Journal of Tropical Biodiversity and Biotechnology
Volume 08, Issue 02 (2023): jtbb76690
DOI: 10.22146/jtbb.76690

Research Article

Diversity and Community Structure of Dragonflies (Odonata) in Various Types of Habitat at Lakarsantri District, Surabaya, Indonesia

Muhamad Azmi Dwi Susanto[1], Nirmala Fitria Firdhausi[2], Saiful Bahri[2]*
1)Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Brawijaya, Malang, Indonesia
2)Department of Biology, Faculty of Science and Technology, UIN Sunan Ampel Surabaya, Indonesia
* Corresponding author, email: saifulsi@uinsby.ac.id

Keywords:
Urban area
Aquatic ecosystem
Conservation
Submitted:
29 July 2022
Accepted:
16 January 2023
Published:
03 May 2023
Editor:
Miftahul Ilmi

ABSTRACT
Dragonflies are insects that are very dependent on the existence of freshwater ecosystems, However, the population of dragonflies in urban freshwater ecosystems is at risk due to a number of issues. Consequently, it is essential to carry out research and efforts to preserve dragonflies in urban areas. This study aims to provide information about the diversity and structure of dragonfly communities in various habitat types in the Lakarsantri, Surabaya. Data collection in this study was carried out in the habitat types of ponds, reservoir, river, and rice field in July to September 2021. The study results show there are 22 species from 4 families with a total of 827 individuals. Analysis of the Shannon-Wiener diversity index showed that the highest value of dragonfly diversity was found in a pond, with a value of H' = 2.40, and the location with the lowest value was a river, with a value of H' = 1.77. At four research locations that have different aquatic ecosystems, the community structure of dragonfly is also different. The composition of the dragonfly community structure at the reservoir location has similarities to a pond, and at a river location, it has similarities to a paddy field. Differences in abiotic factors consisting of light intensity, humidity, and temperature at each study location have a correlation with differences in dragonfly community structure. In addition, the composition of the vegetation at each location is also one of the factors causing differences in the structure of the dragonfly community.

INTRODUCTION
Dragonflies are flying insects essential to the ecosystem's ability to balance its food chain (Tang et al. 2010). Dragonflies are insect predators throughout their life cycle, from nymph to adult (Kandibane et al. 2005) so that they can become natural predators for disease vector insects in urban environments such as flies and mosquitoes (Dalia & Leksono 2014). Dragonflies not only keep the food chain in balance but also serve as a bioindicator of the state of the ecosystem. This is because some species of dragonflies also have a very high sensitivity to changes in environmental quality (Tang et al. 2010; Dolný et al. 2012). If the environment that is the dragonfly's natural habitat is disturbed or damaged, the dragonfly will react (Buczyński et al. 2020).

Dragonflies spend most of their lives in water, namely during their egg and larval phases (Choong et al. 2020) so that the main habitat of

dragonflies cannot be separated from freshwater ecosystems (Tang et al. 2010). Generally, dragonflies can be found in locations that have freshwater ecosystems such as lakes, reservoirs, ponds, or rivers in mountainous or urban areas (Paulson 2009). However, aquatic ecosystems in urban areas have problems that can reduce quality to the point of damaging the environment and waters. Examples of problems that often occur are organic and chemical water pollution from household waste. Furthermore, the growing number of developments harms various wetlands and freshwater bodies. This causes the aquatic ecosystems that should be used as natural habitats for dragonflies to be damaged and their populations to be disrupted. This is also supported by IUCN (2021). Which states that more than a quarter of the total dragonfly species in Southeast Asia are threatened with extinction, due to the destruction of the wetlands, which are the natural habitat of dragonflies. Therefore, research and conservation of the diversity of dragonfly species in urban areas are urgently needed.

The existence of damage and pollution in an urban area can be a major factor affecting the differences in the structure of the dragonfly community in an unspoiled area (Vilenica & Mihaljević 2022). The factors that most influence the community of dragonflies in cities are the presence of polluted aquatic habitats and also the presence of riparian vegetation (Maldonado-Benítez et al. 2022). Research on the community structure of dragonfly in a variety of habitats in urban East Java is still very limited, especially in the city of Surabaya. This research is the first research on the community structure of the dragonfly in various types of habitats in the city of Surabaya, and it was carried out in the Lakarsantri District.

Lakarsantri District is an urban area that still has green open space with various freshwater ecosystems, including rice fields, rivers, ponds, and reservoirs. The existence of various types of aquatic ecosystems has a good chance of developing into a natural habitat for different species of dragonflies. But with population growth and increasing human activities that continue to occur, as well as the absence of dragonfly research on various types of ecosystems in the Lakarsantri District, this research is very important to do. Therefore, the purpose of this study was to ascertain the diversity and community structure of dragonflies in various habitat types in the Lakarsantri District.

MATERIALS AND METHODS

Time and Location Study

Data collection was carried out from July to September 2021. Data collection was carried out once a month during sunny conditions with observation time from 08.00 am to 04.00 pm with rest time from 11.00 am to 01.30 pm. This research was conducted in Lakarsantri District, Surabaya City, East Java, Indonesia. The observation location based on the various types of habitats that can be found in each of the four research locations namely Pond, Reservoir, River, and Rice field (Figure 1) so that each location represented one habitat type (Figure 2).

Data Collection

Data collection used the modified Visual Encounter Survey (VES) technique, which is a direct observation technique. These observations were carried out by tracing all the observation locations determined by noting the variety of dragonfly species and counting the number of each species' individuals that were observed. Observation of dragonflies using the VES method on several habitat types in Lakarsantri District was modified us-

ing the Transect method (Oppel 2006) and Belt Transect (Haritonov & Popova 2011). The transect method was an observation method by following a predetermined straight line and was used at a river research location. While the Belt Transect method involved making observations while traveling along a predetermined circular line and was used at research sites of pond, reservoir, and rice field. The research sites were selected based on the different habitat types from every location and their potential as dragonfly natural habitats (Purposive Random Sampling).

Data was collected by captured dragonflies using a sweeping net, then each body part was documented in detail using a camera. Every dragonfly found is also documented when in the wild for aesthetic purposes. Each individual that has been collected or documented is then

Table 1. Description of research location.

Location	Coordinate point		Description
	Latitude	Longitude	
Pond	S7° 19' 33.8	E112° 40' 25.6	A pond is a body of stagnant water located in cultural heritage areas and near settlements. This location consists of water plants, herbaceous vegetation, and some trees.
Reservoir	S7° 18' 2.3	E112° 39' 40.9	A reservoir is a body of stagnant water that is used as a tourist and fishing spot and is located near settlements. This location consists of herbaceous vegetation and some trees.
River	S7° 19' 13.0	E112° 41' 8.0	A river is a body of water that flows. This location is dominated by grass vegetation.
Rice field	S7° 20' 7.7	E112° 39' 54.2	A rice field is a land that has stagnant waters and a pond as an irrigation system. This location is dominated by rice plants.

