

Diversity and conservation status of dragonflies (Odonata) at three streams in Donomulyo Sub-district, Malang District, Indonesia

MUHAMAD AZMI DWI SUSANTO^{1,✉}, FATHURRAHMAN SIDIQ², SUFRAHA ISLAMIA³,
MUHAMMAD IQBAL PRATAMA⁴

¹Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Brawijaya. Jl. Veteran, Malang 65145, East Java, Indonesia.
Tel.: +62-341-554403, ✉email: muhammadazmidwi@gmail.com

²Green Community, Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang. Sekaran, Gunung Pati, Semarang 50229, Central Java, Indonesia

³Perhimpunan Kebun Binatang Se-Indonesia-Global Species Management Plan. Jakarta, Indonesia

⁴Department of Biology, Faculty of Science and Technology, UIN Sunan Ampel Surabaya. Jl. Dr. Ir. H. Soekarno No.682, Gn. Anyar, Surabaya 60294, East Java, Indonesia

Manuscript received: 12 November 2023. Revision accepted: 20 April 2024.

Abstract. Susanto MAD, Sidiq F, Islamia S, Pratama MI. 2024. Diversity and conservation status of dragonflies (Odonata) at three streams in Donomulyo Sub-district, Malang District, Indonesia. *Nusantara Bioscience* 16: 139-147. The aquatic environment is currently experiencing massive threats, especially from anthropogenic activities. Polluted effluent discarded in streams damages the existing ecosystems and negatively impacts various organisms. Donomulyo, a sub-district in Malang District of East Java Province, Indonesia, has many rivers and streams that are pivotal for local people and wildlife. Water quality in these aquatic bodies can be monitored using bioindicators. Odonata (dragonflies and damselflies) are bioindicators indicating environmental change in rivers and streams. Unfortunately, there has been no data regarding Odonata in the Donomulyo streams. Hence, this research aims to determine the diversity of dragonfly species at three streams in Donomulyo and its meaning for the environmental status. The research was conducted at Sengik, Kedungceleng, and Kedungsalam streams using a Visual Encounter Survey (VES) to count individuals of each dragonfly species. This study recorded 258 individuals identified into 25 species of 4 families. Aside from *Copera vittata javana* (Lieftinck, 1940) which International Union for Conservation of Nature (IUCN) Red List status is Not Evaluated, all other dragonflies are Least Concern evaluated. The three streams studied in this research generally had moderate Odonata diversity ($2.02 < H' < 2.41$), indicating good habitat conditions.

Keywords: Habitat, insect, microclimate, river, wildlife

INTRODUCTION

Dragonflies are flying insects included in the order Odonata, with two suborders, Anisoptera (common dragonflies) and Zygoptera (damselflies) (Orr and Kalkman 2015). Dragonflies undergo incomplete metamorphosis with three cycles: egg, nymph, and adult (Paulson 2009). In general, eggs are laid by female dragonflies on the water's surface or in water close to aquatic plants and will hatch into nymphs in 1–21 days (Setiyono et al. 2017). The nymphs will molt up to 15 times and take up to several months before emerging as adult dragonflies (Setiyono et al. 2017). The egg and nymph phases require aquatic bodies (Orr and Kalkman 2015; Choong et al. 2020), while adults live terrestrially and aerially. Dragonflies highly depend on waterbodies to accomplish their life cycle. Adult dragonflies can generally be found around aquatic ecosystems such as rivers (Zaman et al. 2020), waterfalls (Koneri et al. 2020; Susanto and Arianti 2021), reservoirs or ponds (Susanto et al. 2023), and lakes (Potapov et al. 2020); either in lowlands or highlands (Leksono et al. 2017).

As they associate with and depend highly on water quality, dragonflies are sensitive to disturbances and changes in aquatic environmental quality (Dolný et al. 2012), thus leading to the use of dragonflies as

bioindicators to determine water quality (Buczyński et al. 2020). In addition, dragonflies also indicate the quality of the terrestrial environment as they react to the changes in habitat components' quality, such as landscape conditions (Perez and Bautista 2020), vegetation (Briggs et al. 2019; Oliveira-Junior et al. 2017), and canopy cover (Susanto et al. 2023). Most dragonflies require a specific natural habitat, which determines their disappearance whenever their habitat changes. This situation is practically the reason for using dragonflies as bioindicators in indicating the quality of aquatic environments.

Dragonflies also play an important role in terrestrial and aquatic ecosystems as predators of small insects (Orr and Kalkman 2015). Dragonflies are carnivorous insects that can control insects that are potential vectors of diseases that can harm humans, such as mosquitoes (Samways 2008; Vatandoost 2021; Ramlee and Mohd 2022). In addition, dragonflies are also predators of insect pests in agricultural areas and rice fields (Suroto et al. 2021; Sharma and Oli 2022; Raut et al. 2023). Therefore, the presence of dragonflies in an ecosystem is very important for humans. Population decline and the loss of dragonfly species in a location due to environmental damage can have a negative impact on humans. Research on dragonflies is very important as an early indicator for analyzing terrestrial and

aquatic environmental quality changes.

Streams are lotic aquatic habitats that become natural habitats for dragonflies due to their vegetated banks. Several previous studies in Indonesia confirmed it, such as at Brantas River in Batu-Malang of East Java, with 10 species recorded (Virgiawan et al. 2015), at Kalibendo River in Banyuwangi, East Java with 13 species (Nugrahani et al. 2022), at Gajah Wong River in urban Yogyakarta with 25 species observed (Zaman et al. 2022), at the stream in Ujung Kulon National Park with 17 species found (Sugiman et al. 2020), at Mahaka River in South Sulawesi with 12 species (Nuraeni et al. 2019), and at Batubolong River, in West Lombok with 11 species (Zulhariadi et al. 2022). Despite having a considerable intact lowland forest with a vast riverine area, the data on Odonata from Malang District is still lacking. Donomulyo, a prominent sub-district in this area, is a good representative for studying its dragonflies, as it has never been conducted before. Hence, this study intended to analyze the diversity of dragonflies in Donomulyo, which

is expected to provide basic data for future study and conservation of this insect group.

MATERIALS AND METHODS

Time and location of research

This research was conducted between August–September 2021 at Donomulyo Sub-district ($8^{\circ}16'49.39''\text{S}$, $112^{\circ}25'47.13''\text{E}$), Malang District, East Java Province, Indonesia. Fieldwork occurred at three streams in this sub-district, i.e.: Sengik, Kedungceleng, and Kedungsalam (Figure 1). These three research sites were selected based on the similarity of habitat types, namely streams in the Donomulyo sub-district. The detail on the three streams is provided in Table 1. This research was conducted for six days, with details of each research location being repeated twice on different days. Field sampling occurred during active dragonfly hours, from 07.00 to 13.00 hours, along the transect erected following the stream embankment.

