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Dragonfly (Odonata) diversity in Kedung Klurak Waterfall Area, Mojokerto District, East Java, Indonesia

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Abstract. *Zahro' DM, Rani TE, Agustin EP, Permatasari ASD, Susanto MAD. 2024. Dragonfly (Odonata) diversity in Kedung Klurak Waterfall Area, Mojokerto District, East Java, Indonesia. Intl J Bonorowo Wetlands 14: 1-8.* Kedung Klurak is a tourist spot in Mojokerto District, East Java, Indonesia with a waterfall dominated by pine trees. Furthermore, using Kedung Klurak as a tourist spot increases human activity. This can affect the natural habitat of dragonflies; therefore, this study was conducted to identify the diversity of dragonfly species in the Kedung Klurak Waterfall Area. The sampling method used sweep net and path determination method using transects. The observation location was divided into three stations: waterfall, open area, and pine forest. The results of the study obtained 15 species from seven families. The Diversity Index in Kedung Klurak Waterfall Area is H': 1.605 in the medium diversity category. The highest diversity index is at the waterfall station with H': 1.678, followed by the open area station with H': 1.446, and the lowest diversity index at the pine forest station with H': 1.095. Several factors can affect species diversity differences at the three stations because each station has different environmental conditions, including temperature, light intensity, humidity, and vegetation. Based on the study's results, it can be concluded that the Waterfall station has a habitat following the natural habitat of dragonflies. Some species tolerate the environment and human disturbances, namely *Vestalis luctuosa* and *Euphaea variegata*. Therefore, using Kedung Klurak Waterfall as a tourist attraction can cause a loss of dragonfly diversity due to loss of vegetation, environmental pollution, and human disturbance. These factors cause dragonflies to move away from their habitat, as in the open area station where only five species of dragonflies were found.

Keywords: Anisoptera, habitat, tourism site, Zygoptera

INTRODUCTION

Dragonflies are flying insects belonging to Odonata (Rizal and Hadi 2015). Odonata is derived from the Greek word "jaws" with teeth at the end of the lower lip and sharp protrusions resembling teeth (Pelealu et al. 2022). Odonata comprises two suborders: Anisoptera and Zygoptera (Mendoza-Panagos et al. 2021). The difference between these two suborders can be seen from their morphology; for example, the body size of Anisoptera dragonflies is larger than that of Zygoptera (Salsabiela et al. 2022). The difference between these two suborders can be observed from their morphology; for example, the body size of dragonflies in Suborder Anisoptera is relatively larger when compared to dragonflies in Suborder Zygoptera (Salsabiela et al. 2022). In the dragonfly Suborder Zygoptera, when perched, the position of the wings will be closed upwards. In contrast, in the dragonfly Suborder Anisoptera, the wings will be spread wide to the side (Bybee et al. 2016). In addition to slimmer body size, Zygoptera dragonflies generally have a flying distance close to the ground and are relatively slower than Anisoptera (Wakhid et al. 2014). Dragonflies are insect that have three body parts namely the head, thorax, four wings and six legs attached to the abdomen (Klym and Quinn 2003). The general characteristics of dragonflies are a slender body with two pairs of wings and six legs, short antennae that resemble hair, a chewing mouth, and two compound eyes (Hanum and Salmah 2013; Virgiawan et al. 2015). The body and wings' colors and patterns are one of the characteristics possessed by odonates (Futahashi 2020).

Dragonflies are insects that undergo incomplete metamorphosis, which starts in the egg, nymph, and imago phases (Okude et al. 2017). The nymph cycle in dragonflies can take as long as four years before transforming into imago (Nobles and Jackson 2020). In their life cycle, dragonflies will lay their eggs in waters (Dalia and Leksono 2014) that have a fairly good level of cleanliness (Simbolon 2019). Dragonfly nymphs develop and live in water (Hanum and Salma 2013), and dragonfly nymphs will also transform into imagos in the water (Ubhi and Matthews 2018); even half of the dragonfly life cycle occurs in bottom waters (Maynou et al. 2017; Meland et al. 2019). However, in the imago phase, dragonflies also need terrestrial areas that are used as a place to find food, rest, and mate (Nagy et al. 2019).

