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Research Article

Composition and Diversity of Dragonflies (Odonata) in Several Habitat Types in Lumajang Regency, East Java Province, Indonesia

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ABSTRACT
Lumajang is one of the regency in East Java Province that has various types of freshwater ecosystems and have great potential as habitats for various insects, especially dragonflies. Dragonflies are insects that mostly live aquatically, so their existence is highly dependent on the condition of aquatic ecosystems. This study aims to compare the composition and diversity of dragonfly species in various habitat types in Lumajang. The study was conducted in lentic and lotic ecosystems in Lumajang. The method used was the Visual Encounter Survey (VES) technique adapted from the sweeping net. The data analysis used to determine differences in dragonfly species composition was the Bray-Curtis similarity analysis, while diversity analysis was conducted using the Shannon-Wiener index. This study recorded 29 species from seven families, including seven endemic dragonfly species found only on several islands in Indonesia. In the analysis of the Shannon-Wiener diversity index, the results show that in all research locations have a value of H'= 1.07–2.11, where the Rice Field habitat is the location with the highest value among other locations, with a value of H' = 2.11. The similarity analysis of dragonfly species composition using Bray Curtis similarity showed that it was divided into three groups. The composition of dragonflies found in several habitats in Lumajang is different, which can be influenced by many factors such as site elevation, habitat type (lentic or lotic), and habitat condition, as well as several other factors such as microclimate and vegetation (related to food availability).

INTRODUCTION
Dragonflies are insects that belong to the order Odonata and experience incomplete metamorphosis with three stages, namely eggs, nymphs, and adults (O'Malley et al. 2020). Adult dragonflies can be found in terrestrial ecosystems (Choong et al. 2020), while eggs and nymphs can be found in aquatic ecosystems, especially freshwater ecosystems (Kietzka et al. 2021). Dragonflies spend most of their lives in the nymph stage in freshwater ecosystems (Choong et al. 2020), so their existence is highly dependent on water conditions (Tang et al. 2010; Susanto et al. 2023). Therefore, adult dragonflies can be found around freshwater ecosystems such as rivers, ponds, and lakes (Choong et al. 2020). The ideal habitat for adult dragonflies is in around aquatic ecosystems with good water quality and the presence of riparian and aquatic vegetation (Vilenica et al. 2020; Worthen et al. 2021; Cheri & Finn 2023).

Dragonflies are one of the insects that have sensitivity to change in environmental quality, so dragonflies (certain types) can be used as indicators of water quality. Some dragonfly species are very sensitive to environmental changes (Buczyński et al. 2020), thus dragonflies are suitable as bioindicator agents to measure the quality of an ecosystem (Aziz & Mohamed 2018). This is because the presence of dragonflies is disrupted if their natural habitat is disturbed or damaged (Buczyński et al. 2020; Susanto et al. 2023). Therefore, it is important to monitor dragonfly composition and diversity as early indicators in the assessment of changes in water quality (Koneri et al. 2022).

Research on dragonfly diversity in several habitat types in East Java Province has been conducted in several areas, including the diversity of Odonata along an altitudinal gradient in East Java Province (Leksono et al. 2017), Diversity of dragonflies on the natural reserve areas of Mt. Sigogor and Mt. Picis, Ponorogo Regency, which was carried out in different habitat types, namely the forest-dominated area and open area (Pranoto et al. 2019), diversity of dragonflies (Odonata) in various types of habitat, namely in ponds, reservoirs, rivers, and rice fields in Lakarsantri district, Surabaya (Susanto et al. 2023), Odonata diversity and composition using the ArcGIS in springs, waterfalls, and river habitats in Malang and Batu, East Java (Albab et al. 2019), and diversity and community structure of Odonata in large river and small stream habitats in the Selorejo waterfall area, Ponorogo (Susanto & Zulaikha 2021). Research on dragonflies in Lumajang has been conducted by Abdillah (2020), on several rivers in the Pasrujambe district, and Susanto and Abdillah (2019), who conducted research on Zygoptera diversity in lakes and rivers in Bromo Tengger Semeru National Park (TNBTS). Research on dragonflies in the Lumajang regency is still very limited, so it is necessary to conduct research on dragonflies in a wider area that includes several habitats and regions.

Lumajang is a regency in East Java Province, with land elevations ranging from 0 to >2000 m above sea level and various ecosystems. Lumajang is known to have many freshwater ecosystems such as lakes, rivers, streams, swamps, ponds, fish ponds, and dams (Lumajang Regional Government 2018). The Lumajang Regional Government (2018) states that the freshwater ecosystems in Lumajang are utilized by the surrounding communities to support life. Such as domestic water sources, irrigation of the agricultural sector, and industry, and can even be used as a source of income for tourism or cultivation. Human activities pose a significant threat to aquatic ecosystems (Williams et al. 2016), thus it is necessary to research the composition and diversity of dragonfly species in various habitat types in Lumajang to prevent ecosystem damage. Studies on the latest information on dragonfly biodiversity are also indispensable due to ecological dynamics (Hastomo et al. 2022). The study was conducted in various habitat types to determine the composition and diversity of dragonflies found in various habitats in Lumajang, East Java.

MATERIALS AND METHODS

Time and Location Study

The study was conducted from July to September 2022, with one repetition each month. In July, we conducted research on the 20th–29th, then in August on the 1st–10th, and finally in September on the 1st–10th. The research was conducted in lentic and lotic aquatic ecosystems at eight different locations in Lumajang regency, East Java Province (Figure 1). Rice field, pond, pond city park, and lake were lentic waters. While in lotic waters, among others, waterfalls, agriculture rivers, village rivers, and forest rivers (Table 1). Sampling was carried out every time in sunny conditions, with observation time from 08.00 WIB to 16.00 WIB with a break from 12.00 to 13.30 WIB.

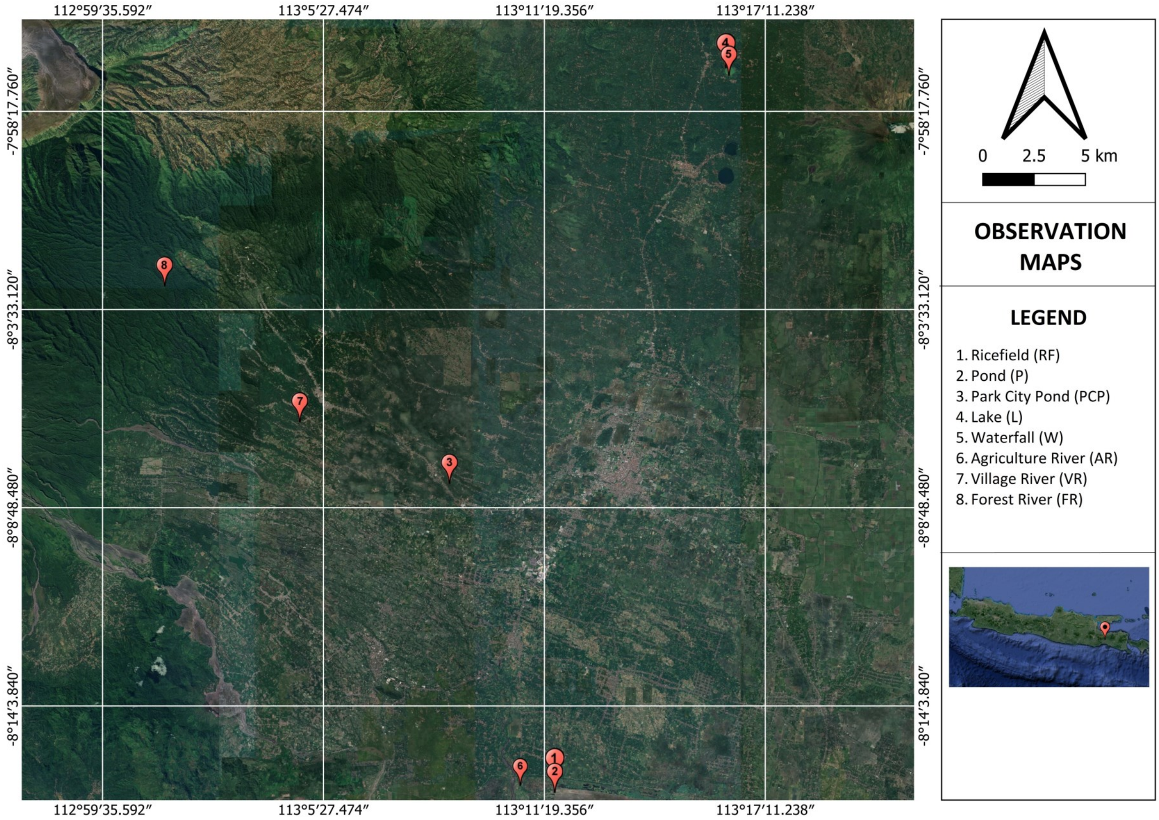

Figure 1. Map of the eight research sites in Lumajang.

