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Diversity of Macrozoobenthos Species in Several Habitats in Peat Techno Park (PTP), University of Palangka Raya

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Abstract

The purpose of this study was to inventory benthic animals in various aquatic ecosystems in Peat Techno Park (PTP) of the University of Palangka Raya. Benthic animals found were studied for their role as indicators of aquatic productivity. The research was conducted in a peat swamp forest in PTP. The research approach was a quantitative descriptive approach with an exploration method with direct sampling. The sampling location included 9 (nine) stations and from each station 3 (three) samples were taken. The results showed that there were only 2 (two) macrozoobenthos groups on PTP peatlands, namely the Annelida and Insecta groups, where the most dominant was the Insecta group from the order Diptera and the Chironomidae family with the most abundant genus being the genus *Chironomus*. Stations that had a high abundance on stations 1, 2, 3, 7 and 9 with their respective habitats, were unploughed rice field, ploughed rice field, swamp, fish pond, and beje. Differences in the diversity and abundance of insect benthic animals at each observation station will be discussed.

Keywords: *Diversity, Macrozoobenthos, Habitat, Species.*

INTRODUCTION

Water-based ecosystems, such as rivers, lakes, bays, marshes, and waterfalls, are referred to as aquatic ecosystems, and they include an astounding variety of flora and fauna(Farooq & Siddiqui, 2020)(Bloodworth et al., 2019). Water invertebrates, which may be observed with the naked eye or with the use of a microscope, are an essential indication of water quality (Helfrich et al., 2019)(Wu et al., 2020)(Chen et al., 2022). In addition, water invertebrates, particularly benthic invertebrate species, have been an attractive focus of biological monitoring efforts because to their diverse, long-lived, and sedentary species that respond considerably to human impacts on aquatic ecosystem (Cairns & Pratt, 1993)(Clark et al., 2020)(Pagter et al., 2021). So the aquatic invertebrate species in the environment can be

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determinants of the good and bad of the aquatic environment (Patang et al., 2018)(Ocaña et al., 2019)(Van Colen et al., 2021).

However, the phylum Protozoa, Porifera, Arthropods, Platyhelmintes, Nemathelmintes, Annelids, Coelenterata, Mollusca, and Echinodermata constitute a group of invertebrates that do not have a spine(Gallo et al., 2016). (Sahidin et al., 2021) explain that invertebrates have a hard exoskeleton, hard spine but generally keel to protect their bodies.

Whereas, the composition of aquatic invertebrates community and the use of such knowledge in assessment of the water quality condition of the aquatic ecosystem have been discussed and implemented in many countries (Rosenberg & Resh, 1993)(Mason, 2002). In contrast, in Central Kalimantan, studies on aquatic invertebrate group are still limited so bioassessment using water invertebrate is poorly understood. Therefore, study on water invertebrate in several habitats in PTP University of Palangka Raya should be performed, so study on the relationship between the abundance of benthic invertebrates in the waters of PTP and the physico-chemical properties of water in the ecosystems, such as dissolved oxygen, temperature, and pH, was needed.

METHOD

The level of benthic invertebrate diversity and water quality influencing benthic invertebrate diversity in the Peat Techno Park (PTP) UPR area were investigated using a quantitative descriptive approach with reconnaissance methods, direct observation, and sampling.

Study Site and Sampling

Observation made in July-September 2022. PTP has 5 hectares land developed by UPR as a model of animal husbandry, integrated agriculture, including crop production, forestry and fisheries forestry. PTP location was shown in Figure 1.

