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Biotic and dragonfly diversity indices as ecological quality evaluation in Lahat District Rivers, South Sumatra, Indonesia

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Abstract. *Rachmawati A, Yustian I, Pujiastuti Y, Suparman Shk, Arinafril. 2023. Biotic and dragonfly diversity indices as ecological quality evaluation in Lahat District Rivers, South Sumatra, Indonesia. Biodiversitas 24: 6059-6068.* The Lematang, Sandaran, and Kungkilan rivers have been reported to be polluted by coal mining activities. This study aimed to evaluate the ecological conditions using a dragonfly as a bio-indicator. Dragonfly surveys were conducted using direct observation procedures in 11 research sites determined by purposive sampling based on positions of the upstream, midstream and downstream of the river entering the coal mining area, including settling ponds managing waste from post-mining activities (stockpiles and disposal). Dragonflies were captured by visual observations, direct capture, and sticky traps. Data were analyzed by calculating the Dragonfly Biotic Index (DBI) and Diversity Index. The correlation between dragonflies and environmental factors was analyzed using Canonical Correspondence Analysis (CCA) according to Jaccard's index. The results showed there were 23 species of dragonflies. Larvae and exuviae were found in Aeshnidae and Libellulidae families. Dragonfly species with the highest DBI values were seen in *Rhyothemis triangularis, Tholymis tillarga, Zyxomma petiolatum, Atrocalopteryx atrata, Libellago lineata* and *Rhinocypha fenestrata*. Sandaran River had the highest DBI value and diversity index because of the undisturbed condition of the area, which had natural vegetation and unpolluted water conditions. The Kungkilan River will become the focus of river rehabilitation, starting with the reclamation of the river riparian area.

Keywords: Bio-indicators, biotic index, CCA, DBI, dragonflies

INTRODUCTION

Lematang is a river flowing in South Sumatra, passing through Pagar Alam City, Lahat District, and its estuary in Muara Enim District. The length of Lematang River is 320 km and the total river basin area is 24,844 km^2 (Dinata et al. 2022). Lematang River has several tributaries, such as Kungkilan and Sandaran Rivers. It plays an important role in the community as a means of irrigation of agricultural land. The agricultural sector in Lahat District is highly dependent on the Lematang River, especially for the production of rice, corn, and vegetables (Sari et al. 2022). Lematang River has been reported to be polluted by coal mining activities (Teristiandi 2018). Coal mining is widespread in several areas of the Lahat Regency, such as in the West Merapi subdistrict, where there are 14 companies running coal mining (Julitra et al. 2022). The mining activities in Lahat generally use open-pit mining (Suroso et al. 2017).

Surface mining destroys natural vegetation, alters landscapes, and eliminates biodiversity (Ma et al. 2021). Acid mine drainage occurs when sulfide minerals in rocks are exposed to air and water, resulting in the production of sulfuric acid. Acid mine drainage has serious environmental consequences as it can contaminate water sources, disrupt aquatic life, and harm ecosystems (Suroso et al. 2017). Opening vegetation during land clearing can affect hydrological systems and disturb aquatic organisms (Palacios-Torres et al. 2020).

Dragonflies are important aquatic organisms that have rarely been observed in post-mining areas. Research discussing the correlation between the influence of environmental conditions in rivers and changes in the composition and diversity of dragonflies is still limited outside the island of Sumatra (Abdu and Naila 2020; Choi et al. 2020; Vilenica and Mihaljević 2022). Dragonflies are important for observation because dragonfly larvae live in water for several months or years and are sensitive to polluted water conditions. Adult dragonflies live in terrestrial areas and have olfactory sensory organs that can detect the condition of a water body (Plotnikova 2010).

This research was conducted on dragonfly species during their young (larvae) and adult (imago) phases. Dragonfly larvae last for a long time in the water. They can live in the air for several months to several years before undergoing metamorphosis into adult dragonflies (Rahadi et al. 2013). The adult phase is the final phase of the dragonfly's lifespan and is easier to observe visually (Piersanti et al. 2014; Agus et al. 2017; Pujiastuti et al. 2017). Decreased environmental quality can reduce the number of dragonflies in the larvae and adult phases (Suhonen et al. 2010). The presence of dragonflies was monitored because population and species diversity are indicators of suitability and success of environmental management (Gunawan et al. 2015).

The methods used to evaluate the environment using dragonflies were OIWI (Odonata Index of Wetland Integrity) (Vorster et al. 2020), DAI (Dragonfly Association Index) (Chovanec et al. 2015), ORI (Odonata River Index) (Golfieri et al. 2016) and DBI (Dragonfly Biotic Index) (Vorster et al. 2020). This research focuses on the DBI method, as it enables a more general application to a diverse range of aquatic habitats. The DBI method considers the area conditions, conservation status, distribution patterns, and sensitivity levels of dragonfly species to evaluate the environmental ecology (Samways and Simaika 2016). The DBI method can be used on all types of water bodies (still or flowing), in comparison to the OIWI method, which can only be used on wetlands, whereas the DAI, OHI, and ORI methods can only be used on rivers (Hart et al. 2014).

This research was about the structure of the dragonfly community by considering the DBI index and diversity indices. The research results could serve as a database and basis for consideration of dragonfly conservation efforts and habitat preservation management in the area, as well as ensuring dragonfly species and composition around Lematang River, Sandaran River and Kungkilan River in the mining area.

MATERIALS AND METHODS

Research areas

The research was conducted at the end of the rainy season (May-June) of 2023 in Merapi Barat sub-district, Lahat District, South Sumatra Province, Indonesia. Dragonflies were observed by purposive sampling based on the upstream, midstream and downstream (Lematang River, Sandaran River, and Kungkilan River) entering the Mining and Settling Pond area manage wastewater from disposal activities and coal mine support facilities (Figure 1 and Table 1).

