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Diversity and community composition of dragonfly (*Insecta: Odonata*) in Tangkoko, Nature Reserve, North Sulawesi, Indonesia

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Analysis of dragonfly diversity is one of the important factors in supporting species conservation. This study was aimed to assess community composition and diversity of dragonfly in the area of Tangkoko Nature Reserve, North Sulawesi. Sampling was carried out along the river in three habitat types. Dragonfly collection was done by a sweeping technique along four transect lines that were applied randomly along 1000 m in every type of habitat. Data analysis included species abundance, richness, diversity and evenness among habitats. The result showed that in these three habitats there were six families, 13 genera, 15 species and 1557 individuals. Family *Libellulidae* was the most common type of species. The family with the most abundance was *Coenagrionidae*, while the family with least abundance was *Platystictidae*. Species with the highest number of individuals was *Pseudagrion sp* and the lowest number was *Pantala plavescens*. The highest abundance and richness of species were found on agricultural land and the lowest was in primary forest. The highest species diversity and evenness were found in primary forest and the lowest was in secondary forests. The highest diversity of dragonflies in all types of habitats was found in primary forest.

Keywords: Dragonfly, abundance, richness, diversity, evenness, primary forest, Tangkoko.

INTRODUCTION

Information about the distribution and diversity of flora and fauna in several habitat types and regional local scale is the key to the conservation of biodiversity, especially for those of little known taxa such as dragonfly (*Odonata*). Dragonfly is one type of insect with 6000 species and subspecies, 630 genera and 28 families (Sharma et al. 2007). They are grouped in two sub-orders: the Zygoptera (2739 species and 19 families) and the sub-order *Anisoptera* (2941 species and 12 families) as well as about 1000 to 1500 undescribed species (Van Tol, 1992; Tallei et al. 2017). The tropic is a region with high diversity and high numbers of dragonfly families. Twelve of the 31 families have habitat in the watershed of tropical forests. Sulawesi is reported to have 124 species, of which 55 species are endemic. Based on these data, Sulawesi endemic population ranks fifth in the world and second in Indonesia (Van Tol, 1987).

Dragonfly research in Indonesia, especially North Sulawesi, is still very rare when compared to other countries in Asia. Some research about the diversity of dragonflies has been reported outside Indonesia, such as the characteristics of

habitat and the abundance and diversity of dragonfly in the River Guadiana, Portugal (Fulan et al. 2008), the diversity, distribution and composition of dragonfly in Similipal Tiger, India (Magguran, 2004), the distribution and diversity of dragonfly in Kerian River, Kedah, Malaysia (Salmah et al. 2005), and the diversity and distribution of dragonfly in Mount Coalcomans, Mexico (Anaya et al. 2011).

Tangkoko Nature Reserve is a conservation area in Indonesia. The nature reserve is located in the northern part of Bitung, North Sulawesi, Indonesia. This region has an area of 3196 hectares, is located on 1°30'-1°34'N and 125°10'-125°81'E. In accordance with Law no. 5/1990, nature reserves are earmarked for research and development of science, education and other activities that support conservation. In the meantime, the Tangkoko nature reserve experiences a great deal of interference from people living around the forest. The disorder comes in the form of transforming forest land into agricultural lands planted with various crops. Disruption of an ecosystem affects biological diversity, including that of the dragonfly. The extent of influence of forest disturbance on the composition and diversity of dragonflies in Tangkoko Nature Reserve has not been well studied and published. In the case of this research, it is very important to remember this insect plays a crucial role in the ecosystem. This study aims to assess the composition and diversity of dragonfly on various types of land use in the area of Tangkoko Nature Reserve, North Sulawesi Indonesia.

MATERIALS AND METHODS

Sampling Site

The research was conducted from May-July 2014. The research location was in the area of Tangkoko Nature Reserve, North Sulawesi (Fig.1). Sampling sites included three types of habitat, namely: primary forest, secondary forest and agricultural land. Four transect lines were made in each habitat, with a length of 1000 m. Transect lines were created along the streams in these three habitat types.