Dragonflies have a variety of habitat types, one of which is a habitat close to water areas. Dragonflies generally utilize water areas with clean waters, although some dragonfly species can live in less clean or even

polluted waters (Rachman and Rohman 2016). For example, water areas that are habitats for dragonflies are ponds, rivers, lakes, puddles, and rice fields (Goertzen and Suhling 2013). These water cleanliness levels can be observed from the presence of dragonfly species vulnerable to water pollution. Dragonflies play an important and large role in maintaining the balance of the food chain (Jakob and Poulin 2016). Dragonflies are also crucial in biological control in the ecosystem (Lino et al. 2019). One of the roles of dragonflies is as predators of small insects (Letsch et al. 2016), such as mosquitoes and pests in agriculture (Pamungkas and Ridwan 2015). Besides being predators, dragonflies also act as bioindicators of water quality (Chovanec and Raab 1997). Dragonflies are also used as bioindicators of water quality because they tend to tolerate various water qualities (Nasirian and Irvine 2017). The reduction of dragonfly populations in an area can indicate environmental change.

Kedung Klurak is one of the tourist attractions with a waterfall dominated by pine trees in Pacet District, Mojokerto District, East Java. Using Kedung Klurak as a tourist area can increase infrastructure development such as building gazebos on the banks of rivers. There are many activities around the water flow such as swimming, setting up a tent for camping, and photography activities. This pollutes the environment because it can disrupt dragonfly activities and impact the dragonfly's natural habitat. The number of human activities also affects the diversity of dragonfly species. Based on this urgency, this research was conducted to identify the diversity of dragonfly species (Odonata) in Kedung Klurak tourism areas.

MATERIALS AND METHODS

Research time and location

The research was conducted in the Kedung Klurak area in Pacet Sub-district, Mojokerto District, East Java Province, Indonesia, in 3 different habitats, i.e. waterfall, open area and pine forest (Table 1, Figure 1). The research was conducted on 28th-30th September 2023, from 07.00-11.00 am. This time was chosen because dragonflies are active during the day (Koneri et al. 2020). The research methods used were sweeping nets and transects. During the research, abiotic factors, such as temperature, humidity, wind speed, and light intensity, were measured at the location. This study divided the data collection station into three consecutive stations: a waterfall, an open area, and a pine forest. The division of three stations was chosen based on differences in environmental conditions such as water flow, vegetation, canopy types, and human activity. Every day research is carried out at all observation stations.

Data collection method

The path determination method uses a transect and the adult dragonfly sampling method uses a sweep net. This method was done by capturing and storing each species found during observation. Some dragonflies were caught as samples are adult dragonflies. Dragonflies found in the location were documented with a digital camera. In addition, each species encountered was counted in tables, stating the number of species and the location where they were found.

Table 1. Observation data on dragonfly species in Kedung Klurak, Mojokerto District, East Java, Indonesia

Station	Description
Waterfall	The waterfall is the main location at Kedung Klurak. This station has a swift flow and a clear pool of water. The type of vegetation at this station is diverse, with the dominant vegetation being bamboo. The type of canopy at this station includes an open canopy that allows maximum sunlight to enter.
Open area	The open area has a lower height than the waterfall with an open canopy. The dominant vegetation type of this station is dense shrubs; with an open canopy type and shrub vegetation type, the station has less sunlight radiation.
Pine forest	Pine forest is a water stream that has pine vegetation. This station has an open canopy type that allows sunlight radiation.

Figure 1. Location of Kedung Klurak, Mojokerto District, East Java, Indonesia. A. Waterfall; B. Open area, C. Pine forest

After capturing the dragonflies, the identification was conducted with the help of identification books (Irawan and Rahadi 2016; Setiyono et al. 2017). This study was conducted in conjunction with measurements of abiotic factors, including temperature, humidity, and light intensity. In addition, the measurement tools are a thermometer and a lux meter. Abiotic factors measurements were carried out in the morning before starting dragonfly data collection. Observations were also made on the vegetation and canopy types around the dragonfly habitat.

Data analysis

Data that obtained in the field were analyzed using the Shannon-Wiener Diversity index, Evenness index, and Dominance index formula as follows:

Diversity index

$H' = -\sum Pi \ln Pi$
$Pi = (ni/N)$

Where, H': Shannon-Wiener Diversity index; Pi: Proportion of the 1st species in the total sample; ni: number of individuals of a species; N: number of individuals of all species.