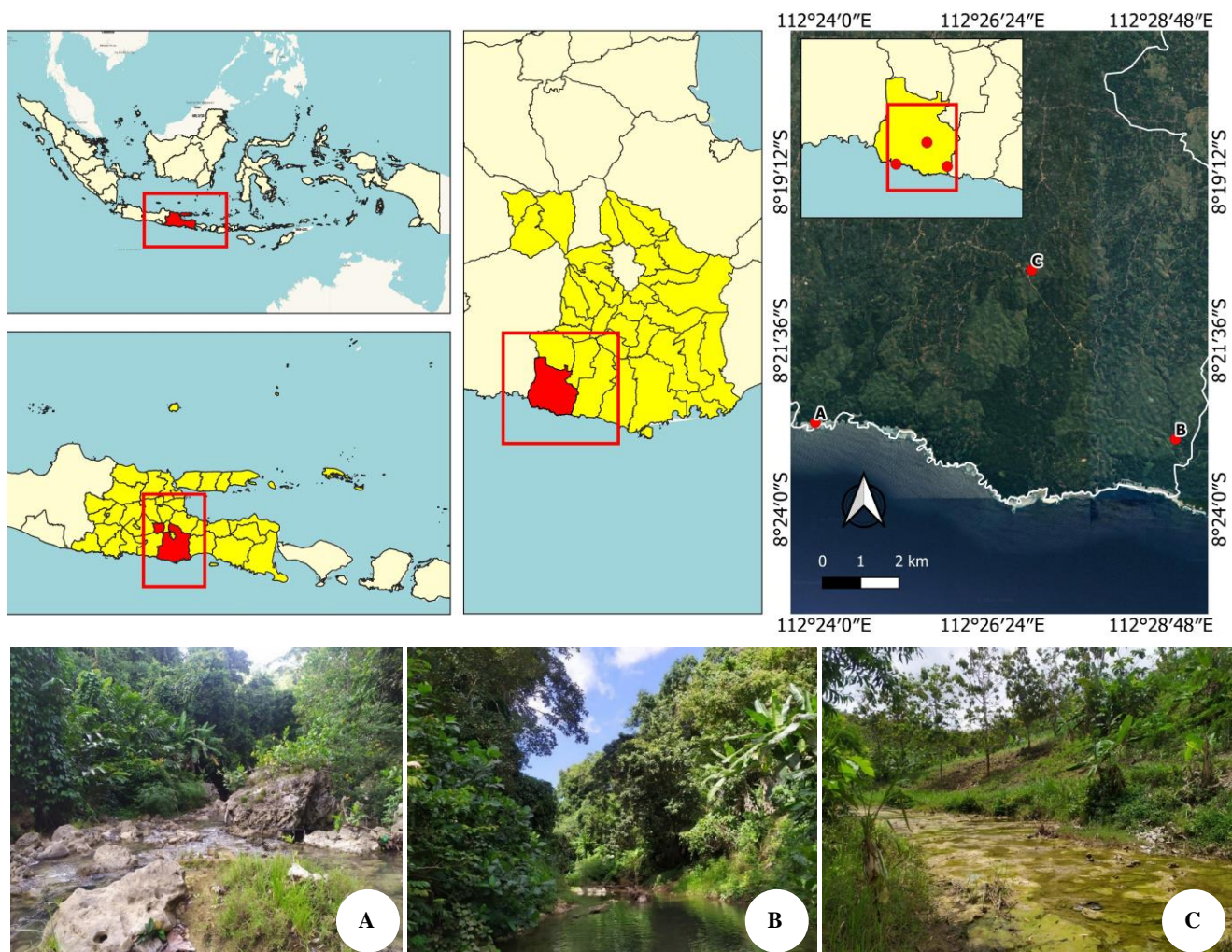


Figure 1. Map and physical appearance of sampling sites in Donomulyo, Malang, Indonesia. A. Sengik, B. Kedungceleng, C. Kedungsalam

Table 1. Coordinate point and description of research sites in Donomulyo, Malang, Indonesia

Stream	Coordinate points		Description
	Latitude	Longitude	
Sengik	8° 22' 45.9"S	112° 23' 52.8"E	Flows through secondary forest and plantation, flanked with ponds
Kedungceleng	8° 22' 59.9"S	112° 29' 0.7"E	Flows through secondary forests and plantations
Kedungsalam	8° 20' 35.7"S	112° 26' 57.8"E	Flows through plantations and in adjacency with settlements

Sampling method

Field data was collected along a 200 m length and 5 m width line transect erected following the stream pathways. Adult dragonflies were recorded using the Visual Encounter Survey (VES) method, equipped with a sweeping net and photography. The individual number from each adult species was counted, while pictorial documentation was used for species identification purposes. Species identification used morphological aspects, including shape, pattern, and color of the body and wings. The identification process was guided with proper references (Rahadi et al. 2013; Setiyono et al. 2017). In addition, environmental factors (air temperature, air humidity, and light intensity) were measured using a thermo-hygrometer and light meter. Air temperature, humidity, and light intensity measurements were observed at each study site's on the beginning of data collection.

Data analysis

Odonata diversity was calculated using some ecological indices (Shannon-Wiener Diversity Index, Evenness Index, and dominance index) ran with PAST (paleontological statistics) 4.03 software. This software also commenced a Principal Component Analysis (PCA) test to determine the correlation between sampling sites and environmental factors. Other factors, such as analysis of taxa numbers and the abundance of dragonfly species, were displayed using graphs generated through Microsoft Excel 2021.

RESULTS AND DISCUSSION

Diversity of species

The fieldwork conducted at three streams in the Donomulyo Sub-district recorded 25 Odonata species of four families identified from 285 observed individuals. Suborder Anisoptera was represented by two families, Aeshnidae and Libellulidae, with a total of 15 species of 118 individuals recorded, while suborder Coenagrionidae and Platycnemididae represented Zygoptera with a total of 10 species of 167 individuals. Libellulidae became a family with the most recorded species, 14 species of 117 individuals, while Aeshnidae, with one species and one individual, was the most scarce. In addition, Libellulidae also had the highest percentage of family composition based on the number of species (Figure 2) and abundance (Figures 3 and 4) at all study sites.

The observation results showed that at the Sengik stream, there were 10 species with 46 individuals; the Kedungceleng stream was with 13 species of 66 individuals; and the Kedungsalam stream was observed with 15 species and 173 individuals (Figure 5). Kedungceleng stream had the highest Odonata diversity ($H' = 2.41$), followed by Kedungsalam stream ($H' = 2.26$) and Sengik stream ($H' = 2.02$) (Figure 6). Furthermore, Kedungceleng had the most evenly distributed species among the other two streams ($E = 0.86$), while the Sengik stream indicated the existence of the most dominant species ($D = 0.17$) (Figure 7).

Conservation status

According to the International Union for Conservation of Nature (IUCN) 2023 assessment, only *Copera vittata javana* possessed discernible status as Not Evaluated (NE), which is considerably higher than the other 24 species that are Least Concern (LC) (Table 2). Moreover, 9 species are categorized as stable populations as indicated in the IUCN database, including *Gynacantha subinterrupta*, *Agrioptera insignis*, *Neurothemis ramburii*, *Neurothemis terminata*, *Orthetrum sabina*, *Pantala flavescens*, *Pseudagrion microcephalum*, *Pseudagrion pruinosum*, and *Prodasineura autumnalis*. Meanwhile, 13 species which comprise of *Camacinia gigantea*, *Orthetrum glaucum*, *Orthetrum pruinosum*, *Potamarcha congener*, *Rhodothemis rufa*, *Trithemis aurora*, *Trithemis festiva*, *Agriocnemis femina*, *Agriocnemis pygmaea*, *Heliocypha fenestrata*, *Pseudagrion rubriceps*, *Copera marginipes*, and *Nososticta insignis* are with unknown population trend. Only *Crocothemis servilia* and *Orthetrum testaceum* were assessed to have an increased population trend.