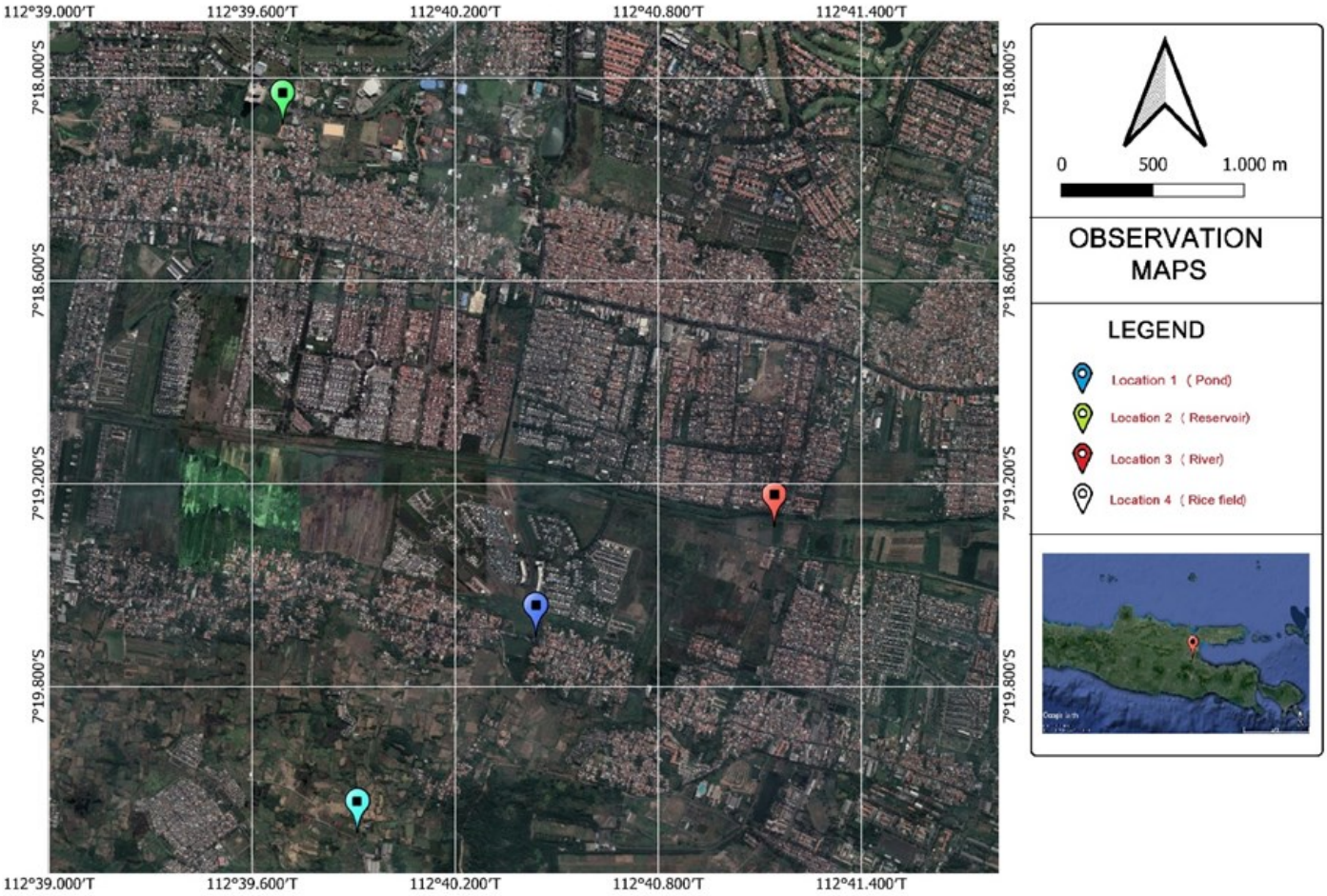

Figure 1. Study location maps.

identified to the species level. Dragonfly species identification was conducted using the morphological feature of each individual according to the identification key including body size, color, pattern, wings venation, and tuft shape. Identification was carried out using an identification manual (Orr 2005; Kalkman & Orr 2013; Orr & Kalkman 2015; Setiyono et al. 2017). This study's data collection included consideration of microclimate elements like light intensity, humidity, and air temperature. The air temperature and humidity factors were measured using a Thermo hygrometer, and the light intensity factor was measured using a light meter. Vegetation data collection was also carried out by identifying the dominant types of plants found at the study site.

Data Analysis

Data obtained was then analysed for the diversity value using the Shannon-Wiener index (Metcalfe 1989), evenness index, dominance index (Magurran 2004), relative abundance, and frequency of attendance. With the following formula:

$$H' = \sum\left(\frac{ni}{N}\, In\, \frac{ni}{N}\right)$$

Information:
H' = Shannon-Wiener diversity index
ni = Number of individuals of type i
N = Number of individuals of all types

$$E = \frac{H'}{\ln\ S}$$

Information:
E = Evenness index

Figure 2. Documentation research site (A) Pond, (B) Reservoir, (C) River, (D), Rice field.

H' = Shannon-Wiener diversity index
S = Number of species

$$D = \sum (\frac{ni}{N})^2$$

Information:
D = Dominance index
ni = Number of individuals of type i
N = Number of individuals of all types

$$RA = \frac{ni}{N} \text{ x } 100\%$$

Information:
RA = Relative abundance
ni = Number of individuals of type i
N = Number of individuals of all types

$$PF = \frac{Total\ posts\ found\ species\ i}{the\ total\ of\ posts} x\ 100\%$$

Information:
PF = Presence frequency

The next analysis was principal component analysis (PCA). This analysis was used to determine the relationship between location of observation with the results of measurements of abiotic factors (environmental) and biotic index (Koneri et al. 2022). PCA analysis using Paleontology Statistical software (PAST 4.03 software). The similarity of dragonfly composition using the UPGMA cluster analysis method (index Bray-Curtis), and the correlation of biotic factors with abiotic factors were analyzed using PAST 4.03. Calculation of the mean and standard deviation using the software of Statistical Program for Social Science (SPSS 24).

RESULTS AND DISCUSSION

Based on observations made on various types of habitats in Lakarsantri District, 22 species from 4 families with a total of 827 individuals were found (Table 2). In the suborder Anisoptera found 15 species of dragonflies from 2 families namely Gomphidae and Libellulidae with a total of 671 individuals. While in the suborder Zygoptera found 7 species from 2 families, namely Coenagrionidae and Platycnemididae with a total of 156 individuals. Most of the dragonfly species that were found, namely 19 species, had a conservation status of Least Concern (LC). However, two species with Data Deficient (DD) conservation status were also found, namely *Neurothemis feralis* and *Pseudagrion nigrofasciatum*, as well as one species with Not Evaluated (NE) conservation status, namely *Zyxomma obtusum*.

The results of this study indicated that dragonflies belonging to suborder Anisoptera had more species and individuals than suborder Zygoptera. Almost all research sites have areas dominated by open habitats with understorey vegetation and some trees, making them suitable habitats for dragonflies of the suborder Anisoptera. Members of the Anisoptera were often found in open habitats to look for food and most of them were flying at a fairly high intensity of sunlight (Kalkman & Orr 2013). In addition, they also have excellent flight abilities leading to a wider range of cruising. Members of Anisoptera can adapt to urban environ-

ments and also with high roaming abilities, the Anisoptera is not very dependent on the availability of food around the waters.

There were fewer members of the suborder Zygoptera in this study than the suborder Anisoptera, which could be because Zygoptera had a higher sensitivity to pollution. This is following (Maldonado-Benítez et al. 2022), who reported that in poor habitat conditions the abundance of Zygoptera was reduced. The presence of aquatic plants and riparian vegetation in the habitat also impacts the presence significantly and abundance of the Zygoptera. Because of the vegetation can be a natural habitat for various small insects that are a source of food for dragonflies. Zygoptera has the ability to fly and a low cruising range makes Zygoptera highly dependent on the availability of food in a location.

