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The Effect of Plankton Community Structure in Tributaries at the Downstream of the Musi River, Palembang

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Abstract: River condition is influenced by both natural and human activities. The tributaries also affect the condition of water in the river. The Musi River is the largest in South Sumatra. Its condition is influenced by its nine major tributaries and other rivers. This research applied the descriptive method. Conducted at the five tributaries of the Musi River, this research aimed: 1) to calculate the plankton abundance (N), evenness index (E), the diversity index (H’), and dominance index (D); 2) to perform a correlation test; 3) to perform ANOVA; 4) to perform factor analysis using PCA (principal component analysis). *Bacillariophyceae* abundance was the highest among other genera, followed by *Chlorophyceae*, *Flagilariophycea*, *Euglenida*, and *Chrysophyceae*. *Crustacea* had the highest abundance in the zooplankton class, followed by *Tubulenia*, *Maxillopoda*, *Mastigophora*, and *Imbricatea*. Plankton's diversity and community stability levels were regarded as moderate; as there was no domination found, the water was classified as heavily polluted. According to the ANOVA hypothesis, the five tributaries' phytoplankton and zooplankton data groups showed different variations. The abundance of phytoplankton was influenced by three factors reaching 76.54%. The condition was indicated by bioindicator pollution: *Nitzchia*, *Chlorococcum*, *Euglena*, *Oscillatoria*, and *Spirogyra*. The waters were categorized as Mesotrophic waters, indicating a moderate level of water fertility. At a low pH value, as the diversity index became low, the abundance of phytoplankton also became low. The polluted condition was also shown by the low diversity, which indicated an unstable ecosystem. These waters could only be used for irrigation. The moderate fertility of the waters and its level of contamination affected the downstream Musi River. Proper water management is required to maintain the environmental sustainability. Any parties associated with water management should take steps to improve the water condition downstream of the Musi River.

Keywords: the tributaries of the Musi River, plankton community, principal component analysis, correlation, ANOVA.

巨港穆西河下游支流浮游生物群落结构的影响

摘要：河流状况受自然和人类活动的影响。支流也影响河流中的水状况。穆西河是南苏门答腊最大的河。它的状况受其九大支流和其他河流的影响。本研究采用描述性方法。本研究在穆西河5条支流进行，旨在：1）计算浮游生物丰度（N）、均匀度指数（乙）、多样性指数（H'）和优势度指数（D）；2) 进行相关性检验；3) 进行方差分析；4）使用主成分分析（主成分分析）进行因子分析。在其他属中，芽孢杆菌属的丰度最高，其次是绿藻纲、鞭毛藻纲、眼虫科和金藻纲。甲壳纲在浮游动物类中的丰度最高，其次是管虫纲、颌足纲、鞭毛纲和覆盆纲。浮游生物的多样性和群落稳定性水平被认为是中等的；由于没有发现支配地位，水被列为重度污染。根据方差分析假设，五个支流的浮

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游植物和浮游动物数据组表现出不同的变化。浮游植物的丰度受三个因素的影响达到76.54%。这种情况由生物指示物污染指示：尼采、绿球藻、眼虫、震荡器和水绵。这些水域被归类为中营养水域，表明水肥水平适中。在低酸碱度值下，随着多样性指数的降低，浮游植物的丰度也随之降低。低多样性也表明了污染状况，这表明生态系统不稳定。这些水只能用于灌溉。中等肥沃的水域及其污染程度影响了下游的穆西河。需要适当的水管理来维持环境的可持续性。任何与水管理有关的各方都应采取措施改善穆西河下游的水状况。

关键词：穆西河支流、浮游生物群落、主成分分析、相关性、方差分析。

1. Introduction

The river is defined as water flowing from upstream to downstream toward a sea which functions for agriculture, irrigation, fisheries, and agriculture [3]. In addition, a river is a living place for organisms such as plankton, benthos, and nekton [20]. The Musi River is the estuary for dozens of rivers whose length reaches 720 km and crosses Palembang, South Sumatra, Indonesia [18]. Palembang, bordered by Banyuasin and Muara Enim District, is the capital city of South Sumatra Province. The Musi River divides this city into two major areas: Seberang Ulu and Seberang Ilir.