Correlation between sampling sites and environmental factors

The measuring of environmental factors hints that the Kedungsalam stream has the highest temperature and light intensity site among other locations ($T = 32.1^{\circ}\text{C}$, $Ev\ 30,272\ \text{lx}$; Table 3), while the Sengik stream recorded the highest humidity ($AH = 72\%$). The analysis tested the relation between three variables of environmental factors and five factors of dragonfly diversity, showing that the total variance of $PC1 = 69.397\%$ and $PC2 = 30.603\%$ (Figure 8). PCA analysis shows that the Kedungsalam stream positively correlates with air temperature, while the Sengik stream positively correlates with air humidity.

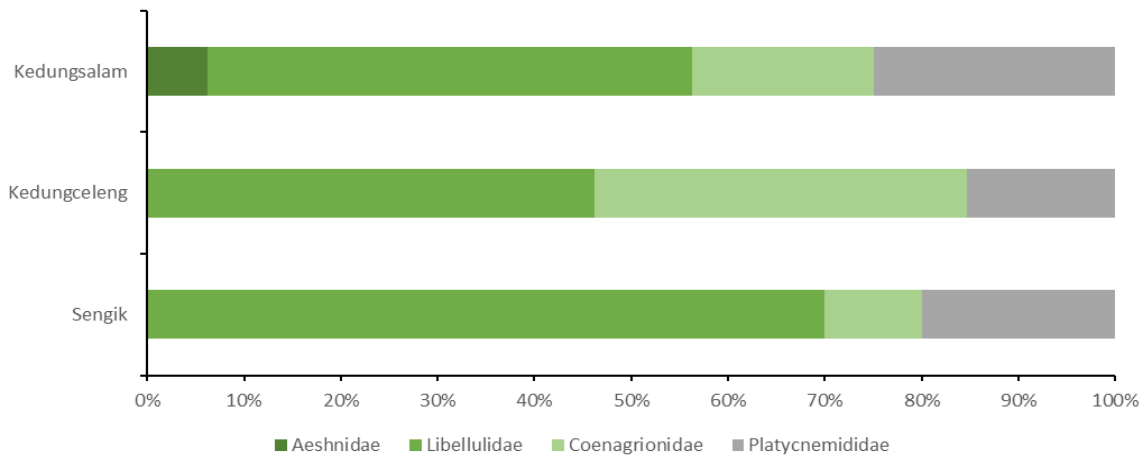


Figure 2. Composition of Odonata families according to its species members at three streams in Donomulyo, Malang, Indonesia

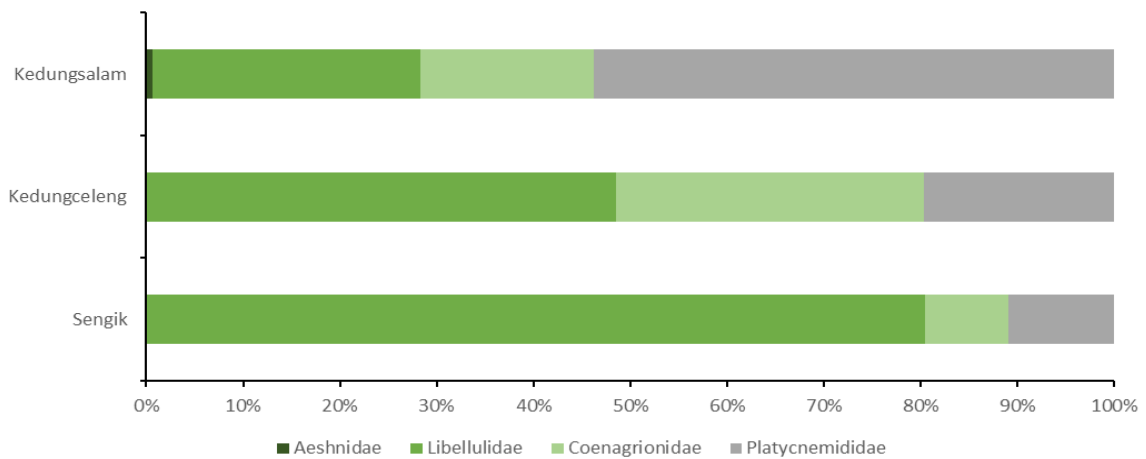


Figure 3. Composition of Odonata families according to abundance at three streams in Donomulyo, Malang, Indonesia

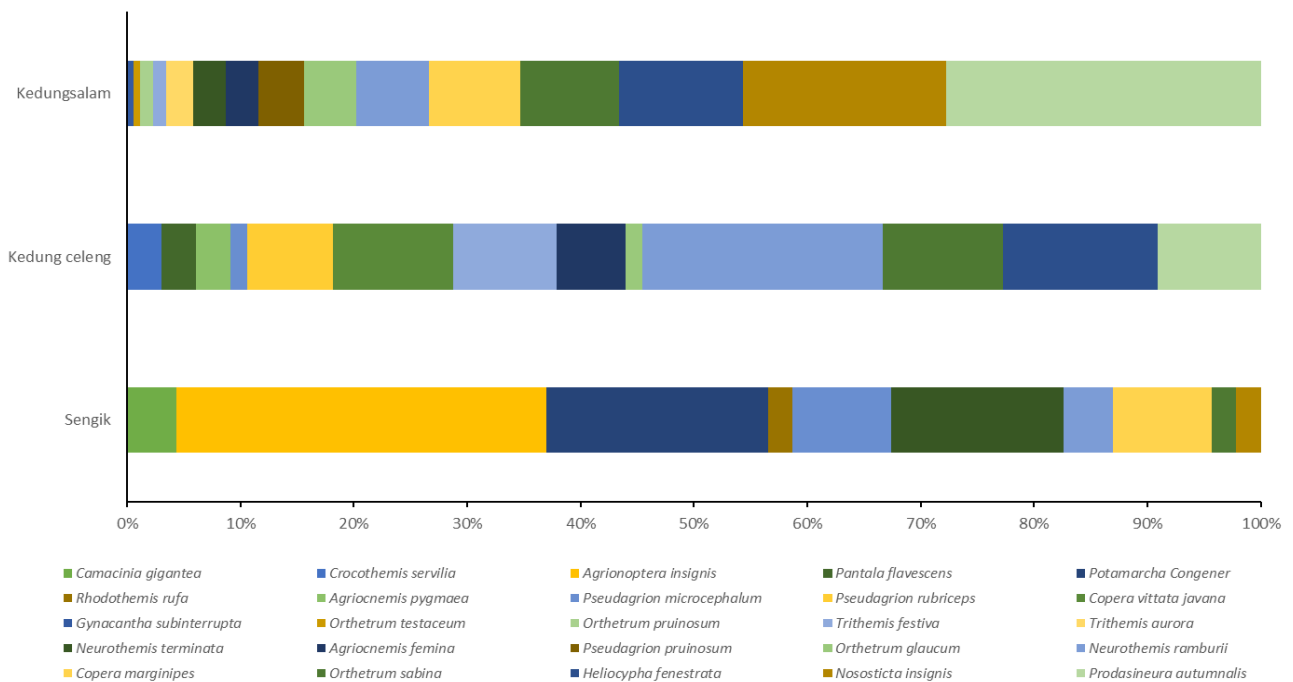


Figure 4. Relative abundance of Odonata species at three streams in Donomulyo, Malang, Indonesia