Primary forest is an intact natural forest that has not been disturbed by human exploitation of both logging and timber extraction. Sampling sites were located at an altitude between 150-350 m above sea level. This primary forest has a temperature of 27°C to 29°C, humidity 75% -85%, and 80-90% vegetation cover.

Secondary forest is the forest that grows and develops naturally after damage / change in the original forests. Forest damage at this location occurred about 10-15 years ago. The habitat is located at an altitude of 80-180 m with a temperature of 28°C - 30°C and humidity of 65% - 80%.

Agricultural land is a habitat that is located outside the Tangkoko Nature Reserve. This habitat is an agricultural land managed by the community and planted with various types of agricultural crops. Sampling site is located at an altitude of 30-70 m above sea level. This habitat has a temperature of 28°C-34°C with a humidity of 65% -79%. Vegetation cover ranges between 40-60%

Sampling method and identification

Dragonfly samples taken in this study were the adult (imago). Sampling was done along the transect line using a sweep net: a cone-shaped net measuring 60 cm, 300-380 cm in diameter and 1 meter long stick nets. Sampling was conducted every month for 3 months from 9:00 am to 3:00 pm, because dragonfly belongs to a group of insects that are active during the day. Captured dragonflies were put into an envelope and then soaked in Acetone for 12 hours. They were then removed from the acetone and dried in the sun, after which the samples were stored in triangular paper envelopes measuring 30 x 20 cm with wings folded into position along the upper body.

The samples were identified and counted by numbers of individuals. The identification process was carried out by external morphological characteristics using several reference books (Borror et al. 1996; Lieftinck, 1949; Orr, 2003; Watson and Farrel, 1991).

Statistical analysis

Analysis of the data in this study covers species abundance (n), species richness (s), the value of species diversity (H), and species evenness value (E). Species abundance is the number of individuals of each species found at each sampling point. Species richness is based on the number of species present in the sites. The level of species diversity was determined using Shannon and Wiener index, with the following formula:

