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MONITORING OF MACROINVERTEBRATES ALONG STREAMS OF BILAH RIVER, NORTH SUMATRA, INDONESIA

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Abstract

The present study reports the first comprehensive study on the freshwater macroinvertebrates and its habitat preferences in Bilah River, the largest river in the Northern Sumatra. The riverside is characterized by the presence of anthropogenic and industrial activities which may alter the macroinvertebrate assemblage and biodiversity. Five months of investigation on 10 sampling stations from December 2016 to October 2017 were conducted based on the river flow in Bilah River. Principal component analysis indicated a decrease of trophic status from upstream to downstream of the river. A total of 27 taxa were recorded, with the most abundant group were members of Odonata, Gastropoda, and Decapoda. The highest density of macroinvertebrate was observed from station 1 (160 ind·m^{-2}), while the lowest density was observed from station 9 (38.64 ind·m^{-2}). Based on species distribution and similarity, two groups of habitats may be distinctively recognized based on the Bray-curtis similarity coefficient. Group 1 consisted of station 1, 2, 3 and 4 while group 2 consisted of station 5, 6, 7, 8, 9, and 10. Based on the diversity indices as ecological parameters, the habitat condition in Bilah River was categorized from low to moderately polluted. Spatial patterns in both environmental conditions affecting the macroinvertebrate assemblage was observed using canonical correspondence analysis (CCA) revealed the preferences from each macroinvertebrate species towards environmental conditions.

***Keywords**: Bivalvia; Bray-curtis; CCA; Density, Gastropoda; Trophic status*

Introduction

Anthropogenic activities, such as sand-mining, agricultural and urban runoffs, domestic and industrial wastes, have been identified as potential threats to the freshwater ecosystems [1]. Under excessive nutrient availabilities and lacking proper nutrient and sediment cycles, phytoplankton may grow abundantly leading to a reduced light penetration condition and oxygen depletion in the water bodies or eutrophication [2]. In addition, direct disposal of xenobiotic-contaning wastes may contaminate the health of a freshwater ecosystem and limit its carrying capacity to the biodiversity [3]. Preserving a healthy aquatic environment is still an

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undergoing process following the rapid development of urban and industrial sites to certain freshwater region in Indonesia [4, 5].

The distribution and species composition of benthic macroinvertebrates may be monitored to assess the stream water quality [6, 7]. Macroinvertebrates are sensitive to water qualities and therefore, being used as the most frequent bioindicators of natural and polluted streams [8]. Macroinvertebrates are sessile organisms with limited mobilities, yet depicting its whole life cycle or fate in the aquatic environment. Owing to their characteristics, distinct macroinvertebrate species may indicate the health status of an aquatic environment for any records on polluting activities which affect any stage of their developments [9].

Macroinvertebrates may be present in abundant and dense population in relation to its environmental factors. Some macroinvertebrates respond to significant changes in water conditions in the form of presence and absence of certain species. Practically, the macroinvertebrates may be studied readily and consist of identifiable taxa within specific groups or orders. Identification of the macroinvertebrate diversity and community will aid in determining the overall species richness and abundance in the aquatic environment, especially for the suspected polluted rivers [10].

Bilah River is the largest river flowing in the Northern Sumatra, located along populous urban areas in Rantauprapat, Labuhanbatu Regency. The river area was reported to be significantly utilized or altered into industrial and commercial sectors, e.g agriculture, fishery, sand-mining,and transportation with an indication of pollution to the habitat [11]. Based on the previous study, the macroinvertebrates were influenced by the water conditions, in specific to the total dissolved solids (TDS) explaining the rough estimate of sand-mining contribution to the environment. To date, a comprehensive study on the biodiversity and its inter-relation with the recent physicochemical characteristics is still poorly studied. This study reveal a unique species composition of macroinvertebrate communities along the streams of Bilah River, from the upstream to the downstream in relation to its physicochemical parameters to classify the similar habitat characteristics and its distinctiveness.

Materials and methods

Study area and station selection

The study area is located in Rantauprapat City, Labuhanbatu Regency, North Sumatra, Indonesia with an area lies between 2º6'-2º30'N and 99º48'-100º7'E with an altitude ranging from 2 to 18m above sea level. Field sampling was conducted during the dry (February, May, August) and rainy seasons (October, December) in 2016 and 2017. Ten sampling sites were randomly established from the upstream (18m asl) along the downstream (2m asl) of the Bilah River with final discharge to the Malacca strait (Fig. 1).

The Bilah River is 80km in length and 16 to 75m in width. The riversides are characterized by the presence of effluent sites for rubberplant and oil palm industry waste discharge sites. Anthropogenic or community activities are also observed around the area such as sand mining, sources of drinking water for companies and community, agriculture, fisheries, and public local transportation.

Physicochemical parameters of water quality

Water samples were taken prior the macroinvertebrates collection from each stations. Transparency or Secchi depth (cm) was measured in the field during sampling dates. Water temperature (ºC), pH, conductivity ($mS \cdot cm^{-1}$), dissolved oxygen (DO, $mg \cdot L^{-1}$), total dissolved solids (TDS), and turbidity (NTU), were measured in near 0.5m of bottom sediment water using portable devices. Sediments were also sampled for estimation on the C-organics content (%) using the gravimetric method in the laboratory.