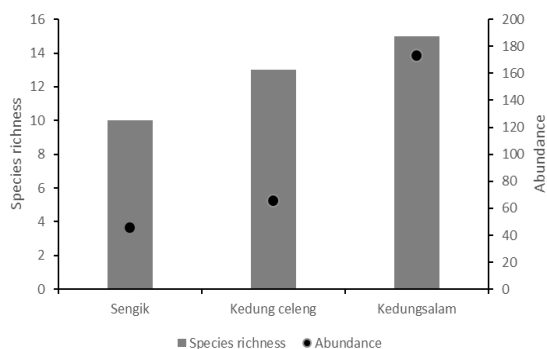


Figure 5. The richness and abundance of Odonata species at three streams in Donomulyo, Malang, Indonesia

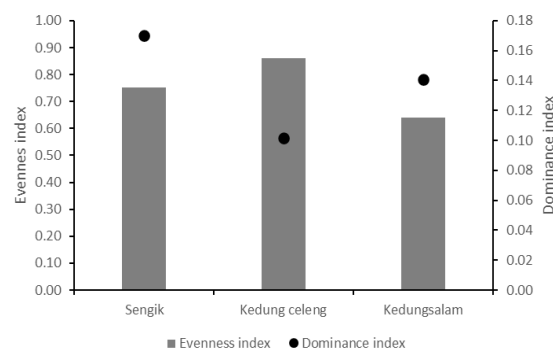


Figure 7. The distribution and dominance of Odonata species at three streams in Donomulyo, Malang, Indonesia

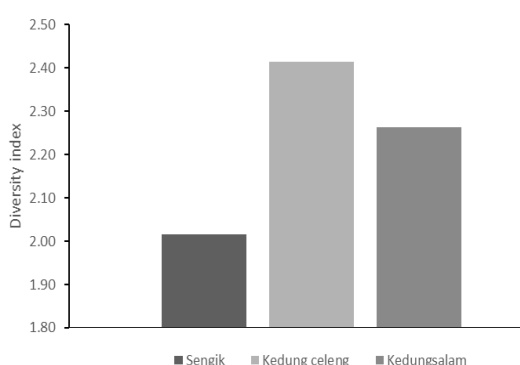


Figure 6. Odonata diversity at three streams in Donomulyo, Malang, Indonesia

Discussion

Analysis of family composition based on the number of members of the species shows that Libellulidae is the Odonata family that has the highest number of species in this study, namely 14 species, at the three research sites and also has the highest percentage of 46.15% to 70% of all species recorded during the study (Figure 2). Therefore, Libellulidae also had the highest number of individuals of all individuals in this study, namely 117 individuals, and the three research sites also had the highest percentage of 48.48% to 80.43% of all individuals recorded during the study (Figure 3). As a family with the most members within the Order Odonata, Libellulidae is commonly found in various habitats (Setiyono et al. 2017). In addition, its members generally have good flight ability and wide mobility.

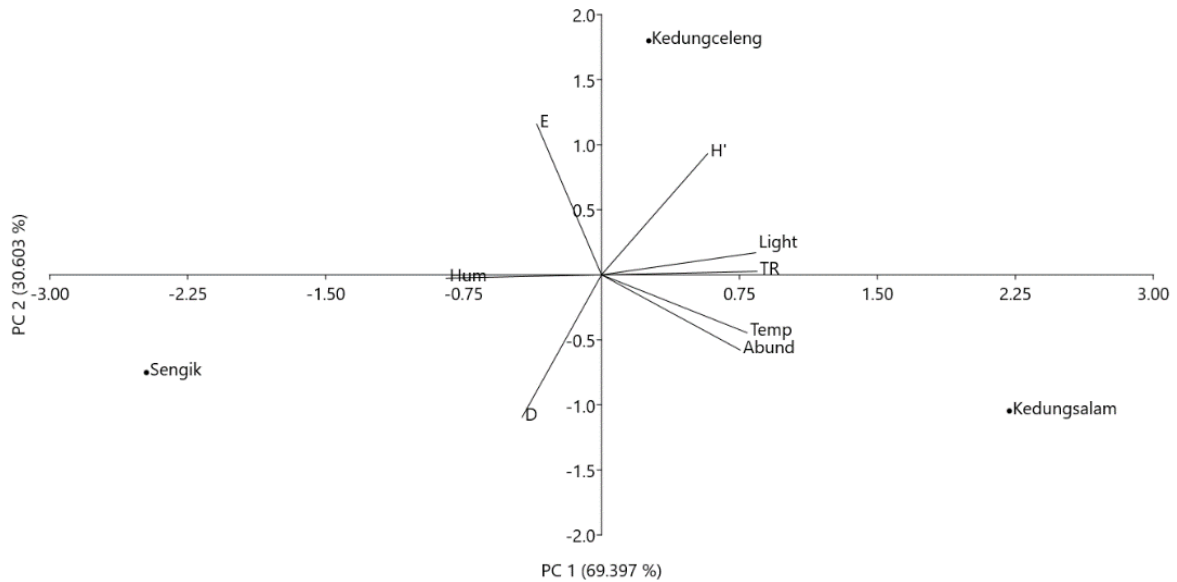
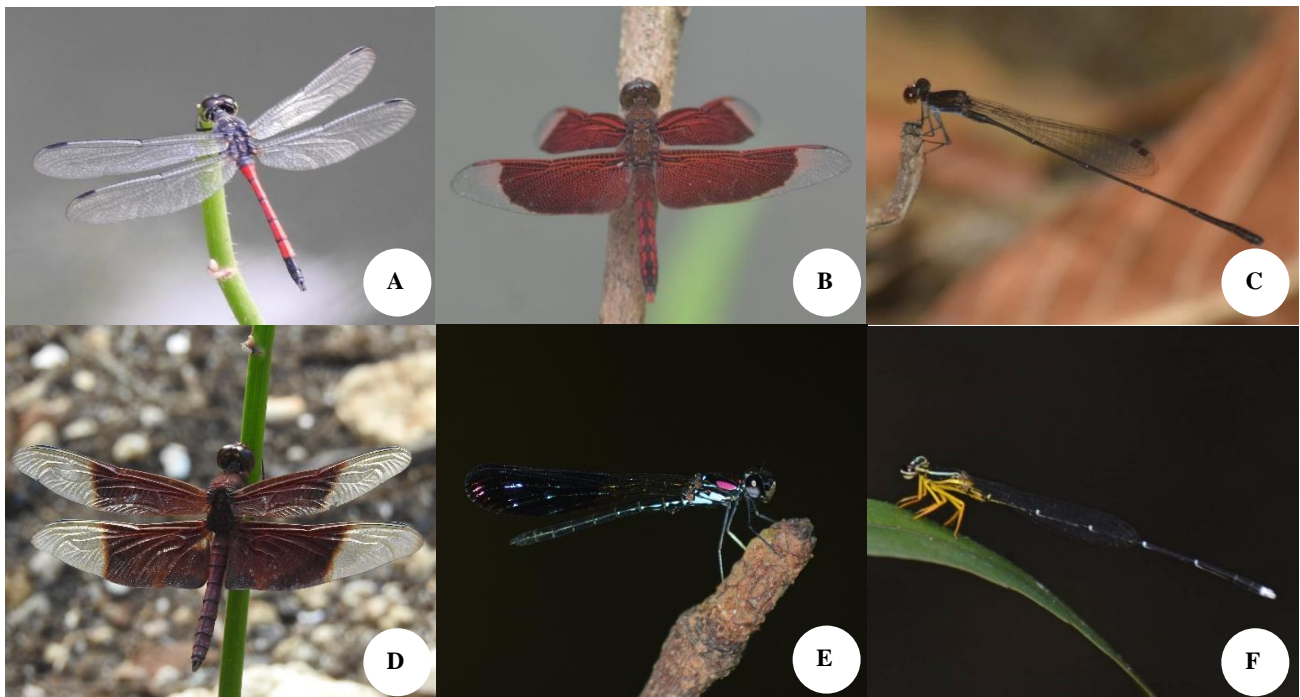
Table 2. List of species and conservation status of Odonata at streams in Donomulyo, Malang, Indonesia