Procedures

Dragonfly data collection

Dragonfly data were collected using visual observations, direct capture, and sticky traps. Visual observations were performed at each location once a week for one month. The observation times were carried out twice, namely 08.00 to10.00 am and 02.00 to 04.00 pm, since they were active during these times. Each team consists of three observers. Observations were focused on three locations per day so that 11 locations could be carried out over five days. Dragonflies were captured directly using an insect net, a cone-shaped net with a height of 60 cm, a diameter of 30 cm, and a net stick length of 1.5 meters (Pujiastuti et al. 2017). The sticky trap to capture dragonflies was made of bamboo with a length of 1.5 meters and each bamboo was smeared with glue (Agus et al. 2017). Five sticky traps were installed at each location. Sticky traps were installed in the morning and were checked in the afternoon. Larvae were collected using a square-shaped pond-dipping net with dimensions of 40×40 cm and a hole size of 1 mm (Willacker et al. 2023). The identified species were identified using identification books (Orr & Kalkman 2013; Orr et al. 2005; Kalkman et al. 2009; Buchori et al. 2019).

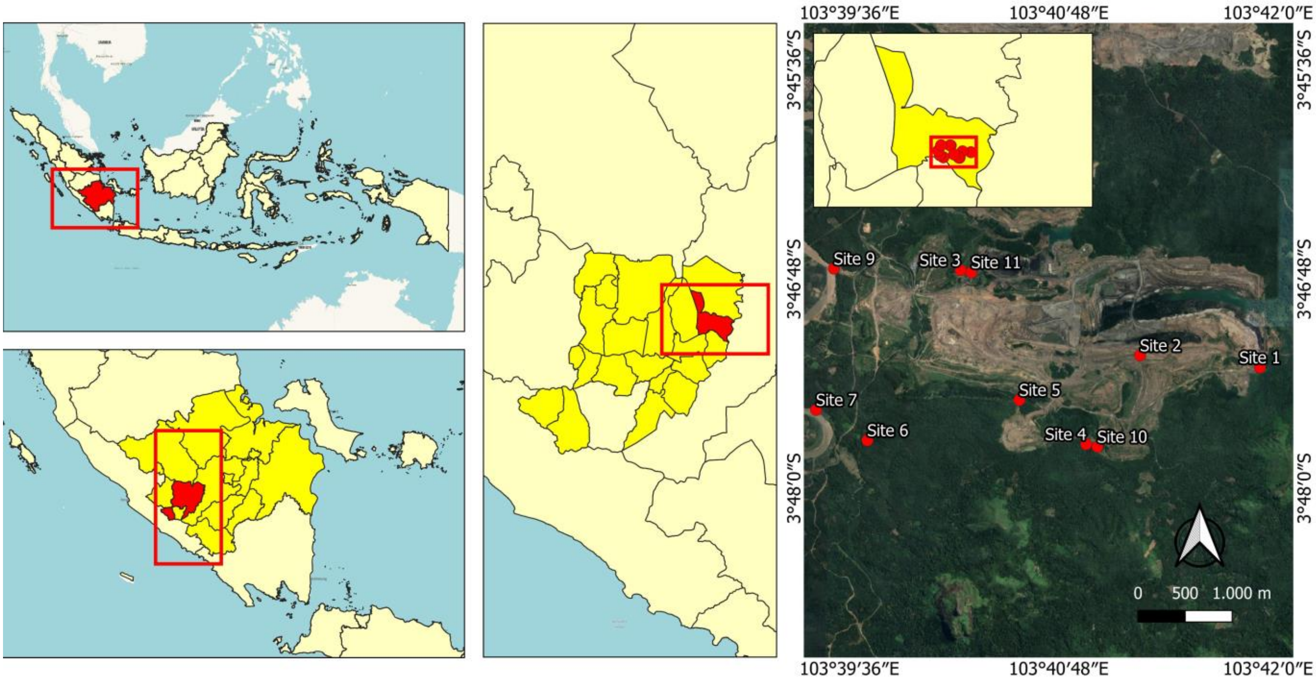

Figure 1. Research sites in Merapi Barat sub-District, Lahat District, South Sumatra Province, Indonesia

Table 1. Coordinates of the research site

Code	Location name	Coordinates	
		South latitude	East longitude
Small River			
Site 1	Upstream of Kungkilan River	3° 47' 18.328"	103° 41' 57.215"
Site 2	Midstream of the Kungkilan River	3° 47' 14.177"	103° 41' 16.000"
Site 3	Downstream of Kungkilan River	3° 46' 44.824"	103° 40' 14.249"
Site 4	Upstream of Sandaran River	3° 47' 44.748"	103° 40' 57.422"
Site 5	Midstream of the Sandaran River	3° 47' 29.523"	103° 40' 34.455"
Site 6	Downstream of Sandaran River	3° 47' 43.414"	103° 39' 42.159"
Middle River			
Site 7	Upstream of Lematang River	3° 47' 32.927"	103° 39' 24.513"
Site 8	Midstream of the Lematang River	3° 47' 10.567"	103° 39' 16.771"
Site 9	Downstream of Kungkilan River	3° 46' 44.332"	103° 39' 30.650"
Settling Pond			
Site 10	Settling pond of disposal	3° 47' 45.621"	103° 41' 1.292"
Site 11	Settling pond of stockpile	3° 46' 45.590"	103° 40' 17.931"

Environmental data collection

Environmental factors observed in this research were air temperature, rainfall, pH, iron metal (Fe), manganese (Mn), and suspended solid concentration (Astuti et al. 2022). Water sampling uses a method that refers to SNI 6989.57:2008. The analysis was performed at the *Dinas Lingkungan Hidup* (DLH) Environmental Laboratory of South Sumatra Province.

Data analysis

Dragonfly Biotic Index (DBI)

The DBI value for each dragonfly species was determined based on three sub-indices: distribution pattern, International Union for Conservation of Nature (IUCN) criteria, and dragonfly sensitivity level (Samways & Simaika 2016). DBI sub-indices each range from 0-3 (Table 2). The DBI value of a species is the sum of the scores for the three sub-indices and ranges from to 0-9. Table 3 describes the DBI scale categories used to interpret environmental conditions (Samways & Simaika 2016). The conservation status of each species is checked at https://www.iucnredlist.org/.