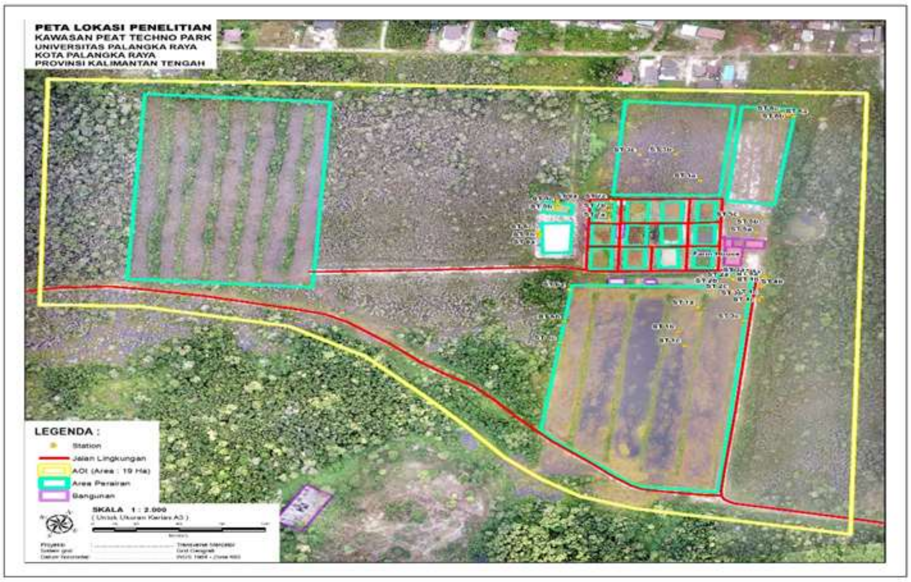

Figure 1. Research Location in PTP Area

The sampling stations were determined using a method of purposive sampling. Observations were based on the geographical representation of the waters, which contained 9 points of sampling stations, with each station containing three data collection locations. It was anticipated that the water area of the PTP would be reflected by the stations chosen for the investigation. The sites of the research samples were stations 1 (unploughed rice field), 2 (ploughed rice field), 3 (marsh), 4 (connected ditch), 5 (ancient beje), 6 (natural peat swamp forest), 7 (fish pond), 8 (reservoir), and 9 (new beje).

Data Collection

At each specified monitoring station, environmental characteristics in the form of the physical and chemical state of water bodies were measured to collect data. The resulting measurement data were acquired via two methods: direct data measurement (in situ) and laboratory sample analysis. In situ measurements included water depth, temperature, pH, and dissolved oxygen (DO).

The Petersen grab was used three times at a single water site to collect samples of the benthic invertebrate substrate by opening its mouth and putting it into the bottom of the water to collect benthic invertebrate substrate samples. The benthic invertebrate substrate sample was then placed in a plastic bag and washed with a benthic invertebrate net. The plastic bags were named after the sample waters for benthic invertebrates.

All samples of benthic invertebrates were cleaned with a benthic benthos net. The debris was then placed in a plastic container containing a tiny quantity of water in order to gather the benthic creatures. On a substrate that had been scrubbed and placed in a plastic container, benthic invertebrate species were extracted with tweezers. The gathered organisms were then placed in a vial containing 10% formalin in order to identify the benthic invertebrate animals. As the creatures were collected, they were identified using a stereo zoom microscope, binocular microscopes, and an identification book.

Identification and Counting of Benthic Invertebrates

The identification of benthic invertebrates comprised of species identification and abundance estimation. Each monitoring station's samples were identified in the laboratory using a microscope. The observed benthic species were tallied, photographed, and their names and densities were recorded in the observation table.

Aquatic invertebrate abundance was calculated using the formula proposed by (Odum et al., 2005):

$$Ki = \frac{\sum Xi}{L}$$

Where:
Ki = abundance of invertebrates (ind/m^2)
Xi = number of invertebrate individuals at the station (individuals)
L = area of the Petersen grab mouth (m^2)

The acquired data were then presented as abundance values in tables and line/bar graphs (total abundance and dominant species). Using diversity index analysis, the diversity of benthic invertebrates was determined. Diversity index (H') was computed using the following Odum-proposed formula (Gani et al., 2017):

$$H' = -\sum_{i=1}^{s} pi \ln pi$$

Where:
pi = ni/N
ni = Number of individuals of the 1st benthic invertebrate species
N = Total number of benthic invertebrate individuals
H' = Index of species diversity

The diversity index value was used to determine water quality based on pollution levels (Ningrum & Kuntjoro, 2022)(Trisnaini et al., 2018)(Ustaoğlu et al., 2020). If the value of diversity index was more than 3, then the degree of diversity was high, if the value was between 1-3, then the value of the degree of diversity was moderate, and if it was less than 1, then the degree of diversity was low (Arazi et al., 2019)(Dimenta et al., 2020)(Brugnoli et al., 2021).

Uniformity Index (E)

The evenness index (E) described the number of individuals between species in an invertebrate community. The more uniform the distribution of individuals between species, the more balanced the ecosystem. The uniformity index of aquatic invertebrates was calculated using the formula proposed by (Odum et al., 2005) as follows:

$$E = \frac{H'}{Hmaks}$$

Where:
E = index of uniformity
H' = species diversity index
H max = ln S
S = number of species

The uniformity index ranged from 0-1. If the value was close to 1, it meant that the distribution of individuals among species was uniform, while a value close to 0 meant that the distribution of individuals among species was uneven or certain species were dominant.