Evenness index

$E = H'/\ln S$

Where, E: Evenness index; H': Diversity index; S: number of species.

Dominance index

$D = (ni/N)$

Where, D: Dominance index; ni: number of individuals of a species; N: number of individuals of all species.

RESULTS AND DISCUSSION

The study results found 15 species identified in Suborder Anisoptera and Zygoptera. In Suborder Anisoptera, 12 species were found from four families, including Libellulidae, Gomphidae, Corduliidae, and Aeshnidae (Table 2). While in Suborder Zygoptera, three species were found from three families: Euphaeidae, Calopterygidae, and Chlorocyphidae.

The results showed that the Anisoptera suborder had more species than the Zygoptera suborder. Almost all stations in this study have aquatic habitats with open canopy types and surrounding tree vegetation, making it a suitable habitat for Anisoptera dragonflies. This is supported by Susanto et al. (2023), who reported that the dragonfly suborder Anisoptera is suitable in habitats with open canopy types. Anisoptera has a high-flying ability to explore areas widely (Susanto et al. 2023). Dragonfly Suborder Zygoptera has fewer species because this suborder is sensitive to habitat changes. This statement is supported by Albab et al. (2019), who reported that Zygoptera has a lower habitat tolerance than Anisoptera. According to Gomez-Tolosa et al. (2022), Zygoptera dragonfly diversity decreases when habitat quality decreases, while Anisoptera diversities can survive on habitat change. Anisoptera has a high roaming ability and its life is not very dependent on the availability of food around the waters (Susanto et al. 2023).

Table 2. Observation data on dragonfly species in Kedung Klurak, Mojokerto District, East Java, Indonesia

Suborder and Family	Species	Relative Abundance (%)			
		Waterfall	Open Area	Pine Forest	Total
Zygoptera					
Calopterygidae	*Vestalis luctuosa* (Burmeister, 1839)	33.962	43.077	52.857	44.149
Chlorocyphidae	*Heliocypha fenestrata* (Burmeister, 1839)	0.000	26.154	10.000	12.766
Euphaeidae	*Euphaea variegata* (Rambur, 1842)	35.849	18.462	32.857	28.723
Anisoptera					
Aeshnidae	*Gynacantha subinterrupta* (Rambur, 1842)	3.774	0.000	0.000	1.064
Corduliidae	*Idionyx montana* (Karsch, 1891)	5.660	0.000	0.000	1.596
Gomphidae	*Heliogomphus drescheri* (Lieftinck, 1929)	0.000	1.538	0.000	0.532
Libellulidae	*Cratilla lineata* (Brauer, 1878)	0.000	0.000	1.429	0.532
	Diplacodes trivialis (Rambur, 1842)	0.000	3.077	0.000	1.064
	Neurothemis ramburii (Brauer, 1866)	3.774	0.000	0.000	1.064
	Orthetrum glaucum (Brauer, 1865)	0.000	0.000	2.857	1.064
	Orthetrum pruinosum (Burmeister, 1839)	3.774	0.000	0.000	1.064
	Pantala flavescens (Fabricius, 1798)	3.774	0.000	0.000	1.064
	Potamarcha congener (Rambur, 1842)	0.000	4.615	0.000	1.596
	Trithemis festiva (Rambur, 1842)	3.774	0.000	0.000	1.064
	Zygonyx ida (Selys, 1869)	5.660	3.077	0.000	2.660

