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DETERMINANT PARAMETERS FOR UPSTREAM ECOLOGICAL STATUS ASSESSMENT OF CITARUM RIVER, INDONESIA

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ABSTRACT: This study was aimed to identify physicochemical and biological determinant parameters in assessing the ecological status of the upstream area of CitarumRiver during the dry and rainy season. This study consisted of two steps: 1) Principle Component Analysis to classify environmental parameters and select the determinant environmental parameters significantly affecting the status, and 2) matrix arrangements using the selected determinant parameters for ecological status assessment. The PCA results showed that during the dry season, genera macrozoobenthic and physicochemical parameters grouped the slightly-quite-moderately polluted status. In the rainy season, macrozoobenthic and physicochemical parameter grouped the quite-moderately polluted status. Based on the selected determinant parameters, it could be stated that 1) *Leuctra sp.*, *Perlesta sp*, and total sediment nitrogen determine the slightly polluted status, 2) *Baetis sp.*, *Sulcospira sp.*, conductivity, and NO_3^-determine the quite polluted status, 3) *Lumbriculus sp.*, *Chironomus sp.*, NO_2, silt, and BOD determine the moderately polluted status. While the determinants during the rainy season in quite and moderately polluted location were: 1) *Hydropsyche sp.*, *Rhyacophila sp.* and gravel in the quite polluted status, 2) *Placobdella sp.*, *Tubifex sp.*, TSS and NH_3 in the polluted status. The assessment matrix arranged using determinant parameters were able to determine the ecological status of the Citarum upstream in the rainy (quite-moderately polluted) and the dry season (slightly-quite-moderately polluted).

Keywords: Ecological status, Polluted status, Determinant parameters

1. INTRODUCTION

Citarum River basin is the largest watershed in West Java Province with a length of 297 km and a water catchment area of about 6,617 km^2. It supports ten districts including two cities and irrigates 271.364 ha rice fields. The development of anthropogenic activities and land conversion especially in the upper areas of the river basin has significant ecological impacts, one of which is water quality degradation from the 60% household waste disposal, 30% liquid chemical industry waste and 10% agricultural and farm waste. The waste volume in the upper areas of the Citarum River has reached 500,000 m^3/year. These conditions lead to changes in the ecosystem function, ecological status, and pollution in the Citarum watershed [1], thus requiring a tool to assess the ecological status accurately, quickly, and cost-effectively. Various assessment tools have been developed related to ecological status and river pollution in Indonesia such as FBI and LQI by Kusumaningrum et al. [2], Muntalif et al. [3], Wimbaningrum et al. [4], Sandi et al. [5], and Krisanti et al. [6].

River ecological status has been an important environmental concern during the past few decades. Assessing the ecological status using scoring system was performed to monitor water quality, and even to compose a comprehensive river management plan. Generally, ecological scoring system uses indices based-approaches. It uses several physicochemical parameters, such as; total suspended solid (TSS), turbidity and total phosphate. Since water quality changes will affect the sedimentary particles in the river, the scoring system also considered sediment physicochemical parameters such as the percentage of Carbon-Organic, total nitrogen, and the percentage of gravel whereas the biological parameters considered in the scoring system including diversity and abundance of macrozoobenthic fauna [7].

The many parameters used in the scoring system often results in large and complex data sets making interpretation and understanding hard and at the same time also time-consuming and cost-intensive. This critical challenge has led to the development of new strategies that allows rapid, more efficient, and cost-effective assessment with the selection of physicochemical and biological key parameters being one of such strategy. The use of certain key parameters that most determine the ecological status of rivers would ease the assessment and provide efficient water quality evaluation and monitoring. This study aims to identify physicochemical and biological determinant parameters in assessing the ecological status of the upstream area of Citarum River during the dry and rainy season using principal component analysis (PCA).

PCA is a multivariate method that reduces many dimensions and interrelated variables while retaining as much variability as possible in the data set [8]. The development of PCA biplot model would depict the significant parameters that most determine the ecological status of the upstream area of Citarum River. The results obtained from this new approach above will be used in the preparation of an assessment matrix that will strengthen the determination of the ecological status of the commonly used scoring system. Various studies have been conducted with this new approach by Gabriel [9], Duran [10], Li et al. [11], Villamarin et al. [12], Cortelezzi et al. [13], Torres-Salinas et al. [14], Tan and Beh [15]. Given the different conditions for each aquatic ecosystem, especially the factors affecting ecological status, this multivariate analysis application to determine environmental factors affecting ecological status is essential for analyzing different conditions and locations rare in the tropical area.

2. MATERIALS AND METHODS

2.1 Study Area

The study area consisted of seven sampling stations in the upstream area of Citarum River basin, West Java, Indonesia. These were spread along the coordinate 107°39'20.30"S - 107°44'53"S longitude 07°04'29"E - 07°13'27.27"E latitude (Fig. 1). Four stations (Station 1-4) were selected to serve as a reference site for its minimal disturbance in the surrounding area, while the other three stations (Station 5-7) were selected for land use conversion in its surrounding area. In these areas, lands were used for various purposes such as; settlement, cattle farm, farming, and traditional sand mining. This research was conducted from July 2014-September 2015. The study area description is shown in Table 1.

2.2 Ecological Status

The ecological status of the upstream area of Citarum River basin was determined by a scoring system developed by Chazanah et al. [7] as shown in Table 2 and calculated according to Eq. (1). Physicochemical parameters used in this scoring system were turbidity, TSS, total nitrogen, total phosphate, carbon- organic and gravel percentage.