Dominance Index

The index of dominance of benthic invertebrate species was calculated using the formula proposed by (Odum et al., 2005) as follows:

$$D = \sum_{i=1}^{s} (n/N)^2$$

Where:

D = dominance index
ni = number of individuals of type i
N = total number of individuals

The criteria for the value of dominance index were as follows: If D was close to 0, there was no dominant species and if D was close to 1, there was a dominant species. The dominance index (D) was used to evaluate the dominance of a particular species in an ecosystem. Dominance of a species large enough led to unstable or depressed ecosystem or community conditions. The categories of diversity, uniformity, and dominance index were shown in Table 1 (Laraswati et al., 2020):

Table 1. Categories of value indeks

Value	Categories
Diversity (H')	
H' < 2,0	Low
2,0 < H' < 3,0	Medium
H' > 3,0	High
Uniformaty (E)	
0,00 < E < 0,50	Low
0,50 < E < 0,75	Medium
0,75 < E < 1,00	High
Dominance (D)	
0,00 < D < 0,50	Low
0,50 < D < 0,75	Medium
0,75 < D < 1,00	High

Correlation Analysis

Correlation analysis was used to see the correlation between physical and chemical parameters of water bodies on the value of plankton abundance. Correlation analysis included the relationship between water transparency and abundance of benthic invertebrates, temperature and abundance of benthic invertebrates, pH and abundance of benthic invertebrates, DO and benthic invertebrates.

For the correlation analysis or the analysis of the relationship between physico-chemical parameters and the abundance of benthic invertebrates, Spearman correlation analysis was used with the SPSS Statistic 24 software. The degree of relationship in this analysis was expressed by the correlation index value (0-1).

In this study, the proposed hypothesis was:

- H0: There was no significant relationship between benthic abundance and other research variables
- H1: There was a significant relationship between benthic abundance and the other research variables

The significance thresholds used were = 5% (0.05) and = 1% (0.01), with the following test criteria:

- Rejected H0 if sig < α
- Accepted H0 if sig > α

RESULTS AND DISCUSSION

Benthic Presentation and Abundance

The results of the calculation of the abundance index of the organisms found at each site were presented in Table 2.

Table 2. Number of Organisms Found at Each Station During Observation

No	Species	Station									Σ
		1	2	3	4	5	6	7	8	9	
1	*Aelosoma*	0	1	0	0	0	0	0	0	0	1
2	*Dero*	0	1	1	1	1	1	7	1	1	14
3	*Slavina*	0	0	0	0	0	0	1	0	0	1
4	*Traverelia*	1	1	1	0	1	0	1	0	0	5
5	*Ephemerella*	1	0	0	0	0	0	0	0	0	1
6	*Cinygma*	1	0	0	0	0	0	0	0	0	1
7	*Procleon*	0	1	0	0	0	0	0	0	0	1
8	*Isotoma*	1	0	1	1	1	1	0	1	0	6
9	*Ephemerella*	0	1	0	0	0	0	0	0	0	1
10	*Sialis*	0	0	0	0	0	0	0	1	0	1
11	*Gomphus*	0	0	0	1	0	0	0	0	1	2
12	*Hagenius*	0	0	0	0	0	0	1	0	0	1
13	*Traverelia*	0	0	1	0	0	0	0	1	0	2
14	*Neureclipsis*	1	0	1	0	0	1	1	0	0	4
15	*Polycentropus*	0	0	0	1	0	1	0	1	0	3
16	*Helochares*	1	1	1	1	1	1	0	1	0	7
17	*Dytiscus*	0	0	0	0	1	1	0	0	0	2
18	*Micridium*	1	0	0	1	0	1	0	0	0	3
19	*Chironomus*	25	3	17	1	1	4	7	1	2	61
20	*Polypedilum*	1	1	1	0	0	1	3	1	1	9
21	*Dicrotendipes*	0	0	0	0	0	0	1	0	0	1
22	*Microtendipes*	1	1	2	1	0	1	0	0	1	7
23	*Clinotanypus*	1	1	2	1	0	1	0	1	1	8
24	*Larsia*	2	1	1	1	1	1	1	1	1	10
25	*Procladius*	1	1	1	0	0	1	1	0	1	6
26	*Microspetra*	1	1	4	0	1	1	1	1	0	10

