflies and damselflies occurring in the riparian ecosystem of Andanan Watershed Forest Reserve. Field collection using sweep nets was done in three locations along the riparian area. Odonatans (n=79) were recorded belonging to 19 species, comprising 58% dragonflies and 42% damselflies. Out of 19 species recorded in the area, one species of dragonfly and six species of damselfly are endemic to the Philippines, with 36.84% endemicity in the area. All dragonflies documented are ground skimmers with a high tolerance for anthropogenic disturbances in freshwater systems. The genus *Orthetrum* Newman, 1833 is relatively abundant and obtained the highest number of species. On the other hand, the genus *Euphaea* Selys, 1840 in damselflies, was recorded to have the highest abundance. The genus *Risiocnemis* Cowley, 1934 has the highest species richness. All species of *Risiocnemis* were also reported endemic. Despite the high diversity (H'=2.77; H'/H_{max}=0.94) of the Odonata fauna in Andanan Watershed Forest Reserve, human activities and intervention were still observed around the riparian ecosystem. The results shown in the current study may be utilized as primary information to allow local conservation efforts for odonatans found in the watershed and its tributaries.

Keywords: *dragonfly, damselfly, riparian, forest reserve*

1 Introduction

Odonata is a group of insects that includes dragonflies (suborder Anisoptera) and damselflies (suborder Zygoptera) and play an essential role in the environment as they are excellent bioindicators in the freshwater ecosystem (Watson et al. 1982; Corbet 1990; Brown 1991). Dragonflies are generally broader, with wings that are perpendicular to their body while resting and demonstrate an agile movement when flying, whereas damselflies are slender and hold their wings parallel to their body with a fluttering motion when in flight (Corbet 1980; Stoks & Cordoba-Aguilar 2012; Vilela et al. 2017).

In the Philippine archipelago, approximately 300 species of Odonata are known, and about 43% of these species are found on Mindanao Island (Hamalainen & Muller 1997). As an ecological indicator, Odonata is extensively studied in environmental and evolutionary research (Cordoba-Aguilar 2008). Most species are considered essential subjects to ecological studies and significant role players in overall biodiversity conservation (Samways & Taylor 2004; Samways 2008). Odonata are good indicators of ecosystem health and can be used to assess the impact of human disturbance and the effectiveness of conservation efforts in the area (Jumawan et al. 2012). Also, they are highly distributed in diverse ecological niches despite their sensitive ability to changes in habitat structure (Clausnitzer 2004;

Schindler et al. 2003). Odonata were reported to prefer dense forests and undisturbed vegetation, with favorable temperatures and aquatic habitat (Villanueva & Mohagan 2010; Quisil et al. 2013).

The Andanan Watershed Forest Reserve is located along the town of Sibagat and Bayugan City. According to the Department of Environmental and Natural Resources – Caraga Region, the forest reserve is within the Diwata Mountains. According to Abell (2002), area-sensitive species with substantial spatial requirements are increasingly used to establish size limits for reserves that protect other biodiversity features. However, little is known regarding the amount and quality of habitat these area-sensitive species require to survive. Many forest reserves and protected areas in Mindanao, like Andanan Watershed in Agusan del Sur, received little attention on the possible exploration of insect fauna, particularly Odonata, despite its potential value for watershed management practices. These aquatic insects have not yet been studied in the area, and there are only limited published studies of Odonata in Mindanao, particularly in the Caraga Region. As such, there is a need to study the Odonata fauna present in Andanan Watershed Forest Reserve's riparian system to assess the various occurring taxa.

2 Materials and Methods

The Study Area

Three collection sites were established in the riparian system of Andanan Watershed Forest Reserve (Fig. 1), with a two-km transect walk in each area to collect Odonata. These sites are represented by three barangays which are Calaitan (8.7927°N, 125.7789°E; 209.1 masl), Berseba (8.8552°N, 125.8007° E; 219.7 masl), and Santo Niño (8.8451°N, 125.7871°E; 261.7 masl), that are interconnected with various tributaries along Andanan river. The field expedition was conducted during July, August, and September 2019. The ocular observation was documented in photos and videos using a digital camera. At the same time, coordinates of the location and the elevation were determined using Global Positioning System (GPS) device. Other essential remarks while on the field were also recorded.