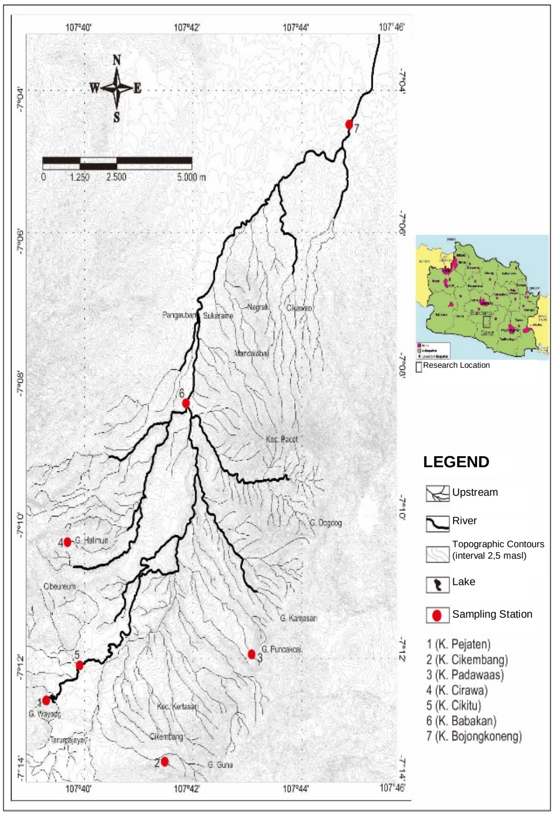


Fig. 1 The location of sampling stations

While biological parameters used was diversity index (H') of macrozoobenthic community.

$$\textit{Final Score} = \frac{\textit{average score parameter}_{1-6} + H'}{2} \quad (1)$$

Criteria for the ecological status were as follows:
1) Not polluted/slightly polluted = final score ≤ 2;
2) Quite polluted = final score 2 - 4;
3) Moderately polluted = final score 4 - 6;
4) Heavily polluted = final score > 6.

2.3 Data Analysis

To explore the general interrelationship between parameters and the ecological status was performed a Principal Component Analysis (PCA). PCA is a mathematical method that allows data to be normally distributed and simplify the complex picture data into two dimensions [14,16]. The analysis was performed based on the dry and rainy seasons using SPSS software version 25.

Twenty two physicochemical variables were chosen for use in the PCA: (1) temperature, (2) TSS, (3) turbidity, (4) conductivity, (5) current velocity, (6) pH, (7) DO, (8) COD, (9) BOD, (10) TOC, (11) TN, (12) NO_3, (13) NO_2, (14) NH_3, (15) TP, (16) C-Organic, (17) $TN_{sediment}$, (18) $TP_{sediment}$, (19) $pH_{sediment}$, (20) sand, (21) gravel, and (22) silt.

Table 1 The study area description

Station	Location	Area Description
St. 1	Located in Kampong Pejaten, Tarumajaya Village, Kertasari District, Bandung Regency. (1586 m a.s.l.)	The area was a natural spring and surrounded by dense riparian vegetation with 7% - 15% slope.
St. 2	Located in Mt. Guha, Kampong Cikembang, Cikembang Village, Kertasari District, Bandung Regency. (1811 m a.s.l.)	The area was a natural spring, and the station was situated 3,24 km away from Citarum mainstream. The surrounded area was still dominated by dense riparian vegetation with 15%-30% slope. There was also a farming area near the station.
St. 3	Located in Mt. Puncak Cae, Kampong Padawas, Cihawuk Village, Kertasari District, Bandung Regency. (1672 m a.s.l.)	The station was situated 4 km away from Citarum mainstream, and the surrounded area was still dominated by dense riparian vegetation with 30%-70% slope. Similar with St. 2, there was also a farming area near the station.
St. 4	Located in Mt. Halimun, Kampong Cirawa, Cibeureum Village, Kertasari District, Bandung Regency. (1720 m a.s.l.)	The station was situated 2.38 km away from Citarum mainstream and was still dominated by riparian vegetation with 30% - 70% slope. Similar with St. 2, there was also a farming area near the station.
St. 5	Located in Kampong Cikitu, Cibeureum Village, Kertasari District, Bandung Regency. (1794 m a.s.l.)	The station was situated 1.82 km away from St. 1 and was dominated by cogon grass with 7% - 15% slope. There was a cattle farm near the station, and the effect of pollution can be seen physically in the water. There was also a residential area near the station.
St. 6	Located in Kampong Babakan, Sukarame Village, Pacet District, Bandung Regency. (1057 m a.s.l.)	The station was dominated by residential area and farming area. The vegetation around was dominated by grass with 7% - 15% slope.
St. 7	Located in Kampong Bojongkoneng, Wangisagara Village, Majalaya District, Bandung Regency. (745 m a.s.l.)	The station was dominated by residential area, and traditional sand mining manage by local people. Only a few vegetation grow near the station. Vegetation was dominated by bamboo.