Suborder & family	Species	Locations			Conservation Status	
		Sengik	Kedungceleng	Kedungsalam		
Anisoptera						
Aeshnidae	<i>Gynacantha subinterrupta</i> (Rambur, 1842)	-	-	+	LC	
Libellulidae	<i>Agrionoptera insignis</i> (Rambur, 1842)	+	-	-	LC	
	<i>Camacina gigantea</i> (Brauer, 1867)	+	-	-	LC	
	<i>Crocothemis servilia</i> (Drury, 1770)	-	+	-	LC	
	<i>Neurothemis ramburii</i> (Brauer, 1866)	+	+	+	LC	
	<i>Neurothemis terminata</i> (Ris, 1911)	+	-	+	LC	
	<i>Orthetrum glaucum</i> (Brauer, 1865)	-	+	+	LC	
	<i>Orthetrum pruinosum</i> (Burmeister, 1839)	-	-	+	LC	
	<i>Orthetrum sabina</i> (Drury, 1770)	+	+	+	LC	
	<i>Orthetrum testaceum</i> (Burmeister, 1839)	-	-	+	LC	
	<i>Pantala flavescens</i> (Fabricius, 1798)	-	+	-	LC	
	<i>Potamarcha congener</i> (Rambur, 1842)	+	-	-	LC	
	<i>Rhodothemis rufa</i> (Rambur, 1842)	+	-	-	LC	
	<i>Trithemis aurora</i> (Burmeister, 1839)	-	-	+	LC	
	<i>Trithemis festiva</i> (Rambur, 1842)	-	+	+	LC	
Zygoptera						
Coenagrionidae	<i>Agriocnemis femina</i> (Brauer, 1868)	-	+	+	LC	
	<i>Agriocnemis pygmaea</i> (Rambur, 1842)	-	+	-	LC	
	<i>Heliocypha fenestrata</i> (Burmister, 1839)	-	+	+	LC	
	<i>Pseudagrion microcephalum</i> (Rambur, 1842)	+	+	-	LC	
	<i>Pseudagrion pruinosum</i> (Burmeister, 1839)	-	-	+	LC	
	<i>Pseudagrion rubriceps</i> (Selys, 1876)	-	+	-	LC	
	Platycnemididae	<i>Copera marginipes</i> (Rambur, 1842)	+	-	+	LC
		<i>Copera vittata javana</i> (Lieftinck, 1940)	-	+	-	NE
<i>Nososticta insignis</i> (Selys, 1886)		+	-	+	LC	
<i>Prodiasineura autumnalis</i> (Fraser, 1922)		-	+	+	LC	

Note: (+) present and (-) absent. LC: Least Concern & NE: Not Evaluated (IUCN 2023)

Table 3. Environmental factors during field time at three streams in Donomulyo, Malang, Indonesia

Location	Temperature (°C)	Humidity (%)	Light intensity (lx)
Sengik	30.6	72	14,786
Kedungceleng	31.0	69	25,643
Kedungsalam	32.1	67	30,272

**Figure 8.** Correlation between sampling sites and environmental factors at three streams in Donomulyo, Malang, Indonesia**Figure 9.** Odonata representatives from Donomulyo, Malang, Indonesia: A. *Agrionoptera insignis*, B. *Neurothemis ramburii*, C. *Prodasineura autumnalis*, D. *Camacinia gigantea*, E. *Heliocypha fenestrata*, F. *Copera vittata javana*

The dominance of the Libellulidae family has been confirmed through previous studies from various locations in Indonesia, such as at Batubolong River in West Lombok, with 7 species and 17 individuals out of a total of 11 species and 33 individuals (Zulhariadi et al. 2022), at Gajahwong River in Yogyakarta with 13 species recorded out of total 25 species (Zaman et al. 2020), at Kuningan Resort of Mount Ciremai National Park in West Java Province with 14 species and 342 individuals out of total 24 species and 591 individuals (Hastomo et al. 2022), at lowland forest in Central Kalimantan with 18 species out of total 22 species (Hendriks et al. 2023), at Mount Bromo's Forest Area in East Java with 13 species out of total 23 species (Astuti et al. 2022), and at protected forests in Bengkulu with 22 species out of total 52 species (Janra et al. 2022).

The only member of the Aeshnidae family recorded in this study was with a single individual, hence contributing 6.25% and 0.58%, respectively, toward family and species composition. During observation, *G. subinterrupta* was spotted at the Kedungsalam stream and, at the same time, perched by hanging among dense shrubs and bushes within the stream embankment. The members of Aeshnidae are always scantily recorded in many studies. Observations at Gajahwong River and Nglangeran Ancient Volcano Area in Yogyakarta recorded only *G. subinterrupta* (Zaman et al. 2020; Setyawati and Triatmanto 2022). One at Ujung Kulon National Park in West Java observed only *G. basigutatta* (Sugiman et al. 2020). A study in Bengkulu Province listed 4 species, *Anax panybeus*, *Anaeschna jaspidea*, *Gynacantha dohrni*, and *Gynacantha basiguttata* (Janra et al. 2022), similar to one conducted in Nusakambangan Island of Central Java which observed *Anax guttatus*, *Gynacantha musa*, *G. subinterrupta* and *Tetracanthagyna plagiata* (Nu'manuddin et al. 2021).

Further analysis showed that each site in the current study had different species with the highest relative abundance, i.e., *A. insignis* in Sengik stream, *N. ramburii* in Kedungceleng stream, and *P. autumnalis* in Kedungsalam stream (Figure 9. A-C). In this study, *A. insignis* perched on branches around stagnant water on the streamside, considerably shaded by a canopy. This species prefers perching on vegetation in the nearby stagnant waters under a fairly closed canopy (Kosterin 2014; Setiyono et al. 2017). This species ranges stream habitats (Kosterin 2014; Pratama and Rosalini 2016; Setiyono et al. 2017; Kartini et al. 2022; Zulhariadi et al. 2022;) and ponds (Saefullah et al. 2021) in the lowlands, with an altitude range of 0 to 365 m (Dow 2020a).