Considering the analysis of the study's dragonfly's presence data for frequency, it showed that most of the dragonfly species encountered had the characteristics of their respective natural habitats. So that not all species can be found in all research locations. Of all the species found, there were only four species that had a presence frequency value of 100%, which means that these species were found in all locations of this study (although not always found every month), namely at the pond, reservoir, river, and rice field (Table 1). The four species are *Brachythemis contaminata* (Figure 4-C), *Crocothemis servilia* (Figure 4-E), *Orthetrum sabina* (Figure4-I), and *Agriocnemis femina* (Figure 3-A). These four species can be found in all locations because these four species have a relatively high tolerance for environmental disturbances or changes. This is in accordance with (Kulkarni & Subramanian 2013; Irawan & Rahadi 2016), who reported that *Brachythemis contaminata* species have low sensitivity to disturbances, therefore, they are still present in contaminated waters. There are several different habitats where *Brachythemis contaminata* species can be found, including riverbanks, lakes, ponds, and other calm waters (Lieftinck 1934; Irawan & Rahadi 2016).

Figure 3. Documentation of suborder Zygoptera (A) *Agriocnemis femina*, (B) *Agriocnemis pygmaea*, (C) *Ceriagrion praetermissum*, (D) *Ischnura senegalensis*, (E) *Pseudagrion rubriceps*, (F) *Copera marginipes* (Photo: Muhamad Azmi Dwi Susanto, 2021).

Table 2. Species richness and abundance.

Taxa	Conservation Status	Presence Frequency (%)	Relative Abundance (%)	Number of individuals				
				Pond	Reservoir	River	Rice field	Total
Gomphidae								
Ictinogomphus decoratus (Selys, 1854)	LC	50	2.18	2	16	0	0	18
Libellulidae								
Acisoma panorpoides (Rambur, 1842)	LC	75	2.78	20	1	0	2	23
Brachythemis contaminata (Fabricius, 1793)	LC	100	30.96	107	108	3	38	256
Brachydiplax chalybea (Brauer, 1868)	LC	50	14.51	95	25	0	0	120
Crocothemis servilia (Drury, 1770)	LC	100	3.87	10	5	13	4	32
Diplacodes trivialis (Rambur, 1842)	LC	75	1.33	9	1	0	1	11
Macrodiplax cora (Brauer, 1867)	LC	75	3.39	0	13	3	12	28
Neurothemis feralis (Burmeister, 1839)	DD	25	3.02	25	0	0	0	25
Orthetrum sabina (Drury, 1770)	LC	100	7.86	25	14	12	14	65
Pantala flavescens (Fabricius, 1798)	*LC*	75	3.14	0	4	16	6	26
Potamarcha congener (Rambur, 1842)	LC	75	2.18	5	11	0	2	18
Rhyothemis phyllis (Sulzer, 1776)	LC	50	0.60	3	2	0	0	5
Rhodothemis rufa (Rambur, 1842)	LC	75	1.93	12	2	0	2	16
Tholymis tillarga (Fabricus, 1798)	LC	75	3.14	15	2	0	9	26
Zyxomma obtusum (Albarda, 1881)	NE	25	0.24	2	0	0	0	2
Coenagrionidae								
Agriocnemis femina (Brauer, 1868)	LC	100	6.29	16	21	11	4	52
Agriocnemis pygmaea (Rambur, 1842)	LC	50	1.45	4	8	0	0	12
Ceriagrion praetermissum (Lieftinck, 1929)	LC	25	0.60	5	0	0	0	5
Ischnura senegalensis (Rambur, 1842)	LC	75	1.69	8	2	4	0	14
Pseudagrion nigrofasciatum (Lieftinck, 1934)	DD	25	0.60	5	0	0	0	5
Pseudagrion rubriceps (Selys, 1876)	LC	25	3.87	32	0	0	0	32
Platycnemididae								
Copera marginipes (Rambur, 1842)	LC	25	4.35	36	0	0	0	36
Total Abundance				463	235	62	94	827
Species richness				20	16	7	11	22
Mean ± Standard Deviation				**21.80 ±28.94**	**14.69 ±26.00**	**8.86 ±5.39**	**8.55 ±10.69**	

Information: NE (Not Evaluated), DD (Data Deficient) & LC (Least Concern) Source: (IUCN 2022)

Crocothemis servilia Species is present in many different kinds of ecosystems, including ponds, rice fields, rivers, and swamps (Pamungkas 2016). Additionally, species of *Crocothemis servilia* are frequently observed perching on the tips of nearby plants (Setiyono et al. 2017). The *Orthetrum sabina* species can also be found in various types of habitats (Kalita & Ray 2015). According to (Haissoufi et al. 2015), *Orthetrum sabina* species can be found in habitats of lakes, ponds, rice fields, to swamps. And can develop well in non-flowing waters (Pamungkas 2016), to slow-flowing streams (Kumar 1984). Also, the *Agriocnemis femina* species can be discovered in a variety of habitats. that have grass vegetation around puddles (Setiyono et al. 2017). In addition, the *Agriocnemis femina* species can also be found in waters containing aquatic plants such as water hyacinth (Nicolla et al. 2021).

The similarity level of the research locations was analyzed using the Bray-Curtis index. The parameter used is the species composition of dragonflies in each research location. Based on the similarity analysis of the composition of dragonflies, there are two groups: river and rice field, and reservoir and pond (Figure 5). River and rice field have the same level of dragonfly composition similarity; there are six species found in these two locations, namely *Agriocnemis femina*, *Pantala flavescens*, *Macrodiplax cora*, *Crocothemis servilia*, *Orthetrum sabina*, *and Brachythemis contaminata* (Table 2). Whereas in other groups, reservoir and pond have the same

Figure 4. Documentation of suborder Anisoptera (A) *Ictinogomphus decoratus*, (B) *Acisoma panorpoides*, (C) *Brachythemis contaminata* (D) *Brachydiplax chalybea*, (E) *Crocothemis servilia*, (F) *Diplacodes trivialis*, (G) *Macrodiplax cora*, (H) *Neurothemis feralis*, (I) *Orthetrum sabina*, (J) *Pantala flavescens*, (K) *Potamarcha congener*, (L) *Rhyothemis phyllis*, (M) *Rhodothemis rufa*, (N) *Tholymis tillarga* (Photo: Muhamad Azmi Dwi Susanto, 2021).

level of composition similarity; there are 14 species that can be found in these two locations, namely *Agriocnemis femina*, *Agriocnemis pygmaea*, *Ischnura senegalensis*, *Acisoma panorpoides*, *Brachydiplax chalybea*, *Brachythemis contaminata*, *Crocothemis servilia*, *Diplacodes trivialis*, *Orthetrum sabina*, *Potamarcha congener*, *Rhodothemis rufa*, *Rhyothemis phyllis*, *Tholymis tillarga*, *and Ictinogomphus decoratus* (Table 2).