The collection was done in open streams with wide spacious areas along the riparian zone. The stream and its tributaries were about two to ten m wide, ranging from 0.2 to one m in depth, with various sizes of cobbles and rocks on the streambed that may provide shelter to the naiads underwater. Algae usually dominated the areas with still waters, while the bank had few decaying logs and was covered with leaf litter. Trees, bushes, grasses, and other flora dominate both sides of the stream. Trees and shrubs such as *Falcataria falcata* (falcata), *Leucaena leucocephala* (ipil-ipil), *Terminalia catappa* (talisay), and *Gmelina arborea* (gmelina) were observed, and fruit-bearing trees particularly *Lansium parasiticum* (lanzones), and *Artocarpus odoratissimus* (marang) were also noticed growing in an estimated of 10-20 m in height. Canopy cover was also evident in most areas, with canopy vines

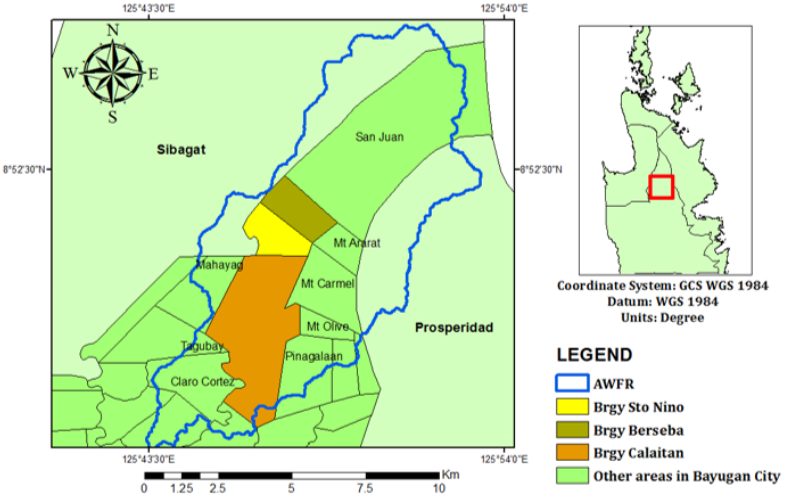

Figure 1. Map of Andanan Watershed Forest Reserve, Philippines, showing the three sites.

and epiphytes present in trees, while ferns and fern allies were also found along the riparian zone. The stream is also utilized as a water source for the locals, while farmlands are noticed around the river ecosystem. The small-scale quarry was also being operated upstream. Other human activities such as slashing, burn farming, and small-scale mining were also noticed, destroying the steepest slopes of the stream.

The specimens were collected through sweep nets and treated with ethyl acetate. All collected individuals were properly pinned and sorted. The pinned specimens were then relaxed with phenol for two days, making the muscles more flexible. All individuals were appropriately labeled, photo-documented, and deposited in the Biology Laboratory at Caraga State University. Preliminary identification was performed using Alindanaw Guide Book (Medina et al. 2016) and further validated by experts. Species diversity, richness, and evenness were generated using tools such as Paleontological Statistics Software (PAST) (Hammer et al. 2001). For the diversity, a Shannon-Weiner (H') index (Shannon 1948) was used to compare the diversity scale (0–1 = low diversity, 1–2 = moderate diversity, and >2 = high diversity). The equitability (H'/H_{max}) was also determined using the data of diversity index, and the maximum evenness {[LN(S)] = natural log of species richness} to support the inference of the data.

3 Results and Discussion

Species Diversity

Odonatans collected in Andanan Watershed Forest Reserve comprise various species from the suborder Anisoptera (dragonflies) with 58% of the total individuals collected, and suborder Zygoptera (damselflies), comprising 42% of the population (Table 1). Members of Odonata (n=19) were recorded in Andanan Watershed Forest Reserve from six families, nine subfamilies, and 19 species. Among the dragonflies, only family Libellulidae known as ground skimmers was reported (Fig. 2), with *Orthetrum* as the most abundant genus (n=18) collected or 39% among anisopterans. In the studies of Last and Whitman (1999-2000) and Pratama and Rosalini (2016), Libellulidae has been considered as an indicator in both clean and unpolluted streams; and they are also the dominating group of dragonfly fauna of standing waters (Kaize & Kalkman 2009). Among the species present, *O. pruinosum, O. sabina,* and *O. testaceum*; *Orthetrum* have the most number (3) of species. The genus *Orthetrum* is one of the most diverse groups among dragonflies, as it breeds in wide ranges of aquatic habitats, (Clausnitzer 2003; Subramanian 2005), is highly tolerant to various disturbances (Mitra 2013), and can inhabit localized areas even in urban biotopes and eutrophic conditions (Samways & Steytler 1996; Norm-Rashid et al. 2008).