The Musi River is the largest river with the three largest tributaries: Komering River, Ogan River, and Keramasan River. Besides, it also has several smaller tributaries that function as urban drainage [19]. One of the tributaries, the Komering River, is located in Serdang Menang Village. The river water is used for household activities, fishing, sand mining, and agriculture, which leads to changes in the aquatic environment [5].

At the upstream of the Musi River, various activities such as the urea fertilizer industry, oil refinery, natural rubber processing, densely populated settlements, and community activities affect the quality of the river water [25]. The decline of the water quality in Area 10 of Ulu in Palembang was caused by waste disposal in the Musi River, low levels of education, the absence of landfill facilities, and the low awareness of the impact of waste disposal on the river [13].

Based on nutritional needs, plankton is divided into two groups: phytoplankton and zooplankton [21]. Phytoplankton is a unicellular microorganism that can perform photosynthesis and is the food pyramid foundation [1]. This microorganism plays an important role in water as it is the first in the aquatic food chain [6].

2. Material and Methods

2.1. Research Object

This research was conducted downstream of the Musi River, crossing Palembang, South Sumatra, Indonesia. The research was carried out from August to October 2020. After being collected through observation, it was descriptive research whose data were used to provide an overview, concept, or symptom [24]. The research was done at the five tributaries of the Musi River, i.e., Belalai Creek (Be) ($2^0$57’11” S and $104^0$53’03” E), Kundur Creek (Ku) ($2^0$58’30” S and $104^0$51’50” E), Komering River (Ko) ($2^0$59’20” S and $104^0$50’07” E), Ogan River (Og) ($3^0$00’44” S and $104^0$44’59” E), and Buaya Creek (Bu) ($3^0$01’22” S and $104^0$46’07” E) (Fig. 1).

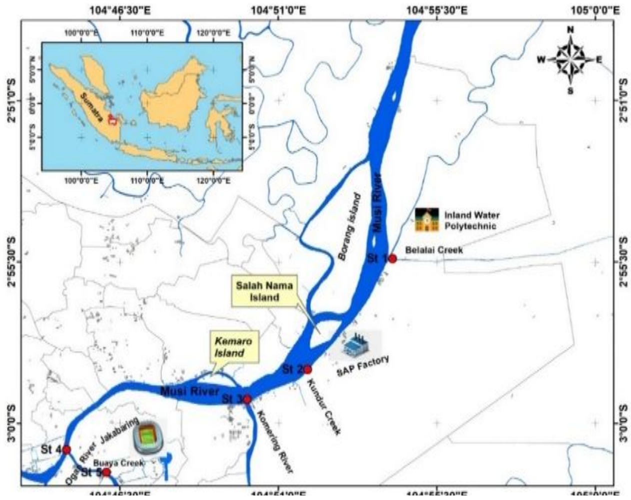

Fig. 1 Research sampling point

2.2. Data Collection Methods

2.2.1. Sampling and Plankton Identification

The phytoplankton sample was collected using a plankton net size of 25 μm, while the zooplankton sample was collected using a plankton net size of 40 μm. One hundred liters of the water was obtained and poured into a ten-liter bucket. The phytoplankton sample was then poured into a thirty-milliliter sample bottle, whereas the zooplankton sample was poured into a fifty-milliliter sample bottle. Then, 10 drops of liquid Lugol were added. The samples were then preserved and brought to the laboratory [14]. The plankton sample was collected three times at one sampling point, i.e., water on the surface, in the middle, and at the bottom.

2.2.2. Research Parameters

The physical and chemical parameters used in this research included temperature, salinity, TDS (total dissolved solids), TSS (total suspended solid), nitrate, nitrite, pH, phosphate, BOD (biochemical oxygen demand), DO (dissolved oxygen), oil, grease, and turbidity. Other measurements such as water current, depth, and brightness were also conducted. The measurement results obtained directly from the field research were temperature, salinity, water current, depth, brightness, and turbidity. On the other hand, the laboratory tests included TDS, TSS, nitrate, nitrite, pH, phosphate, BOD, DO, oil, and fat. Sample examination was carried out at Research Center and Standardization Industry Palembang (Baristand).