Table 1. Description of the eight research sites in Lumajang.

Location	Coordinate Point		Elevation (masl)	Description
	Latitude	Longitude		
Ricefield (RF)	S8° 16' 6,4"	E113° 11' 37,1"	4–12	Lentic aquatic habitats in rice fields
Pond (P)	S8° 16' 22,5"	E113° 11' 36,5"	4–12	Lentic water habitats are utilized by the community as fishing grounds and irrigation sources
Park City Pond (PCP)	S8° 8' 5,8"	E113° 13' 25,1"	55–58	Lentic water habitats are used by the community as a place to travel
Lake (L)	S7° 56' 57,7"	E113° 16' 10,0"	167	Lentic water habitats are used by the community as tourist attractions and for fishing
Waterfall (W)	S7° 57' 9,9"	E113° 16' 14,7"	167–280	Lotic water habitats are utilized by the community as tourist attractions
Agriculture River (AR)	S8° 16' 11,0"	E113° 10' 41,3"	4–12	Lotic water habitat that is used by the community as a fishing spot and irrigation source
Village River (VR)	S8° 6' 26,9"	E113° 4' 49,2"	432	Lotic water habitats near residential areas
Forest River (FR)	S8° 2' 48,3"	E113° 1' 13,2"	1103–1420	Lotic water habitats are located in conservation forests that are utilized by the community as a water source.

Sampling Methods

Determination of the research path using the Transect method (Oppel 2006) and Belt Transect (Haritonov & Popova 2011). The Transect method was used to observe dragonflies by following a predetermined straight line. Meanwhile, the Belt Transect method is carried out by walking along a predetermined circular line. We used transection lines and transection belts with a size of 250 m in length and 4 m in width, with a total area of 1000 m^2. Data collection of adult dragonflies was conducted through direct observation using the Visual Encounter Survey (VES) technique adapted to the sweeping net. Observations began with capturing individuals of each species first using a sweeping net, and then individuals of the same species were observed visually. Then, to minimize potential bias in individual counts, we captured certain species that had high flight rates and then released them again at a later time after observation. Adult dragonfly data was collected by recording and counting the number of individuals of each species found. In addition, unidentified species were captured using insect nets, and each individual was documented in detail using a camera. Also, dragonflies found in the wild were documented for aesthetic purposes. Each individual collected or documented is identified at the species level. Dragonfly species identification is done by observing individual morphological characteristics such as body size, colour, pattern, wing venation, and umbilical shape. Identification was carried out using manual identification guides (Orr 2005; Orr & Kalkman 2015; Setiyono et al. 2017).

The research data collection also considered microclimate factors such as light intensity, air humidity, and temperature. Temperature and humidity factors were measured using a thermohygrometre, while light intensity was measured using a light meter. Vegetation data were also documented by identifying the dominant plant species present at the study site.

Data Analysis

The qualitative analysis was conducted by describing dragonflies to generate an interpretation of dragonflies and its habitat (Hastomo et al. 2022). The quantitative analysis was conducted through the analysis of obtained data for diversity using the Shannon-Wiener index (Metcalfe 1989), dominance index (Magurran 2004), relative abundance, and presence frequency. With the following formula:

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

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

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

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

$$RA = \frac{ni}{N} \times 100\%$$

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

N = Number of individuals of all types

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

Information:
PF = Presence frequency

Furthermore, a principal component analysis (PCA) and Canonical Correspondence Analysis (CCA) were conducted to understand the relationship between observation locations and abiotic factors (environment) as well as biotic indices (Koneri et al. 2022). To assess the similarity of dragonfly composition, the UPGMA clustering analysis method was employed using the Bray-Curtis index. The correlation between biotic and abiotic factors was analysed using Pearson's correlation. All analyses were performed using PAST (paleontological statistics) 4.03 software (Hammer 2001). The data on the composition and abundance of dragonflies is also used to calculate the important value index (IVI), which is used to assess the importance of species present at each location (Nguyen et al. 2014). The formula for calculating the important value index (IVI) is as follows IVI = RA + FR, where RA is relative abundance (%), FR is the relative frequency (%) (Febriansyah et al. 2022).

RESULTS AND DISCUSSION

The results of dragonfly observations at the eight research sites showed 29 species of dragonflies belonging to seven families (Table 2). In this study, the family with the highest number of species was the Libellulidae, with 14 species. The Libellulidae family is a family from the suborder Anisoptera that is commonly found. The Libellulidae family was found to have the highest number of species, which can be because this family has many members of species that have generalist properties or can be found in various habitat types. Koneri et al. (2022) are also mentioned that the Libellulidae family is a family that has excellent adaptability, so this family is very common in lentic and lotic water habitats. The Libellulidae family is a family that is very common in various lentic and lotic water habitats (Orr & Kalkman 2015). In this study, six species of the Libellulidae family were found in three or more habitat types, namely *Crocothemis servilia*, *Diplacodes trivialis*, *Orthetrum sabina*, *Pantala flavescens*, *Potamarcha congener*, and *Rhodothemis rufa* (Table 2).

The species with the highest presence frequency in this study were *Orthetrum sabina* with 87.5%, which was found in seven study sites and *Rhodothemis rufa* with 75%, which was found in six study sites (Table 2). *O. sabina* was found perched on aquatic vegetation or woody branches at the water's edge. In addition, *O. sabina* is also found in grass and shrub vegetation near or far from the water, thus *O. sabina* species include generalist species or those that can be found in various habitat types. This is in accordance with the research of Leksono et al. (2017) conducted at various altitudes in East Java Province, which found that *O. sabina* is the most dominant species in various locations and is very common. Another study from Susanto et al. (2023), who conducted research on various types of aquatic habitats in Lakarsantri district, Surabaya, found that *O. sabina* species were found in all observed aquatic habitats, namely rice fields, rivers, reservoirs, and ponds.

R. rufa was found perched on aquatic vegetation in the water, but also found on grass and shrub vegetation near the water. This is in accordance with Susanto et al. (2023), who reported that *R. rufa* was found perched on aquatic vegetation in aquatic habitats of ponds, reservoirs, and rice fields. In another study conducted by Chaudhry et al. (2015), they also found *R. rufa* in grass vegetation around rivers, ponds, and swamps.

At the study site, seven endemic dragonfly species were found that are only found on several islands in Indonesia, or called multiple island endemics (Figure 2). The encounter of several endemic species in Lumajang is an important finding to discuss. This is because endemic species

Table 2. List of species found in the eight research sites in Lumajang.