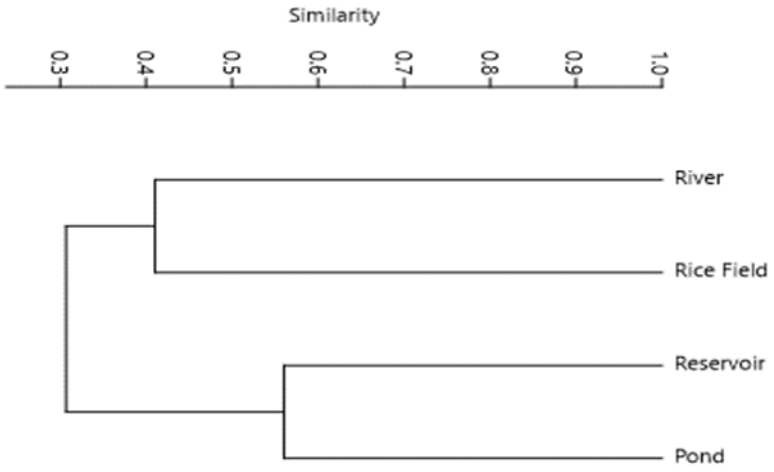

Figure 5. Similarity of dragonfly composition.

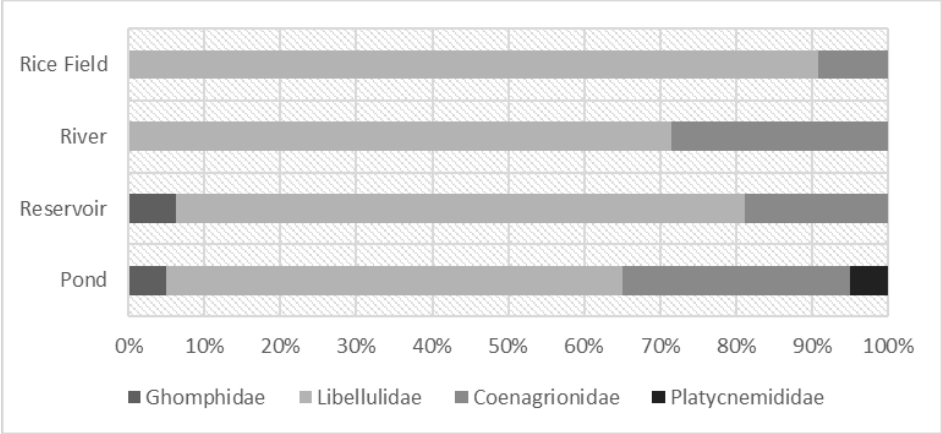

Figure 6. Differences in family composition.

The composition of the dragonfly family found in this study showed that the Libellulidae and Coenagronidae families could be found in all research locations (Figure 6). Meanwhile, in the Platycnemididae family, it can only be found at the pond location and only one species is found, namely *Copera marginipes* (Figure 3-F). This can be due to the fact that the pond location has a type of aquatic stagnant ecosystem with a closed canopy and there is quite dense vegetation, so that at this location it has characteristics that match the natural habitat of the *Copera marginipes* species. This statement is supported by (Furtado 1974), who reported that *Copera marginipes* species are often found perching on aquatic plants or grasses in stagnant waters such as ponds. *Copera marginipes* species are also often found in habitats with closed canopies (Irawan & Rahadi 2016).

In the Gomphidae family, only one species was found, namely *Ictinogomphus decoratus* (Figure 4-A), and also only found in two locations, namely Pond and Reservoir. This is because at both locations, the members of the Gomphidae family have a stagnant aquatic ecosystem type and have tree vegetation and bamboo vegetation. This statement is supported by (Pamungkas 2016), who reported that the species

Ictinogomphus decoratus can be found in stagnant water habitats. In addition, the species *Ictinogomphus decoratus* is typically observed perched on the ends of dry branches, bamboo, or tree trunks (Rahadi et al. 2013; Setiyono et al. 2017).

Based on the evenness index analysis, the location with the most value is along the river, namely E = 0.88, and the lowest is the reservoir, namely E = 0.45 (Figure 7). Meanwhile, the highest dominance index is the reservoir with a value of D = 0.24 and the lowest is a pond with a value of D = 0.13 (Figure 7). The river location has the lowest evenness value because it has species with an abundance that is not much different, namely the species that has the highest number, namely *Pantala flavescens* (16 individuals), and the least *Brachythemis contaminata* and *Macrodiplax cora* with a total of 3 individuals. While the reservoir location has the lowest evenness value as well as the highest dominance value because at this location there is a species that dominates, namely *Brachythemis contaminata* with a total of 108 individuals.

Based on analysis of the Shannon-Wiener index, it shows that the highest value of dragonfly diversity is in a variety of habitats in Lakarsantri, namely at the observation location of Ponds with a value of H'= 2.40. Furthermore, at the reservoir location, namely H'=1.94, the rice field location, namely H'=1.88, and at the river observation location the location with the lowest dragonfly diversity index value with a value of H'= 1.77 (Figure 7). The difference in species diversity of dragonfly influences vary depending on the observation location, including the habitat type (Perez & Bautista 2020), microclimate (Borisov 2006), and vegetation (Silva et al. 2010).

At the location of the pond, 20 species from 4 families were found with a total of 463 individuals (Table 2). There are 6 species found only in this location, namely *Neurothemis feralis*, *Zyxomma obtusum*, *Ceriagrion*