Table 2. DBI sub-indices

Score	Distribution	IUCN	Sensitivity level
0	Very common (found at all research sites)	LC	Insensitive, almost tolerant to habitat disturbance, and may even benefit from habitat change, as found in Settling ponds
1	It only exists at some research sites	NT	Low sensitivity to habitat change and river relocation with artificial vegetation.
2	Limited to specific sites	VU	Moderately sensitive to habitat disturbance, found in small vegetated streams
3	It was found at only one location	EN	Only rivers and naturally vegetated areas were found to be very sensitive to habitat change

Diversity and dominance index

Diversity and dominance index values were analyzed using PAST (Paleontological Statistics) software (Hammer 2023).

Similarity index

Similarity values from research sites and species were analyzed using the statistical software PAST with multivariate cluster analysis, the unweighted paired group algorithm (UPGMA), and the Jaccard similarity index (Hammer 2023).

Canonical Corresponding Analysis (CCA)

Abiotic factors, such as the effect of rainfall on the diversity index, were analyzed using SPSS. The correlation between dragonfly data and abiotic values such as air temperature, pH, Fe, Mn, and suspended solid concentration was analyzed using canonical correspondence analysis (CCA) with PAST software (Hammer 2023).

RESULTS AND DISCUSSION

Species of dragonflies captured and identified

There were 23 species found in the research areas, consisting of 14 species from the sub-order Anisoptera and nine species belonging to the sub-order Zygoptera (Figure 2). The species found in the sub-order Anisoptera were *Ictinogomphus decoratus, Acisoma panorpoides, Brachythemis contaminata, Crocothemis servilia, Diplacodes trivialis, Neurothemis ramburii, Orthetrum glaucum, Orthetrum sabina, Orthetrum testaceum, Pantala flavescens, Rhyothemis phyllis, Rhyothemis triangularis, Tholymis tillarga* and *Zyxomma petiolatum*. The species found in the sub-order Zygoptera were *Euphaea variegata, Neurobasis chinensis, Libellago lineata, Heliocypha perforata, Agriocnemis femina, Agriocnemis pygmaea, Ischnura senegalensis, Pseudagrion microcephalum* and *Copera marginipes.* Larvae and Exuviae were found in the Aeshnidae and Libellulidae families. The Libellulidae family was the most widespread dragonfly family because it has the largest number of members (Pujiastuti et al. 2017; Astuti et al. 2022). Aeshnidae samples were collected only in the exuviae phase because the adult movement was very fast and agile, making it difficult to photograph and capture.

The dragonflies found were categorized as least concern based on the International Union for Conservation of Nature (IUCN). Least-concern status indicates that the species has a stable population and wide geographical distribution. Least-Concern status is not considered threatened, but further monitoring is needed to maintain the sustainability of their populations (Sadasivan et al. 2022). The absence of endemic species in research sites was due to allegedly reduced habitat quality as a result of land clearing and human activities resulting in environmental pollution (Schilling et al. 2019).

The larvae of Aeshnidae and Libellulidae (Figure 2) had a fairly large body size, which makes them easier to observe. Observing larvae was easier by looking at dragonfly exuviae. The exuviae of Aeshnidae family was ± 35 mm in size, whereas those of Libellulidae family were ± 28 mm. The dragonfly larvae were predatory and had strong legs, so they moved quickly in water (Willacker et al. 2023).

Dragonfly Biotic Index (DBI)

The dragonfly species with the highest DBI value were *R. triangularis*, *T. tillarga*, *Z. petiolatum*, *A. atrata*, *L. lineata* and *R. fenestrata* (Table 3). Species with high DBI values have a narrower tolerance than other species; therefore, they can only live in specific habitat types (Golfieri et al. 2016). The Dragonfly species with the lowest DBI values was *O. sabina* species, with a DBI value of 0 (Table 3), because *O. sabina* species were found in at all research sites. According to IUCN conservation status, this species was categorized as least concern, tolerant to habitat disturbance and may even benefit from habitat change. *O. sabina* is a species with high adaptability and is able to live in extreme environmental conditions (Potapov et al. 2020).

The highest DBI value was observed in the Sandaran River, with a value of 34–64, whereas the lowest DBI value was observed in Site 11 (Settling Pond, which manages wastewater from coal stockpile activities) with a value of 2 (Table 3). Site 11 was ± 3.5 km from the Sandaran River. It is thought that the long distance will make it difficult for dragonfly species in the Sandaran River to reach site 11. However, the mining activity separates Site 11 from the Sandaran River. DBI value of Sandaran River was high due to several species that possessed high DBI values (*R. triangularis, T. tillarga, Z. petiolatum*, *A. atrata*, *L. lineata* and *R. fenestrata*). DBI values are based on distribution patterns, International Union for Conservation of Nature (IUCN) criteria, and dragonfly sensitivity levels (Samways & Simaika 2016).