No	Species	Family	Conservation status	PF (%)	Lentic				Lotic			
					RF	P	PCP	La	W	AR	VR	FR
1	*Paragomphus reinwardtii* (Selys, 1854)*	Gomphidae	LC	25.0	-	-	+	-	-	+	-	-
2	*Ictinogomphus decoratus* (Selys, 1854)	Gomphidae	LC	37.5	+	-	-	+	+	-	-	-
3	*Acisoma panorpoides* (Rambur, 1842)	Libellulidae	LC	12.5	+	-	-	-	-	-	-	-
4	*Brachythemis contaminata* (Fabricius, 1793)	Libellulidae	LC	37.5	+	+	-	+	-	-	-	-
5	*Crocothemis servilia* (Drury, 1770)	Libellulidae	LC	50.0	+	+	-	+	-	+	-	-
6	*Diplacodes trivialis* (Rambur, 1842)	Libellulidae	LC	37.5	+	-	+	+	-	-	-	-
7	*Neurothemis ramburii* (Brauer, 1866)	Libellulidae	LC	25.0	-	-	-	+	+	-	-	-
8	*Neurothemis terminata* (Ris, 1911)	Libellulidae	LC	25.0	-	-	-	+	+	-	-	-
9	*Orthetrum glaucum* (Brauer, 1865)	Libellulidae	LC	12.5	-	-	-	-	+	-	-	-
10	*Orthetrum pruinosum* (Burmeister, 1839)	Libellulidae	LC	25.0	-	-	-	-	+	-	-	+
11	*Orthetrum sabina* (Drury, 1770)	Libellulidae	LC	87.5	+	+	+	+	+	+	+	-
12	*Orthetrum testaceum* (Burmeister, 1839)	Libellulidae	LC	25.0	-	-	-	+	+	-	-	-
13	*Pantala flavescens* (Fabricius, 1798)	Libellulidae	LC	50.0	+	-	+	+	-	+	-	-
14	*Potamarcha congener* (Rambur, 1842)	Libellulidae	LC	37.5	+	+	+	-	-	-	-	-
15	*Rhodothemis rufa* (Rambur, 1842)	Libellulidae	LC	75.0	+	+	+	+	+	+	-	-
16	*Rhyothemis phyllis* (Sulzer, 1776)	Libellulidae	LC	12.5	-	+	-	-	-	-	-	-
17	*Vestalis luctuosa* (Burmeister, 1839)*	Calopterygidae	LC	25.0	-	-	-	-	+	-	+	-
18	*Rhinocypha anisoptera* (Selys, 1879)*	Chlorocyphidae	LC	25.0	-	-	-	-	+	-	-	+
19	*Heliocypha fenestrata* (Burmeister, 1839)*	Chlorocyphidae	LC	12.5	-	-	-	-	-	-	+	-
20	*Agriocnemis femina* (Brauer, 1868)	Coenagrionidae	LC	25.0	+	+	-	-	-	-	-	-
21	*Agriocnemis pygmaea* (Rambur, 1842)	Coenagrionidae	LC	12.5	+	-	-	-	-	-	-	-
22	*Ischnura senegalensis* (Rambur, 1842)	Coenagrionidae	LC	37.5	+	+	-	+	-	-	-	-
23	*Pseudagrion microcephalum* (Rambur, 1842)	Coenagrionidae	LC	25.0	+	-	-	+	-	-	-	-
24	*Pseudagrion pruinosum* (Burmeister, 1839)	Coenagrionidae	LC	25.0	-	-	-	-	-	+	+	-
25	*Pseudagrion rubriceps* (Selys, 1876)	Coenagrionidae	LC	12.5	-	-	-	-	-	+	-	-
26	*Euphaea variegata* (Rambur, 1842)*	Euphaeidae	LC	25.0	-	-	-	-	+	-	+	-
27	*Coeliccia membranipes* (Rambur, 1842)*	Platycnemididae	LC	25.0	-	-	-	-	-	-	+	+
28	*Copera marginipes* (Rambur, 1842)	Platycnemididae	LC	25.0	-	-	-	-	-	+	+	-
29	*Nososticta insignis* (Selys, 1886)*	Platycnemididae	LC	25.0	-	-	-	-	+	-	+	-

Note: (*) Endemic species, (+) Present, (-) Absence. PF= Presence frequency. Status conservation: LC= Least Concern (IUCN 2023)

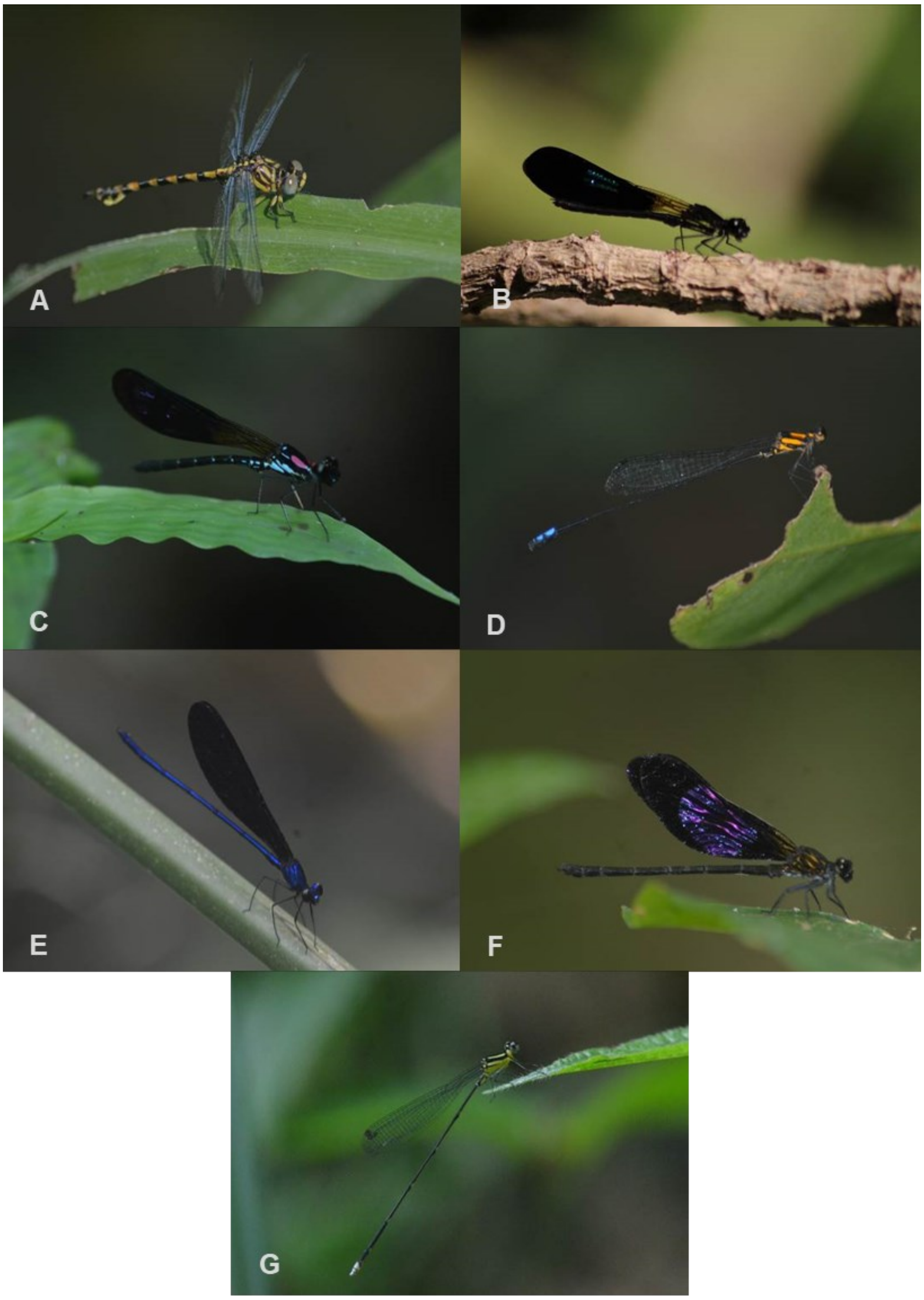

Figure 2. Several of the endemic species in the eight research sites in Lumajang, East Java Province. A. *Paragomphus reinwardtii*, B. *Rhinocypha anisoptera*, C. *Heliocypha fenestrata*, D. *Nososticta insignis* E. *Vestalis luctuosa*, F. *Euphaea variegata*, G. *Coeliccia membranipes.* (Photo: M. Azmi Dwi Susanto 2022).

can only be found on certain islands or regions, so meeting endemic species in their natural habitat can be useful in knowing suitable habitats that can be useful in future conservation efforts.