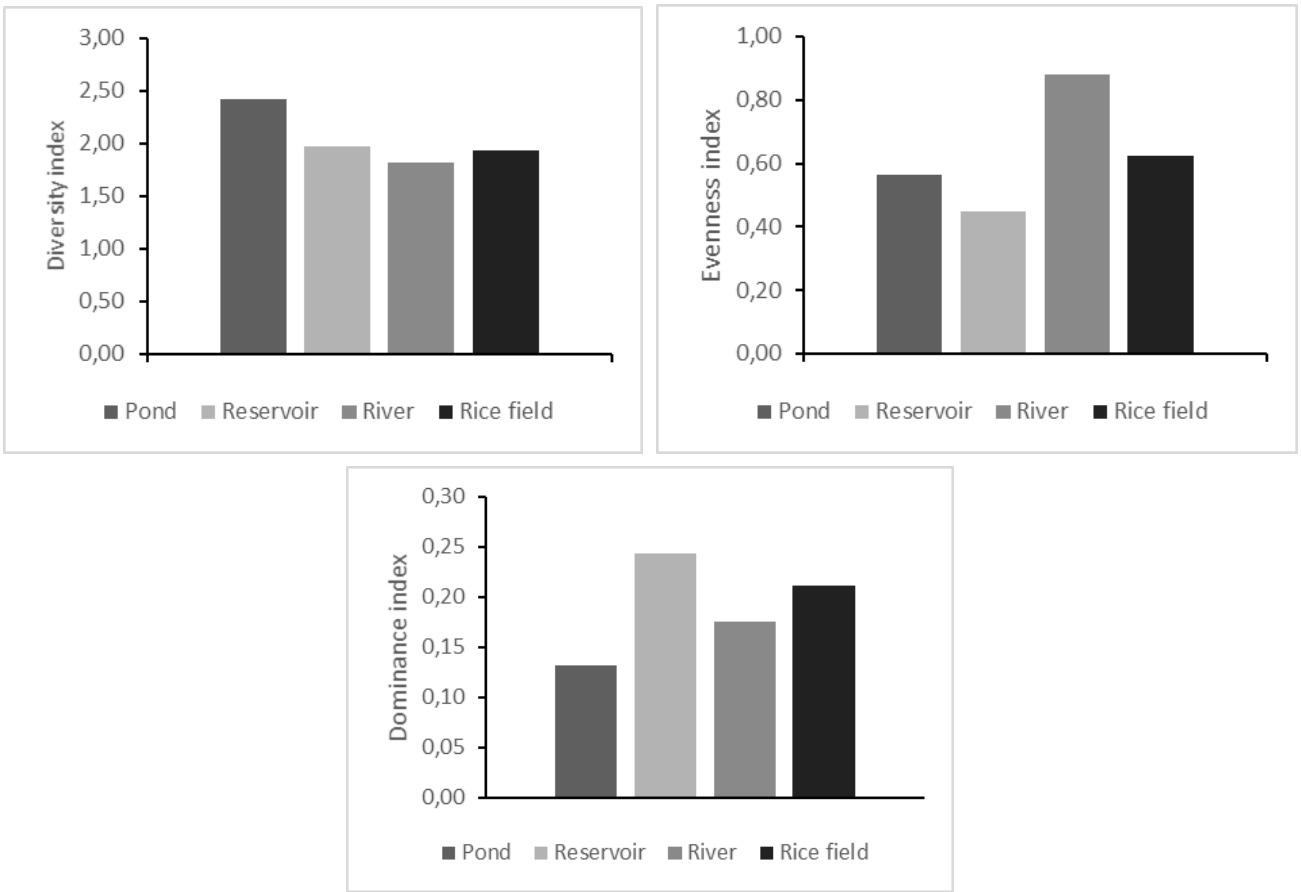

Figure 7. Result of diversity, evenness and dominance index.

praetermissum, *Pseudagrion nigrofasciatum*, *Pseudagrion rubriceps* dan *Copera marginipes*. The pond has the highest diversity index value of any research site (Figure 7), this can be because at this location a variety of vegetation supports the survival of dragonflies. The vegetation factor at the location of the pond is one of the important factors in a natural habitat for the dragonfly community (Nagy et al. 2019). Vegetation conditions are one of the key elements that significantly influences the presence and diversity of dragonfly species in a place. Some dragonfly families also need vegetation such as understorey to lay eggs when breeding, especially the Suborder Zygoptera such as Coenagrionidae (Remmers et al. 2017). Additionally, plants along riverbanks are necessary for dragonfly larvae to find food and defend themselves from predators. Adult dragonflies use the vegetation on riverbanks as a perch, a place to sunbathe, and a place to rest (Silva et al. 2010).

There is some vegetation in the pond location, including aquatic plant vegetation, herb, and tree vegetation (Table 3), these three types of vegetation have different dragonfly community structures. The aquatic plant vegetation (*Ipomoea aquatica* and *Eichhornia crassipes*) found species of *Ceriagrion praetermissum*, *Pseudagrion rubriceps*, *Copera marginipes*, *Brachythemis contaminata*, *Rhodothemis rufa*, and *Ischnura senegalensis*. In the herb vegetation found on the banks (*Eleusine indica* dan *Pennisetum* sp.) and around the pond, species *Ischnura senegalensis*, *Agriocnemis pygmaea*, *Agriocnemis femina*, *Diplacodes trivialis*, *Acisoma panorpoides*, *Neurothemis feralis*, *and Orthetrum sabina* and was found. In addition, in the grass (*Eleusine indica*) vegetation which is quite dense at the edge of the pond, the species *Tholymis tillarga* was found. The presence of herbs (*Bambusa* sp.) and tree vegetation (*Ficus benjamina*, *Muntingia calabura*, and *Swietenia macrophylla*) at the pond location can be a factor in the discovery of *Ictinogomphus decoratus* and *Zyxomma obtusum* species in this study.

In addition to the vegetation factor, the pond location also has an open canopy condition and some locations have a closed canopy condition. The canopy is one of the important factors in the composition of the natural habitat of dragonflies. In the natural habitat of dragonflies, the canopy is one component that affects the diversity and abundance of dragonfly food sources, namely small insects (Davis et al. 2011). Some varieties of dragonflies need a canopy to shield them from excessively bright sunlight (Nugrahani et al. 2014). An open canopy at a location increases the light's intensity, which will change the area's air temperature. So that in open canopy conditions, dragonflies are usually used to sunbathe. Meanwhile, the denser canopy condition causes the speed of air temperature and the intensity of sunlight to not be hindered from entering. So in closed canopy conditions, dragonflies are usually used to rest (Paulson 2009).

Table 3. Types of plants at the research site.

No	Type	Plant Species	Pond	Reservoir	River	Rice field
1	Tree	*Ficus benjamina*	+	-	-	-
2	Tree	*Muntingia calabura*	+	+	-	-
3	Tree	*Swietenia macrophylla*	+	-	-	-
4	Herb	*Musa paradisiaca*	+	+	-	-
5	Herb	*Bambusa* sp.	+	+	-	-
6	Herb	*Pennisetum* sp.	++	++	+	-
7	Herb	*Eleusine indica*	++	+	++	+
8	Herb	*Oryza sativa*	-	-	-	++
9	Aquatic plant	*Ipomoea aquatica*	+	+	-	-
10	Aquatic plant	*Eichhornia crassipes*	+	-	++	-

The river is the research location in this study with the lowest diversity index value (Figure 3), with 7 species from 2 families found with a total of 62 individuals (Table 2). At the location, the river has a flowing water ecosystem type with a very open canopy condition with a sunlight intensity of 32767 lx (Figure 8). So that some species of dragonflies do not have a place to shelter when the sunlight intensity is very high. Therefore, the composition of dragonflies found in open areas mostly has the ability to adapt in places with high sunlight intensity. Species found at this location were *Agriocnemis femina*, *Ischnura senegalensis*, *Orthetrum sabina*, *Macrodiplax cora*, *Pantala flavescens*, *Crocothemis servilia* and *Brachythemis contaminata*.

Sunlight is one of the factors in providing dragonfly flying activity (Goforth 2010). This is because most dragonflies live diurnal and only fly in cloudy sunny conditions or at dusk (Samways 2008). In their natural habitat, dragonflies' activity is primarily influenced by the brightness of the light. Dragonflies will sunbathe and hunt for food at the ideal light intensity, but if the light is too high or too low, they will rest and seek shelter (Corbet 1962). In addition to the intensity of sunlight, which affects the presence and activity of dragonflies at a location are temperature (Schalkwyk et al. 2014) and humidity (Samraoui et al. 1998). Temperature and humidity also determine the activity of dragonflies to locate a place to rest, a time to fly, and a moment to mate (Corbet 1962).

Microclimate differences which include temperature, humidity, and light intensity at each location and time of observation, caused not all species to be found in the three repetitions in each month (Table 4). In addition, the flying ability of each dragonfly can also affect the difference in the presence of dragonflies in each repetition. This is because the roaming ability of each type of dragonfly is different and if it has a high cruising ability, it will have great potential to move locations easily.

In the analysis of this community structure study, there are abiotic factors that influence the community structure of the dragonfly. The sunlight intensity was negatively correlated with diversity index, abundance, and species richness of dragonflies (Figure 9). The intensity of sunlight greatly affects the abundance and species richness of dragonflies, the higher the light intensity, the lower the abundance and species richness. As the results of observations show, the river location, which has the highest sunlight intensity value (Figure 8), has the lowest species richness and abundance, namely 7 species and 62 individuals (Table 2). While the location with the lowest light intensity, namely a pond with an intensity value (Figure 8), has the highest species richness and abundance, namely 20 species and 463 individuals (Table 2). This can be because dragonflies generally have a sensitivity to sunlight intensity that is too high, but some species are resistant to high light intensity.