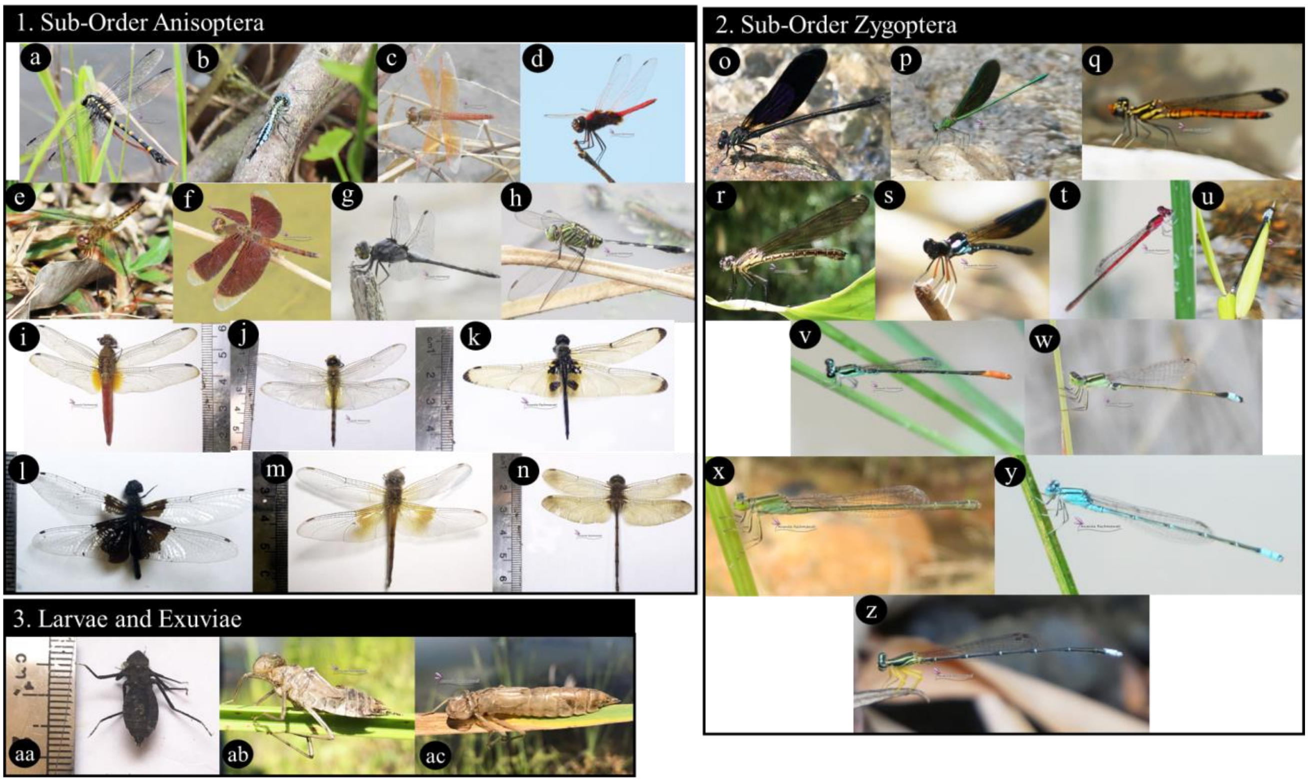

Figure 2. Dragonflies found at the research sites 1. Sub-order Anisoptera (a. *I. decoratus*, b. *A. panorpoides*, c. *B. contaminata*, d. *C. servilia*, e. *D. trivialis*, f. *N. ramburii*, g. *O. glaucum*, h. *O. sabina*, i. *O. testaceum*, j. *P. flavescens*, k. *R. phyllis*, l. *R. triangularis*, m. *T. tillarga*, n. *Z. petiolatum*), 2. Sub-order Zygoptera (o. *E. variegata* p. *N. chinensis*, q. *L. lineata* (male), r. *L. lineata* (female), s. *H. perforata*, t. *A. femina* (female), u. *A. femina* (male), v. *A. pygmaea*, w. *I. senegalensis*, x. *P. microcephalum* (female), y. *P. microcephalum* (male), z. *C. marginipes*), 3. Larvae and Exuviae (aa. Libellulidae larvae,ab. Libellulidae exuviae,ac. Aeshnidae exuviae)

Table 3. DBI values within species and at each research site

Species	DBI value				DBI value of research sites										
	A	**B**	**C**	**Total**	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**	**S11**
Sub-order Anisoptera															
Ictinogomphus decoratus	1	0	0	1	1	1	1	1	1	1	-	-	-	1	-
Acisoma panorpoides	2	0	1	3	3	-	-	3	3	3	-	-	-	3	-
Brachythemis contaminata	1	0	0	1	1	1	1	-	-	-	1	1	1	1	1
Crocothemis servilia	0	0	1	1	1	1	1	1	1	1	1	-	1	1	-
Diplacodes trivialis	1	0	1	2	2	-	2	2	2	2	-	-	-	2	-
Neurothemis ramburii	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1
Orthetrum glaucum	2	0	2	4	4	-	-	4	4	4	-	-	-	-	-
Orthetrum sabina	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Orthetrum testaceum	1	0	1	2	2	-	-	2	2	-	2	2	2	-	-
Pantala flavescens	2	0	1	3	3	-	-	-	-	-	3	3	3	-	-
Rhyothemis phyllis	2	0	2	4	-	-	-	4	4	-	-	-	-	4	-
Rhyothemis triangularis	3	0	3	6	-	-	-	6	-	-	-	-	-	-	-
Tholymis tillarga	3	0	3	6	-	-	-	-	-	6	-	-	-	6	-
Zyxomma petiolatum	3	0	3	6	-	-	-	6	-	-	-	-	-	-	-
Sub-order Zygoptera															
Atrocalopteryx atrata	3	0	3	6	-	-	-	6	6	-	-	-	-	-	-
Neurobasis chinensis	2	0	2	4	-	-	-	4	4	4	4	-	-	-	-
Libellago lineata	3	0	3	6	-	-	-	6	-	-	-	-	-	-	-
Rhinocypha fenestrata	3	0	3	6	-	-	-	6	-	-	-	-	-	-	-
Agriocnemis femina	1	0	1	2	2	-	-	2	2	2	2	2	2	2	-
Agriocnemis pygmaea	1	0	1	2	2	-	-	2	2	2	2	-	-	2	-
Ischnura senegalensis	1	0	1	2	2	-	2	2	2	2	2	-	-	2	-
Pseudagrion microcephalum	2	0	1	3	-	-	-	3	3	3	-	-	-	3	-
Copera marginipes	1	0	2	3	3	-	-	3	3	3	3	3	3	-	-
Total					**27**	**4**	**8**	**64**	**40**	**34**	**21**	**12**	**13**	**28**	**2**

Note:
A : Distribution value
B : Conservation value
C : Sensitivity level value
\- : Not found
S1 : Upstream of Kungkilan River
S2 : Midstream of the Kungkilan River
S3 : Downstream of Kungkilan River
S4 : Midstream of the Kungkilan River
S5 : Midstream of the Sandaran River
S6 : Downstream of Sandaran River
S7 : Upstream of Lematang River
S8 : Midstream of the Lematang River
S9 : Downstream of Kungkilan River
S10: Settling Pond of Disposal
S11: Settling Pond of Stockpile

The high total DBI value at each research site reflects the good environmental quality of dragonflies. The discovery of dragonflies with special distribution characteristics, which are endemic and sensitive, is a characteristic of environmental conditions that are still natural and do not threaten the existence of dragonflies (Sadasivan et al. 2022). Habitat suitability is an essential factor in supporting dragonfly conservation. A decrease in environmental quality can reduce dragonfly diversity (Choi et al. 2020).