Table 1. Record of Odonata entomofauna collected in Andanan Watershed Forest Reserve, showing various species from different taxa groups.

Suborder	Superfamily	Family (Number of Individuals)	Subfamily	Species
Anisoptera	Libelluloidea	Libellulidae (46)	Libellulinae	*Diplacina bolivarii* Selys, 1882 *Orthetrum pruinosum* Burmeister, 1839 *Orthetrum sabina* Drury, 1770 *Orthetrum testaceum* Brumeister, 1839 *Potamarcha congener* Rambur, 1842
			Sympetrinae	*Neurothemis ramburii* Brauer 1866 *Neurothemis terminata* Ris, 1911
			Trameinae	*Pantala flavescens* Fabricius, 1798
			Trithemistinae	*Trithemis aurora* Burmeister, 1839 *Trithemis festiva* Rambur, 1842
Zygoptera	Calopterygoidea	Calopterygidae (4)	Calopteryginae	*Vestalis melania* Selys, 1873
		Chlorocyphidae (4)	Chlorocyphinae	*Rhinocypha turconii* Selys, 1891
		Euphaeidae (15)	Euphaeinae	*Euphaea amphicyana* Ris, 1930 *Euphaea cora* Ris, 1930
		Coenagrionidae (3)	Pseudagrioninae	*Pseudagrion pilidorsum* Brauer, 1868
	Coenagrionoidea	Platycnemididae (7)	Calicnemiinae	*Coeliccia dinocerus* Laidlaw, 1925
				Risiocnemis appendiculata Brauer, 1868 *Risiocnemis erythrura* Brauer, 1868 *Risiocnemis flammea* Selys, 1882

On the other hand, among the damselflies, the family Euphaeidae has the highest number of individuals collected (Fig. 2). Most species belonging to this family group are also endemic in the Philippines that favor good vegetation and flowing waters (Villanueva 2009; Medina et al. 2015). The genus *Euphaea* is the most abundant, accounting for 45% of the zygopteran fauna, supported by the findings of Villanueva (2009) and Villanueva and Gil (2011) since the group was also reported to be an abundant group of Odonata found in the Babuyan and Batanes group of islands, as it favors open areas with good quality and clear water sources. The genus *Risiocnemis* reported the highest number of species among damselflies – *R. appendiculata, R. erythrura* and *R. flammea*. This group is also endemic in the Philippines, which may imply that *Risiocnemis* is endemic to Andanan Watershed Forest Reserve.

There is a high species diversity index (H=2.77) of dragonflies and damselflies in Andanan Watershed Forest Reserve (Table 2). Generally, the diversity of Odonata may be determined by the presence of a sufficient source of water, as they inhabit most of their life on the water as naiads (Theischinger & Hawking 2006). Since odonata exhibits a wide range of different habitat preferences, from sand, sediments, and various aquatic habitats and can inhabit localized areas as well, even among closely related species (Lausnitzer 2004; Norma-Rashid et al. 2008; Villanueva et al. 2010), most of the species have acquired tolerance and adaptability in almost all types and forms of the freshwater ecosystem too (Schindler et al. 2003).

The area's high diversity of Odonata fauna may be explained by the various vegetation growing around the vicinity of the riparian zone. The floral ecosystem near rivers and streams allows the aquatic invertebrates to thrive, providing food for other insects that the dragonflies and damselflies prey on. According to Subramanian and Babu (2017) and Kalkman et al. (2008), forested rivers in the tropical region can support more endemic species of Odonata, which was also observed on the different canopy covers of Andanan Watershed Forest Reserve. The canopy can also offer a fair shade that gives off cool air. In most cases, Odonata prefers cooler environments where they can hover and spawn near streams and rivers; however, several studies have reported that several groups of Odonata have conquered lowlands and residential areas and may have tolerated almost all forms of anthropogenic activities already (Villanueva 2012; Medina et al. 2015 a, b). These reports have shown different environmental adaptations of various odonata groups.