The *N. ramburii* was found perched on dry twigs and vegetation on streambanks with open canopy. This species was reported to abundantly inhabit irrigated areas with open canopy (Ilhamdi et al. 2021). It has a high tolerance to disturbance (Dow 2019; Potapov et al. 2020) and is adaptable to various environmental conditions, which explains its observation in all sites of the current study. In addition, it also inhabits flowing waters (Ilhamdi et al. 2021; Astuti et al. 2022) or stagnant waters (Potapov et al. 2020; Susanto and Arianti 2021), between 0-800 meters above sea level (Dow 2019).

The *P. autumnalis* was observed perched on vegetation and woody branches on the streambanks with open to closed canopy conditions in this study. Susanto and Arianti (2021) reported that *P. autumnalis* was found in small streams with fairly open canopy. It prefers perching on wooden branches (Astuti et al. 2022) within forested habitats (Koneri et al. 2022), rivers, ponds, and rice fields (Setiyono et al. 2017). It is known as a damselfly species with a fairly high tolerance toward disturbance (Dow 2020b), including water locations with poor environmental conditions.

The three sites in this study had moderate Odonata diversity ($2.02 > H' > 2.41$; Figure 6). Kedungceleng stream had the highest Odonata diversity, with 13 species and 66 individuals recorded, opposite to the Sengik stream, where the diversity was lowest (10 species and 46 individuals) (Figure 5). Differences in Odonata diversity among locations are thought to be due to various factors such as ecological conditions and microclimate (Table 3). Previous studies indicated the difference in diversity in Odonata is caused by habitat conditions (Susanto and Zulaikha 2021), vegetation (Simaika et al. 2016; Maldonado-Benítez et al. 2022), canopy cover (Paulson 2009), food availability, water quality, temperature (Schalkwyk et al. 2014; Simaika et al. 2016), and light intensity (Monteiro-Júnior et al. 2013).

The three stream locations have different species compositions, with only two species found in all three streams, i.e., *N. ramburii* and *O. sabina*. Some species are typical in one certain location, such as Sengik stream with *A. insignis*, *C. gigantea*, *P. congener*, and *R. rufa*; Kedungceleng stream with *C. servilia*, *P. flavescens*, *A. pygmaea*, *P. rubriceps*, and *C. v. javana*; and Kedungsalam stream with *G. subinterrupta*, *O. pruinosum*, *O. testaceum*, *T. aurora*, and *P. pruinosum*. Despite having streams as a common feature in all locations, unique microhabitats, and certain ecological conditions, they have greatly affected the diversity of dragonfly species. Many Odonata species also require specific habitat preferences, creating species composition differences among studied locations.

The PCA analysis indicated the differences in microclimates among the three streams. Sengik stream, characterized by high humidity, was observed to have low Odonata diversity, taxa richness, and abundance. On the other hand, the Kedungsalam stream with high temperature seemed favorable for having high taxa richness and abundance. The analysis further showed a correlation between air humidity with species dominance. Air humidity is believed to affect the flight of dragonflies; hence, the higher it is, the fewer dragonfly individuals or species flying in that area. On the contrary, light intensity positively correlates with dragonfly diversity, as it is needed for sunbathing, mating, and foraging (Goforth 2010).

All dragonfly species found in this study have low conservation status. As many as 24 species retain the Least Concern (LC) status as having a very low extinction threat and wide-range distribution (IUCN 2023). Conservation status is an indicator applied to animals or plants to show the threat level that affects the distribution and abundance

of their populations in an area (Laikre et al. 2009). Despite having low conservation status, it is necessary to assess the local population status for each species as it is likely to differ from the comforting global status. There is always the possibility that species with LC conservation status face regional or local threats that are not detected globally. In addition to this concern, there are 13 Odonata species in this study whose current population trend is unknown, including *C. gigantea* and *H. fenestrata*.

The *C. gigantea* (Figure 9. D) was spotted perching at a plant stem atop a small pond near the beach of the stream. Its main habitat is near shallow, stagnant waters, such as ponds near mangroves and beaches (Sharma 2010) and natural freshwater ponds (Sugiman et al. 2020). This is also supported by Leksono et al. (2017), who reported that *C. gigantea* was reported to have slight tolerance to habitat disturbance and was confined in low altitudes. Coastal areas are currently experiencing tremendous anthropogenic disturbances, threatening the existence of habitat for *C. gigantea* (Sharma 2010).

The *H. fenestrata* (Figure 9. E) was found perching and basking on rocks in the middle of a stream or at vegetation on the stream banks. The *H. fenestrata* is an exclusive inhabitant in shaded, clean, rocky forest streams (Günther 2019, Sugiman et al. 2020). Its range includes streams in natural forests down to the rivers in agricultural areas and aquatic tourism (Astuti et al. 2022, Nafisah and Soesilohadi 2021). Land conversion and forest alteration create huge changes in the landscape, which later threaten the life of *H. fenestrata* (Günther 2019).

Among other species recorded in this study, only *C. v. javana* (Figure 9. F), whose conservation status is slightly higher as Not Evaluated (NE). This conservation status implies that despite a species not being assessed for its extinction risk, it still requires being conserved and cared for (IUCN 2022). This member of the Platycnemididae family prefers stream banks with dense canopy, which in this study recorded only from the Kedungceleng stream. Damselfly *C. v. javana* was historically only recorded from the southern coast of West Java and Central Java which then its distribution included Nusakambangan Island, off-south of Central Java, based on a recent study (Nu'manuddin et al. 2021).

This study's results show that differences in dragonfly richness and diversity were found in locations with the same habitat type (stream) but different habitat conditions. Diversity analysis showed that the value of dragonfly diversity in the three research locations was $H' = 2.41-2.02$, with the Kedungceleng stream being the location with the highest value. All dragonfly species found in this study are non-threatened except one species, *C. v. javana*, whose conservation status has not been evaluated.

ACKNOWLEDGEMENTS

We thank all those who have helped with this research. Thanks also to friends who have helped with data analysis and writing. We thank Muhammad Nazri Janra and

Magdalena Putri Nugrahani for their review and improvement of the manuscript.