Diversity and dominance of dragonflies

The highest species diversity was observed at upstream of Sandaran River, with an average value of 2.77 (Figure 3). The high diversity value in Sandaran River was due to the presence of undisturbed areas. It still has natural vegetation, and the water conditions remain unpolluted. Dragonflies require a vegetated environment that is both safe and comfortable (Simaika et al. 2013). The availability of resources such as food for dragonflies affects dragonfly diversity (Potapov et al. 2020). The beginning of Sandaran River has a low dominance index value, with an average value of 0.07 (Figure 4). A low dominance index means that no one species dominates significantly over another.

Settling ponds that manage coal stockpile wastewater (site 11) had the lowest diversity index with an average value of 0.81 (Figure 3). The water in some waste management ponds had low pH and high suspended solid concentration, making it unsuitable for the growth and development of dragonfly larvae. Dragonflies require vegetated areas for their activity and foraging (Sadasivan et al. 2022). The area around the settling pond had no vegetated area; therefore, this area was not favorable for dragonflies to move and forage.

The low diversity value in the settling pond (site 11) was due to this area having the highest dominance index value of 0.48 (Figure 4). The high dominance index value resulted from the population of certain species dominating the ecosystem. Dominant species tend to have a wider range of limits to certain environmental factors, so they can grow and develop better than other species (Hart et al. 2014). Site 11 was dominated by *O. sabina* because of its tolerance and wide habitat distribution.

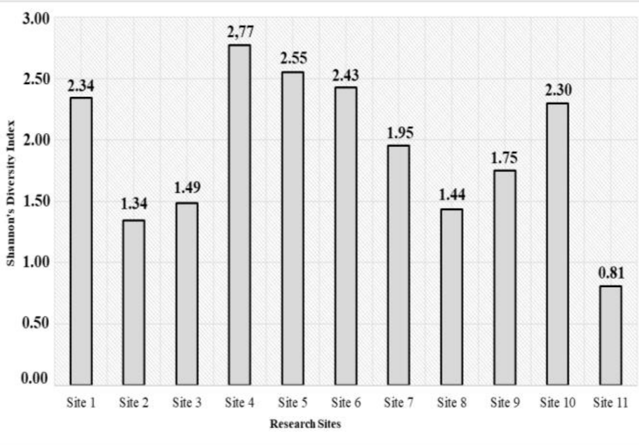

Figure 3. Diversity index values in the research sites

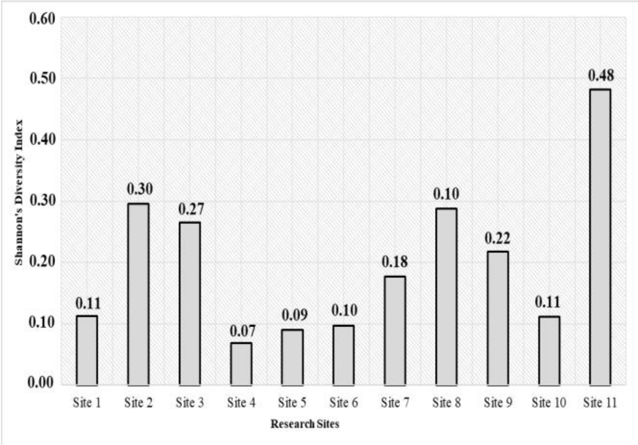

Figure 4. Dominance index value in the research sites

Sites 11 and 10 are settling ponds with different waste sources. Site 10 is a settling pond that manages the runoff water originating from disposal. This disposal area was replanted in 2018 to ensure that the runoff water from this disposal area was good. The distance between Site 10 and the Sandaran River was 0.10 km. The distance between Sites 10 and 4 was 1 km. Site 10 showed a medium diversity index with an average value of 2.30 (Figure 3). The settling pond has environmental characteristics that can support dragonfly life, such as the presence of water sources, vegetation, and open areas. Dragonflies preferred to habitat in the form of water surrounded by vegetated areas because it was directly related to the life cycle of dragonflies (Rahadi et al. 2013).

Dragonfly diversity values in the midstream and downstream of Kungkilan River were relatively low, with an average value of 1.41 (Figure 3). The middle of Kungkilan River was very close to mining activities, whereas the downstream of the Kungkilan River was very close to that of coal stockpiles. Mining and stockpile activities were thought to affect the presence of dragonflies. The presence of dragonflies was influenced by air temperature (Flenner et al. 2010). Mining areas with many open areas created higher air temperatures. The low diversity values at the mid and end points of Sandaran River may be due to the location having a high dominance index value (Figure 4). There were dominant species in the ecosystem, as indicated by the high dominance index score. The dragonfly populations in the river were dominated by *O. sabina* and *N. ramburii*.

The midstream of Lematang River had a low diversity index value, with an average value of 1.44 (Figure 3). This was very close to residential areas; therefore, it was suspected to reduce water quality. Decreased water quality could cause pollution due to anthropogenic activities around the river (Laveti et al. 2021). Anthropogenic activities had the greatest potential to change the condition of the aquatic environment around the river.

Similarity index

A high similarity index indicates the more similar the species composition in the area. A low similarity index may represent differences in the species composition of an area (Rindyastuti et al. 2021). The similarity analysis conducted by examining the correlation between research sites and dragonfly composition was known as Site 1 (upstream of Kungkilan River), Site 10 (settling pond of the disposal), Site 6 (downstream of Sandaran River), Site 5 (Midstream of Sandaran River), and Site 4 (upstream of Sandaran River). They could be grouped in cluster I and had a similarity index in the same dragonfly composition with good environmental conditions (Figure 5). These sites supported the presence and abundance of a diverse range of dragonfly species. The species of *R. phyllis, R. triangularis, Z. petiolatum, A. atrata, L. lineata* and *R. fenestrata* were grouped in cluster I (Figure 5) and were only found in sites with good conditions.