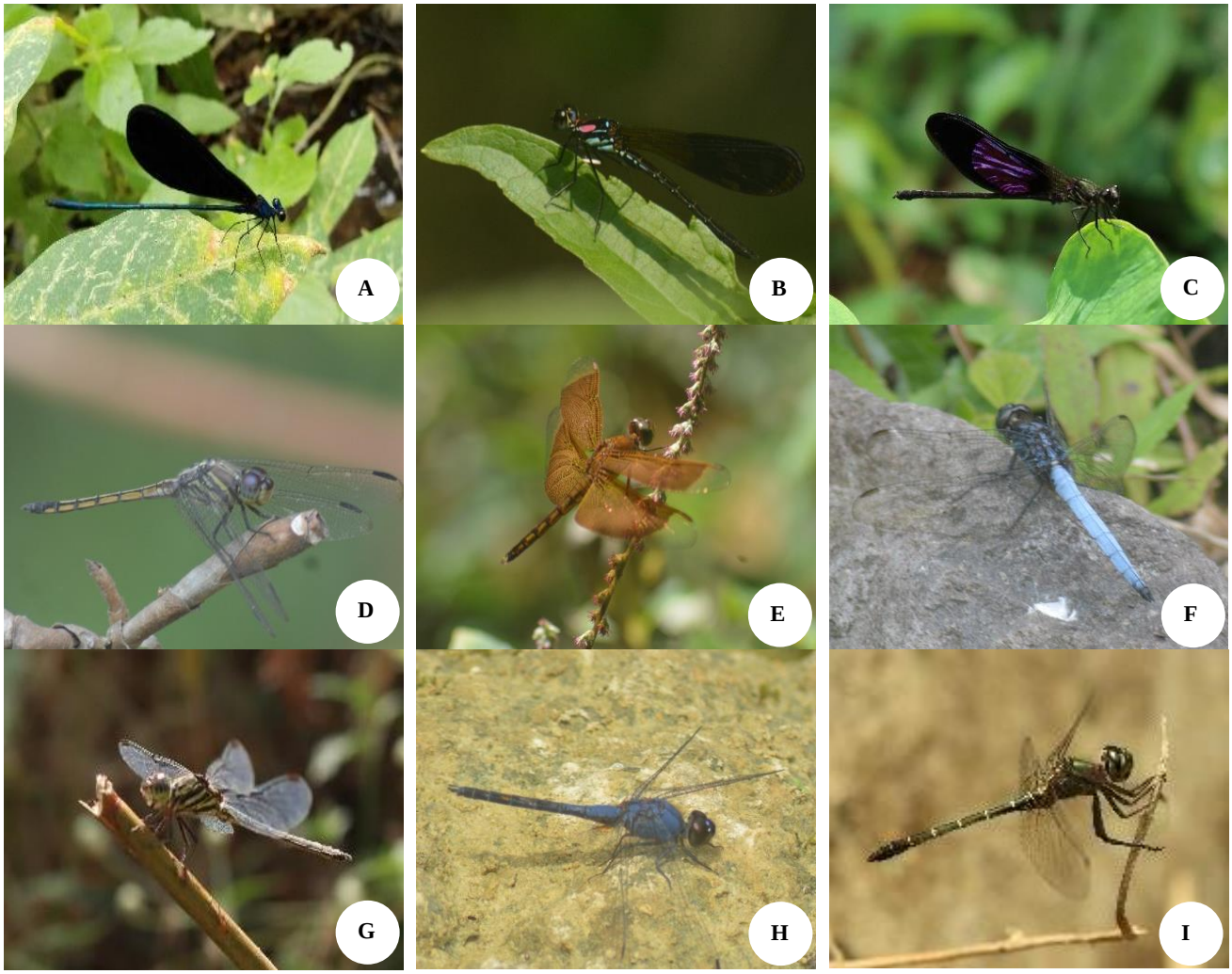

Figure 2. Photo of dragonfly species: A. *Vestalis luctuosa* (Photo: DM Zahro' 2023); B. *Heliocypha fenestrata* (Photo: MAD Susanto 2023); C. *Euphaea variegata* (Photo: EP Agustin 2023); D. *Potamarcha congener* (Photo: MR Zumar 2023); E. *Neurothemis ramburii*; F. *Orthetrum glaucum*; G. *Cratilla lineata*; H. *Trithemis festiva* (Photo: MAD Susanto 2023); I. *Zygonyx ida* (Photo: MR Zumar)

The study shows that the Family in Suborder Anisoptera has the highest number of species from the Family Libellulidae. The family Libellulidae has the highest number of species found. The family Libellulidae has a high level of tolerance for the environment, so it is found in almost all habitat types. This is supported by Patra et al. (2016), who reported that the family Libellulidae has high adaptability. Another study revealed that one of these adaptations can survive in waters with low oxygen (Walia and Singh 2022).