Table 2 The ecological status scoring [7]

Variable	Score			
	1	3	6	10
Total Suspended Solids (mg/L)	<20	20 - 100	>100 - 400	>400
Turbidity (NTU)	<15	15 - 30	>30 - 45	>45
Total Nitrogen in sediment (mg/L)	<2	2 - 4	>4 - 6	>6
Total Phosphate (mg/L)	<0,5	0,5 - 1	>1 - 2	>2
C-Organic (%)	>30	20 - 30	10 - 20	<10
Gravel (%)	>20	>10 - 20	5 - 10	<5
H' (Diversity Index)	>2,5	1,5-2,5	1-1,5	<1

Fifty seven genera of macrozoobentos were used: *Polypedilum sp., Paucispinigera sp., Chironomus sp., Cricotopus sp., Rhyacophila sp., Simulium sp., Chimarra sp., Allocapnia sp., Capnia sp., Leuctra sp., Neumora sp., Nemorinae sp., Perlesta sp., Hydropsyche sp., Isoperla sp., Prionocera sp., Hexatoma sp., Tipula sp., Pseudolimnophila sp., Antocha sp., Ormosia sp., Hydraenida sp., Eubriinae sp., Phylocentropus sp., CalliBaetis sp., Psedocloeon sp., Baetis sp., Agabus sp., Gyrinus sp., Chrysops sp., Ephemerella sp., Lepidostoma sp., Dixa sp., Rhapium sp., Parargyractis sp., Pentagenia sp., Bellura sp., Brachydeutera sp., Ephydra sp., Nectopsyche sp., Caenis sp., Talitrus sp., Gammarus sp., Syncaris sp., Potamonautes sp., Parathelphusa sp., Thiara sp., Melanoides sp., Tarebia sp., Lymnaea sp., Physastra sp., Sulcospira sp., Placobdella sp., Helobdella sp., Lumbriculus sp., Tubifex sp., dan Babronia sp.*

The resulting data was plotted to demonstrate co-occurrence and determine any informative patterns within the variables and the stations using Biplot. A Biplot is a graphical representation of multivariate data, where the elements of a data matrix are represented according to dots and vectors associated with the rows and columns of the matrix [14]. Finally, the group of dominant variables was identified by interpreting and analyzing the Biplot graph. Physicochemical and macrozoobenthic key parameters on specific pollution status and seasonal were obtained by analyzing the factor values formed from each of the PCA variables. The analysis was done by looking at the strongest relationship between each variable in the group from the biplot result and indicated by the factor value for component 1 approaching 1 or -1.

The determinant parameters from the previous analysis were arranged into a matrix of determinant parameters for the dry and rainy seasons. The matrix contains the range of values for each physicochemical parameter and the abundance of predominant macrozoobenthos which determine the ecological status. The determination of the concentration range of physicochemical parameters is based partly on literature studies such as total sediment nitrogen and percent of gravel [7]; TSS [7,16,17]; conductivity [16,17]; and NO_3, NO_2, BOD, NH_3 [17].

3. Results and Discussion

3.1 Ecological Status During The Dry and Rainy Season

The ecological status of all sampling stations during the dry and rainy season are shown in Table 3. The scoring result indicates that the ecological status of all stations in the dry season ranged from slightly polluted to moderately polluted while in the rainy season ranged from quite polluted to moderately polluted [7]. This is phenomenon occurs as during the rainy season, the runoff from the rainwater brought eroded particles as well as fertilizers from farming activities from the surrounding the area [18,19]. Other studies determining the pollution status of upstream Citarum River based on organic pollution indicated the pollution status as slightly polluted to moderately polluted [20].

Table 3 Ecological status of seven sampling stations in the upstream area of Citarum River

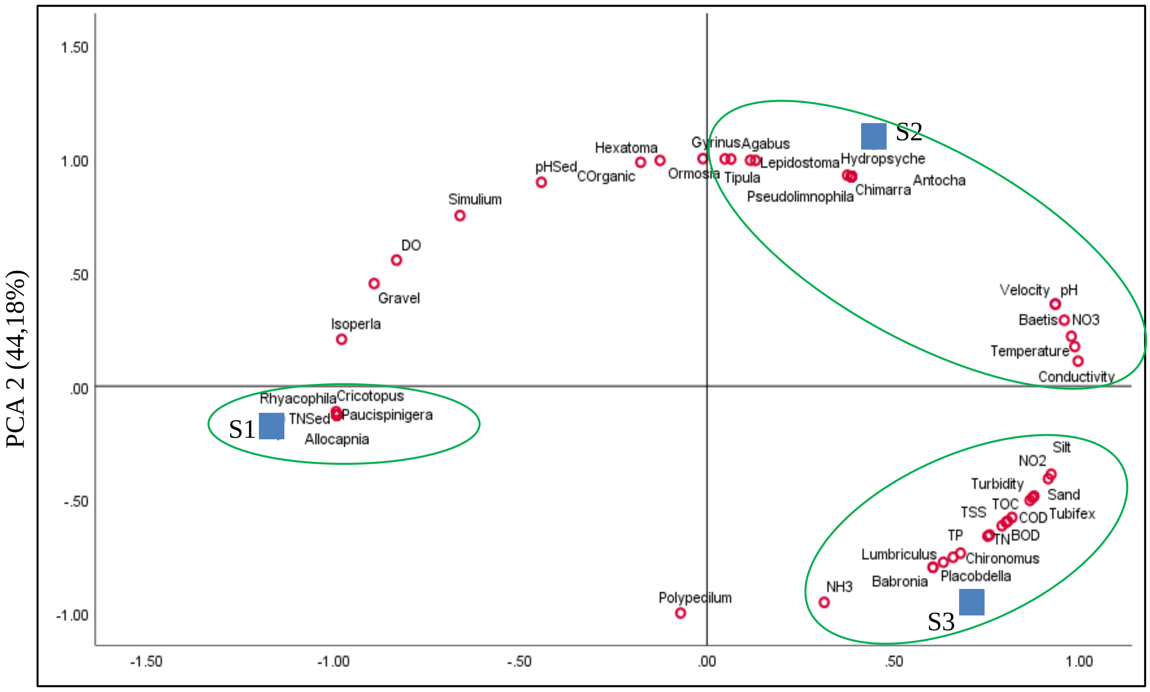
St.	Dry Season		Rainy Season	
	Score	Status	Score	Status
1	2,02	Quite polluted	2,3	Quite polluted
2	1,9	Slightly polluted	2,21	Quite polluted
3	1,56	Slightly polluted	2,42	Quite polluted
4	2,53	Quite polluted	2,08	Quite polluted
5	4	Moderately polluted	4,8	Moderately polluted
6	3,38	Quite polluted	3,79	Quite polluted
7	3,37	Quite polluted	4,13	Moderately polluted