Site 3 (downstream of Kungkilan River), Site 2 (Midstream of Kungkilan River), and Site 11 (settling pond from stockpile activities) could be grouped into cluster III. This cluster indicated poor environmental conditions to support the presence and abundance of dragonfly species. Significant differences in dragonfly species composition among these sites indicated the presence of disturbances or environmental changes affecting species diversity. The poor environmental conditions in these areas might hinder the presence and abundance of dragonfly species. Deforestation or conversion of land into open or mining areas could result in the loss of natural habitats for dragonflies (Šigutová et al. 2022). The reduction in vegetation and shelter for dragonflies might also increase the risk of dragonfly loss (Lozano et al. 2022).

The species of *O. testaceum, A. femina, C. marginipes, P. flavescens, C. servillia, N. ramburii, O. sabina* and *B. contaminata* can be grouped in cluster II. These species were a group of dragonflies that have better adaptability to environmental changes; therefore, they can survive and reproduce better than other species. The existence of these species can also be affected by other factors, such as habitat destruction; therefore, efforts to conserve and protect the environment need to be made to maintain the existence of dragonfly species and biodiversity as a whole.

The research site in cluster III was inhabited by cluster II species. Species from cluster II, such as the *O. sabina* species, were found in cluster III. Cluster III locations were characterized by areas with poor conditions, so the only dragonflies that were able to survive in this location are those with high tolerance abilities. Cluster III locations must improve air quality and develop aquatic vegetation to improve environmental quality so the dragonfly population can increase

Effects of abiotic and biotic environmental factors

The presence of dragonflies depends on abiotic factors such as air temperature and rainfall, and the distribution pattern of dragonfly species follows the environmental conditions suitable for their life (Golfieri et al. 2016). Furthermore, the insect community fluctuated with rainfall (Harvey et al. 2023). The highest average rainfall occurred during the second week of the study period (Figure 6). The highest average rainfall was recorded. Consequently, the correlation between rainfall and dragonfly diversity was 0.94, indicating that rainfall was correlated with high dragonfly diversity.

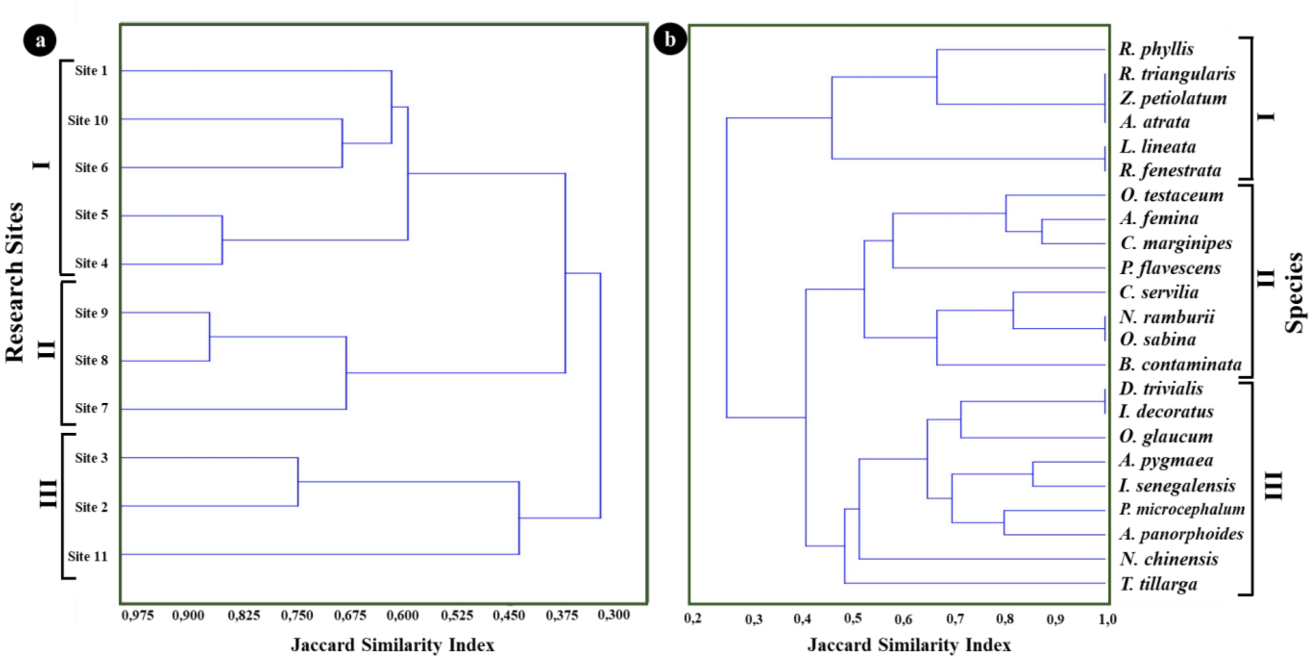

Figure 5. Dendrogram based on the similarity index of the research sites on dragonfly composition (a) and (b) dragonfly species. Roman numerals I, II, and III describe clusters of similarity values