No	Species	Station									Σ
		1	2	3	4	5	6	7	8	9	
27	*Culicoides*	1	0	0	1	1	1	0	0	1	5
28	*Micronecta*	0	0	0	1	0	1	1	0	0	3
	Total	**40**	**15**	**34**	**12**	**9**	**19**	**26**	**11**	**10**	

Table 1 showed that the most organisms overall were found at Station 1 (40 organisms) and the fewest at Station 5 (9 organisms). The most abundant organisms found belonged to Chironomus species (61 organisms) and the least to *Aelosoma, Slavina, Ephemerella, Cinygma, Procleon, Ephemerella, Sialis, Hagenius, Dicrotendipes,* where 1 organism was found each. Several benthic organisms found in research site were shown in Figure 2.

Figure 2. Some Benthic Species Found on Research Sites

The abundance index of the organisms found at the study site were presented in Table 2. It revealed that the organism with the highest abundance index was *Chironomus* at station 1 with a value of 1085, followed by station 3 with a value of 738. The average value of the organism with the highest abundance index was *Chironomus* with a value of 287. The highest abundance was at station 1 of 1444, followed at station 3 with 1230, then station 7 with 909, and the lowest abundance was at station 5 with 108 point.

Table 3. Number of observed benthic in each station during July-September 2022

Organism	Station									Average
	1	2	3	4	5	6	7	8	9	
Annelida										
Oligochaeta										
Aelosoma	0	9	0	0	0	0	0	0	0	1
Dero	0	18	18	18	9	9	303	9	9	44
Slavina	0	0	0	0	0	0	9	0	0	1
Insecta										
Ephemeroptera										
Traverelia	27	27	18	0	9	0	18	0	0	11
Ephemerella	18	0	0	0	0	0	0	0	0	2
Cinygma	9	0	0	0	0	0	0	0	0	1
Procleon	0	9	0	0	0	0	0	0	0	1
Collembola										
Isotoma	18	0	18	9	18	18	0	9	0	10
Ephemerella	0	9	0	0	0	0	0	0	0	1
Megaloptera										
Sialis	0	0	0	0	0	0	0	9	0	1
Odonata										

Organism	Station									Average
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
Gomphus	0	0	0	9	0	0	0	0	18	3
Hagenius	0	0	0	0	0	0	9	0	0	1
Ephemeroptera										
Traverelia	0	0	9	0	0	0	0	9	0	2
Trichoptera										
Neureclipsis	27	0	18	0	0	9	9	0	0	7
Polycentropus	0	0	0	9	0	9	0	9	0	3
Coleoptera										
Helochares	36	9	18	9	9	27	0	9	0	13
Dytiscus	0	0	0	0	9	9	0	0	0	2
Micridium	9	0	0	18	0	18	0	0	0	5
Diptera										
Chironomus	1085	134	738	18	9	169	311	36	80	287
Polypedilum	27	9	9	0	0	27	125	9	9	24
Dicrotendipes	0	0	0	0	0	0	45	0	0	5
Microtendipes	27	9	63	18	0	27	0	0	9	17
Clinotanypus	36	27	89	9	0	9	0	9	18	22
Larsia	54	36	18	18	18	9	27	9	18	23
Procladius	36	9	36	0	0	27	9	0	9	14
Microspetra	18	9	178	0	9	27	36	9	0	32
Culicoides	18	0	0	9	18	9	0	0	9	7
Hemiptera										
Micronecta	0	0	0	9	0	9	9	0	0	3
Total	**1444**	**313**	**1230**	**153**	**108**	**411**	**909**	**126**	**179**	

There were only 2 (two) macrozoobenthos groups on PTP peat bogs, namely Annelida and insects. This was in contrast to several research findings, which stated that peatlands were a good habitat for many invertebrates [17]. In addition, the most dominant group in insect belonged to the ordo Diptera, and family Chironomidae with the most common genus *Chironomus*. Conversion of peat swamp forest to rice fields and fish ponds promoted greater diversity and abundance of macroinvertebrate communities, with the depth significantly affecting them.

Diversity, Uniformity and Dominance Indexes

The diversity index, uniformity, and dominance at each observation site during the 4 months of observation were shown in Figures 3, 5, and 5, respectively.