2.3. Data Analysis

2.3.1. Calculation of Abundance (N)

Plankton abundance was determined using the Sedgwick-Rafter cell.

2.3.2. Evenness Index (E)

It is defined as an index that shows if the pattern of biota distribution is even or not. If the evenness index value is relatively high, the presence of each type of biota in the waters is evenly distributed. If $E = 0$, the evenness between species is low, meaning that the richness of each species is different; if $E = 1$, the evenness between species is relatively even, or the number of individuals of each species is relatively equal.

2.3.3. Diversity Index (H')

It is an index used to determine the diversity of biota species. $H' < 1$ = unstable biota community or heavily polluted water; $1 < H' < 3$ = moderate stability of biota community or moderately polluted water; $H' > 3$ = biota community is stable or the water is clean.

2.3.4. Dominance Index (D)

This index is used to identify the dominance of certain species in waters. If $D = 0$, no species dominate other species, or the community structure is stable; if $D = 1$, there are species that dominate other species, or the community structure is unstable due to ecological stress.

2.3.5. Pearson Correlation Test

Correlation is one of the techniques in statistics that is used to identify the relationship between two quantitative variables [22]. This test aims to examine the correlation between two variables which the level of significance can identify; if there is a correlation, this test will determine how strong the correlation is.

2.3.6. ANOVA Test

This test investigates three or more unrelated samples, one of which has more than two categories. If the significance > 0.05, H_0 is accepted; if sig < 0.05, H_0 is rejected. In this research, samples were taken to identify the differences in abundance between phytoplankton and zooplankton in the five estuaries which emptied into the Musi River.

2.3.7. Factor Analysis Using PCA

Factor analysis requires that the data matrix have a sufficient correlation, i.e., > 0.3. If the MSA value is < 0.5, the factor analysis can not be carried out [7].

3. Results

Thirteen genera were found in phytoplankton's *Bacillariophycea* class, nine genera in *Chlorophyceae* class, and one genus in *Flagilariophycea*, *Euglenoida*, and *Chrysophycea.* In the zooplankton class, there were four genera in the *Crustacea* class, two genera in *the Tubulinea* class, and only one genus in *Maxillopoda*, *Mastigophora*, and *Imbricatea* classes.

Phytoplankton's *Cyanophyceae* was the most abundant class reaching 3938.89 cells/liter in Ko, followed by the *Chlorophyceae* class reaching 1396.04 cells/liter in Og. The abundance of *Cyanophyceae* in Ko, Og, and Be was high, reaching 3938.89 cells/liter, 3792.86 cells/liter, and 3603.17 cells/liter. *Chrysophyce*a class had the lowest average density reaching 0.318 cells/liter (Fig. 2). The abundance average of phytoplankton in the five tributaries reached 4471.94 cells/liter, indicating that the water's fertility was moderate.