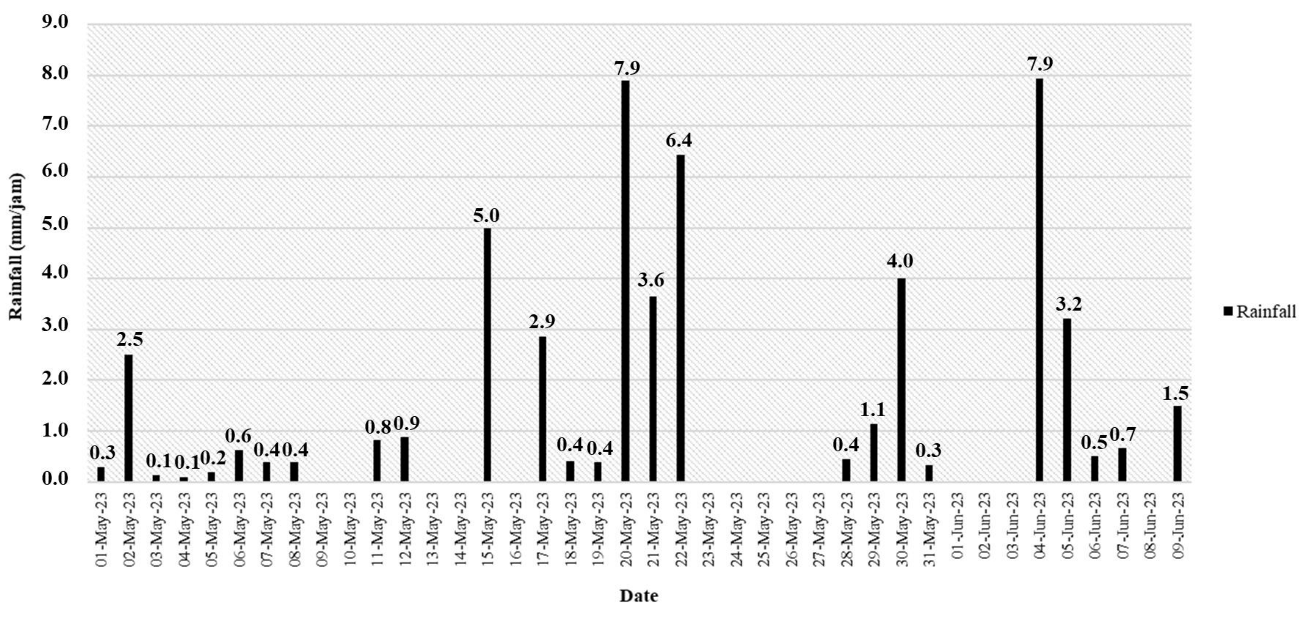

Figure 6. Rainfall at the time of the research (Source: PT Bara Alam Utama)

Air temperature data represent the average values recorded during the first to the fourth week of observation. The highest air temperature value of 36°C was found in the settling-pond of the stockpile area, and the lowest temperature value of 29°C was observed in upstream of Sandaran River (Table 4). The high air temperature value in the settling pond of the stockpile was due to this area temporarily stacking coal before distribution. The stockpile area was an open area; therefore, there was no vegetation cover, which resulted in a higher air temperature in this area. The air temperature in Sandaran River area was 29°C (Table 4) because of the large amount of natural vegetation covering it.

The presence of *C. servillia, N. ramburii, T. tillarga*, and *I. decoratus* was influenced by water pH (Figure 7). The balance of pH can affect aquatic organisms. Water pH values that are too high or too low could interfere with the activity of enzymes and the ability of the organism's body. Fluctuating water pH can cause aquatic organisms to experience stress (Li et al. 2018). The pH value affects the presence and distribution of dragonfly larvae (Willacker et al. 2023).

Fe and suspended solid concentration values were negatively correlated with the species presence of *A. panorphoides, D. trivialis, O. glaucum, R. triangularis, N. chinensis* and *L. lineata* (Figure 7). Therefore, the lower the suspended solid concentration and Fe values, the higher the presence of dragonfly species. High Fe concentrations in water can be toxic to aquatic organisms. The concentration of suspended solid concentration can affect water turbidity and disturb health because it can cover the respiratory system of aquatic organisms (Suroso et al. 2017).

The species of *C. servillia, I. senegalensis, D. trivialis, I. decoratus, N. ramburii,* and *B. contaminata* had DBI values between 1-2 (Figure 7), which could survive under environmental conditions with higher air temperature and water Mn content. Locations with higher air temperature and water Mn content were found at downstream of Kungkilan River and settling pond of stockpile. High value of water Mn was thought to be due to mining activities. Mn compounds contained in the soil layer can be released during mining activities (Sitorus et al. 2022). *A. femina, N. chinensis, O. glaucum, P. flavescens, C. marginipes* and *O. testaceum* were species with DBI values ranging from 2-4. These six species were negatively correlated with Mn and air temperature parameters, as they had narrower tolerance limits.

Libellago lineata, P. flavescens and *A. atrata* were species with DBI values ranging from 3 to 6. These three species were negatively correlated with the Fe and suspended solid concentration parameters (Figure 8). The lowest values of Fe and suspended solid concentration were observed upstream of Sandaran River and downstream of Lematang River. An increase in Fe and suspended solid concentration concentrations in water could be an indication of environmental pollution (Fitriani et al. 2023). High values of Fe and suspended solid concentration in water could disrupt the overall aquatic ecosystem, including *L. lineata, P. flavescens,* and *A. atrata*, which were species with high DBI values.