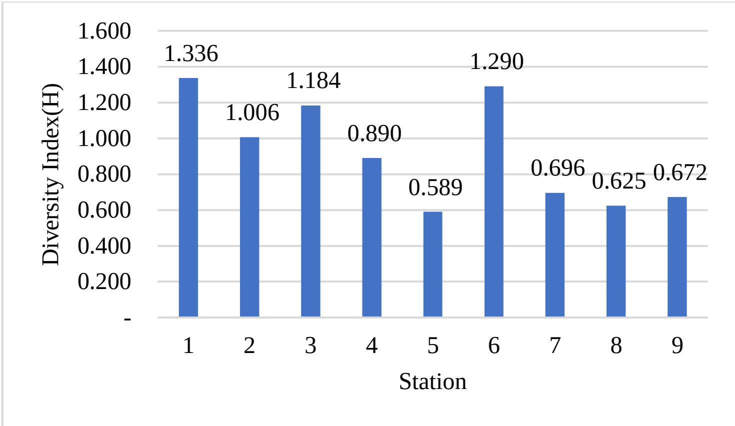

Figure 3. Benthic Diversity Index at Each Observation Station

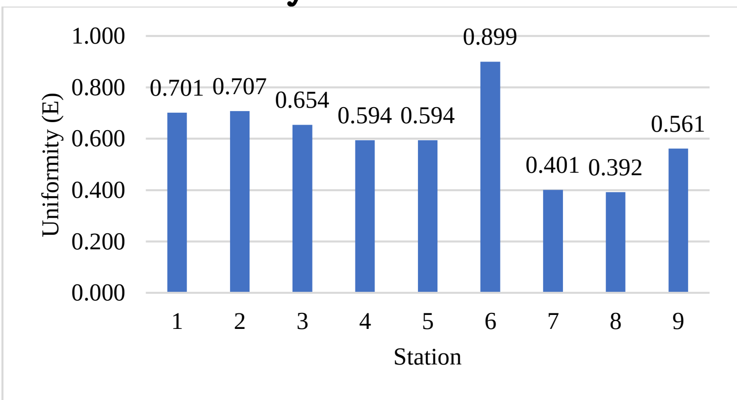

Figure 4. Benthic Uniformity Index at Each Observation Station

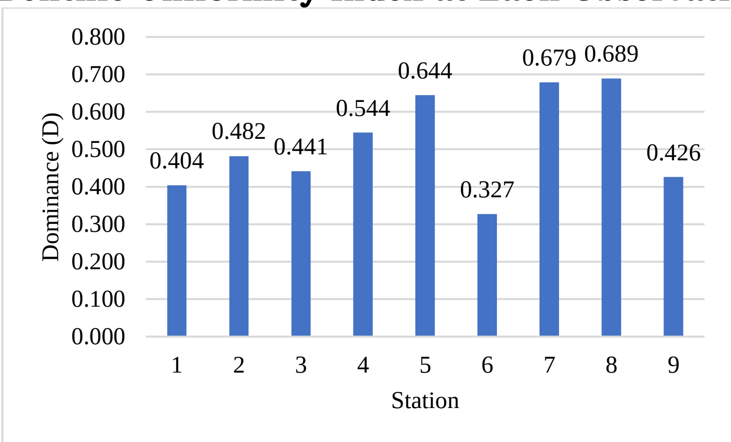

Figure 5. Benthic Dominance Index at Each Observation Station

Figure 3 showed that the highest benthic abundance was found at Station 1 with 1444, followed by Station 3 with 1230 and Station 7 with 909. The lowest benthic abundance was found at Station 5 with 108. The diversity values at all observation stations were categorized into the low value, with the highest H value at station 1 at 1,336 and then at station 6 at 1,290. The lowest H' value was at station 5 with 0.589.

Figure 4 showed the diversity values at all observation stations that fall into the low category, with the highest H value at station 1 at 1,336 and then at station 6 at 1,290. The lowest H' value was at Station 5 with 0.589. Overall, diversity at all stations was in the low category with an H-value of 0.921. The highest uniformity index was at station 6 with an E value of 0.899 while the lowest uniformity index was at station 7 with an E value of 0.401.

Figure 5 showed that the highest dominance index was found at station 8 with D value of 0.689, followed by station 7 with 0.679. The lowest D value was at station 6 with 0.327.

Correlation Test

Table 3 described the correlation between benthic abundance with temperature, pH, depth, and DO of water body in research site. Significant results were shown for the relationship between abundance and depth with the calculated r value of 0.429 (negative direction) and sig value of 0.003 (less than 005 and less than 0.1).