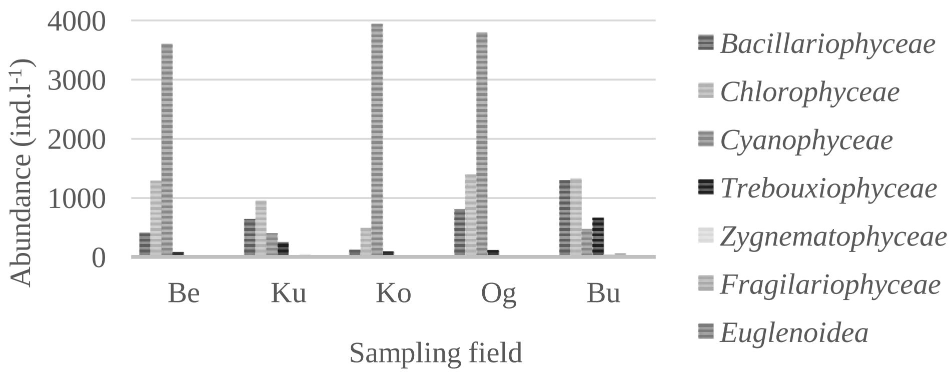

Fig. 2 The average density of phytoplankton in the five tributaries

The average density of classes found in zooplankton included: *Crustacea* 1.37-12.72 cells/liter with the highest density found in Og; *Tubulinea* 0-1.06 cells/liter with the highest density found in Be, and *Euglenoids* 0.61 and 4.22 cells/liter with the highest density found in Og. The *Cilliates*' density ranged between 0.17 and 1.61 cells/liter, with the highest density in Ku. Mastigophora and Imbricatea had the highest density in Be, reaching 2.22 and 1.17 cells/liter, respectively. The highest average was found in *Crustacea*, followed by *Euglenoid* and *Mastigophora* (Fig. 3).

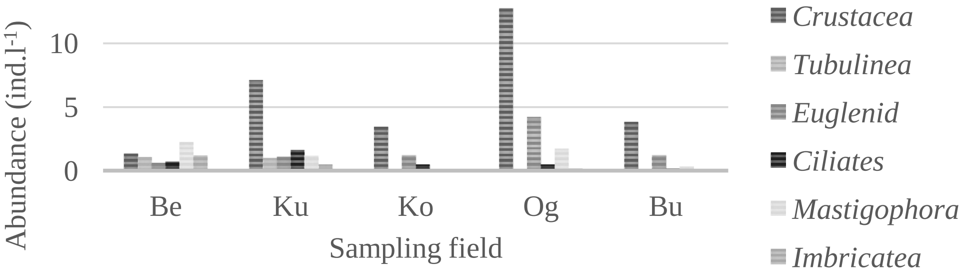

Fig. 3. The average density of zooplankton in the five tributaries

The plankton's diversity index (H') ranged between 1.29 and 2.32, with an average of 1.78. The average value of H' indicated that the community stability of plankton was moderate or the water's level of contamination was moderate to high. This condition showed that the ecosystem was not stable, the abundance was low, and diversity was low. The uniformity index (E) ranged between 0.51 and 0.8, with an average value of 0.632. This value indicated that the species' uniformity was moderate. With the greater value of E, the number of individuals in the genera was relatively the same. The dominance values (D) ranged between 0.12 and 0.43, with an average level of 0.296, indicating that there were no dominant species in Musi's tributaries and the waters were heavily polluted. The diversity index (H') of the zooplankton ranged between 1.14 and 1.83, with an average value of 1.482. The diversity value was low (< 2.306), leading to low community stability.

Based on the research, there was moderate negative significant correlation of temperature-phosphate (r = 0.599, p < 0.05) and nitrite-temperature (r = -0.545, p < 0.05). On the other hands, the negative significant correlation of pH-TDS (r = -0.749, p < 0.01) and DO-TDS (r = -0.688, p < 0.01) was strong. However, there was a significant negative correlation on a moderate scale (r = -0.534, p < 0.05) in BOD-TDS. Moreover, there was a strong significant correlation between nitrite and TSS (r = 0.597, p < 0.05). Meanwhile, DO-BOD had moderate negative significant correlation (r = -0.530, p < 0.05) (Table 1).

Table 1 Correlation matrix of five tributaries of the Musi River

	Temp	**TDS**	**TSS**	**pH**	**P**	**BOD**	**DO**	**Nitrate**	**Nitrite**	**O & F**
Temp	1									
TDS	0.043	1								
TSS	-0.482	0.139	1							
pH	0.015	-0.749**	-0.28	1						
P	-0.599*	0.112	0.322	-0.208	1					
BOD	-0.289	-0.534*	0.035	0.297	0.161	1				
DO	0.143	-0.688**	0.251	-0.416	-0.03	-0.530*	1			
Nitrate	0.152	0.135	0.262	-0.42	-0.335	0.353	0.108	1		
Nitrite	-0.545*	0.181	0.597*	-0.029	0.444	-0.185	0.044	-0.278	1	
O & F	-0.495	0.484	0.417	-0.0489	0.087	0	0.161	0.391	0.437	1