3.2 Grouping of Physicochemical and Biological Parameters

Grouping of physicochemical and biological parameters determining the ecological status of the upstream area of the Citarum River basin was performed with PCA Biplot. The physicochemical and biological parameters were grouped based on the ecological status during the dry and rainy seasons obtained from Table 3. The results of PCA Biplot analysis for the dry and rainy season are shown in Fig. 2 and Fig. 3.

Based on Fig. 2, component 1 represented 55,82% of variables analyzed, while component 2 represented 44,18% of variables analyzed. The grouped physicochemical and biological parameters that have a positive correlation with slightly polluted status (S1) were total sediment nitrogen with macrozoobenthos composition *Rhyacophila sp., Paucispinigera sp., Cricotopus sp.* and *Polypedilum sp.* However, some genera of macrozoobenthos did not appear in the biplot (Fig. 2) and have similar ordinate with slightly polluted status (S1), where PC 1 is negative and PC 2 is negative (Table 4), among others: *Allocapnia sp., Capnia sp., Leuctra sp., Neumora sp., Perlesta sp., Prionocera sp., Eubriinae sp., Phylocentropus sp., Chrysops sp., Ephemerella sp., Nectopsyche sp., Talitrus sp., Gammarus sp., Potamonautes sp.* and *Parathelphusa sp.*

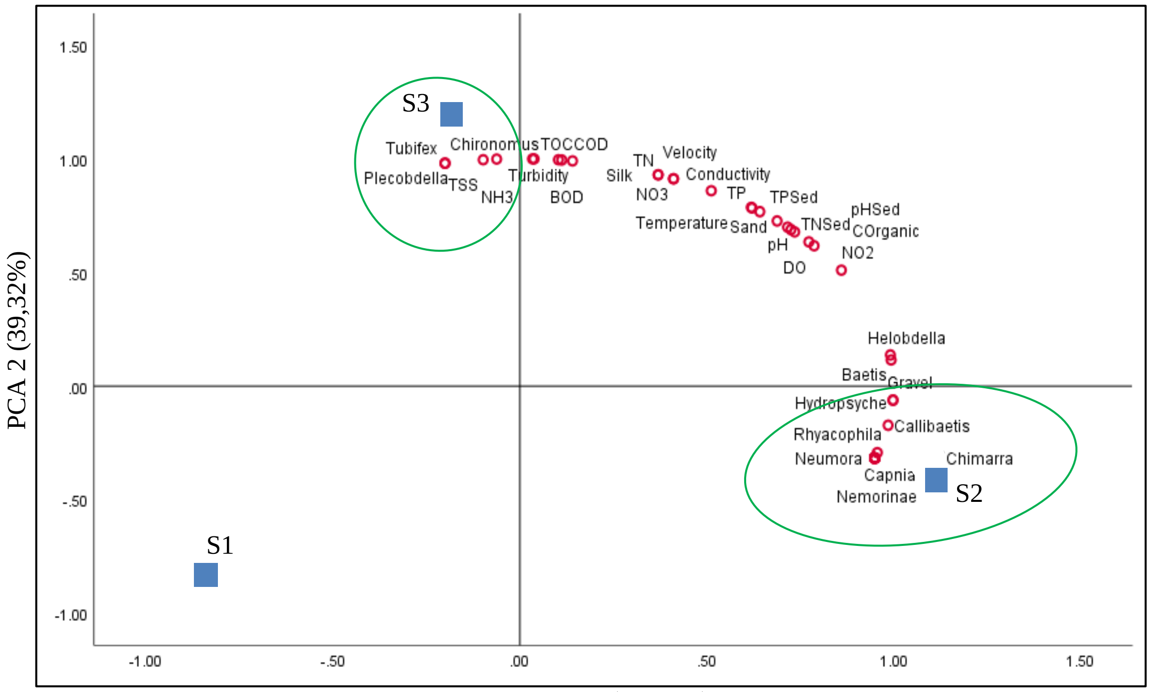
The grouped physicochemical and biological parameters that have a positive correlation with quite polluted status (S2) consisted of: temperature, conductivity, current velocity, pH, NO_3 with macrozoobenthos composition of *Gyrinus sp., Tipula sp., Lepidostoma sp., Ormosia sp., Agabus sp., Antocha sp., Hydropsyche sp., Pseudolimnophila sp., Chimarra sp.* and *Baetis sp.* However, some genera of macrozoobenthos did not appear in the biplot (Fig. 2) and have similar ordinate with S1, where PC 1 is positive and PC 2 is positive (Table 4), among others: *CalliBaetis sp., Psedocloeon sp., Dixa sp., Rhapium sp., Parargyractis sp., Ephydra sp., Caenis sp., Thiara sp., Melanoides sp., Tarebia sp., Physastra sp.* and *Sulcospira sp.*