The value of correlation coefficient was 0.429, which means that there was a moderate correlation between abundance and depth. The negative direction indicated a non-unidirectional relationship, i.e. when depth increases, abundance decreases and vice versa. The sig value was 0.003, which means that there was a significant relationship between depth and abundance (at 5% and 10% significance levels).

Table 4. Spearman correlation test

variable	r count	Sig	α	
			5%	10%
temperature	-0.041	0.789	-	-
pH	-0.234	0.122	-	-
Depth	-0.429	0.003	Significant	Significant
DO	0.225	0.137	-	-

Significant results were shown in the relationship between benthic abundance and water temperature at station 5, with a calculated r value of 0.973 (negative direction) and a Sig of 0.005 (less than 005 and less than 0.1). The correlation coefficient was 0.973, indicating that there was a very strong relationship between benthic abundance and temperature. The negative direction indicated a non-unidirectional relationship, i.e., when temperature increases, benthic abundance decreases and vice versa. The sig value was 0.005, which means that there was a significant relationship between temperature and benthic abundance (at the 5% and 10% significance levels).

Significant results were also seen in the relationship between benthic abundance and water depth at Station 2, with a calculated r value of 0.821 (negative direction) and a Sig of 0.089 (less than 0.1). The correlation coefficient was 0.821, indicating that there was a very strong relationship between benthic abundance and water depth. The negative direction indicated a non-unidirectional relationship, i.e., as depth increases, abundance decreases and vice versa. The sig value was 0.089, which means that there was a significant relationship between depth and abundance (at a 10% significance level).

Finally, significant results were shown in the relationship between benthic abundance and the DO value at station 7, with a calculated r value of 0.872 (positive direction) and a Sig of 0.054 (less than 0.1). The correlation coefficient was 0.872, indicating that there was a very strong relationship between abundance and DO. The positive direction indicated a unidirectional relationship, i.e., when DO increases, abundance increases and vice versa. The sig value was 0.054, which means that there was a significant relationship between DO and abundance (at 10% significance level) (Danise et al., 2019)(Girard & Edmunds, 2023).

This study found that temperature and water depth had a significant effect on benthic abundance at the study site, which was in line with previous findings(Danovaro et al., 2016)(Pansch et al., 2018)(Henseler et al., 2019)(Hammond et al., 2020). Temperature and water depth were interrelated factors that influenced the number and diversity of benthic species. Temperature was generally related to the amount of light penetrating the bottom and the type of land cover over the bottom. For open land, such as agricultural land, temperature and water depth were limiting factors for benthic tolerance to the environment (Rafi'i & Maulana, 2018)(Bayba et al., 2022)(Liu et al., 2022). The value of DO also had a significant effect on benthic abundance. This was consistent with previous findings (1, 2, 3, 4) that emphasized the need to regulate oxygen levels in aquaculture ponds to allow abundance of benthos, which was an indicator of soil suitability for agriculture. Oxygen was also needed by aquatic fauna, such as fish, which were widely farmed by farmers along with agricultural crops such as rice. The amount of oxygen available in water affected the diversity and variety of organisms living in the ecosystem (Zenteno et al., 2019)(Sanchis et al., 2021)(Becker et al., 2020). Meanwhile, pH did not have a significant effect on benthic abundance because pH was relatively uniform at each research station.

CONCLUSION

There were only 2 (two) macrozoobenthos groups on PTP peat bogs, namely Annelida and insects. The most dominant group in insect belonged to the ordo Diptera, and family Chironomidae with the most common genus *Chironomus*. Conversion of peat swamp forest to rice fields and fish ponds promoted greater diversity and abundance of macroinvertebrate communities and water depth significantly affecting them. Benthic organisms were particularly abundant in Station 1 (unploughed rice field), Station 2 (ploughed rice field), Station 3 (peat swamp forest), Station 7 (fish pond), and Station 9 (new beje). The benthic diversity index was low at all sites with H' < 1. The optimal environment parameter values of water temperature, pH, DO, and water depth for benthic growth were 27.2-37.2ºC, 4.9-6.6, 2.0-4.5 mg/L, and 17-125 cm, respectively.

REFERENCES

Arazi, R., Isnaini, I., & Fauziyah, F. (2019). Struktur Komunitas dan Kelimpahan Fitoplankton serta Keterkaitannya dangan Paramater Fisik Kimia di Perairan Pesisir Banyuasin Kabupaten Banyuasin. *Jurnal Penelitian Sains*, *21*(1), 1–8.