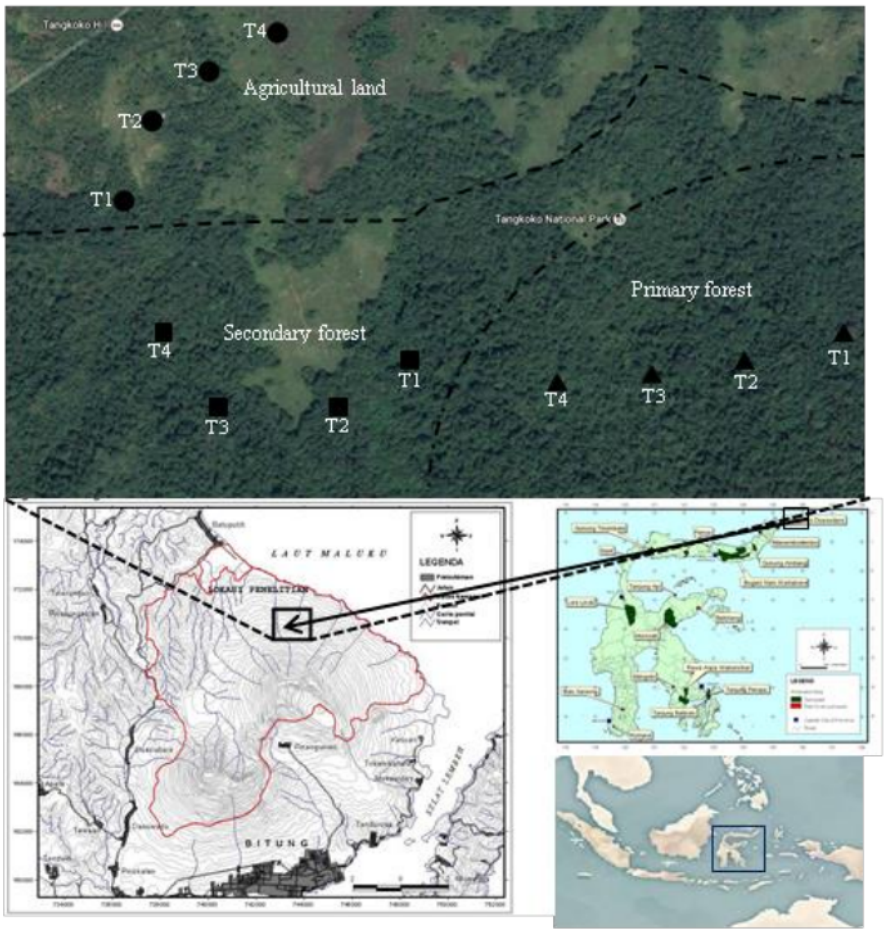


Figure: 1 The map of sampling sites in Tangkoko Nature Reserve, North Sulawesi Indonesia.

Species diversity index (H') = $-\sum_{i=1}^{s}$ [(n/N)*(ln (n/N))]

where n is the number of individuals or amount of each species and N is the total number of individuals per site, and ln is natural log of the number (Manwar and Wankhade, 2014). To determine the level of species evenness, the Shannon evenness index was used (E) (Magguran, 2004) as follows:

E = H/ln(S); S = number of species

STATISTICA Version 6, Anova one-way (one-way ANOVA) and Tukey's test at the 95% confidence were used to determine differences in species richness, abundance of species, the value of species diversity and evenness of species in each habitat type (Ohsawa, 2005; StatSoft, 2011).

RESULTS

Dragonflies found during the study comprised of two suborders (*Anisoptera* and *Zygoptera*), 6 families, 13 genera, 15 species and 1557 individuals. Suborder Anisoptera consisted of only one family (*Libellulidae*), 7 species and 240 individuals. *Zygoptera* consisted of 5 families (*Coenagrionidae, Chlorocypidae, Calopterygidae, Platycnemididae,* and *Platystictidae*), 8 species and 1317 individuals (Table 1).

Table: 1. Number of families and species found in a variety of habitat types

No	Sub Ordo/Famili/Spesies	PF		SF		AL		Total	
		∑	%	∑	%	∑	%	∑	%
Anisoptera									
I	**Libellulidae**								
1	*Celebothermis delecollei*	15.00	0.96	32.00	2.06	8.00	0.51	55.00	3.53
2	*Diplacina sp*	16.00	1.03	16.00	1.03	33.00	2.12	65.00	4.17
3	*Neurothemis stigmatizans*	1.00	0.06	2.00	0.13	10.00	0.64	13.00	0.83
4	*Neurothermis ramburii*	11.00	0.71	13.00	0.83	6.00	0.39	30.00	1.93
5	*Orthetrum glaucum*	0.00	0.00	0.00	0.00	12.00	0.77	12.00	0.77
6	*Orthetrum pruinosum*	0.00	0.00	19.00	1.22	44.00	2.83	63.00	4.05
7	*Pantala plavescens*	1.00	0.06	1.00	0.06	0.00	0.00	2.00	0.13
Zygoptera									
II	**Calopterygidae**								
8	*Neurobasis kaupi*	74.00	4.75	153.00	9.83	108.00	6.94	335.00	21.52
III	**Chlorocypidae**								
9	*Libellago daviesi*	1.00	0.06	31.00	1.99	98.00	6.29	130.00	8.35
10	*Libellago xanthocyana*	3.00	0.19	139.00	8.93	108.00	6.94	250.00	16.06
11	*Rhinocypha frontalis*	7.00	0.45	0.00	0.00	0.00	0.00	7.00	0.45
IV	**Coenagrionidae**								
12	*Pseudagrion sp*	95.00	6.10	129.00	8.29	126.00	8.09	350.00	22.48
13	*Teinobasis sp*	20.00	1.28	63.00	4.05	71.00	4.56	154.00	9.89
V	**Platycnemididae**								
14	*Lochmaeocnemis malacodora*	1.00	0.06	42.00	2.70	42.00	2.70	85.00	5.46
VI	**Platystictidae**								
15	*Celebargiolestes cinctus*	6.00	0.39	0.00	0.00	0.00	0.00	6.00	0.39
Grand Total		**251**	**16.12**	**640**	**41.1**	**666**	**42.77**	**1557**	**100**