Notes: P - phosphate, O & F - oil and fat; * Correlation is significant at the 0.05 level (2-tailed); ** Correlation is significant at the 0.01 level (2-tailed)

The hypotheses for the ANOVA test on phytoplankton abundance in this research: H_0 = the data group of phytoplankton abundance in the five estuaries had the same variance, H_a = the data group of phytoplankton abundance in the five tributaries had different variance. The homogeneity test of variances on phytoplankton abundance in the five estuaries was 0.012. Since 0.012 < 0.05, H_0 was rejected, indicating that the data group of phytoplankton abundance in the five tributaries had different variances. On the other hand, the ANOVA test found that the value of F_{count} reached 0.595 and F_{table} = 3.478. Since $F_{count} < F_{table}$, H_0 was rejected, indicating that the data group of phytoplankton abundance in the five tributaries had different variances.

The hypotheses on zooplankton abundance are as follows:

H0: The data group of zooplankton abundance in the five estuaries had the same variance;

Ha: The data group of zooplankton abundance in the five tributaries had different variances.

The homogeneity of the variance test's value was 0.015. Thus, the sign < 0.05 and H_0 were rejected, indicating that the data group of zooplankton abundance in the five tributaries had different variances. On the other hand, the ANOVA test obtained F_{count} = 2.407, while F_{table} = 1.615. Thus, H_0 was also rejected, or H_a was accepted, indicating that the data group of zooplankton abundance in the five estuaries had different variances.

The water temperature in the five tributaries ranged between 28.73^{0}C and 29.77^{0}C, with an average temperature of 29.44^{0}C. The water temperature had met the requirements for biota life with a maximum deviation of 5. Salinity in these waters showed 0 ppt which indicated that the condition of the waters had not been affected by the coastal area. TDS ranged at 35.67 and 62 ml, while TSS ranged from 3.33 and 170.17 mg/l. The TDS and TSS values still met the water quality standards for class IV functioned as irrigation [8].

The pH content ranged between 4.74 and 5.8, indicating that the water was acidic. The phosphate levels ranged from 0.08 to 0.14 mg/l. BOD ranged from 0.17 to 0.53 mg/l, while DO ranged from 8.13 to 8.83 mg/l. The levels of oil and fat in the five tributaries were 1.33 mg/l and 3.07 mg/l, which were above the threshold. The turbidity ranged from 29.57 to 127.5 NTU, indicating that the waters were turbid, which could detain organism abundance. The water flow rate at the edge of Musi's tributary was slow, ranging from 0 to 0.8 m/s, affecting the abundance of plankton (Table 2).

Table 2 Physical and chemical parameters on the Musi River's tributaries (Mean and SD)

Parameter	Tributaries' Name					
	Be	**Ku**	**Ko**	**Og**	**Bu**	**Quality Standards***
Temperature (^{0}C)	28.73 ± 0.67	29.6 ± 0.17	29.4 ± 0.3	29.77 ± 0.21	29.57 ± 0.40	Deviation 5
Salinity (ppt)	0	0	0	0	0	
TDS (mg. l^{-1})	35.67 ± 3.51	62 ± 4.58	48.67 ± 0.58	53.33 ± 2.31	56.33 ± 0.58	2000
TSS (mg. l^{-1})	170.17 ± 97.87	84.8 ± 90.68	3.33 ± 0.23	9.6 ± 8.4	35.93 ± 28.32	4000
Nitrate (mg. l^{-1})	0.01 ± 0	0.01 ± 0	0.01 ± 0	0.01 ± 0	0.01 ± 0	20
Nitrite (mg. l^{-1})	0.01 ± 0.01	0.01 ± 0	0.01 ± 0	0.01 ± 0	0.01 ± 0	0
pH	5.41 ± 0.06	4.74 ± 0.29	5.72 ± 0.11	5.80 ± 0.08	5.76 ± 0.11	5-9
Phosphate (mg. l^{-1})	0.14 ± 0.06	0.10 ± 0.04	0.09 ± 0.04	0.08 ± 0.03	0.08 ± 0.04	5
BOD (mg. l^{-1})	0.53 ± 0.21	0.17 ± 0.12	0.37 ± 0.21	0.40 ± 0.10	0.20 ± 0.1	12
DO (mg. l^{-1})	8.57 ± 0.06	8.83 ± 0.06	8.13 ± 0.35	8.43 ± 0.38	8.83 ± 0.06	0
Oil & Fat (mg. l^{-1})	3.07 ± 1.01	2.80 ± 1.60	1.33 ± 0.61	1.60 ± 1.06	1.60 ± 0.80	0
Turbidity (NTU)	127.50 ± 46.70	75.83 ± 42.71	30.63 ± 4.76	29.57 ± 7.39	59.27 ± 15.37	< 5
Current (m. s^{-1})	0	0	0.4	0.8	0.2	
Depth (m)	0.9	0.5	8.1	2.7	5.8	
Brightness (m)	0.05	0.1	0.23	0.34	0.32	