The dragonfly species with the highest relative abundance values are *Vestalis luctuosa* and *Euphaea variegata* (Table 2). The relative abundance value of *V. luctuosa* was at the waterfall station (33.962%), in the open area (43.077%), in the pine forest (52.857%), and total (44.149%). The relative abundance value of *E. variegata* was at the waterfall station (35.849%), in the open area (18.462%), in the pine forest (32.857%), and total (28.723%). Both species were found at all observation stations. The *V. luctuosa* has a common name is dark-blue metalwing. In male dragonflies, the entire body is metallic blue, darker in the eyes and wings, while in females, the eyes are black, the thorax is metallic green, and the abdomen and wings are metallic brown (Setiyono et al. 2017) (Figure 2.B). The *V. luctuosa* is found perched on the leaves or branches of shady plants close to the water.

The *V. luctuosa* and *E. variegata* are species that have almost the same habitat. *E. variegata* has a characteristic metallic black abdomen and wings have a purple and blue metallic rainbow pattern when the wings are folded (Setiyono et al. 2017) (Figure 2.A). The *E. variegata* is perched on leaves, twigs, and rocks near water. The two species often live together due to habitat similarities (Setiyono et al. 2017). The habitat of *V. luctuosa* and *E. variegata* is in clear rivers with open and closed canopy vegetation (Saefullah et al. 2021).

The Kedung Klurak waterfall area is suitable for dragonflies' natural habitat. This is due to the presence of aquatic ecosystems, namely waterfalls and river flows that dragonflies can utilize to become their habitat when laying eggs and becoming nymph. This is supported by Susanto (2022), who reported that dragonflies utilize waters to

become a place to continue their life cycles, namely in the egg and nymph phases.

The diversity index in Kedung Klurak is H': 1.605, which is included in the medium diversity category. If the diversity value of H' 1≤H≤3, it is classified as moderate diversity (Rachman and Rohman 2016). Based on the diversity index value obtained, it can be seen that the Kedung Klurak area has an environment that is still maintained and follows a dragonfly habitat. Dragonflies only live in clean and well-maintained water environments.

The evenness index in Kedung Klurak shows a value of E: 0.593, indicating a low evenness category. The dominance index shows a value of D: 0.296, indicating a low category. Evenness values close to one indicate evenness, while values close to zero indicate the presence of a dominating species (Cerda et al. 2011; Aziz and Mohamed 2018).

This study explores three observation stations. The waterfall station has the highest diversity index of the three stations observed, namely H': 1.678 (Figure 3); at the open area station, H': 1.446, while at the pine forest area station, H': 1.095. In addition, the highest evenness index was found at the waterfall station (E: 0.764), the open area station (E: 0.743), and the lowest evenness at the pine area location (E: 0.681) (Figure 4). The dominance index at the waterfall station is D: 0.257; at the open area station, D: 0.292; and the highest dominance value is at the pine area station, E: 0.398. That shows the value of evenness is inversely proportional to the dominance value. The higher the dominance value, the lower the species evenness; for example, the pine area station has a high dominance among the individuals found, but the number of species found is uneven.

The dragonfly species present at the waterfall, open area, and pine forest stations were found to be different. Furthermore, different microclimates and vegetation influence the differences in dragonfly species diversity in a location (Susanto and Bahri 2021). The microclimate is important in providing a habitat for small insects that will become dragonfly prey (Abdillah et al. 2019). The microclimate parameters measured in this study include temperature, humidity, and light intensity.

Micro-climate data showed that temperature, humidity, and light intensity at the waterfall station (31.2°C, 57%, 21300 lx) were lower than at the open area station (34.1°C, 60%, 22100 lx), temperature and humidity at the pine forest station (32.7°C, 62%) were higher than at the waterfall and open area stations, while light intensity at the pine forest station (19800 lx) had the lowest value (Table 3). The temperature results are the average temperature at the station. Temperature measurements at each station aim to determine temperature differences that can affect the presence of dragonflies. Temperature greatly affects dragonfly diversity; according to Koneri et al. (2020), dragonflies require higher temperatures for wing movement; dragonfly venation works effectively when temperature exceed 30°C. The increasing temperature more than 30°C affect the diversity of dragonflies. The higher temperature and humidity affect small insects that are the main food for dragonflies and plants diversity as a place to perch (Susanto and Zulaikha 2021).