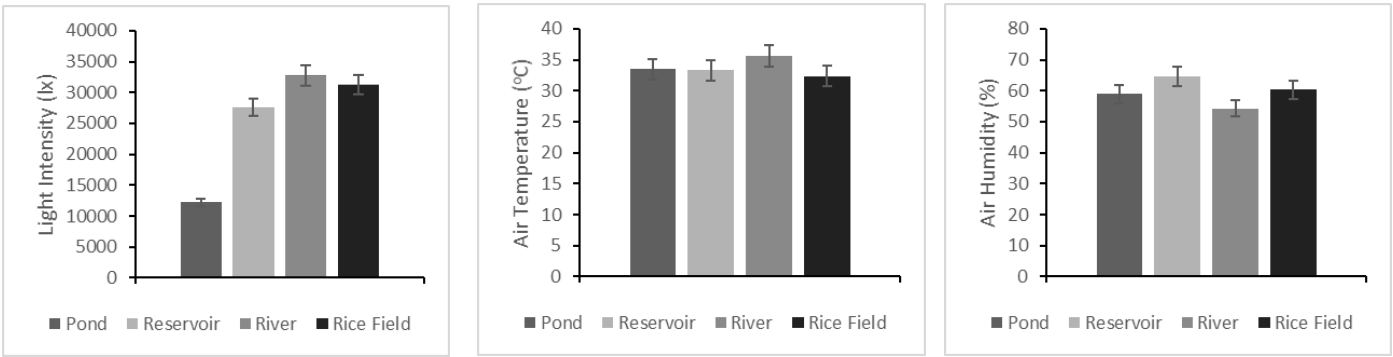

Figure 8. Results of light intensity, air temperature, and air humidity.

Table 4. Presence of species at three months.

Species	July				August				September			
	L1	L2	L3	L4	L1	L2	L3	L4	L1	L2	L3	L4
Ictinogomphus decoratus	√	√	-	-	√	√	-	-	-	√	-	-
Acisoma panorpoides	√	-	-	-	√	-	-	√	√	√	-	-
Brachythemis contaminata	√	√	√	√	√	√	-	√	√	√	-	√
Brachydiplax chalybea	√	√	-	-	√	√	-	-	√	√	-	-
Crocothemis servilia	√	√	√	√	√	√	√	-	√	√	√	√
Diplacodes trivialis	√	-	-	√	-	√	-	-	-	-	-	-
Macrodiplax cora	-	√	√	-	-	√	-	√	-	-	-	-
Neurothemis feralis	√	-	-	-	√	-	-	-	√	-	-	-
Orthetrum sabina	√	√	√	√	√	√	√	√	√	-	√	√
Pantala flavescens	-	√	√	√	-	-	√	-	-	√	-	-
Potamarcha congener	√	√	-	-	-	√	-	√	-	√	-	√
Rhyothemis phyllis	√	√	-	-	-	√	-	-	-	-	-	-
Rhodothemis rufa	√	√	-	-	-	√	-	√	√	-	-	-
Tholymis tillarga	√	√	-	√	√	-	-	-	√	-	-	-
Zyxomma obtusum	√	-	-	-	-	-	-	-	-	-	-	-
Agriocnemis femina	√	√	√	-	√	√	√	√	√	√	√	√
Agriocnemis pygmaea	√	√	-	-	-	-	-	-	-	-	-	-
Ceriagrion praetermissum	√	√	-	-	-	√	-	-	-	√	-	-
Ischnura senegalensis	√	√	√	-	√	√	√	-	√	-	√	-
Pseudagrion nigrofasciatum	√	-	-	-	√	-	-	-	-	-	-	-
Pseudagrion rubriceps	√	-	-	-	√	-	-	-	√	-	-	-
Copera marginipes	√	-	-	-	√	-	-	-	√	-	-	-

The intensity of sunlight has a negative correlation with the diversity index, so an index of sunlight intensity that is too high will cause a low catch of dragonflies. As the observation results show, the location of the river that has the highest sunlight intensity value has the lowest diversity index value, namely H' = 1.77 (Figure 7). Meanwhile, the pond location that has the lowest light intensity has the highest diversity index value, namely H' = 2.40 (Figure 7). This can be because dragonflies choose to rest and roost to avoid the high intensity of sunlight.

Humidity negatively correlates with the evenness index (Figure 9). This shows that the higher the humidity value, the lower the evenness of the dragonfly. As the observation results show, the results showed that the reservoir location which had the highest humidity value, namely 64.6% (Figure 8), had the lowest evenness index value, namely E = 0.7 (Figure 7). Meanwhile, the river location that has the lowest humidity value of 54.33% (Figure 8), has the highest index value of E = 0.91 (Figure 7). This can be because most species of dragonflies require sufficient humidity to support their flight activity. If the humidity value is too high, only certain species can survive, so the evenness value is low and a certain species dominance is formed.

The PCA analysis findings regarding the interaction between abiotic and abiotic factors to the structure of the dragonfly community showed that the two axes of the main components made up the total contribution of 95.01% (Figure 10). All variables have almost the same vector length, but the dominance, humidity, and evenness variables have longer vectors, which means that these 3 variables have more varied values than other variables. The light intensity variable (abiotic factor) with the dominance variable (biotic index) has a positive correlation (Figure 10). This shows that the higher the light intensity value, the