* Based on [2], [8]

The value of KMO (Kaiser-Meyer-Olkin) was 0.526, above 0.5, while the value of Barlett's test of sphericity was also 0.00. Of 14 variables studied, three variables were excluded: phosphate, BOD, and nitrite because the anti-image correlation value was small. Thus, 11 variables were analyzed by PCA: TDS, TSS, pH, DO, nitrate, oil and fat, turbidity, water current, brightness, and depth. Based Scree Plot chart, three factors (with a value above 1) that affected phytoplankton abundance in the Musi River's tributaries were obtained. These three factors explained phytoplankton abundance reaching 76.54%, while the rest was explained by other factors.

The first greatest factor reached 48.26%, the second 17.80%, and the third 10.48%. The first factors with a very strong and strong positive correlation were the temperature (0.9), brightness (0.78), and water current (0.65). On the other hand, a negative correlation occurred to TSS (-0.77) and oils and fats (-0.65). The second factors with a very strong and strong positive correlation were TDS (0.96) and DO (0.77), whereas a strong negative correlation occurred to pH (-0.79) and depth (-0.60). The third factors with a very strong and strong positive correlation were nitrate (0.89) and turbidity (0.64). The first factors, including temperature, brightness, water current, TSS, and oil-fat, were natural; the second factors, including TDS, DO, pH, and depth, were internal; the third factors, including nitrate and turbidity, were anthropic pressure factors, such as discharge activity and agricultural waste (Fig. 4).

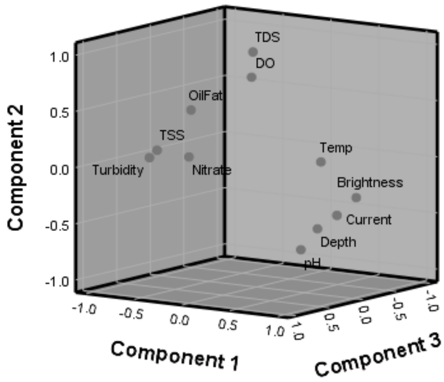

Fig. 4 PCA analysis of factors influencing the abundance of phytoplankton

4. Discussion

Bacillariophyceae class had most genera due to its adaptation capability, so it could perform fast reproduction and is classified as autotroph [10]. In these waters, more than two genera were found as bioindicators of heavy pollution: *Nitzchia, Chlorococcum, Euglena, Oscilatoria, and Spirogyra*, which indicated polluted waters, and phytoplankton population explosion could occur, which resulted in genera dominance in these waters [29].

The number of genera in zooplankton was less than in phytoplankton since phytoplankton was the foundation of the aquatic food web and the primary food producers; its number should be more abundant than the zooplankton's [26].

The highest phytoplankton abundance was in Og, 6118.25 ind/l, while the lowest was found in Ku (2289.67 ind/l). This finding was since Og was wider in size and had greater water discharge than Ku, which is the Pertamina's inspection river. However, the research conducted in the Komering River showed that *Bacillariophycea* was the most dominant class (14 genera), followed by *Chlorophyceae* (13 genera) and *Cyanophyceae* (7 genera) [27].