Bayba, S., Burlakova, L. E., Karatayev, A. Y., & Warren II, R. J. (2022). Non-native Dreissena associated with increased native benthic community abundance with greater lake depth. *Journal of Great Lakes Research*, *48*(3), 734–745.

Becker, L. R., Ehrenberg, A., Feldrappe, V., Kröncke, I., & Bischof, K. (2020). The role of artificial material for benthic communities–establishing different concrete materials as hard bottom environments. *Marine Environmental Research*, *161*, 105081.

Bloodworth, J. W., Baptie, M. C., Preedy, K. F., & Best, J. (2019). Negative effects of the sea lice therapeutant emamectin benzoate at low concentrations on benthic communities around Scottish fish farms. *Science of the Total Environment*, *669*, 91–102.

Brugnoli, E., Muniz, P., Venturini, N., & García-Rodríguez, F. (2021). Benthic community responses to organic enrichment during an ENSO event (2009–2010), in the north coast of Rio de la Plata estuary. *Journal of Marine Systems*, *222*, 103597.

Cairns, J., & Pratt, J. R. (1993). A history of biological monitoring using benthic macroinvertebrates. *Freshwater Biomonitoring and Benthic Macroinvertebrates*, *10*, 27.

Chen, F., Topper, T. P., Skovsted, C. B., Strotz, L. C., Shen, J., & Zhang, Z. (2022). Cambrian ecological complexities: Perspectives from the earliest brachiopod–supported benthic communities in the early Cambrian Guanshan Lagerstätte. *Gondwana Research*, *107*, 30–41.

Clark, D. E., Pilditch, C. A., Pearman, J. K., Ellis, J. I., & Zaiko, A. (2020). Environmental DNA metabarcoding reveals estuarine benthic community response to nutrient enrichment–Evidence from an in-situ experiment. *Environmental Pollution*, *267*, 115472.

Danise, S., Clémence, M.-E., Price, G. D., Murphy, D. P., Gómez, J. J., & Twitchett, R. J. (2019). Stratigraphic and environmental control on marine benthic community change through the early Toarcian extinction event (Iberian Range, Spain). *Palaeogeography, Palaeoclimatology, Palaeoecology*, *524*, 183–200.

Danovaro, R., Molari, M., Corinaldesi, C., & Dell'Anno, A. (2016). Macroecological drivers of archaea and bacteria in benthic deep-sea ecosystems. *Science Advances*, *2*(4), e1500961.

Dimenta, R. H., Agustina, R., Machrizal, R., & Khairul, K. (2020). Kualitas Sungai Bilah Berdasarkan Biodiversitas Fitoplankton Kabupaten Labuhanbatu, Sumatera Utara. *Jurnal Ilmu Alam Dan Lingkungan*, *11*(2).

Farooq, S., & Siddiqui, P. J. A. (2020). Assessment of three mangrove forest systems for future management through benthic community structure receiving anthropogenic influences. *Ocean & Coastal Management*, *190*, 105162.

Gallo, V. P., Accordi, F., Chimenti, C., Civinini, A., & Crivellato, E. (2016). Catecholaminergic system of invertebrates: comparative and evolutionary aspects in comparison with the octopaminergic system. *International Review of Cell and Molecular Biology*, *322*, 363–394.

Gani, A., Rosyida, E., & Serdiati, N. (2017). Keanekaragaman jenis invertebrata yang berasosiasi dengan ekosistem terumbu karang di perairan teluk palu kelurahan panau kota palu. *AgriSains*, *18*(1), 38–45.

Girard, J. F., & Edmunds, P. J. (2023). Effects of arborescent octocoral assemblages on the understory benthic communities of shallow Caribbean reefs. *Journal of Experimental Marine Biology and Ecology*, *561*, 151870.

Hammond, M., Bond, T., Prince, J., Hovey, R. K., & McLean, D. L. (2020). An assessment of change to fish and benthic communities following installation of an artificial reef. *Regional Studies in Marine Science*, *39*, 101408.

Helfrich, L. A., Neves, R. J., & Parkhurst, J. A. (2019). *Sustaining America's Aquatic Biodiversity Why is Aquatic biodiversity declining?*

Henseler, C., Nordström, M. C., Törnroos, A., Snickars, M., Pecuchet, L., Lindegren, M., & Bonsdorff, E. (2019). Coastal habitats and their importance for the diversity of benthic communities: a species-and trait-based approach. *Estuarine, Coastal and Shelf Science*, *226*, 106272.