According to Dolny et al. (2011), both disturbed and undisturbed areas may show different diversity of Odonata fauna, implying that habitat types and conditions are still important factors for species composition of the taxa. Despite the high diversity of the Odonata fauna in Andanan Watershed Forest Reserve in the present time, this data might still change in the coming times if various human activities and interference become intense in the area and no proper actions will be taken. Also, the Odonata fauna is essential to the ecosystem, often utilized as bioindicator species (Chovanec & Waringer 2001).

Furthermore, aside from their function in maintaining the ecosystem, Odonata is now acknowledged for their importance in indicating the quality of their habitat (Subramanian & Babu 2017; Medina & Cabras 2018). Any changes in water quality can significantly disturb its population, and its sensitivity to environmental alterations makes them visible indicators of aquatic health and diversity (Klym & Quinn 2003). In addition, sensitivity to pollutants, anthropogenic activities, particularly livestock raising, and global warming also contributes to the decline of Odonata, which implies that they suffer more often than any other taxa (Clark & Samways 1996; Hornung & Rice 2003; Hassall & Thompson 2008). Several studies have also reported that most species of aquatic insects, including the Odonata, are already lost from habitat destruction by increasing agricultural and infrastructural development; hence, they become harder to find (Nelson et al. 2011; Villanueva et al. 2012), since this insect fauna is still prone to larger-scale interventions by the local people such as human habitation, clearing of forest for agricultural uses and irresponsible mining.

Table 2. Diversity of Odonata fauna from Andanan Watershed showing the diversity index and equitability values.

Species Richness (S)	Total Number of Individuals (N)	Diversity Index (H)	Maximum Evenness (Hmax)	Equitability (H/Hmax)	Qualitative Inference
19	79	2.77	2.94	0.94	High diversity

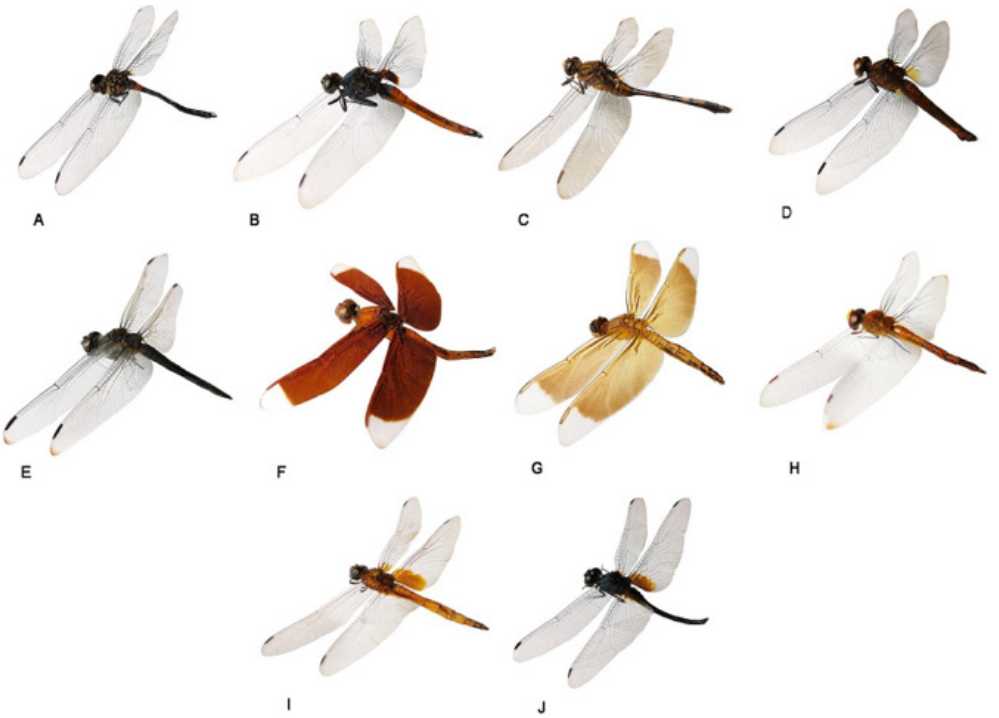

Figure 2. Dragonflies of Andanan Watershed Forest Reserve. (A) *Diplacina bolivarii* Selys, 1882; (B) *Orthetrum pruinosum* Burmeister, 1839; (C) *Orthetrum sabina* Drury, 1770; (D) *Orthetrum testaceum* Brumeister, 1839; (E) *Potamarcha congener* Rambur, 1842; (F) *Neurothemis ramburii* Brauer, 1866; (G) *Neurothemis terminata* Ris, 1911; (H) *Pantala flavescens* Fabricius, 1798; (I) *Trithemis aurora* Burmeister, 1839; (J) *Trithemis festiva* Rambur, 1842.