Paragomphus reinwardtii (Figure 2-A) is a species that can only be found in Java and Bali (Dow et al. 2022). *P. reinwardtii* species were found roosting in riparian vegetation with open to slightly closed canopy conditions and many trees in urban park ponds and agricultural rivers. *P. reinwardtii* found in agricultural rivers are teneral individuals, individuals that have just molted from the naiad to adult phase, so agricultural rivers are likely habitats for *P. reinwardtii* to lay eggs and become nymphs. This is consistent with Dow et al. (2022) who reported that *P. reinwardtii* species can be found in waters in agricultural areas or rice fields, and this species has a tolerance to low levels of environmental pollution.

Rhinocypha anisoptera (Figure 2-B) and *Heliocypha fenestrata* (Figure

2-C) are members of the Chlorocyphidae family and are endemic species. *R. anisoptera* can only be found in Java and Sumatra (Günther 2019b), while *H. fenestrata* can only be found in Java and Bali (Günther 2019a) In this study, *R. anisoptera* was found perched on twigs and tree branches at the edge of forest waters, namely at the location of waterfalls and forest rivers. This is in accordance with Abdillah & Lupiyaningdyah (2020), who reported that *R. anisoptera* can be found perched on twigs or tree branches on the banks of forest rivers. Meanwhile, *H. fenestrata* was found perched on riparian vegetation and rocks on the banks or middle of the river in open canopy conditions at the village river location. Susanto & Bahri (2021), are also mentioned that *H. fenestrata* can be found in forest rivers with open canopies.

Nososticta insignis (Figure 2-D) is a species that has a distribution in Java, Sumatra, and Bali (Dow 2019c). *N. insignis* was found perched on slightly dense vegetation with a slightly closed canopy near the water at the waterfall location. This is in accordance with the research of Dharmawan et al. (2022), which reported that *N. insignis* was found in the location of Alas Purwo National Park with a fairly high humidity of 72% and a fairly low light intensity of 596 Lux. In addition, the research of Rachman & Rohman (2016) also found *N. insignis* in the waterfall area in secondary forest.

Based on the conservation status assessment from IUCN (2023), three endemic dragonfly species found in this study have declining populations, namely *V. luctuosa* (Figure 2-E), *E. variegata* (Figure 2-F), and *C. membranipes* (Figure 2-G). *V. luctuosa* and *E. variegata* are species that can only be found in Java, Sumatra, and Bali (Dow 2019b; Dow 2019d). *V. luctuosa* was found to spend more time perching on riparian vegetation and tree branches on riverbanks with slightly closed to open canopy conditions. In addition, *V. luctuosa* was also found perched on rocks in the middle or on the banks of the river. This is consistent with Aswari (2004), who reported that *V. luctuosa* is not very active in flight and more often perches on vegetation with closed to open canopy conditions in flowing waters. *V. luctuosa* species are often found perched on vegetation on riverbanks with open or closed canopy conditions (Susanto & Bahri 2021; Nafisah & Soesilohadi 2021).

E. variegata and *V. luctuosa* were found in almost the same habitat conditions, and also both species were only found in the same two places, namely the waterfall and village river locations. *E. variegata* has a similar habitat to *V. luctuosa* (Abdillah & Lupiyaningdyah 2020; Nafisah & Soesilohadi 2021; Susanto & Bahri 2021). *E. variegata* is found perched on riparian vegetation, tree branches, and rocks on riverbanks. There were the same results on Susanto and Zulaikha (2021), who found *E. variegata* in streams with open and closed canopy conditions. *E. variegata* is more often found perched on rocks in the middle or banks of rivers under open canopy conditions (Nafisah & Soesilohadi 2021). *C. membranipes* is a species that can only be found in Java and Sumatra (Dow 2019a). *C. membranipes* was found perched on fairly dense riparian vegetation with closed to slightly open canopy conditions. Susanto and Zulaikha (2021), are also founded *C. membranipes* in waters with fairly dense riparian vegetation and closed canopy conditions.

The results of the analysis of the species richness value at the study site showed that the Rice Field location had the highest species richness value, with 13 species (Figure 3). The high species richness value at the Rice Field location can be attributed to the fact that this location is stagnant water with various types of vegetation, and there are various types of abundant small insects that have the potential to become a food source for dragonflies. In addition, the rice field location is in the lowlands, so it can be a habitat for various types of dragonflies, especially generalist dragonflies. In rice fields dominated by rice plants, there are many small insects that damage agricultural crops or are called pests (Oo et al. 2020; Wakhid et al. 2020). These pest insects have great potential to be a source of food for various types of dragonflies. This is also supported by Suroto et al. (2021), who reported that dragonflies are one of the insects that are often found and have an important role in the rice field ecosystem, namely acting as predators of insect pests such as leafhoppers.

The results of the abundance analysis at the research site showed that the lake location had the highest abundance of 338 individuals (Figure 3). The high abundance of dragonflies at the lake location could be due to the fact that this location is surrounded by lowland community forests, so at the lake location there is minimal human activity and there are not many changes in environmental quality. At the lake location, there are two species that have high abundance, namely *N. ramburii* with 109 individuals and *O. sabina* with 70 individuals.

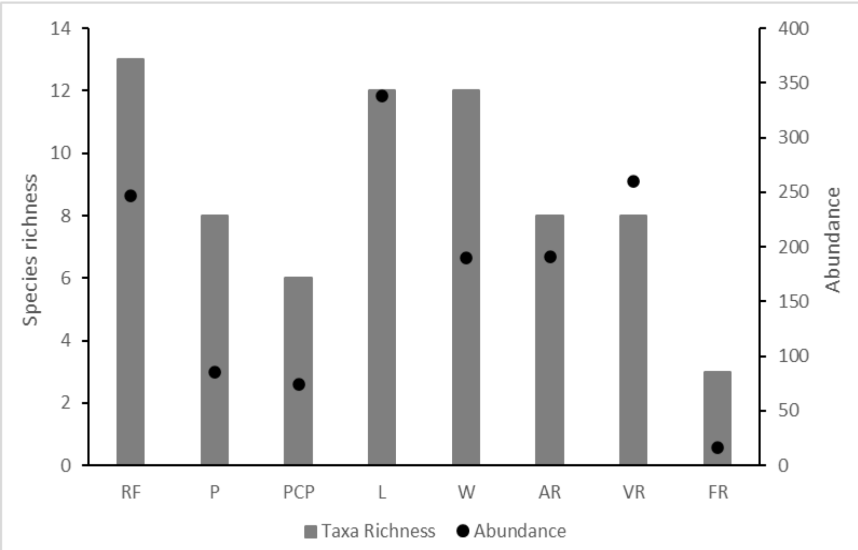

Figure 3. Species richness and abundance of dragonflies in the eight research sites in Lumajang, East Java Province. Note RF: Ricefield, P: Pond, PCP: Park City Pond, L: Lake, W: Waterfall, AR: Agriculture River, VR: Village River, & FR: Forest River.

Forest river is the location with the lowest species richness and abundance, with only three species, namely *Orthetrum pruinosum*, *Rhinocypha anisoptera*, and *Coeliccia membranipes* with a total of 16 individuals. The research location in the highlands, with dense vegetation and closed canopy conditions, can be one of the factors that cause low diversity values at this location. This is supported by Kinvig & Samways (2000), who reported that a dense canopy (especially invasive vegetation) can be a factor in reducing dragonfly diversity. The study by Briggs et al. (2019) also assumed that canopy cover could be the cause of low dragonfly diversity. If the canopy conditions are closed, the sunlight intensity will be blocked and the humidity will be higher, so it is not optimal for dragonflies to use it for basking. Humidity measurement results showed that the forest river location has the highest average humidity of all observation locations.