(PF: Primary forest; SF; Secondary forest; AL: Agricultural land)

The most commonly found family were *Libellulidae* (seven species) and *Chlorocypidae* (three species). Three other families (*Calopterygidae, Platycnemididae and Platystictidae*) had the fewest species (one species, respectively). The most abundant family was *Coenagrionidae* (504 individuals or 32.37%) and *Chlorocypidae* (387 individuals or 24.86%), while the family *Platystictidae* had the least (6 individuals or 0.39%) (Table 1 and Figure 2).

Dragonfly species with the highest number of individuals was *Pseudagrion* sp. (350 individuals or 22.48%), followed by *Neurobasis kaupi* (335 individuals or 21.52 %), *Libellago xanthocyana* (250 individuals or 16.06%), and *Teonobasis* sp (9.89%) (Fig. 3). The least species found were *Pantala plavescens*, 2 individuals (0.13%), and *Celebargiolestes cinctus*, 3 individuals (0.17%) (Table 1).

The location of study that has the highest individual abundance is agricultural land (666 individuals or 42.77%), then in secondary forest habitats (640 individuals or 41.10%). Primary forest habitat has the least abundance of individuals compared to other habitats with only 251 individuals (16.12%) (Table 1). High abundance in agricultural land is due to more water pooling in this area.

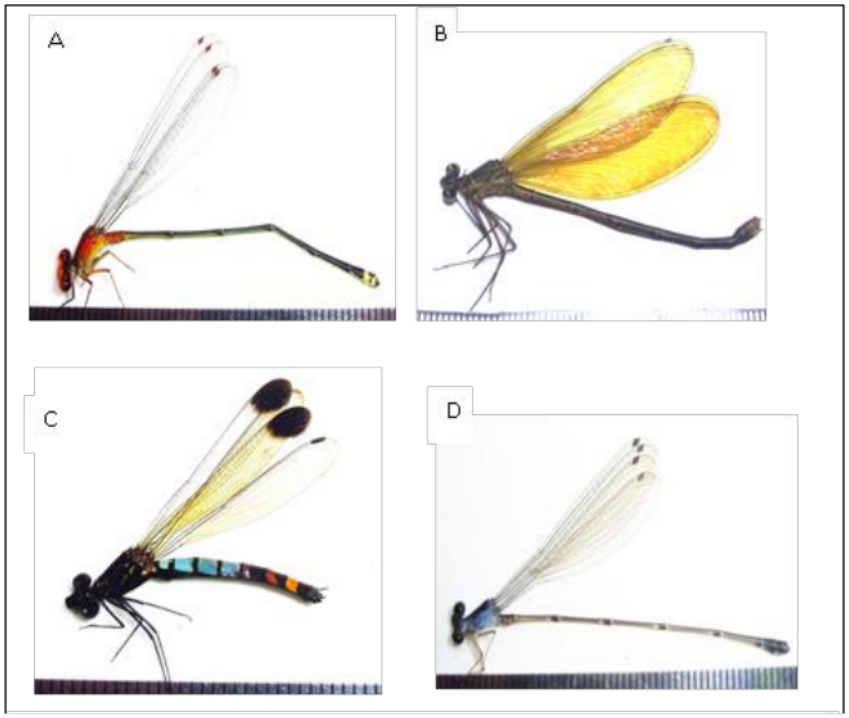
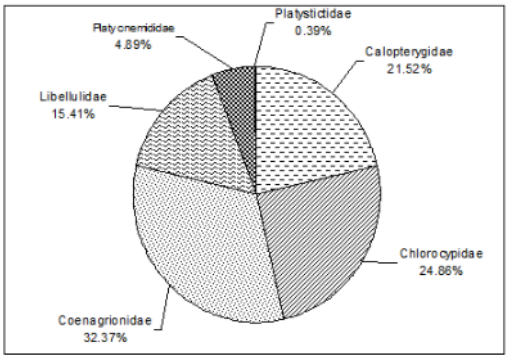


Figure: 3 Photographs of Odonates (A-D). A. *Pseudagrion Sp.*, B. *Neurobasis Kaupi*, C. *Libellago xanthocyana*, D. *Teinobasis Sp.*

compared to the river or primary forest.