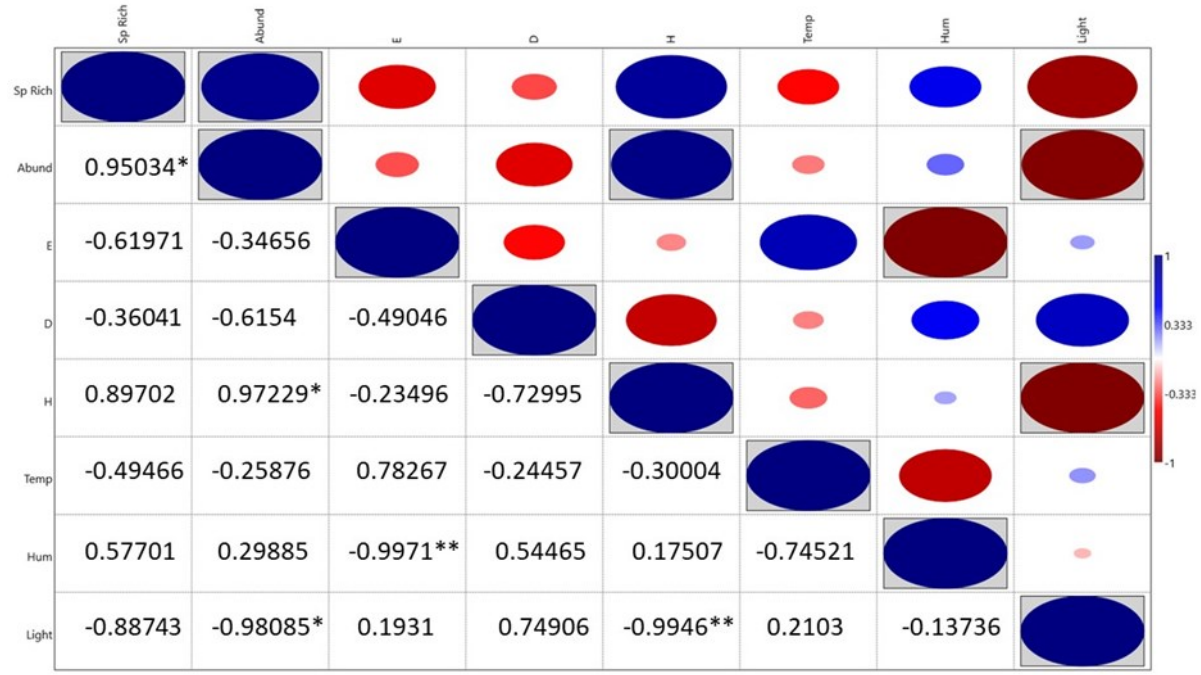

Figure 9. Correlation between biotic and abiotic factors at the research site. Sp rich = Species richness, Abund = Abundance, E = Evennes index, D = Dominance index, H' = Diversity index, Temp = Temperature, Hum = Humidity, and Light = Sunlight intensity. **significant >0.001, *significant 0.01-0.05.

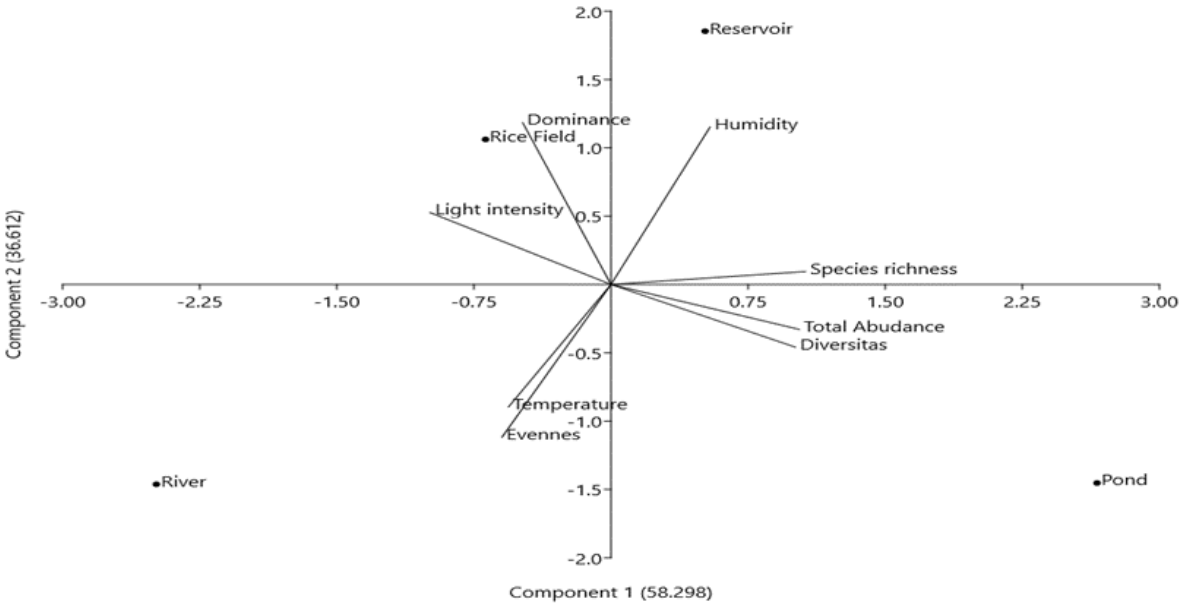

Figure 10. PCA ordinations of four locations.

higher the dominance index will be. This is because only certain species can adapt to high sunlight intensity, so that it will form the dominant of certain species and cause species diversity to be lower. In addition, air temperature also has a positive correlation with evenness index values.

CONCLUSION

The diversity of dragonflies found in various types of habitats in the Lakarsantri Sub-District includes 22 species from 4 families: Gomphidae, Libellulidae, Coenagrionidae, and Platycnemididae. Ponds are the observation sites that have the highest diversity index value, with a value of H' = 2.40, while the river location has the lowest diversity index value, with a

value of H' = 1.77. Because of the pond's location in stagnant waters with a variety of vegetation, this location has a composition of the dragonfly community structure that does not change quickly and has the highest diversity value. At the level of similarity in the composition of the dragonfly community structure, the location of the river has similarities to rice fields, while the location of the reservoir has the same level as ponds. This research shows that various aquatic ecosystems in urban areas can become natural habitats for dragonfly communities, especially pond ecosystems. Therefore, the quality of the aquatic environment in urban areas must be maintained so that dragonfly populations are maintained.

AUTHOR CONTRIBUTION

M.A.D.S designed the research, collected and analyzed the data, and wrote the manuscript, N.F.F. designed the research and supervised all the process, S.B designed the research, assisted in manuscript revision and supervised all the process.

ACKNOWLEDGEMENTS

The authors would like to thank the KUTRIK entomology study group. We also thank M. Iqbal Pratama, Ahmad Alfin Romzalis, Najwa Maulidina Putri, Okta Fina Arianti, Fachrul Asaddin Nuri A., and Yudha Ari Setiawan who participated in the field data collection process. Thank to Najmatul Millah, Siti Zulaikha, Satria Febriansyah, and Zainul Muttaqin Sany who have helped in the writing process. Especially thanks to the late Muhibbuddin Abdillah who helped me learn about dragonflies.

CONFLICT OF INTEREST

The authors declare there is no conflict of interest in any part of this research.

REFERENCES

Borisov, S.N., 2006. Adaptations of dragonflies (Odonata) under desert conditions. *Entomological Review*, 86(5), pp.534–543

Buczyński, P. et al., 2020. Dragonflies (Odonata) of the city of Lublin (Eastern Poland). *Polish Journal of Entomology*, 89(3), pp.153–180. doi: 10.5604/01.3001.0014.4239.

Choong, C.Y. et al., 2020. Diversity of Odonata Species at Kangkawat, Imbak Canyon, Sabah. *Journal of Tropical Biology and Conservation*, 17, pp.1–10.

Corbet, P.S., 1962. *A BIOLOGY OF DRAGONFLIES*, H. F. & G. WITHERBY LTD.

Dalia, B.P.I. & Leksono, A.S., 2014. Interaksi antara capung dengan arthropoda dan vertebrata predator di kepanjen, kabupaten malang. *Jurnal Biotropika*, 2(1), pp.26–30.

Davis, A.J., Sutton, S.L. & Brendell, M.J.D., 2011. Vertical distribution of beetles in a tropical rainforest in Sulawesi : the role of the canopy in contributing to biodiversity. *Sepilok Bulletin*, 13(14), pp.59–83.

Dolný, A. et al., 2012. Aquatic insects indicate terrestrial habitat degradation: changes in taxonomical structure and functional diversity of dragonflies in tropical rainforest of East Kalimantan. *Tropical Zoology*, 25(3), pp.141–157. doi: 10.1080/03946975.2012.717480.

Furtado, J.I., 1974. The reproductive behaviourof Copera marginipes (Rambur) and C. vittata acutimargo(Kruger) (Zygoptera: Platycnemididae). *Odonatologica*, 3(3), pp.167–177.