Grouping locations based on the similarity of dragonfly composition can be useful in analysing the similarity of habitat conditions so that it becomes a suitable habitat for the life of certain dragonfly species. In addition, it can also be useful in determining the preferences of dragonfly species in choosing habitat types. The analysis of the Bray-Curtis similarity index showed that the composition of dragonfly species between research locations is in three groups (Figure 4).

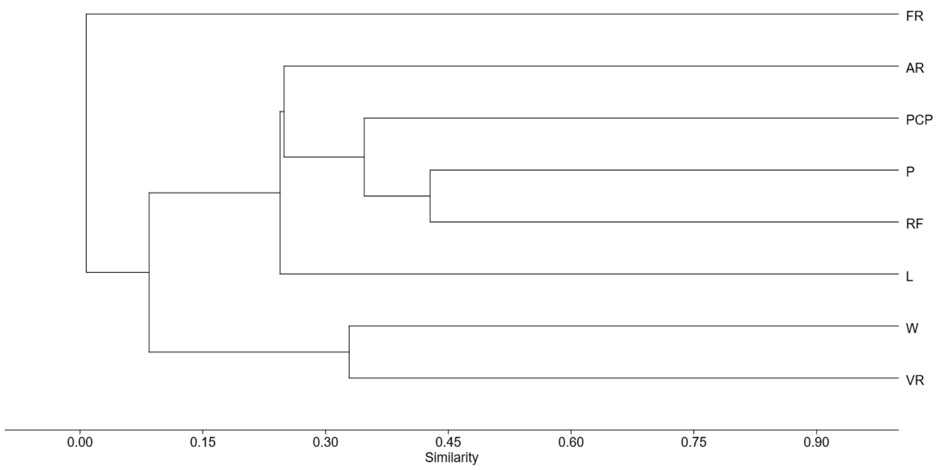

Figure 4. Similarity of dragonfly composition of dragonflies in the eight research sites in Lumajang, East Java Province. Note: RF: ricefield, P: pond, PCP: park city pond, L: lake, W: waterfall, AR: agriculture river, VR: village river, & FR: forest river.

In group one, the waterfall and village river locations have similar water types, namely lotic waters. In this location, there were four species found in both locations, namely *Orthetrum sabina*, *Vestalis luctuosa*, *Euphaea variegata*, and *Nososticta insignis.* In group two, namely rice field, pond, park city pond, agriculture river, and lake, most of which are lentic waters (only the agriculture river location is lotic) located in the lowlands, the composition of these five locations is mostly generalist species. The dragonfly composition at the five sites in this group is most likely also due to the elevation factor, where all sites are in lowlands, with four sites below 100 msal and one site, Lake, below 200 msal. In group three, forest river has the lowest similarity value, which indicates a different composition from other locations. This can be due to the forest river location in the highlands and in secondary forests, so the composition of dragonfly species in this location has the least number of three species.

The results of the dominance index analysis showed that six locations have a dominance index value in the low category, which has a value below 0.40, namely the location of the rice field, pond, park city pond, lake, waterfall, and village river. And there are two locations that have a medium category, with a value of D = 0.40–0.60, namely the location of the forest river D = 0.49, and the agriculture river D = 0.47 (Figure 6). The high dominance value at the forest river location can be explained by the fact that at this location only three species were found, each of which had a high IVI value, namely *Rhinocypha anisoptera* 111.61%, *Orthetrum pruinosum* 47.32%, and *Coeliccia membranipes* 41.07% (Figure 5). Whereas in the agriculture river location, which has the second highest dominance index value after the forest river, there are two codominant species with high IVI values, namely *Pseudagrion pruinosum* (83.35%) and *Orthetrum sabina* (46.18%).

High dominance at the forest river site does not necessarily indicate a degraded habitat, but it can indicate a shift in habitat structure and composition due to environmental conditions and quality. Although the forest river had the highest dominance index value, two of the three species found were endemic. This can be due to the condition of the forest river location which is located at an altitude of 1103–1420 masl with

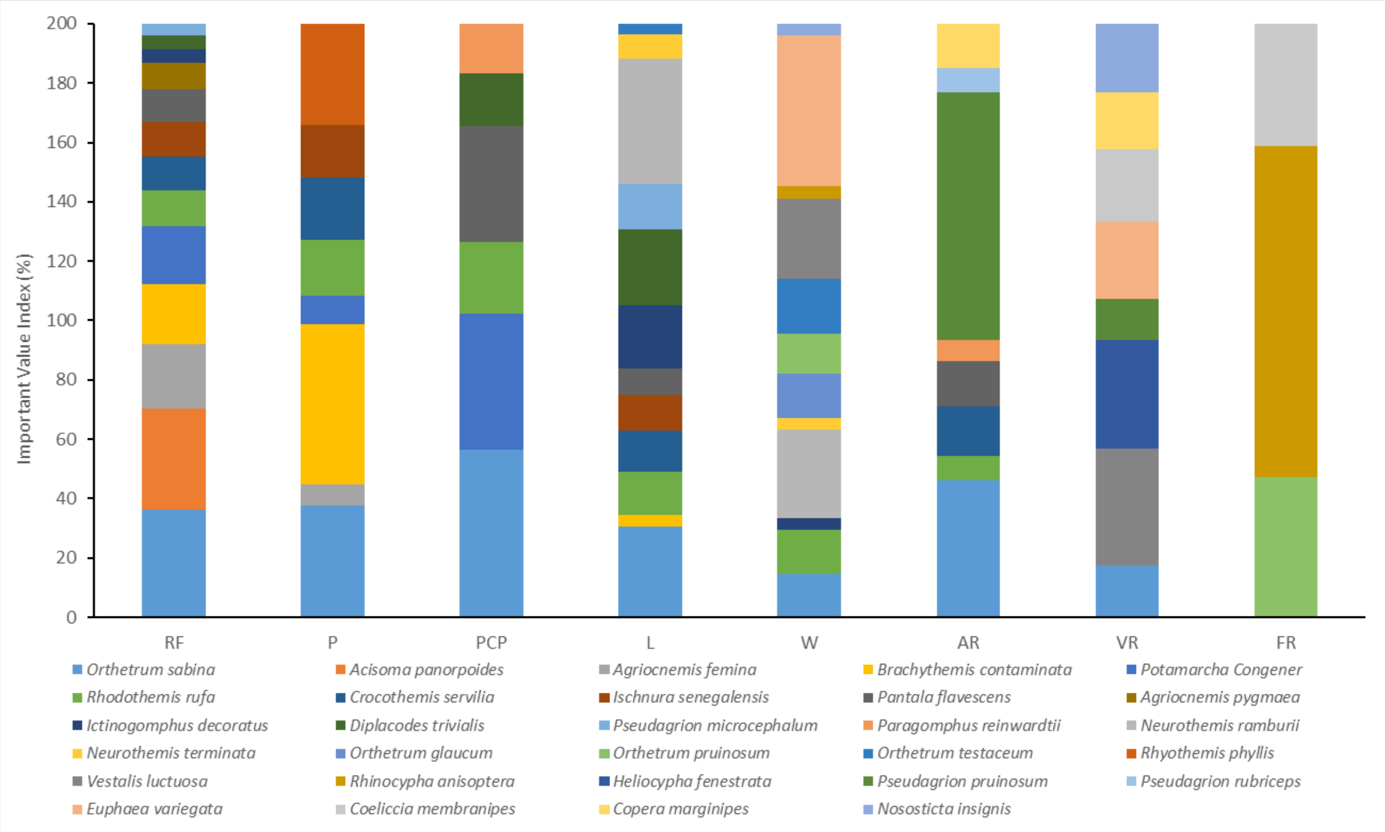

Figure 5. Important Value Index (IVI) of dragonflies in the eight research sites in Lumajang, East Java Province. Note: RF: ricefield, P: pond, PCP: park city pond, L: lake, W: waterfall, AR: agriculture river, VR: village river, & FR: forest river

closed canopy conditions and has the highest humidity in this study, so that only a few species can live in such conditions.