Figure: 2. Family abundance of dragonflies in three types of habitat at Tangkoko Nature Reserve, North Sulawesi, Indonesia.



Distribution of dragonfly in the third habitat varied greatly. Dragonfly species with even distribution were *Celebothermis delecollei, Libellago daviesi, Libellago xanthocyana, Lochmaeocnemis malacodora, Neurobasis kaupi, Neurothermis ramburii, Neurothermis stigmatizans, Pseudagrion* sp, *Diplacina* sp. and *Teinobasis* sp (Table 1). There were two species found only in primary forest habitat namely *Celebargiolestes cecinctus* and *Rhinocypha frontalis*. *Pantala plavescens* were found both in primary and secondary forests. Dragonfly which found only on farmland and not in other habitats was *Orthetrum glaucum* (Table 1).

Dragonfly community structure includes abundance, richness, diversity and evenness of species. The highest average abundance and species richness of dragonflies were in agricultural land, then in secondary forest. Abundance and species richness of dragonflies were the lowest in the primary forest. Statistical test results showed that the abundance and diversity of dragonfly species between habitats were significantly different ($p<0.05$), while the richness and evenness of dragonfly species were not significantly different between habitats ($p> 0.05$) (Fig. 4).

On average, the highest diversity of dragonfly species was found in primary forest,

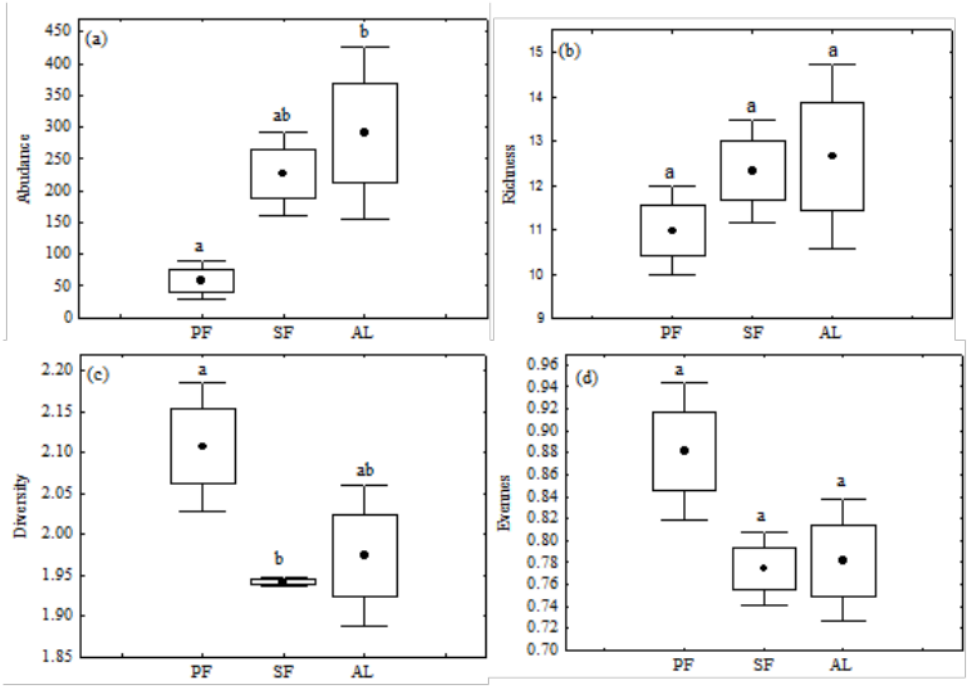


Figure: 4. (a) Abundance, (b) richness, (c) diversity and (d) species evenness of dragonflies at three types of habitat (PF: Primary forest; SF; Secondary forest; AL: Agricultural land; (•) : Mean, (□) : ±SE , (⊥) : ±SD, PF: primary forest, SF: secondary forest, AL: agricultural land. The same letter in the same picture did not differ significantly according to Tukey's test at 95% confidence level.