REFERENCES

- Astuti A, Nayasilana IN, Sugiyarto S, Budiharjo A. 2022. Community structure of dragonflies (Odonata) in Gunung Bromo's Forest Area with Special Purpose (FASP), Karanganyar, Central Java, Indonesia. *Biodiversitas* 23 (5): 2493-2501. DOI: 10.13057/biodiv/d230529.
- Briggs A, Pryke JS, Samways MJ, Conlong DE. 2019. Macrophytes promote aquatic insect conservation in artificial ponds. *Aquat Conserv* 29 (8): 1190-1201. DOI: 10.1002/aqc.3157.
- Buczyński P, Buczyńska E, Baranowska M, Lewniewski Ł, Góral N, Kozak J, Tarkowski A, Szykut KA. 2020. Dragonflies (Odonata) of the city of Lublin (Eastern Poland). *Pol J Entomol* 89 (3): 153-180. DOI: 10.5604/01.3001.0014.4239.
- Choong CY, AD DF, AA MAA, Chung AYC, Maryati M. 2020. Diversity of Odonata Species at Kangkawat, Imbak Canyon, Sabah. *J Trop Biol Conserv* 17: 1-10. DOI: 10.51200/jtbc.v17i.2644.
- Dolný A, Harabiš F, Bárta D, Lhota S, Drozd P. 2012. Aquatic insects indicate terrestrial habitat degradation: changes in taxonomical structure and functional diversity of dragonflies in tropical rainforest of East Kalimantan. *Trop Zool* 25 (3): 141-157. DOI: 10.1080/03946975.2012.717480.
- Dow RA. 2019. *Neurothemis ramburii*. The IUCN Red List of Threatened Species 2019: e.T163690A83302471. DOI: 10.2305/IUCN.UK.2019-3.RLTS.T163690A83302471.en.
- Dow RA. 2020a. *Agrionoptera insignis*. The IUCN Red List of Threatened Species 2020: e.T167298A83373853. DOI: 10.2305/IUCN.UK.2020-1.RLTS.T167298A83373853.en.
- Dow RA. 2020b. *Prodasineura autumnalis*. The IUCN Red List of Threatened Species 2020: e.T167139A138284262. DOI: 10.2305/IUCN.UK.2020-1.RLTS.T167139A138284262.en.
- Goforth CL. 2010. Behavioural responses of Enallagma to changes in weather (Zygoptera: Coenagrionidae). *Odonatologica* 39 (3): 225-234.
- Günther A. 2019. *Heliocypha fenestrata*. The IUCN Red List of Threatened Species 2019: e.T122798694A122799250. DOI: 10.2305/IUCN.UK.2019-3.RLTS.T122798694A122799250.en.
- Hastomo SOE, Muttaqin Z, Cita KD. 2022. Inventory and diversity of dragonflies (Odonata) at Kuningan Resort of Mount Ciremai National Park, West Java Province. *IOP Conf Ser: Earth Environ Sci* 959 (1): 012019. DOI: 10.1088/1755-1315/959/1/012019.
- Hendriks JA, Mariaty, Maimunah S, Anirudh NB, Holly BA, Erkens RH, Harrison ME. 2023. Odonata (Insecta) Communities in a Lowland Mixed Mosaic Forest in Central Kalimantan, Indonesia. *Ecologies* 4 (1): 55-73. DOI: 10.3390/ecologies4010006.
- Ilhamdi ML, Idrus AA, Santoso D, Hadiprayitno G, Syazali M. 2021. The species richness and conservation priority of dragonflies in the Suranadi Ecotourism Area, Lombok, Indonesia. *Biodiversitas* 22 (4): 1846-1852. DOI: 10.13057/biodiv/d220430.
- IUCN. 2022. Guidelines for Using the IUCN Red List Categories and Criteria. Version 15.1. Prepared by the Standards and Petitions Committee. <https://www.iucnredlist.org/documents/RedListGuidelines.pdf>.
- IUCN. 2023. The IUCN Red List of Threatened Species. <https://www.iucnredlist.org/en>.
- Janra MN, Gusman D, Singkam AR, Susanto A, Yatap H, Fahrudin A, Andriyansyah F, Prameswara A, Melian M, Herwina H. 2022. Into the database of Bencoolen Odonata: Synthesis of two years dragonfly survey in Bengkulu Province. *IOP Conf Ser: Earth Environ Sci* 1097 (1): 012056. DOI: 10.1088/1755-1315/1097/1/012056.
- Kartini J, Syachruddin S, Ilhamdi ML. 2022. The diversity of dragonflies (Odonata) in the Joben Resort Area, East Lombok. *Jurnal Biologi Tropis* 22 (2): 675-688. DOI: 10.29303/jbt.v22i2.3458.
- Koneri R, Nangoy M, Maabuat PV. 2020. Composition and diversity of dragonflies (Insecta: Odonata) in Tunan waterfall area, North Minahasa, North Sulawesi, Indonesia. *Pak J Zool* 52 (6): 2091-2100. DOI: 10.17582/journal.pjz/20181214071225.
- Koneri R, Nangoy MJ, Siahaan P. 2022. Species diversity of dragonflies on The Sangihe Islands, North Sulawesi, Indonesia. *Appl Ecol Environ Res* 20 (2): 1763-1780. DOI: 10.15666/aecer/2002_17631780.