Laraswati, Y., Soenardjo, N., & Setyati, W. A. (2020). Komposisi dan kelimpahan gastropoda pada ekosistem mangrove di Desa Tireman, Kabupaten Rembang, Jawa Tengah. *Journal of Marine Research*, *9*(1), 41–48.

Liu, J., Du, L., Sun, Z., & Zhang, H. (2022). Comparison of structure and diversity of benthic communities in the Okinawa Trough and Mariana Trench by environmental DNA metabarcoding. *Deep Sea Research Part I: Oceanographic Research Papers*, *185*, 103806.

Mason, C. F. (2002). *Biology of freshwater pollution*. Pearson Education.

Ningrum, N. C., & Kuntjoro, S. (2022). Kualitas Perairan Sungai Brangkal Mojokerto Berdasarkan Indeks Keanekaragaman Makrozoobentos. *LenteraBio: Berkala Ilmiah Biologi*, *11*(1), 71–79.

Ocaña, F. A., Pech, D., Simões, N., & Hernández-Ávila, I. (2019). Spatial assessment of the vulnerability of benthic communities to multiple stressors in the Yucatan Continental Shelf, Gulf of Mexico. *Ocean & Coastal Management*, *181*, 104900.

Odum, E., Barrett, G., & Brewer, R. (2005). Fundamentals of ecology Thomson brooks. *California: Cole.*

Pagter, E., Nash, R., Frias, J., & Kavanagh, F. (2021). Assessing microplastic distribution within infaunal benthic communities in a coastal embayment. *Science of The Total Environment*, *791*, 148278.

Pansch, C., Scotti, M., Barboza, F. R., Al-Janabi, B., Brakel, J., Briski, E., Bucholz, B., Franz, M., Ito, M., & Paiva, F. (2018). Heat waves and their significance for a temperate benthic community: A near-natural experimental approach. *Global Change Biology*, *24*(9), 4357–4367.

Patang, F., Soegianto, A., & Hariyanto, S. (2018). Benthic macroinvertebrates diversity as bioindicator of water quality of some rivers in East Kalimantan, Indonesia. *International Journal of Ecology*, *2018*.

Rafi'i, M., & Maulana, F. (2018). Jenis, Keanekaragaman Dan Kemelimpahan Makrozoobentos di Sungai Wangi Desa Banua Rantau Kecamatan Banua Lawas. *Jurnal Pendidikan Hayati*, *4*(2).

Rosenberg, D. M., & Resh, V. H. (1993). *Freshwater biomonitoring and benthic macroinvertebrates*. Chapman and Hall.

Sahidin, A., Zahidah, H. H., Hamdani, H., Herawati, H., Arief, M. C. W., Syawal, M. S., Ibrahim, A., Sewiko, R., & Octavina, C. (2021). Assessment of water quality based on biological indices of macrobenthos: a river under pressure from tourism activities. *Assessment*, *10*(3).

Sanchis, C., Soto, E. H., & Quiroga, E. (2021). The importance of a functional approach on benthic communities for aquaculture environmental assessment: Trophic groups–A polychaete view. *Marine Pollution Bulletin*, *167*, 112309.

Trisnaini, I., Sari, T. N. K., & Utama, F. (2018). Identifikasi habitat fisik sungai dan keberagaman biotilik sebagai indikator pencemaran air sungai musi kota Palembang. *Jurnal Kesehatan Lingkungan Indonesia*, *17*(1), 1–8.

Ustaoğlu, F., Tepe, Y., & Taş, B. (2020). Assessment of stream quality and health risk in a subtropical Turkey river system: A combined approach using statistical analysis and water quality index. *Ecological Indicators*, *113*, 105815.

Van Colen, C., Moereels, L., Vanhove, B., Vrielinck, H., & Moens, T. (2021). The biological plastic pump: Evidence from a local case study using blue mussel and infaunal benthic communities. *Environmental Pollution*, *274*, 115825.

Wu, K., Zhao, W., Li, M., Picazo, F., Soininen, J., Shen, J., Zhu, L., Cheng, X., & Wang, J. (2020). Taxonomic dependency of beta diversity components in benthic communities of bacteria, diatoms and chironomids along a water-depth gradient. *Science of the Total Environment*, *741*, 140462.

Zenteno, L., Cárdenas, L., Valdivia, N., Gómez, I., Höfer, J., Garrido, I., & Pardo, L. M. (2019). Unraveling the multiple bottom-up supplies of an Antarctic nearshore benthic community. *Progress in Oceanography*, *174*, 55–63.