PCA 1 (55,82%)

Description of ecological status:
S1 = slightly polluted; S2 = quite polluted; S3 = moderately polluted

Fig 2. Biplot graph of physicochemical and biological parameters during the dry season



PCA 1 (60,68%)

Description of ecological status:
S1 = slightly polluted; S2 = quite polluted; S3 = moderately polluted

Fig. 3 Biplot graph of physicochemical and biological parameters during the rainy season

The grouped physicochemical and biological parameters that have positive correlation with moderately polluted status (S3) were NO_2, NH_3, turbidity, TSS, total phosphate, total nitrogen, COD, BOD, TOC, sand and silt with macrozoobenthos composition *Tubifex sp.*, *Placobdella sp.*, *Chironomus sp.*, *Lumbriculus sp.*, *Babronia sp.* and *Helobdella sp.* (Fig. 2).

Based on Fig. 3, component 1 represented 60,68% of variables analyzed, while component 2 represented 39,32% of variables analyzed. The results showed that in the rainy season all parameters were only clustered on two ecological status (quite and moderately polluted). Water degradation from slightly polluted to quite and moderately polluted occurs as hilly and mountainous areas with mixed vegetation were thought to have a quantitative and qualitative impact on rivers with climate change [19] affected by rainfall [21]. The rainfall fluctuation event is an essential factor that can significantly affect the water quality of a river, particularly in a tropical country where the seasonal variations of river water quality are mainly dominated by precipitation [22].

The grouped physicochemical and biological parameters that have a positive correlation with quite polluted status (S2) were gravel with macrozoobenthos composition of *Hydropsyche sp.*, *Rhyacophila sp.*, *CalliBaetis sp.*, *Neumora sp.*, *Capnia sp.*, *Nemourinae sp.* and *Chimarra sp.* However some genera of macrozoobentos did not appear in the biplot (Fig. 3) and have similarity of ordinate with S1, where PC 1 is positive and PC 2 is negative (Table 5), among others: *Hexatoma sp.*, *Tipula sp.*, *Ormosia sp.*, *Hydraenida sp.*, *CalliBaetis sp.*, *Agabus sp.*, *Parargyractis sp.*, *Pentagenia sp.*, *Bellura sp.*, *Brachydeutera sp.*, *Gammarus sp.*, *Syncaris sp.*, *Parathelphusa sp.*, *Thiara sp.*, *Melanoides sp.*, *Lymnaea sp.*, *Sulcospira sp.* and *Lumbriculus sp.* While the grouped physicochemical and biological parameters that have positive correlation with moderately pollutted status (S3) were TSS and NH_3 with macrozoobentos composition *Tubifex sp.* dan *Placobdella sp.*

3.3 Selection of Determinant Parameters

The selection of the environmental parameter significantly affecting the ecological status was performed by analyzing the factor value in component 1 of the PCA results for each grouping based on the pollution status that has the strongest relationship with values close to 1 or -1 (Table 4 and Table 5). The selection of the value factor in component 1 is due to the number of variants that can be explained by component 1 is greater than that of component 2 (55,82%) (Table 4) thus can better describe all the variables processed in PCA. The selection of key parameters not only looks at the rank of the factor value but also consider the physicochemical parameters affecting the pollution status as well as the characteristics and abundance of the macrozoobenthos genus. Factor value of each variable in certain pollution status during the dry season can be seen in Table 4.

According to Table 4, the variable at the slightly polluted location with a strong correlation of 0,992 is total sediment nitrogen, *Leuctra sp.* and *Perlesta sp.* The riparian conditions around the river were quite dense, and the riverbed was dominated with moss and litter. The condition might have been from the macrophytes decomposition process by microbes that fell into the body of water. The total nitrogen parameters in the sediments might have originated from the decaying crops in the water as the nutrients needed for macrozoobenthic growth. This is reinforced by Sudarso and Wardiatno [16], stating that nutrient content in the sediments derived from moss and litter can increase the growth of macrozoobenthos and algae. The abundance of *Leuctra sp.* ranged from 0-127 individuals/m^2, while the abundance of *Perlesta sp.* ranged from 0-202 individuals/m^2. *Leuctra sp.* larvae were most often found hiding between detritus and substrate. The larvae were not commonly found except close to hatching as they spend most of their time hiding in the substrate [23,24]. *Perlesta sp.* larvae were found in small rivers [23,24]. Genera *Leuctra sp.* and *Perlesta sp.* were included in the Plecoptera order which has a low tolerance value [24] and was least tolerant with organic pollution [25]. In locations with another contamination status, there was no *Leuctra sp.* and *Perlesta sp.* This indicates that the genus was intolerant and constitutes as a key parameter of macrozoobenthos at sites with slightly polluted status during the dry season.