Occurrence and Distribution Status

Diplacina bolivarii (Fig. 2A) is the only endemic dragonfly found in Andanan Watershed Forest Reserve and is a widespread endemic species occurring in most areas of the Philippine islands. This species is often tolerant to disturbance and can thrive from disturbed to pristine areas (Caparoso et al. 2016; Villanueva 2012; Mapi-ot et al. 2013). The three species of *Orthetrum* – *O. pruinosum* (Fig. 2B), *O. sabina* (Fig. 2C), and *O. testaceum* (Fig. 2D) are widespread in the Oriental region, and among the most diverse group of Odonata that breeds on a wide range of aquatic habitat types. They have flattened sternum, which can support muddy to fine-sand patches with slow-moving waters. *O. sabina* is also found in wet patches, ponds, marshes, and rivers and may usually found in areas where human settlement and open field arenas are also found (Subramanian 2005; Siregar 2006; Allen 2009; Malawani et al. 2014).

Similarly, two cosmopolitan species of *Neurothemis* were also collected in the forest reserve. These two Oriental species – *N. ramburi*i (Fig. 2F) and *N. terminata* (Fig. 2G) are locally common over much of its range, however, few others have become secondarily adapted for a more active existence among the availability of growing vegetation (Gillott 2005). This species has been observed to be closely associated with open spaces benefiting from a favorable microclimate created by the canopy of weed plants and rice crop cover (Jomoc et al. 2013). The genus *Trithemis* is also abundant in all collecting sites in the riparian area. In several studies of Tiple et al. (2012); Emiliyamma & Radhakrishnan (2002) and Norm-Rashid et al. (2008), this group is also widespread in the Oriental region ranging from South Asia to Southeast Asia. In the paper of Aspacio et al. (2013), *T. aurora* (Fig. 2I) and *T. festiva* (Fig. 2J) are widely distributed in Lanao and Iligan of Northern Mindanao. Furthermore, the bioindicator species like *N. ramburii, O. pruinosum, O. sabina, T. aurora,* and *T. festiva* are found dominating in areas that are greatly disturbed.