Open vegetation affects the incoming light intensity dragonflies require (Koneri et al. 2022); the more open the vegetation, the greater the light intensity. Meanwhile, a more closed canopy and the number of trees around it can obstruct the air flow rate (Susanto and Zulaikha 2021). Dragonflies require light intensity for activities such as basking and foraging (Susanto and Zulaikha 2021). According to Susanto et al. (2023), sunlight intensity affects the species richness and abundance of dragonflies; the higher the light intensity, the lower the species richness and abundance.

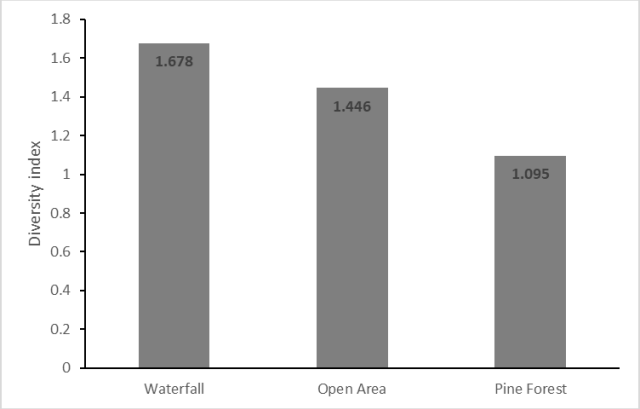

Figure 3. Result of Diversity Index

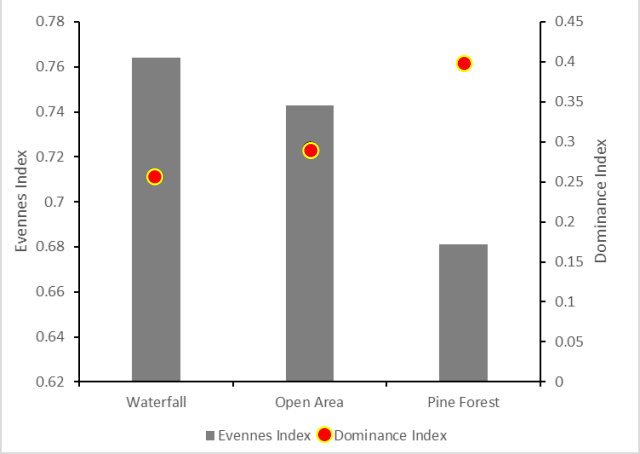

Figure 4. Results of Evenness Index and Dominance Index

Table 3. Abiotic factors in Kedung Klurak, Mojokerto District, East Java, Indonesia

Location	Temperature (°C)	Humidity (%)	Light intensity (lx)
Waterfall	31.2	57	21300
Open area	34.1	60	22100
Pine forest	32.7	62	19800

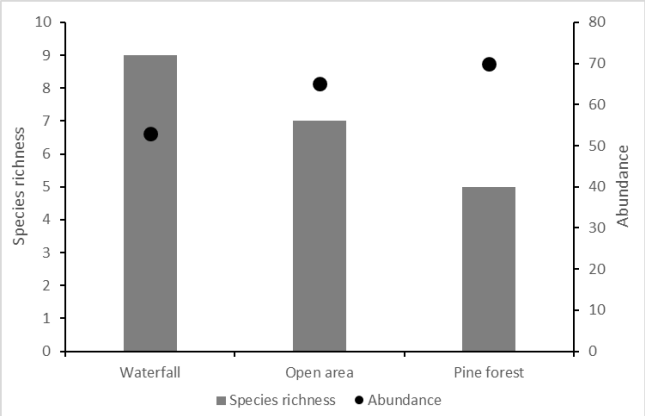

Figure 5. Species richness and abundance values

The waterfall station is the mainstream in the Kedung Klurak area. At this station, there is a clear stream and puddle. The dominant vegetation around the waterfall is bamboo plants with an open canopy. The open canopy determines the intensity of light entering and affects the surrounding air temperature (Susanto and Zulaikha 2021). The waterfall has the highest diversity index value (Figure 3) and species richness (Figure 5). At the waterfall station, five families were found, with a total of nine species. Species that are only found at the waterfall location are *Orthetrum pruinosum*, *Neurothemis ramburii*, *Trithemis festiva*, *Pantala flavescens*, *Idionyx montana*, and *Gynacantha subinterrupta*.