Variables at a quite polluted location with a strong correlation of 0,994; 0,976 and 0,957 are conductivity, NO_3, and *Baetis sp.* (Table 4). While the macrozoobenthos variable with a factor value of 0,387 consists of several genera. The macrozoobenthos selected at the value of these factors is *Sulcospira sp.* because it is abundant in the protected river location. The content of minerals and other compounds in rivers and soil erosion due to the altitude differences, from 1586 masl to 745 masl, may affect conductivity values ranging from 2,1-324 μS/cm. According to Sylvester [26] in Suantika [27], the water conductivity value of 500 μS/cm is the upper limit that can still support the life of the fresh aquatic animal. Mayaningtyas [28] states that changes in conductivity values will affect the small number of nutrients contained in water bodies. Nutrients derived from agricultural fertilizer waste in addition to increasing the conductivity value of water bodies [29], also increased the content of NO_3 in water [30]. The content of NO_3 ranging from 0,17-9,72 mg/L may be influenced by agricultural activity around the site. The abundance of *Baetis sp.* ranged from 0-513 individuals/m^2, while *Sulcospira sp.* ranged from 0-433 individuals/m^2. *Baetis sp.* larvae were widespread and found in a wide variety of habitats. Some *Baetis sp.* were found in a stream with fast and slow currents. Some *Baetis sp.* could live in polluted rivers [23,24]. *Sulcospira sp.* generally prefers a sheltered location and were usually abundant in shady locations, such as clinging under rocks, roots, under leaf litter, or burrowing shells into the muddy sand on rivers, tributaries, or shallow waters. Substrates in *Sulcospira sp.* habitat were in the form of stones, gravel, sand, aquatic plants, and plant roots [31]. Thus, *Sulcospira sp.* is specific to a location in a protected condition. Genus *Baetis sp.* is in the order of Ephemeroptera which has moderate tolerance [24] and was least tolerant with organic pollution [25]. *Baetis sp.* and *Sulcospira sp.* was not present in rivers with quite polluted status. This shows that those genera with conductivity and NO_3 were key parameters at locations with quite polluted status during the dry season.

Table 4 The result *principle component analysis* during the dry season

Variable	PC1	PC2
Eigenvalue	39,63	31,37
% variable	55,82	44,18
Temperature	,985	,174
TSS	,790	-,614
Turbidity	,865	-,502
Conductivity**	**,994**	**,110**
Velocity	,933	,361
pH	,933	,361
DO	-,832	,554
COD	,817	-,577
BOD***	**,805**	**-,593**
TOC	,801	-,599
TN	,752	-,659
NO_3**	**,976**	**,219**
NO_2***	**,922**	**-,387**
NH_3	,314	-,950
TP	,757	-,654
C-Organic	-,178	,984
TNSed*	**-,992**	**-,126**
pHSed	-,444	,896
Sand	,872	-,490
Gravel	-,892	,451
Silt***	**,914**	**-,407**
Polypedilum sp.	-,071	-,997
Paucispinigera sp.	-,992	-,126
Chironomus sp.***	**,679**	**-,734**
Cricotopus sp.	-,994	-,112
Rhyacophila sp.	-,992	-,126
Simulium sp.	-,662	,750
Chimarra sp.	,387	,922
Allocapnia sp.	-,992	-,126
Capnia sp.	-,992	-,126
Leuctra sp.*	**-,992**	**-,126**
Neumora sp.	-,992	-,126
Perlesta sp.*	**-,992**	**-,126**
Hydropsyche sp.	,376	,927
Isoperla sp.	-,979	,206
Prionocera sp.	-,992	-,126
Hexatoma sp.	-,126	,992
Tipula sp.	,064	,998
Pseudolimnophila sp.	,387	,922
Antocha sp.	,387	,922
Ormosia sp.	,048	,999
Eubriinae sp.	-,992	-,126
Phylocentropus sp.	-,992	-,126
CalliBaetis sp.	,387	,922
Psedocloeon sp.	,387	,922
Baetis sp.**	**,957**	**,290**
Agabus sp.	,116	,993
Gyrinus sp.	-,011	1,000
Chrysops sp.	-,992	-,126
Ephemerella sp.	-,992	-,126
Lepidostoma sp.	,130	,992
Dixa sp.	,387	,922
Rhapium sp.	,387	,922
Parargyractis sp.	,387	,922
Ephydra sp.	,387	,922
Nectopsyche sp.	-,992	-,126
Caenis sp.	,387	,922
Talitrus sp.	-,992	-,126
Gammarus sp.	-,992	-,126
Potamonautes sp.	-,992	-,126
Parathelphusa sp.	-,992	-,126
Thiara sp.	,387	,922
Melanoides sp.	,387	,922
Tarebia sp.	,387	,922
Physastra sp.	,387	,922
Sulcospira sp.**	**,387**	**,922**
Placobdella sp.	,633	-,774
Helobdella sp.	,605	-,796
Lumbriculus sp.***	**,876**	**-,483**
Tubifex sp.	,605	-,796
Babronia sp.	,659	-,752

Note:
* Slightly Polluted
** Quite Polluted
*** Moderately Polluted

Variables in locations with moderately polluted status with strong linkages of 0,922; 0,914; 0,805; 0,876 were NO_2, Silt, BOD and *Lumbriculus sp.*, whereas the macrozoobenthos with a strong correlation of 0,679 is *Chironomus sp.* (Table 4). Substrate conditions at this location were dominated by sludge ranging from 8%-33%. NO_2 concentrations at the site ranged from 0,03-0,34 mg/l, and BOD concentrations ranged from 4,1-34,11 mg/l which possibly from the anthropogenic activities, i.e., settlements and a traditional cattle ranch around the site. Therefore, waste entering the waters was included in the high organic matter content, thus included as organic pollution [3]. The abundance of *Lumbriculus sp.* ranged from 0-175 individuals/m^2, while *Chironomus sp.* ranged from 294-9697 individuals/m^2. *Lumbriculus sp.* most commonly lived in streams with low or calm streams. *Lumbriculus sp.* was most commonly found in soft sediments, but some can be found in rough detritus, in vegetation, and in the coarse substrate. *Lumbriculus sp.* can live in organically polluted waters with extremely low levels of dissolved oxygen [23,24,32]. *Chironomus sp.* were found in every water habitat, such as rivers and soft sediments, on rocks, in and around vegetation. Some types of *Chironomus sp.* can survive in situations with low dissolved oxygen [23,24]. Genus *Chironomus sp.* was in the order of Diptera and *Lumbriculus sp.* was included in the order Lumbriculida. Both have a high tolerance [24]. Both genera were found in rivers with slightly polluted to moderately polluted status. This shows that those genera with NO_2, silt and BOD were key parameters at locations with moderately polluted status during the dry season.