Low diversity values were also found in the research conducted in the waters of Tallo River's estuary, Makassar. Within the waters, there were six types of phytoplankton with low plankton stability [15]. In addition, research conducted on the Yulin River, a tributary of the Three Gergos reservoir in China, showed that human activities influenced the changes in nutrient content and a decrease in plankton diversity; the tributaries could reduce the ecological health of the main river [12].

The low diversity was influenced by physical factors such as water, nutrients, and the ability of plankton to adapt [4]. The uniformity value (E) reached 0.69 and 0.94 with an average level of 0.868. This low uniformity indicated species dominance [17].

Research conducted in the Krueng Daroy River in Aceh showed moderate plankton diversity (H' = 2.57), indicating that the water was moderately polluted and that the fertility of the waters had changed [28].

TSS contained the remains of organisms such as plankton, organism feces, sludge, and industrial waste [16]. The content of nitrate and nitrite reached 0.01 mg/l. Nitrate was a compound that accelerated the growth of plankton, while the low content of nitrite, below 1 mg/l, indicated water's infertility [9].

Research conducted in Maninjau Lake and Ranggeh River in Agam Regency showed that temperature, dissolved oxygen, pH, conductivity, and TDS had influenced the phytoplankton abundance in one of the *Bacillaryophta* phylum [23]. In addition, a study on the Babon River in Semarang, Central Java, showed that community participation and a river care community are required to perform river conservation [11].

5. Conclusion

Based on the research conducted in the five tributaries of the Musi River, *Bacillariophyceae* abundance was the highest among other genera, followed by *Chlorophyceae*, *Flagilariophycea*, *Euglenida*, and *Chrysophyceae*. *Crustacea* had the highest abundance in the zooplankton class, followed by *Tubulenia*, *Maxillopoda*, *Mastigophora*, and *Imbricatea*. On the other hand, *Cyanophyceae* abundance was the highest in the phytoplankton class, followed by *Chrophyceae*. *Crysophycea* was found the lowest. *Crustacea* was the most abundant genus of zooplankton, followed by *Euglenoid* and *Mastigophora*. Plankton's diversity and community stability levels were regarded as moderate; as there was no domination found, the water was classified as heavily polluted.

According to the ANOVA hypothesis, the phytoplankton and zooplankton data groups in the five tributaries showed different variations. The abundance of phytoplankton was influenced by three factors reaching 76.54%. The factors included: 1) temperature, brightness, currents, TSS, oil, and fat; 2) TDS, DO, pH, and water depth; 3) nitrate and turbidity.

The waters of the five tributaries at the Musi River downstream were heavily polluted as bioindicators of pollution, namely *Nitzchia*, *Chlorococcum*, *Euglena*, *Oscillatoria*, and *Spirogyra*, were found. Based on the abundance of phytoplankton, Ogan and Komering Rivers had the greatest influence on the Musi River as their abundance was the highest among other tributaries. On the other hand, the Kundur River had the lowest abundance as an inspection river. Based on zooplankton abundance, the Ogan River exerted the greatest influence on the Musi River due to its width and highest water flow rate among other tributaries.

There was a strong positive correlation between nitrite and TSS. Based on the research, the high oil content indicated that the water was polluted. This condition was due to human activities along the river, such as transportation, factories, and settlement waste. These waters were less fertile, shown by their low nitrite content. Based on the value of TDS and TSS found, the waters at the estuary of the five tributaries and the waters at the Musi River itself could not be used as drinking water; the waters could only be used for irrigation.

As for phytoplankton, the diversity (H') was moderate, indicating an unstable ecosystem. The uniformity (E) was also moderate, while the dominance value (D) indicated no dominance. On the other hand, the values of H', E, and D of zooplankton were low, indicating a low stability community and a low abundance.

The research was limited to the large tributaries at the downstream of the Musi River, where the Ogan and Komering Rivers greatly influenced the Musi River. However, there were also tributaries at the upstream of the Musi River, which also influenced the river, namely Batanghari Leko, Lematang, Rawas, Lakit, and Kelingi

River. Thus, research needs to be conducted on the influence of the tributaries at the upstream of the Musi River.

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