followed by agricultural land, while the lowest species diversity was found in secondary forest. Statistical test results showed average diversity of dragonfly species were significantly different between habitats ($p< 0.05$) (Fig. 4). On average, the highest dragonfly species evenness was found in primary forest, then agricultural land, while the lowest species evenness was found in secondary forest. Statistical test results showed that the average evenness of species was not significantly different between habitats ($p>0.05$) (Fig.4).

DISCUSSION

Coenagrionidae family was found in abundance because the carrying capacity of the environment such as air temperature, air humidity and vegetation habitat was still good. *Libellulidae* was the common family found with numerous species and individuals. This is consistent with research of Dolny et al. (2012) that the dominant species found was 38 species of *Libellulidae* family (43%) and more than 2420 individuals (45%). Kaize and Kalkman (2011) reported that in the Asmat and Mapii (Papua, Indonesia), of the 47 species of dragonflies found mostly from the family *Coenagrionidae* (14 species) and from the family *Libellulidae* (26 species). Das et al. (2012) also reported that of 58 species found belonged to the dominant family *Libellulidae* (31 species) and *Coenagrionidae* (11 species). Results of the above studies were in accordance with the results of Paulson (2004) in several areas of the tropics. Two dominant *Odonata* families were found in his research, namely *Libellulidae* with 966 individuals and *Coenagrionidae* with 1070 individuals. In addition, the study reported by Siregar et al. (2005) also stated that *Platycnemididae* (suborder Zygoptera) and *Libellulidae* (suborder Anisoptera) were two families predominantly found in the rice field ecosystem of Northern Peninsula Malaysia. Based on the results of the above study there is a tendency that the family *Libellulidae* and *Coenagrionidae* are commonly found in Asia,

particularly in the rice field Muda Malaysia (Bambaradeniya and Amerasinghe, 2003). The two families Coenagrionidae and Libellulidae are, according to experts, families that have the most members. Both of these families have a wider distribution of habitat and are believed to be the largest and relatively new. They exist in almost every type of habitats, and dominate the unshaded habitats with stagnant water. Both families have the capacity of the largest migration, including the distribution that spans more than one region and almost all were found in isolated islands (Van Tol and Gassmann, 2005).

Abundance and richness of dragonflies were high on agricultural land due to the high light intensity and a lack of vegetation around the river. Dragonflies have a habit of basking in the sun to warm the body and to strengthen the wing muscles to fly (Susanti, 1998). The high light intensity and a lack of vegetation cover on agricultural land were the reason that dragonflies were found in abundance on agricultural land.

The high diversity of dragonflies in primary forest was affected by environmental capacity such as air temperature, humidity, vegetation cover (canopy), availability of food, clean water and vegetation along the river. Primary forest is very densely populated with trees with no human disturbances, nor forest conversion, which results in the high diversity of dragonflies (Dolny et al. 2011). Water quality is still good in primary forests because there was no human activity. This is a crucial factor that explains the high diversity of dragonflies found in this area.

High evenness in primary forest was found, but none dominate in term of the number of individuals per species in the area. Lack of evenness in secondary forests was due to the existence of certain dragonfly species that dominated in the number of individuals per species. Dragonfly species that dominated the secondary forest were *N. kaupi* and *L. xanthocyana*. The dragonfly domination along the rivers of the agricultural land was the area where litter and dead wood are commonly found. This is a habitat mostly preferred by both species.

CONCLUSIONS

Total 15 species of dragonflies belonging to two sub orders, 6 families, 13 genera, and 1557 individuals were observed in Tangkoko Nature Reserve, North Sulawesi. Species that with the highest number of individual was *Pseudagrion* sp. The highest abundance and richness of species were found on agricultural land and the lowest were in primary forest. The highest species diversity and evenness were found in primary forest and the lowest in secondary forests.

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