Factor value of physicochemical and macrozoobenthos parameters based on certain pollution status during the rainy season can be seen in Table 5.

Based on Table 5, the variables in locations with quite polluted status with strong linkages of 0,998 and 0,956 were gravel, *Hydropsyche sp.*, and *Rhyacophila sp.* The condition of river substrate with quite polluted status was dominated by pebbles and rocks ranging from 7-44%. The abundance of *Hydropsyche sp.* ranged from 0-225 individuals/m^2 whereas the abundance *Rhyacophila sp.* ranged from 0-291 individuals/m^2. This is due to the two genera living attached to rocks. *Hydropsyche sp.* was limited to running water, from small to large rivers. *Hydropsyche sp.* was most often found in areas with coarse rock substrates or solid structured bedrock enabling net instillation preventing drift. *Hydropsyche sp.* could also be found in large woody debris and submerged vegetation [23,24]. *Rhyacophila sp.* larvae were found in running water and most often in clean and fast t-flowing rivers. *Rhyacophila sp.* lives under a rock or in a collection of moss and algae [23,24]. Genus *Hydropsyche sp.* is in the Trichoptera order of moderate tolerance [24], while the *Rhyacophila sp.* genera is in the order of Trichoptera that has a low tolerance [24]. This shows that *Hydropsyche sp.* and *Rhyacophila sp.* with the total nitrogen in sediment were key parameters at locations with quite polluted status during the rainy season.

Variables in moderately polluted locations with less strong relationships of -0,204; -0,102; and -0,066 were *Placobdella sp.*, *Tubifex sp.*, TSS, and NH_3 (Table 5). The condition of rivers with contaminated status was likely to be contaminated by organic waste and fertilizer due to anthropogenic activities around the site such as settlements, agriculture, traditional cattle ranch and traditional sand excavation with concentrations of TSS ranging from 24-1.898 mg/l and NH_3 ranging from 0,03-1,34 mg/l. Also, the possibility of erosion in the rainy season can affect the content of TSS in the river due to changes in land use in the upstream area. Lenat et al. [33] stated that agricultural land clearing activity had been known to increase the sediment load in waters, temperatures, and turbulent flow to decrease the density and wealth of macrozoobenthic taxa. Suspended particles and sedimentary sediments directly affect the life of macrozoobenthos through changes in substrate composition and preferences in some taxa, covering, and can also disrupt respiratory organs [34]. In addition to the TSS content, NH_3 at the site was likely to be affected by settlements and farming around the site. According to Apriyanti et al. [35], the increase of ammonia in water bodies was due to a large amount of urea content and ammonification process from the decomposition of organic matter by microbes. *Placobdella sp.* has an abundance of 123 individuals/m^2, while the abundance of *Tubifex sp.* is 14 individuals/m^2. *Placobdella sp.* lives in both small and big rivers. Some species live under rapid flow conditions. They are usually located in vegetation, attached to the prey or on other solid substrates [23,24]. *Tubifex sp.* commonly live in rivers with low or quiet streams. Some small species are found in the swiftly flowing region. *Tubifex sp.* is most commonly found in soft sediments, but some can be found in rough detritus, on vegetation, and the coarse substrate. *Tubifex sp.* can live in highly polluted and very organically rich waters with very low levels of dissolved oxygen [23,24]. Genus *Placobdella sp.* is included in the order Rhynchobdellida and *Tubifex sp.* in the order Haplotaxida, both have a high tolerance [24]. This indicates that *Placobdella sp.* and *Tubifex sp.* with the total nitrogen of sediment were key parameters at moderately polluted status locations during the rainy season.

Table 5 The result *principle component analysis* during the rainy season

Variable	PC1	PC2
Eigenvalue	30,927	20,073
% Variable	60,641	39,359
Temperature	,619	,786
TSS**	**-,102**	**,995**
Turbidity	,030	1,000
Conductivity	,509	,861
Velocity	,408	,913
pH	,723	,691
DO	,733	,680
COD	,137	,991
BOD	,108	,994
TOC	,099	,995
TN	,366	,930
NO_3	,408	,913
NO_2	,858	,513
NH_3*	**-,066**	**,998**
TP	,616	,788
COrganic	,785	,620
TNSed	,771	,637
TPSed	,639	,769
pHSed	,713	,701
Sand	,685	,728
Gravel*	**,998**	**-,058**
Silt	,366	,931
Chironomus sp.	,034	,999
Rhyacophila sp.*	**,956**	**-,295**
Chimarra sp.	,950	-,313
Capnia sp.	,950	-,313
Neumora sp.	,950	-,313
Nemorinae sp.	,950	-,313
Hydropsyche sp.*	**,998**	**-,057**
Hexatoma sp.	,950	-,313
Tipula sp.	,950	-,313
Ormosia sp.	,950	-,313
Hydraenida sp.	,950	-,313
Callibaetis sp.	,978	-,209
Baetis sp.	,992	,123
Agabus sp.	,950	-,313
Parargyractis sp.	,950	-,313
Pentagenia sp.	,950	-,313
Bellura sp.	,950	-,313
Brachydeutera sp.	,950	-,313
Gammarus sp.	,950	-,313
Syncaris sp.	,950	-,313
Parathelphusa sp.	,950	-,313
Thiara sp.	,950	-,313
Melanoides sp.	,950	-,313
Lymnaea sp.	,950	-,313
Sulcospira sp.	,950	-,313
Placobdella sp.**	**-,204**	**,979**
Helobdella sp.	,990	,141
Lumbriculus sp.	,950	-,313
Tubifex sp.**	**-,204**	**,979**