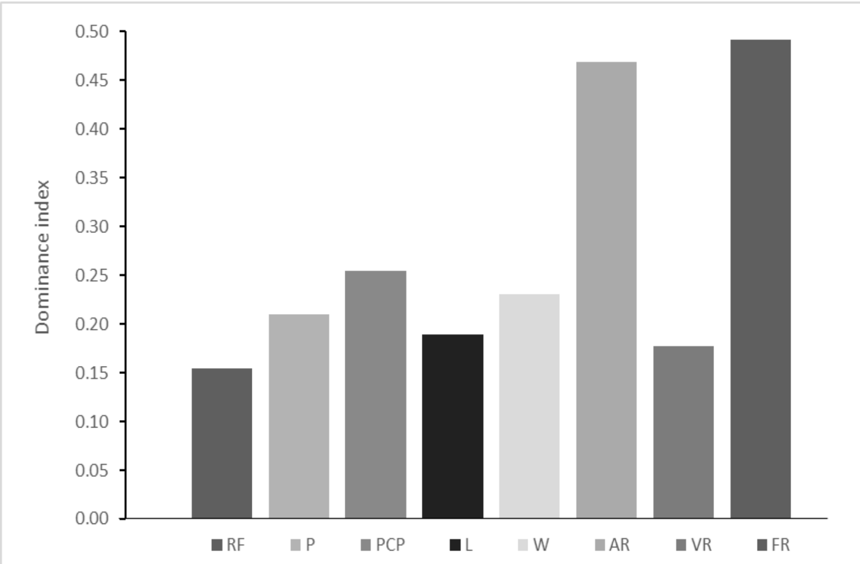

Figure 6. Value of dominance index of dragonflies in the eight research sites in Lumajang, East Java Province. Note: RF: Ricefield, P: Pond, PCP: Park City Pond, L: Lake, W: Waterfall, AR: Agriculture River, VR: Village River, & FR: Forest.

Based on the results of the Shannon-Wiener diversity index analysis, there are two locations that have a low category value, with a value below 1.50, namely the location of the agricultural river and the forest river. And there are six locations that have a value in the medium category, namely with a value of H'= 1.50–3.00, namely the location of the rice field, pond, park city pond, lake, waterfall, and village river (Figure 7). The rice field is the location with the highest diversity value in this study (H = 2.11), but not an endemic species was found in this location. Most of the species found in this location are generalist species, namely species that have tolerance to various environmental conditions so that they can be found in various habitat types. The high value of diversity in the rice field location may also be due to the presence of various insects (especially pests) in the agricultural location. The presence of dragonflies in rice field locations can be useful as natural predators of various pest insects (Wakhid et al. 2020).

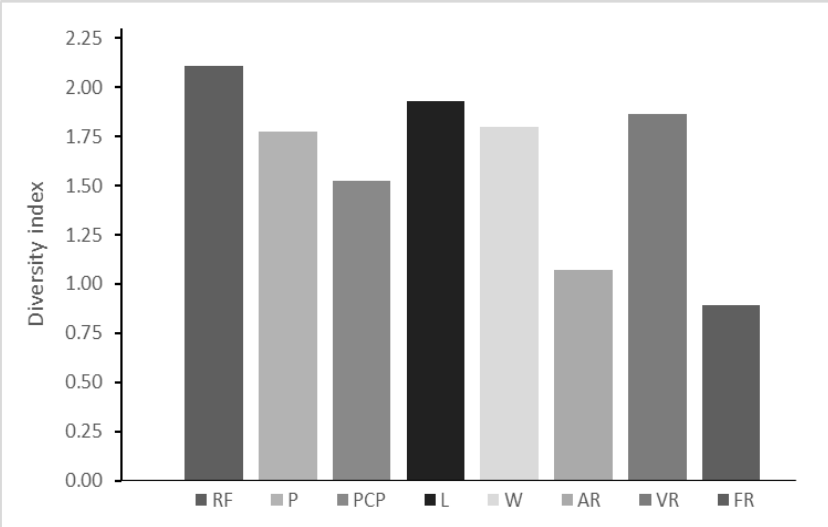

Figure 7. Value of Shannon-Wiener Diversity Index of dragonflies in the eight research sites in Lumajang, East Java Province. RF: Ricefield, P: Pond, PCP: Park City Pond, L: Lake, W: Waterfall, AR: Agriculture River, VR: Village River, & FR: Forest.

The difference in diversity index values at each research location can be due to each location having different habitat types (Table 1), elevations (Table 1), and vegetation composition (Table 3). In addition, differences in microclimate at each location (Table 4), can also be a factor that affects the value of the dragonfly species diversity index at each research location.

Water habitat type is one of the main factors that cause differences in dragonfly diversity (Figure 7). The presence of water in a location is the most important factor in the presence and abundance of dragonflies (Luke et al. 2020). Dragonflies are highly dependent on water for egg-laying and larval development (Clausnitzer et al. 2009). In the larval stage, the presence of water is a very important factor, when water discharge decreases or experiences scarcity, larvae will also decrease (Luke et al. 2020). The results showed that the two locations that had the highest diversity value were in lentic water habitats (rice fields and lakes), while the lowest diversity value was in lotic habitats (agriculture rivers and forest rivers) (Figure 7). Lentic water types tend to have more stable fluctuations in dragonfly composition because lentic waters do not experience extreme changes due to water currents. Meanwhile, lotic water types tend to have a more volatile dragonfly species composition because they are highly affected by water currents.

Differences in elevation at the study site can also be the cause of the different composition and diversity of dragonfly species found. The results showed that the location with the highest diversity value was in the lowlands, namely with an elevation of 4–12 msal. This can be because each elevation has specific environmental conditions. The composition and diversity of dragonfly species in an area can be influenced by landscape conditions such as elevation (Simaika et al. 2016). Lowland sites tend to be more diverse, but many generalist species can live in various habitat types. According to Mafuwe & Moyo (2020) lowland areas generally have higher dragonfly species diversity than highland locations.

Differences in vegetation composition at each study site (Table 3) may be one of the main factors influencing dragonfly diversity. The presence of riparian vegetation in the form of herbs or trees at the study sites can be a component that supports adult dragonfly activities such as roosting, basking, and protecting from predators. The presence of vegetation on the water's edge has a positive correlation with dragonfly abundance and diversity (Deacon et al. 2019; Worthen et al. 2021). In addition, riparian vegetation is also a habitat for small insects that have the potential to become dragonfly food. This is because vegetation is one of the main habitat components of small insects that become dragonfly food resources (Knuff et al. 2020; New et al. 2021). Therefore, the absence of vegetation is also one of the factors that limits the presence of dragonflies (Luke et al. 2020). The presence of aquatic vegetation in aquatic sites can be a component that supports the activities of adult dragonflies (perching

Table 3. List of plant species present in the eight research sites in Lumajang, East Java Province.