Other wide-range species include *Potamarcha*

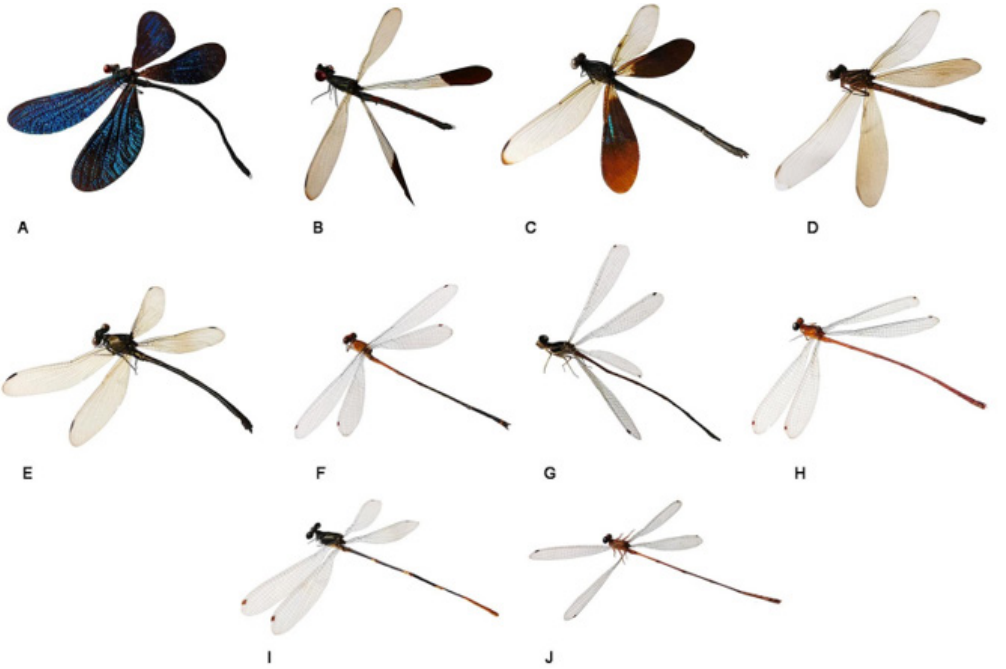

Figure 3. Damselflies of Andanan Watershed Forest Reserve. (A) *Vestalis melania* Selys, 1873; (B) *Rhinocypha turconii* Selys, 1891; (C) *Euphaea amphicyana* ♂ Ris, 1930; (D) *Euphaea amphicyana* ♀; (E) *Euphaea cora* Ris, 1930; (F) *Pseudagrion pilidorsum* Brauer, 1868; (G) *Coeliccia dinocerus* Laidlaw, 1925; (H) *Risiocnemis appendiculata* Brauer, 1868; (I) *Risiocnemis erythrura* Brauer, 1868; (J) *Risiocnemis flammea* Selys, 1882.

congener (Fig. 2E), which have also been reported to inhabit terrestrial areas near bodies of water such as marshes and rice paddies (Mitra et al. 2017), and *Pantala flavescens* (Fig. 2H), which is an obligate migrant and uses temporary ponds as breeding grounds (Boudot et al. 2013).

Six endemic damselfy species were reported, *Vestalis melania* (Fig. 3A) – which is an endemic species found throughout the Philippine islands except in Palawan island (Mapi-ot 2010; Villanueva 2009), one species of *Euphaea* – *E. amphicyana*, male and female (Figs 3C and 3D) respectively (Villanueva 2009). According to Caparoso et al. (2016) *V. melania* and *E. amphicyana* are indicator species often found in pristine sites. These species are at the utmost risk as they are confined to only one or two protected areas and are not widespread (Quisil et al. 2014).

Coeliccia dinocerus (Fig. 3G), is also Philippine endemic species (Cayasan et al. 2013), and all species of genus *Risiocnemis* – *R. appendiculata* (Fig. 3H), *R. erythrura* (Fig. 3I) and *R. flammea* (Fig. 3J). The *Risiocnemis* group is endemic in the Philippines. It is commonly found in Luzon, East Visayas, and Mindanao regions except in the Sulu archipelago and Palawan islands, and can occur only in a limited area within the islands (Hamalainen 2004; Mapi-ot et al. 2014; Hamalainen 2000). It is also limited to streams in rainforests from lowland up to the lower mountain forests (Gassmann & Hamalainen 2002). One occurring species in Andanan Watershed Forest Reserve, *R. appendiculata,* is only confined to Greater Mindanao biogeographic zone, and is the most widely distributed member of its genus in the region (Villanueva 2011). *R. erythrura,* is also common in Mindanao island, and was included in the annotated checklist of Odonata in Mainit Hot Spring Protected Landscape, Davao de Oro (Medina & Cabras 2018), while *R. flammea* is usually found in densely vegetated areas (Nuñeza et al. 2015). However, across its known range, some body size varies from prominent individuals in some areas of Mindanao to relatively smaller ones found in Dinagat islands (Villanueva 2009). The family Platycnemididae – commonly known as white-legged damselflies that includes *Coeliccia* and *Risiocnemis*, is an endemic family that is widely distributed in the

islands of Luzon to Mindanao (Gapud 2006), and is considered one of the most endangered entomofauna in the archipelago (Mapi-ot et al. 2015).

Other widespread species include *Rhinocypha turconii* (Fig. 3B), which is distributed in the Philippines except in Palawan Mapi-ot et al. (2013); *Euphaea cora* (Fig. 3E), which also occurs in the riparian areas of Bega Watershed in Agusan del Sur, a vicinity around Andanan River (Nuñeza et al. 2015); and *Pseudagrion pilidorsum* (Fig. 3F) – which can also occupy most of the freshwater habitats. In the synopsis of the Philippine Odonata by Hamalainen and Muller (1997), from the 309 species identified, 203 or 65.7%, were endemic in the country. It was also reported that 85.5% of these odonata were damselflies, and 35.8% were endemic dragonflies.

4 Conclusion and Recommendations

This preliminary survey of the Odonata fauna in Andanan Watershed Forest Reserve has reported seven endemic species and generated a high diversity with 19 species of six families, which implies a healthy riparian ecosystem. A strict implementation of rules in maintaining a healthy aquatic environment within the forest reserve must be employed to preserve the natural habitat of these dragonflies and damselflies.

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Statement of Conflict of Interest

The author declare that there is no conflict of interest regarding the publication of this paper.

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