Note:
* Quite Polluted
** Moderately Polluted

3.4 Matrix of Determinant Physicochemical and Biological Parameters

The determinant parameters originated from the previous analysis were arranged into a matrix of determinant parameters for the dry and rainy seasons. The matrix contained the range of values for each physicochemical parameter and the abundance of predominant macrozoobenthos which determine the ecological status. Matrix of determinant physicochemical parameters and macrozoobenthic abundance in the dry and rainy seasons can be seen in Table 6 and Table 7. Based on Table 6, six genera of macrozoobenthos found in slightly polluted location were *Leuctra sp.* and *Perlesta sp.*, whereas the genera present in quite polluted location were *Baetis sp.* and *Sulcospira sp.*, while the genera located in a moderately polluted location were *Lumbriculus sp.* and *Chironomus sp.* Habitat of *Lumbriculus sp.* and *Chironomus sp.* were in the silt as stated by McCafferty-Provonsha [23] and Bouchard [24]. The five physicochemical parameters of TNsediment, conductivity, NO_3, NO_2 and BOD. Based on Table 7, there are four genera of macrozoobenthos found in slightly polluted locations are *Hydropsyche sp.* and *Rhyacophila sp.* while the genera present in the quite polluted status are *Placobdella sp.* and *Tubifex sp.* Habitat of *Hydropsyche sp.* and *Rhyacophila sp.* were in the gravel as stated by McCafferty-Provonsha [23] and Bouchard [24]. The two physicochemical parameters of TSS and NH_3.

4. CONCLUSION

The PCA results showed that during the dry season, there were 16 genera macrozoobenthic and one physicochemical parameter. In the quite polluted location, there were 22 genera macrozoobenthic and five physicochemical parameters. While in the moderately polluted location there were six genera macrozoobenthic and 11 physicochemical parameters. During the rainy season, in slightly polluted location there was 25 genera of macrozoobenthic and one physicochemical parameter, while in moderately polluted location there were two macrozoobenthic genera and one physicochemical parameter.

Table 6 Matrix of determinant physicochemical and biological parameters in the dry season

No.	Parameters	Ecological Status			Literatures
		Slightly Polluted	Quite Polluted	Moderately Polluted	
1	TN Sediment (%)	<2	2-4	>4-6	[7]
2	Conductivity (μS/cm)	<50	50-100	>100-500	[16,17]
3	NO_3 (mg/L)	0,05-1,33	>1,33-5	>5-10	[17]
4	NO_2 (mg/L)	0,0001-0,003	>0,003-0,06	>0,06-0,34	[17]
5	BOD (mg/L)	<2,6	2,6-9,7	>9,7	[17]
6	Silt (%)	6-15	15-24	24-33	
7	*Leuctra sp.* (ind/m^2)	1-127	0	0	
8	*Perlesta sp.* (ind/m^2)	1-202	0	0	
9	*Baetis sp.* (ind/m^2)	0	1-513	0	
10	*Sulcospira sp.* (ind/m^2)	0	1-433	0	
11	*Lumbriculus sp.* (ind/m^2)	0	1-50	51-175	
12	*Chironomus sp.* (ind/m^2)	1-676	677-5.049	5.050-9.697	

Table 7 Matrix of determinant physicoochemical and biological parameters in the rainy season

No	Parameters	Ecological Status		Literatures
		Quite Polluted	Moderately Polluted	
1	Gravel (%)	>10-20	>5-10	[7]
2	TSS (mg/l)	>20-82	>83-400	[7,16,17]
3	NH_3 (mg/l)	0,01-0,02	>0,02-1,34	[17]
4	*Hydropsyche sp.* (ind/m^2)	1-225	0	
5	*Rhyacophila sp.* (ind/m^2)	5-291	1-4	
6	*Placobdella sp.* (ind/m^2)	0	1-123	
7	*Tubifex sp.* (ind/m^2)	0	1-14	

The result of the selection determinant parameters during the dry season in slightly-quite- moderately polluted location are as follows: 1) *Leuctra sp.*, *Perlesta sp* and total sediment nitrogen were the key parameters in slightly polluted location, 2) *Baetis sp.*, *Sulcospira sp.*, conductivity and NO_3 are the key parameters in the quite polluted location, 3) *Lumbriculus sp.*, *Chironomus sp.*, NO_2, silt and BOD were the key parameters in moderately polluted location. While during rainy season in quite-moderately polluted location are as follows: 1) *Hydropsyche sp.*, *Rhyacophila sp.* and gravel were the key parameters in the quite polluted location, 2) *Placobdella sp.*, *Tubifex sp.*, TSS and NH_3 were the key parameters in moderately polluted location. Matrix ranges of key parameters such as physicochemical parameters concentration and macrozoobenthic abundance can be used in water quality assessments based on pollution status and seasons can be applied to tropical upstream with the same ecoregion conditions and specific locations.

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