No.	Type	Plant Species	RF	P	PCP	L	W	AR	VR	FR
1	Herb	*Pennisetum purpureum*	++	+	-	++	+	++	+	-
2	Herb	*Digitaria ciliaris*	++	+	-	-	-	+	-	-
3	Herb	*Colocasia esculenta*	++	+	-	-	-	+	-	-
4	Herb	*Eupatorium* sp.	-	-	++	-	-	-	-	-
5	Herb	*Ruellia* sp.	-	-	+	-	-	-	-	-
6	Herb	*Axonopus* sp.	-	-	++	-	-	-	-	-
7	Herb	*Alternanthera* sp.	-	-	-	+	++	-	-	-
8	Herb	*Synedrella* sp.	-	-	-	+	+	-	-	-
9	Herb	*Ageratina riparia*	-	-	-	+	++	-	+	++
10	Herb	*Tridax* sp.	+	+	-	++	+	+	-	-
11	Herb	*Impatiens* sp.	-	-	-	-	-	-	-	++
12	Herb	*Laportea* sp.	-	-	-	-	-	-	-	+
13	Herb	*Colocasia* sp.	-	-	-	-	-	-	++	-
14	Herb	Bambusoideae	-	-	-	+	+	-	++	+
15	Tree	*Muntingia calabura*	+	+	-	+	+	++	-	-
16	Tree	*Albizia chinensis*	+	+	-	-	++	+	-	+
17	Tree	*Cocos* sp.	++	+	-	-	-	+	-	-
18	Tree	*Hibiscus tiliaceus*	+	+	-	+	+	+	-	-
19	Tree	*Ficus* sp.	-	-	+	+	+	-	-	-
20	Tree	*Syzygium oleina*	-	-	+	-	-	-	-	-
21	Tree	*Cupressus* sp.	-	-	+	-	-	-	-	-
22	Tree	*Pterocarpus indicus*	-	-	++	-	-	-	-	-
23	Tree	*Manilkara* sp.	-	-	+	-	-	-	-	-
24	Tree	*Toona sureni*	-	-	-	-	-	-	-	+
25	Tree	*Ficus racemosa*	-	-	-	-	+	-	-	++
26	Tree	*Swietenia mahagoni*	-	-	-	-	-	-	-	++
27	Tree	*Ficus retusa*	-	-	-	-	-	-	-	+
28	Aquatic Plant	*Limnocharis flava*	++	-	-	-	-	+	-	-
29	Aquatic Plant	*Pistia stratiotes*	-	+	-	+	-	-	-	-
30	Aquatic Plant	*Eichhornia crassipes*	-	+	-	-	-	-	-	-
31	Aquatic Plant	*Ipomea aquatica*	++	+	-	+	-	-	-	-

Note: (+) Present, (-) Absence, (++) Dominance. Note: RF: ricefield, P: pond, PCP: park city pond, L: lake, W: waterfall, AR: agriculture river, VR: village river, & FR: forest river

Table 4. Microclimate values and PCA scores in the eight research sites in Lumajang. East Java Province.

Location	Microclimate				PCA Score	
	Temperature (°C)	Humidity (%)	Wind (m/s)	Light (lx)	PC 1	PC 2
RF1	35	52	0.7	44200	1.712	2.111
RF2	32.7	55	0.1	41000	1.066	0.602
RF3	28.1	54	0.1	38100	1.109	-1.014
P1	32.7	50	0.9	52100	-1.296	1.250
P2	30.6	54	1.4	48600	-0.344	1.053
P3	31.6	53	0.7	46600	-0.096	0.763
PCP1	34.2	54	2.8	51600	-2.175	3.249
PCP2	32.5	50	0.1	32800	-0.272	-0.014
PCP3	31.1	56	0.5	39200	-0.142	0.154
L1	32.2	54	1.2	32300	2.149	1.363
L2	32.1	56	0.1	34100	1.292	0.165
L3	32.4	55	0.1	33100	2.008	0.407
W1	30.1	57	0.1	5400	1.691	-1.356
W2	31.9	56	0.1	1900	1.603	-0.909
W3	30.8	56	0.1	3200	1.075	-1.294
AR1	30.5	57	1.1	44000	-2.344	0.173
AR2	30.7	51	0.1	29900	-1.074	-0.909
AR3	32.8	51	0.7	55600	-2.092	0.965
VR1	30.2	56	0.1	7400	1.599	-1.216
VR2	32.4	57	0.1	8700	1.726	-0.426
VR3	31	55	0.1	6500	1.816	-0.933
FR1	27.1	57	0.1	11400	-2.516	-2.936
FR2	29.7	56	0.1	34500	-3.983	-1.688
FR3	33.7	67	0.1	48600	-2.512	0.437

Note: RF: Ricefield, P: Pond, PCP: Park City Pond, L: Lake, W: Waterfall, AR: Agriculture River, VR: Village River, & FR: Forest.

and basking) and dragonfly nymphs (shelter from predators). Deacon et al. (2019) are also reported that dragonfly nymphs utilise aquatic vegetation to hide from predators and hunt prey.

PCA ordination analysis showed the variation of environmental factors in the eight study sites with different aquatic habitats (Figure 8). The results of the analysis obtained showed that there are four distinct groups, namely the first group of lakes and rice fields, which are characterized by high values of abundance, diversity index, and species richness. The second group includes waterfall and village river locations that have adjacent and overlapping plots. According to Koneri et al. (2022), adjacent and overlapping plots indicate that the environmental characteristics between locations have many similarities. The third group of pond and park city pond locations have adjacent and overlapping plots, which are characterized by high values of light intensity and wind speed factors. The fourth group is the agriculture river and forest river locations, which are characterised by high dominance values.

The results of the PCA analysis showed that the first and second axes of the data accounted for 47.949 and 26.114% of the variation in the data, respectively. The environmental variables that contribute most to the diversity and dominance indices are light intensity and temperature. The light intensity variable has a negative correlation with the diversity index, dominance, and species richness, while temperature has a negative correlation with the dominance index.

CCA analysis showed that each dragonfly species had different responses to the microclimate (Figure 9). There are 10 species that have high abundance in locations with high temperatures and low humidity,

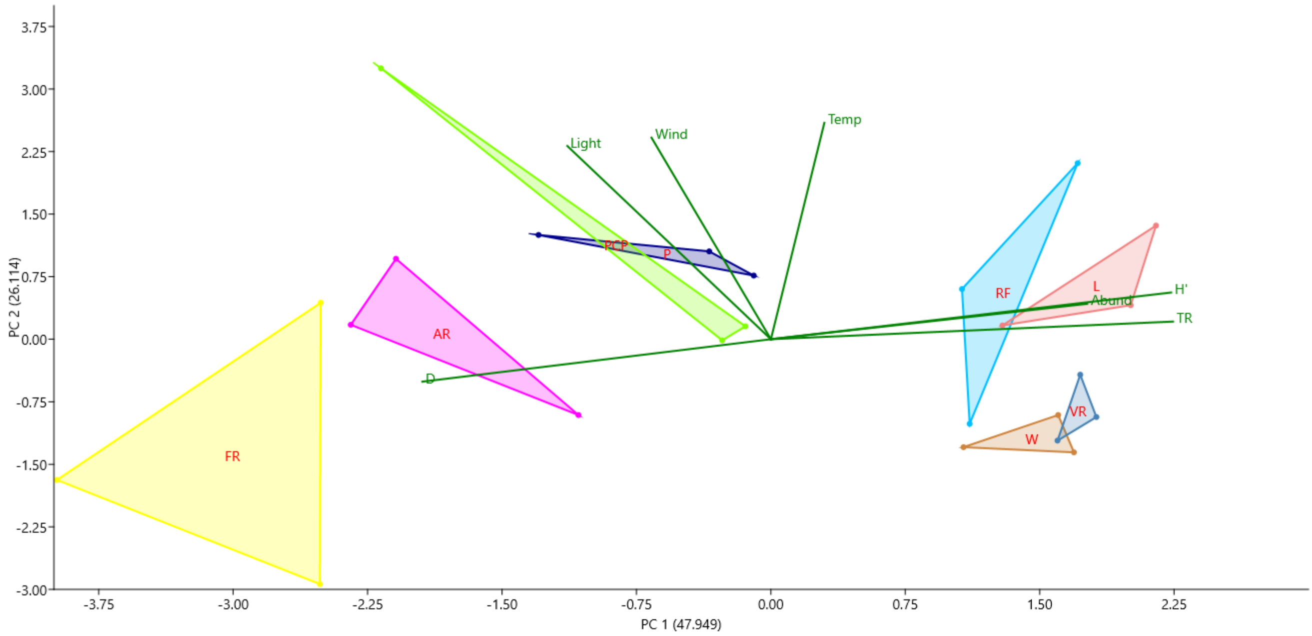

Figure 8. Ordination diagram of the Principal Component Analysis (PCA) in the eight research sites in Lumajang, East Java Province. Note: Hum: humidity, Temp: temperature, Light: light intensity. Location: RF: Ricefield, P: Pond, PCP: Park City Pond, L: Lake, W: Waterfall, AR: Agriculture River, VR: Village River, & FR: Forest.