Goforth, C.L., 2010. Behavioural responses of Enallagma to changes in weather (Zygoptera: Coenagrionidae). *Odonatologica*, 39(3), pp.225–234.

Haissoufi, E.M. et al., 2015. Contribution to the knowledge of the Moroccan Odonata, with first records of Orthetrum sabina, and an overview of first and last dates for all species. *Odonatologica*, 44(3), pp.225–254.

Haritonov, A. & Popova, O., 2011. Spatial displacement of Odonata in south-west Siberia. *International Journal of Odonatology*, 14(1), pp.1–10. doi: 10.1080/13887890.2011.568188.

Irawan, A. & Rahadi, W.S., 2016. *Capung Sumba*, Balai Taman Nasional Manupeu Tanah Daru dan Laiwangi Wanggameti.

IUCN, 2021. Dragonflies threatened as wetlands around the world disappear - IUCN Red List. viewed June 14, 2022 from https://www.iucn.org/news/species/202112/dragonflies-threatened-wetlands-around-world-disappear-iucn-red-list.

IUCN, 2022. The IUCN Red List of Threatened Species, viewed June 10, 2022 from https://www.iucnredlist.org/en.

Kalita, G.J. & Ray, S.D., 2015. Studies on the diversity and habitat preference of odonates in Deepor Beel Bird Sanctuary , Kamrup , Assam. *Journal of Entomology and Zoology Studies*, 3(2), pp.278–285.

Kalkman, V.J. & Orr, A.G., 2013. Field Guide to the damselflies of New Guinea Buku Panduan Lapangan Capung Jarum untuk Wilayah New Guinea. *Brachytron*, 16(2), pp.3–118.

Kandibane, M., Raguraman, S. & Ganapathy, N., 2005. Relative abundance and diversity of odonata in an irrigated rice field of Madurai, Tamil Nadu. *Zoos' Print Journal*, 20(11), pp.2051–2052. doi: 10.11609/jott.zpj.1293.2051-2.

Koneri, R., Angoy, R.N. & Iahaan, M.J.S., 2022. Species Diversity Of Dragonflies on The Sangihe Islands, North Sulawesi, Indonesia. *Applied Ecology And Environmental Research*, 20(2), pp.1763–1780. doi: 10.15666/aeer/2002_17631780.

Kulkarni, A.S. & Subramanian, K.A., 2013. Habitat and seasonal distribution of Odonata (Insecta) of Mula and Mutha river basins , Maharashtra , India Habitat and seasonal distribution of Odonata (Insecta) of Mula and Mutha river basins , Maharashtra , India. *Journal of Threatened Taxa*, 5(7), pp.4084–4095. doi: 10.11609/JoTT.o3253.4084-95.

Kumar, A., 1984. Studies on the life history of Indian dragonflies, Diplacodes trivialis (Rambur, 1842). *Records of the Zoological Survey of India*, 81(3 & 4), pp.13–22.

Lieftinck, M., 1934. An Annotated List of theOdonata of Java, With Notes on Their Distribution, Habits and Life-History. *Treubia*, 14 (3).

Magurran, A.E., 2004. *Ecological Diversity and Its Measurement*, USA: Chapman and Hall.

Maldonado-Benítez, N., Mariani-Ríos, A. & Ramírez, A., 2022. Effects of urbanization on Odonata assemblages in tropical island streams in San Juan, Puerto Rico. *International Journal of Odonatology*, 25, pp.31–42. doi: 10.48156/1388.2022.1917163.

Metcalfe, J.L., 1989. Biological water quality assessment of running waters based on microinvertebrates communities: History and present status in Europe. *Environ*, pp.101–139.

Nagy, H.B. et al., 2019. Landscape-scale terrestrial factors are also vital in shaping odonata assemblages of watercourses. *Scientific reports*, 9 (1), pp.1–8. doi: 10.1038/s41598-019-54628-7.

Nicolla, A.C. et al., 2021. Comparison of Damselfly (Odanata : Zygoptera) diversity in wet dune slack habitat with canopied and non-canopied areas of Gumuk Pasir Parangkusumo , Yogyakarta , Indonesia. In *IOP Conference Series: Earth and Environmental Science*. doi: 10.1088/1755-1315/736/1/012046.

Nugrahani, M.P. et al., 2014. *Peluit Tanda Bahaya: Capung Indikator Lingkungan Panduan Penilaian Kualitas Lingkungan Melalui Capung*, Yogyakarta: Indonesia Dragonfly Society.

Oppel, S., 2006. Using distance sampling to quantify Odonata density in tropical rainforests. *International Journal of Odonatology*, 9(1), pp.81–88.

Orr, A.G., 2005. *Dragonflies of Peninsular Malaysia and Singapore*, Natural History Publication. Kota Kinabalu.

Orr, A.G. & Kalkman, V.J., 2015. *Field guide to the dragonflies of New Guinea Buku Panduan Lapangan Capung Jarum untuk Wilayah New Guinea*, Brachytron.

Pamungkas, B.C., 2016. *UNTRING: Dragonflies of Banyuwangi*, Yogyakarta: Indonesian Dragonfly Society.

Paulson, D., 2009. *Dragonflies and Damselflies of the West*, Princeton University Press.

Perez, E.S.N. & Bautista, M.G., 2020. Dragonflies in the City: Diversity of Odonates in Urban Davao, Philippines. *Journal of Agricultural Science and Technology A*, 10(1), pp.12–19. doi: 10.17265/2161-6256/2020.01.002.

Rahadi, W.S. et al., 2013. *Naga terbang Wendit: keanekaragaman capung perairan Wendit, Malang, Jawa Timur*, Indonesia Dragonfly Society.

Remmers, W. et al., 2017. Elephant (Loxodonta africana) footprints as habitat for aquatic Elephant (Loxodonta africana) footprints as habitat for aquatic macroinvertebrate communities in Kibale. *African journal of ecology*, 55(3), pp.342–351. doi: 10.1111/aje.12358.

Samraoui, B. et al., 1998. Postponed reproductive maturation in upland refuges maintains life-cycle continuity during the hot, dry season in Algerian dragonflies (Anisoptera). *International Journal of Odonatology*, 1(2), pp.119–135. doi: 10.1080/13887890.1998.9748100.

Samways, M.J., 2008. *Dragonflies and damselflies of South Africa*, Pensoft Publishers.

Schalkwyk, J. Van, Samways, M.J. & Pryke, J.S., 2014. Winter survival by dragonfly adults in the Cape Floristic Region. *International Journal of Odonatology*, 17(1), pp.17–30. doi: 10.1080/13887890.2014.880382.

Setiyono, J. et al., 2017. *Dragonfly of Yogyakarta*, Yogyakarta: Indonesia Dragonfly Society.

Silva, D. de paiva, De Marco, P. & Resende, D.C., 2010. Adult odonate abundance and community assemblage measures as indicators of stream ecological integrity: A case study. *Ecological Indicators*, 10 (3), pp.744–752. doi: 10.1016/j.ecolind.2009.12.004.

Tang, H.B., Wang, L.K. & Hämäläinen, M., 2010. *A photographic guide to the dragonflies of Singapore*, Department of Biological Sciences, National University of Singapore.

Vilenica, M. & Mihaljević, Z., 2022. Odonata Assemblages in Anthropogenically Impacted Habitats in the Drava River-A Long-Term Study. doi: 10.3390/w14193119.