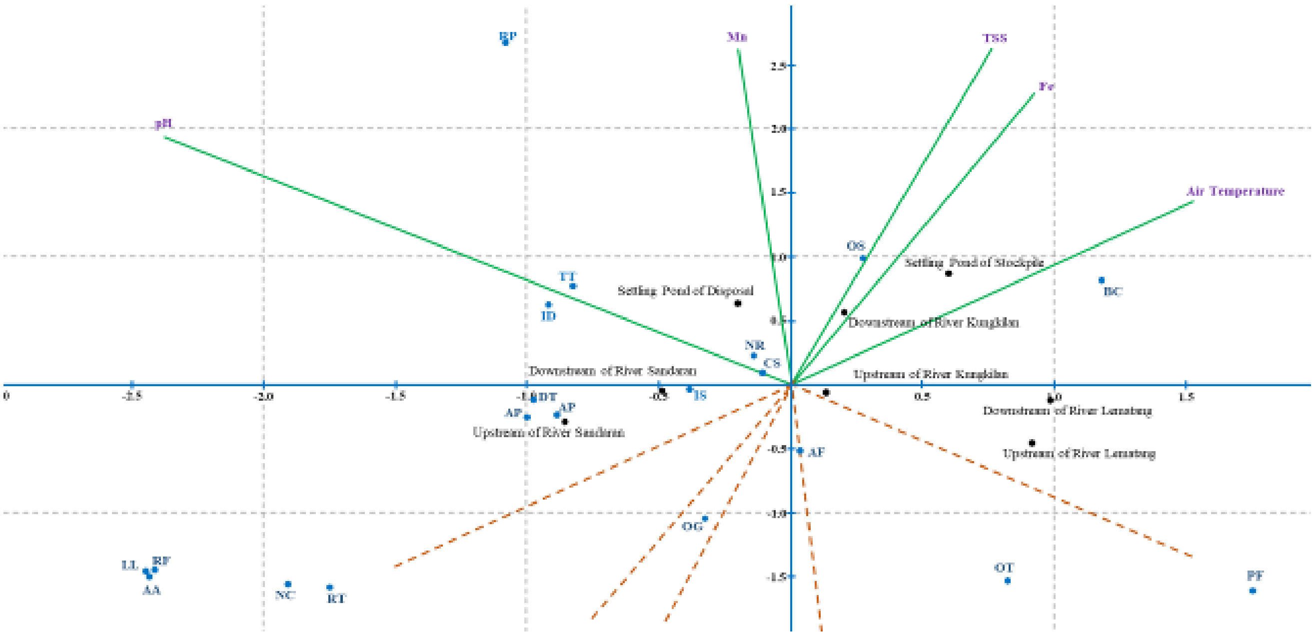

Figure 7. CCA results show a correlation between dragonflies and abiotic factors. ID (*I. decoratus*), AP (*A. panorphoides*), BC (*B. contaminata*), CS (*C. servillia*), DT (*D. trivialis*), NR (*N. ramburii*), OG (*O. glaucum*), OS (*O. sabina*), OT (*O. testaceum*), PF (*P. flavescens*), RP (*R. phyllis*), RT (*R. triangularis*), TT (*T. tillarga*), ZP (*Z. petiolatum*), AA (*A. atrata*), NC (*N. chinensis*), LL (*L. lineata*), RF (*R. fenestrata*), AF (*A. femina*), AP (*A. pygmaea*), IS (*I. senegalensis*), PM (*P. microcephalum*), CM (*C. marginipes*)

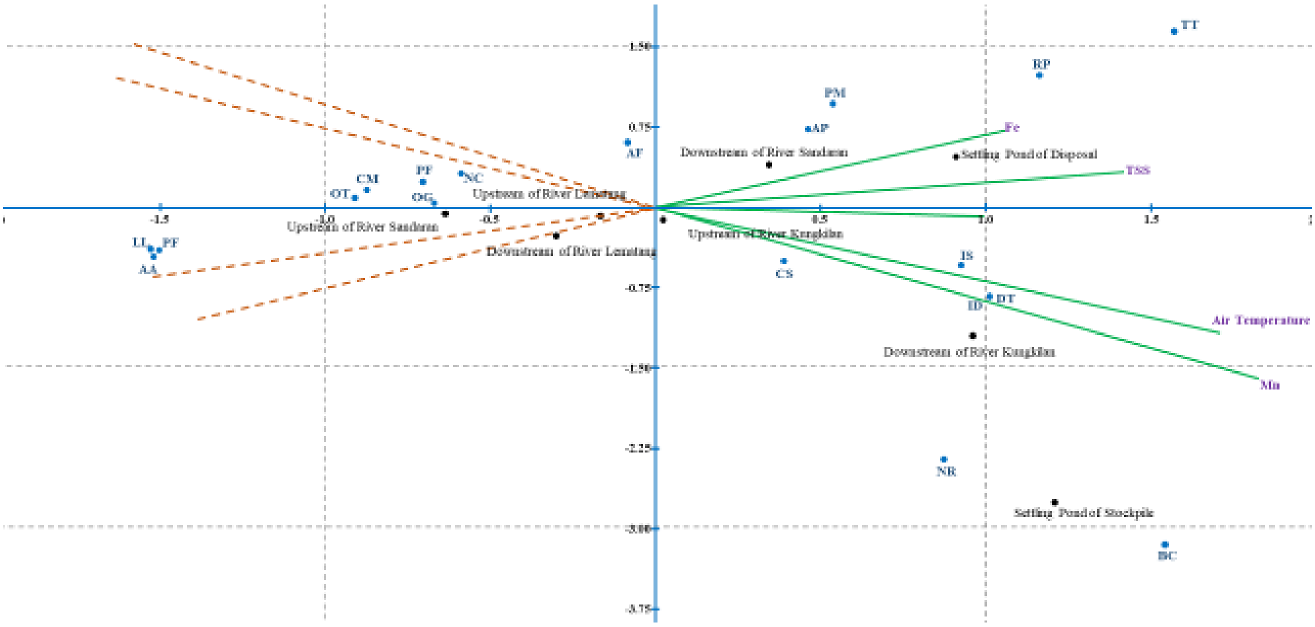

Figure 8. CCA results show a correlation between dragonfly DBI values and abiotic factors. ID (*I. decoratus*), AP (*A. panorphoides*), BC (*B. contaminata*), CS (*C. servillia*), DT (*D. trivialis*), NR (*N. ramburii*), OG (*O. glaucum*), OS (*O. sabina*), OT (*O. testaceum*), PF (*P. flavescens*), RP (*R. phyllis*), RT (*R. triangularis*), TT (*T. tillarga*), ZP (*Z. petiolatum*), AA (*A. atrata*), NC (*N. chinensis*), LL (*L. lineata*), RF (*R. fenestrata*), AF (*A. femina*), AP (*A. pygmaea*), IS (*I. senegalensis*), PM (*P. microcephalum*), CM (*C. marginipes*)

Table 4. Environmental factors in research sites

Location	Air temperature (ºC)	pH*	Fe* (mg/L)	Mn* (mg/L)	Suspended solid concentration* (mg/L)
Upstream of Kungkilan River	33	6.7	0.383	0.064	30.3
Downstream of Kungkilan River	34	6.8	0.310	0.079	78.1
Upstream of Sandaran River	29	6.8	0.204	0.015	25.9
Downstream of Sandaran River	32	6.8	0.214	0.015	23.2
Upstream of Lematang River	33	6.3	0.242	0.015	22.5
Downstream of Lematang River	34	6.5	0.243	0.022	21.7
Settling pond of stockpile	36	6.8	3.970	0.920	96.0
Settling pond of disposal	32º	6.7	0.511	1.550	23.5

Note: * Environmental Laboratory Analysis DLHP South Sumatra Province

The total DBI and dragonfly diversity index values correlated with environmental conditions. High total DBI and dragonfly diversity index values reflected good environmental conditions. Sandaran River was an area with the highest DBI value and diversity index due to the undisturbed condition of the area, which still has natural vegetation and unpolluted water conditions. Kungkilan River had a low DBI value and diversity index, presumably because some species dominated and were influenced by coal mining activities.

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