The *O. pruinosum*, *T. festiva*, and *P. flavescens* are members of the Family Libellulidae only found at the waterfall station. The *O. pruinosum* perched on plants with open canopies near open areas with calm currents. The *P. flavescens* was found in as many as two individuals flying high above the water with an open canopy; based on research from Susanto and Zulaikha (2021) reported that *O. pruinosum* is suitable to live in open habitats with high light intensity during the day and *P. flavescens* is suitable to live in habitats that have open canopies. The *T. festiva* perches on branches close to water and rocks with surrounding bamboo forest vegetation. This is in line with the findings of Irawan and Rahadi (2016), who reported that *T. festiva* was found in a rocky river with fast flow and diverse vegetation surrounding.

The *N. ramburii* was found perched on vegetation exposed to direct sunlight. This species likes open habitats such as waterfall stations. This is supported by Yen (2019), which reports that *N. ramburii* is found in open habitats. In addition Ilhamdi et al. (2021) also reported the same; the highest relative abundance of *N. ramburii* was found at stations with open canopies.

The *G. subinterrupta* is only found at the waterfall station, perched on bamboo plants with a closed canopy. This is in line with Abdillah et al. (2019), who reported that *G. subinterrupta* is found in aquatic habitats with thick canopies. In addition (Zaman et al. 2022) also reported that *G. subinterrupta* was found in a relatively good river with dense vegetation. Vegetation density and light intensity affect dragonfly wing pigmentation because *G. subinterrupta* has dark wings to absorb calories from the environment (Abdillah et al. 2019). Male dragonflies need the canopy to wait for female dragonflies to arrive or to trap other insects to become prey (Zaman et al. 2022).

The *I. montana* at the waterfall station was found flying around bamboo vegetation with a closed canopy. This is supported by Susanto and Bahri (2021), who reported that *I. montana* was found flying near a stream with many trees. This follows the findings of Herlambang et al. (2016) which reported that *I. montana* is a species only found in forest habitats, namely found perched on tree branches in the forest.

The open area station is a flow path from the waterfall with shrub habitats. The diversity value at this location is in the medium category. Five families were found, with seven species at this station. Several species are only found at the open area station: *Potamarcha congener*, *Diplacodes trivialis*, and *Heliogomphus drescheri*.

The pine forest area station is a water stream with pine vegetation. This location is included in a tourist area where there are human activities. The diversity value at the pine area station is medium diversity category. The low habitat diversity is due to the unavailability of food and disturbed habitat due to human activities. Dragonflies are very sensitive to human disturbance, and their diversity decreases with each pollution and disturbance (Kemabonta et al. 2017). Four families were found with a total of five species, and the species that were only found in pine area stations were *Orthetrum glaucum* and *Cratilla lineata*. Due to low water quality, the *O. glaucum* was only found in pine forest stations. This is supported by Leksono et al. (2017), who reported that *O. glaucum* is commonly found in low-water quality.

The location of the pine forest vegetation is a tourist area with quite a lot of human activity around the river, such as camping and swimming, which causes the environment at this location to be polluted. Polluted environments can disrupt natural habitats of dragonflies. Human disturbance in river flows can affect dragonfly communities, leaving only species that are tolerant of habitat changes (Calvão et al. 2018). Dragonflies that are tolerant of the environment and human disturbances found at this station are *V. luctuosa* and *E. variegata*. This is aligned with (Rachman and Rohman 2016), who reported that dragonflies *V. luctuosa* and *E. variegata* were found in locations with many pollutants and human disturbances.

The conclusion based on research conducted in the Kedung Klurak Waterfall Area, there are 15 species from seven families. The highest relative abundance was *V. luctuosa* with a value of 44.149% and *E. variegata* with a value of 28.723%. Waterfall station has the highest index diversity value and species richness value, while pine forest has the lowest index diversity value and species richness. The difference in results is because the waterfall station and the pine forest station have different environmental conditions, pine forests have pine tree vegetation and areas with a lot of human activity.

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