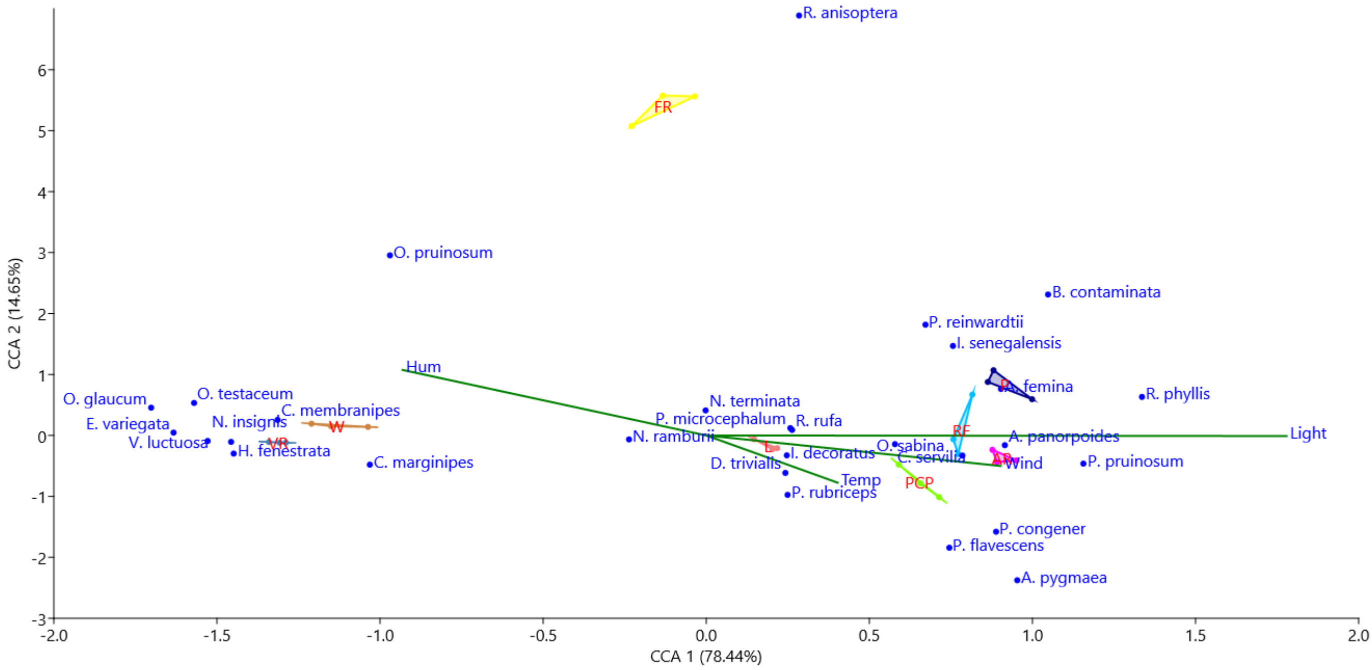

Figure 9. Ordination diagram of the Canonical Correspondence Analysis (CCA) in the eight research sites in Lumajang. Note: Hum: Humidity, Temp: Temperature, Light: Light intensity. Location: RF: Ricefield, P: Pond, PCP: Park City Pond, L: Lake, W: Waterfall, AR: Agriculture River, VR: Village River, & FR: Forest River

namely *A. pymaea*, *P. congener*, *P. flavescens*, *P. rubriceps*, *I. decoratus*, *D. trivialis*, *C. servilia*, *O. sabina*, *A. panorpoides*, and *P. pruinosum*. This is supported by the research of Susanto et al. (2023), who in their research also found 9 of the 10 species (except *P. pruinosum*) in urban areas that have a fairly high temperature of 32.40 to 35.61 °C.

In a different distribution, there were nine species that responded positively to locations with high humidity and low light intensity, namely *O. glaucum*, *O. testaceum*, *O. pruinosum*, *C. membranipes*, *C. marginipes*, *N.*

insignis, *H. fenestrata*, *E. variegata*, and *V. luctuosa*. This is in accordance with the research of Susanto & Zulaikha (2021) which reported that *O. glaucum*, *O. pruinosum*, *C. membranipes*, *E. variegata*, and *V. luctuosa* species were found in locations with high humidity of 74.6 to 75%. However, these results differ from the research of Nafisah and Soesilohadi (2021) who reported that CCA analysis of odonate communities and environmental factors in Petungkriyono forest, Central Java, showed that *O. pruinosum*, *O. glaucum*, and *C. membranipes* had a negative response to humidity and responded positively to high light intensity. This could be due to the different habitat conditions in the two locations, so it can be assumed that *O. pruinosum*, *O. glaucum*, and *C. membranipes* species can be found in areas with low to high humidity and light intensity values. The CCA analysis also showed that *E. variegata* and *V. luctuosa* had similar responses to microclimate, suggesting that these two species have similar habitat preferences.

Revision of species identification

In a study by Susanto et al. (2023), in Lakarsanti District, Surabaya, East Java Province, the damselfly species was identified as *Pseudagrion nigrofasciatum* (Lieftinck, 1934). The species *P. nigrofasciatum* was found in pond habitats near settlements. This is still in accordance with the report from Setiyono et al. (2017) who reported that *P. nigrofasciatum* can be found in residential habitats, fish ponds, rivers, and rice fields. However, the unclear documentation of *P. nigrofasciatum* and not taking specimens make identification complicated. Therefore, the species identification of *P. nigrofasciatum* in by Susanto et al. (2023) needs to be corrected and revised. Therefore, we conducted repeat observations to confirm the validity of the species identification and found two species of the genus *Pseudagrion*, namely *Pseudagrion microcephalum* (Rambur, 1842) (Figure 10) and *Pseudagrion rubriceps* (Selys, 1876).

Figure 10. Documentation of male *P. microcephalum* species during re-observation in Lakarsanti, Surabaya.

The species *P. nigrofasciatum* has a very similar morphology to *P. microcephalum* (Setiyono et al. 2017). Both species have differences in the dorsal part of the 2nd segment; *P. microcephalum* has a narrower black pattern compared to *P. nigrofasciatum*, which has a broad black pattern on the dorsal (Setiyono et al. 2017). After re-observing dragonflies in Lakarsanti district and surrounding areas that still have similar habitats as in Karangpilang and Gununganyar Districts, Surabaya City, the identification results showed that only *P. microcephalum* species were found. Therefore, we revised the species identification of *P. nigrofasciatum* in by Susanto et al. (2023) to the species *P. microcephalum.*

CONCLUSIONS

The dragonfly species in several habitat types in Lumajang recorded 29 species from seven families. The composition and diversity of dragonfly species in some types of habitats in Lumajang are different, especially in lotic and lentic water habitats. The composition of species based on the Bray-Curtis similarity index shows that lotic and lentic waters have different dragonfly compositions (except for the agricultural river, which is included in the lentic group). Most of the study sites had a moderate Shannon-Wiener diversity index value (H' = 1.50–3.00), except for two sites: agricultural rivers and forest rivers, which have low values (H'<1.50). Based on the CCA analysis, five out of a total of seven endemic species responded positively to high humidity and negatively to too-high light intensity. Therefore, human activities that have the potential to change humidity and light intensity, such as the illegal logging of trees around the water ecosystem, can potentially damage one of the factors that make up the natural habitat of endemic dragonfly species. The research is a preliminary study of the composition and diversity of dragonflies in various habitat types, with the limitations of research locations that do not represent all types of dragonfly habitats in their natural habitat, so the results of this study are expected to be understood carefully. Therefore, future research can be conducted in more research locations so that it is expected to represent all dragonfly habitats.

AUTHOR CONTRIBUTION

M.A.D.S designed the research, collected and analysed the data, and wrote the manuscript, N.M. collected the data, and wrote the manuscript, A.S.L. assisted in manuscript revision and supervised all the process, and Z.P.G. assisted in manuscript revision and supervised all the process. This study was supported by the Research and Community Service Institute Universitas Brawijaya, through Professor Grant Scheme, with contract No. 3084.21/UN10.F09/PN/2022.

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CONFLICT OF INTEREST

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

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