- Kosterin OE. 2014. Odonata briefly observed on the islands of Bali and Lombok, Lesser Sundas, Indonesia, in the late February 2014. *J Intl Dragonfly Fund* 74: 1-48.
- Laikre L, Nilsson T, Primmer CR, Ryman N, Allendorf FW. 2009. Importance of genetics in the interpretation of favourable conservation status. *Conserv Biol* 23 (6): 1378-1381. DOI: 10.1111/j.1523-1739.2009.01360.x.
- Leksono AS, Feriwibisono B, Arifianto T, Pratama AF. 2017. The abundance and diversity of Odonata along an altitudinal gradient in East Java, Indonesia. *Entomol Res* 47 (4): 248-255. DOI: 10.1111/1748-5967.12216.
- Lieftinck MA. 1940. Revisional notes on some species of *Coperia* Kirby. With notes on habits and larvae (Odon., Platycnemididae). *Treubia* 17 (4): 281-306. DOI: 10.14203/treubia.v17i4.2577.
- Maldonado-Benítez N, Mariani-Ríos A, Ramfrez A. 2022. Effects of urbanization on Odonata assemblages in tropical island streams in San Juan, Puerto Rico. *Intl J Odonatol* 25: 31-42. DOI: 10.48156/1388.2022.1917163.
- Monteiro-Júnior CDS, Couceiro SRM, Hamada N, Juen L. 2013. Effect of vegetation removal for road building on richness and composition of Odonata communities in Amazonia, Brazil. *Intl J Odonatol* 16 (2): 135-144. DOI: 10.1080/13887890.2013.764798.
- Nafisah NA, Soesilohadi RH. 2021. Community structure of dragonfly (Ordo: Odonata) in natural forest and tourist sites petungkriyono Forest, Central Java, Indonesia. *J Trop Biodivers Biotechnol* 6 (3): 1-9. DOI: 10.22146/jtbb.67328.
- Nugrahani MP, Firmansyah RD, Susintowati, S. 2022. Keanekaragaman dan kelimpahan Odonata di Kawasan Hulu Aliran Sungai Kalibendo, Banyuwangi. *Jurnal Biosense* 5 (1): 175-186. DOI: 10.36526/biosense.v5i01.2160.
- Nu'manuddin M, Rachman HT, Rahadi WS, Pamungkas DW, Kamaludin N, Irawan F, Wardhana PK, Nugrahaningrum A, Soesilohadi RH. 2021. Keanekaragaman Capung (Ordo Odonata) Di Pulau Nusakambangan, Kabupaten Cilacap, Jawa Tengah. *Bioma* 17 (2): 57-64. DOI: 10.21009/Bioma17(2).2.
- Nuraeni S, Budiawan, Yaspeta S. 2019. Identification of dragonfly and damselfly species around Mahaka river, Hasanuddin university teaching forest. *IOP Conf Ser: Earth Environ Sci* 343 (1): 012052. DOI: 10.1088/1755-1315/343/1/012052.
- Oliveira-Junior JMB, Junior PDM, Dias-Silva K, Leitão RP, Leal CG, Pompeu PS, Gardner TA, Hughes RM, Juen L. 2017. Effects of human disturbance and riparian conditions on Odonata (Insecta) assemblages in eastern Amazon basin streams. *Limnologia* 66: 31-39. DOI: 10.1016/j.limno.2017.04.007.
- Orr AG, Kalkman VJ. 2015. Field guide to the dragonflies of New Guinea. *Nederlandse Vereniging voor Libellenstudie, Gelderlandfabriek*.
- Paulson D. 2009. *Dragonflies and Damselflies of the West*. Princeton University Press, Princeton, New Jersey. DOI: 10.1515/9781400832941.
- Perez ESN, Bautista MG. 2020. Dragonflies in the city: Diversity of odonates in urban Davao, Philippines. *J Agric Sci Technol A* 10 (1): 12-19. DOI: 10.17265/2161-6256/2020.01.002.
- Potapov GS, Kolosova YS, Gofarov MY, Bolotov IN. 2020. Dragonflies and damselflies (Odonata) from Flores Island, Lesser Sunda Archipelago: New occurrences in extreme environments and an island-level checklist of this group. *Ecol Montenegrina* 35: 5-25. DOI: 10.37828/em.2020.35.2.
- Pratama R, Rosalini RA. 2016. Dragonflies inventory (Odonata) in Kota Waringin Village, Puding Besar District–Bangka Island. *Biovalentia* 2 (2): 94-103. DOI: 10.24233/BIOV.2.2.2016.43.
- Rahadi WS, Feriwibisono B, Nugrahani MP, Dalia BPI, Makitan T. 2013. Naga Terbang Wendit: Keanekaragaman Capung Perairan Wendit, Malang, Jawa Timur. *Indonesia Dragonfly Society, Yogyakarta*. [Indonesian]
- Ramlee S, Mohd SA. 2022. Odonata nymphs as potential biocontrol agent of mosquito larvae in Malaysia. *Southeast Asian J Trop Med Public Health* 53 (4): 426-435.
- Raut AM, Banu AN, Akram W, Nain RS, Singh K, Wahengbam J, Shankar C, Shah MA. 2023. Impact of pesticides on diversity and abundance of predatory arthropods in rice ecosystem. *Appl Environ Soil Sci* 2023: 1-10. DOI: 10.1155/2023/8891070.
- Saefullah AA, Latifah L, Sa'adah M, Salsabila N, Muslimah S. 2021. The inventory of dragonfly species in Kedung Kopong and Banyak Angkrem Areas in Kalirejo Village, Salaman-Magelang. *Proc Intl Conf Sci Eng* 4: 41-47.
- Samways MJ. 2008. *Dragonflies and damselflies of South Africa*. Pensoft Publishers, Sofia. [Bulgaria]
- Schalkwyk JV, Samways MJ, Pryke JS. 2014. Winter survival by dragonfly adults in the Cape Floristic Region. *Intl J Odonatol* 17 (1): 17-30. DOI: 10.1080/13887890.2014.880382.
- Setiyono J, Diniarsih S, Oscilata ENR, Budi NS. 2017. *Dragonflies of Yogyakarta*. Jenis Capung Daerah Istimewa Yogyakarta, Indonesia Dragonfly Society, Yogyakarta. [Indonesian]
- Setyawati M, Triatmanto T. 2022. Keanekaragaman Capung (Odonata) di Kawasan Gunung Api Purba Nglanggeran Kabupaten Gunungkidul. *Bioscientist* 10 (2): 809-817. DOI: 10.33394/bioscientist.v10i2.5872. [Indonesian]
- Sharma G. 2010. *Camacina gigantea*. The IUCN Red List of Threatened Species 2010: e.T167427A6346507. DOI: 10.2305/IUCN.UK.2010-4.RLTS.T167427A6346507.en.
- Sharma, M, Oli BR. 2022. Odonates (Insecta: Odonata) associated with rice ecosystems in Sunwal municipality, central Nepal. *J Nat Hist Museum* 32 (22): 35-48. DOI: 10.3126/jnhm.v32i1.49951.
- Simaika JP, Samways MJ, Frenzel PP. 2016. Artificial ponds increase local dragonfly diversity in a global biodiversity hotspot. *Biodivers Conserv* 25: 1921-1935. DOI: 10.1007/s10531-016-1168-9.
- Sugiman U, Atmowidi T, Priawandiputra W. 2020. Diversity of dragonflies (Insecta: Odonata) in Ujung Kulon National Park. *IOP Conf Ser: Earth Environ Sci* 457 (1): 012031. DOI: 10.1088/1755-1315/457/1/012031.
- Suroto A, Istiqomah D, Syarifah RNK. 2021. Composition of pests and predators in the early generative phase of rice cultivation in two different conditions. *IOP Conf Ser: Earth Environ Sci* 653 (1): 012088. DOI: 10.1088/1755-1315/653/1/012088.
- Susanto MAD, Arianti OF. 2021. Diversity and abundance of dragonfly (Anisoptera) and damselfly (Zygoptera) at Sabo Dam Complang, Kediri, East Java, Indonesia. *Biosfer* 12 (2): 110-122. DOI: 10.24042/biosfer.v12i2.9883.
- Susanto MAD, Firdhausi NF, Bahri S. 2023. Diversity and community structure of dragonflies (Odonata) in various types of habitat at Lakarsantri District, Surabaya, Indonesia. *J Trop Biodivers Biotechnol* 8 (2): 76690. DOI: 10.22146/jtbb.76690.
- Susanto MAD, Zulaikha S. 2021. Diversity and community structure of dragonfly and damselfly (Odonata) at the Selorejo Waterfall Area, Ponorogo Regency, East Java Indonesia. *Jurnal Riset Biologi dan Aplikasinya* 3 (1): 30-37. DOI: 10.26740/jrba.v3n1.p30-37.
- Vatandoost H. 2021. Dragonflies as an important aquatic predator insect and their potential for control of vectors of different diseases. *J Mar Sci* 3 (3): 13-20. DOI: 10.30564/jms.v3i3.3121.
- Virgiawan C. 2015. Studi keanekaragaman capung (Odonata) sebagai bioindikator kualitas air Sungai Brantas Batu-Malang dan sumber belajar biologi. *JPBI* 1 (2): 188-196. DOI: 10.22219/jpbi.v1i2.3330. [Indonesian]
- Zaman MN, Fuadi BF, Luthfika M. 2022. Struktur komunitas capung dan capung jarum di Sungai Gajah Wong Segmen Perkotaan Daerah Istimewa Yogyakarta. *Bioveritas J Biol* 1 (1): 31-36. [Indonesian]
- Zaman MN, Purwanto PB, Iman DI, Sari AM, Maulany SL, Luthfika M, Rofiah N, Halimah GS, Cahya. 2020. Dragonfly and damselflies at Gajahwong River in Yogyakarta Urban District. *Proc Intl Conf Sci Eng* 3: 73-76. DOI: 10.14421/icse.v3.471.
- Zulhariadi M, Irawan RD, Zulfaeda A, Hidayani N. 2022. Dragonflies diversity and land cover changes in The Batubolong River, West Lombok District. *Biotropia* 29 (2): 112-123. DOI: 10.11598/btb.2022.29.2.1637.