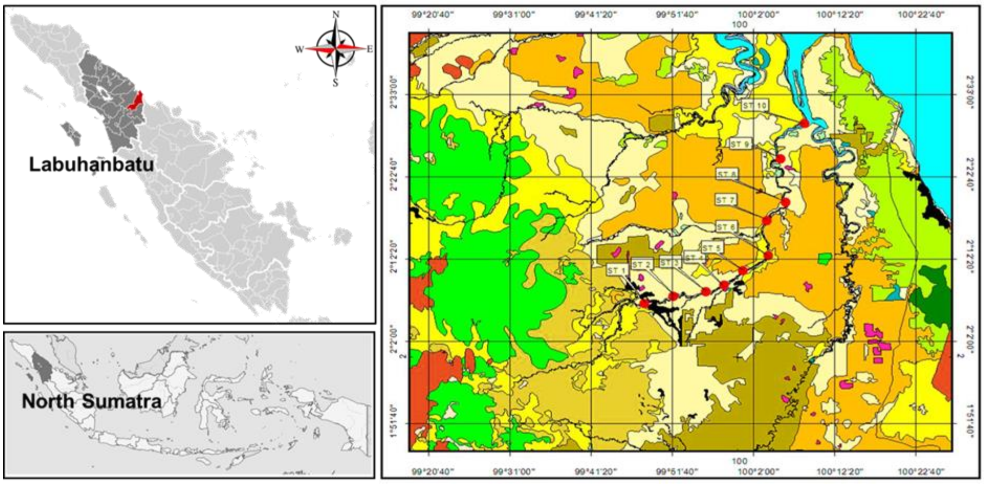

Fig. 1. The sampling stations at Bilah River, Labuhanbatu, North Sumatra, Indonesia

Macroinvertebrates sampling

Benthic samples were collected manually using the square net and Surber samplers. Nine replicate samples were taken as composites from each station and sorted visually by hand. The benthic samples were cleaned from debris with distilled water and preserved into a sample cup containing 70% EtOH solution then labeled. All sorted samples were identified morphologically in the laboratory based on available identification guides [12-16].

Data analysis

Statistical mean ($\bar{X}$) were calculated using the standard software packaging (Microsoft Excel). Published data figure was generated using GraphPad Prism ver. 8.0. A principal component analysis (PCA) was used to analyze the physicochemical or environmental parameters, based on the correlation matrix. Physicochemical data from each parameter were normalized first using the formula of (X-$\bar{X}$)/St.Dev. Relative abundance (%) and density (ind m^{-2}) were calculated based on means of data. Cluster analysis from each station was performed using the MVSP (Multivariate Statistical Package) [17], based on a Bray-Curtis similiarity matrix obtained from the abundance data [18]. Ecological indices, such as Margalef's diversity index ($D\alpha$), Simpson's diversity index (D), Shannon's diversity index (H'), and Evenness (E_H) were calculated as standard ecological analysis. Canonical correspondence analysis (CCA) was used to determine the interaction pattern between macroinvertebrates density and environmental parameters from each station. The CCA, Ecological indices, and PCA were visually generated using PAST (Paleontological Statistics ver. 3.25) [19].

Results and discussion

Water quality

Table 1 summarizes the physicochemical measurements taken at 10 sampling stations. For example, the TDS, dissolved oxygen, and C-organics ranged between 32.11 and 59.19mg·L^{-1}, 4.82 and 7.5mg·L^{-1}, 1.93 and 3.26%, respectively. In general, the trophic status varied greatly among sites with the trend of increasing/decreasing value following the downstream of Bilah River.

The parameters e.g water temperature, conductivity, turbidity, TDS, and C-organics followed a consistent spatial pattern by increasing its value from west to east or upstream to downstream along Bilah River. In contrary, the parameters e.g transparency, pH, and dissolved oxygen decreased following the spatial pattern. PCA analysis was performed which showed the first 2 components accounted for 89.79 and 5.81% of the total variance of environmental parameters, respectively (Fig. 2). The PC1 showed a strong relationship with water temperature, conductivity, TDS, and turbidity while a negative relationship with pH, transparency and dissolved oxygen. The PC2 was most strongly related to C-organics (positive relationship). Comprehensively, the PCA suggested the presence of trophic gradient from upstream to downstream in Bilah River.

Table 1. Physicochemical parameters of aquatic environments ($\bar{X}$) from each station at Bilah River, Labuhanbatu regency, North Sumatra, Indonesia

Parameters	Stations									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Water temp. (°C)	25.06	25.04	25.36	26.12	26.6	26.08	26.28	27.16	28.16	29.02
Transparency (cm)	46	37.8	34.8	35.4	37.8	36.8	35.2	26	18	9.8
Conductivity ($mS \cdot cm^{-1}$)	45.62	49.38	50.86	52.18	54.86	52.64	61.14	81.65	89.2	91.96
Turbidity (NTU)	64.61	76.14	72.21	75.74	73.74	56.77	73.5	119.02	148.23	221.15
TDS ($mg \cdot L^{-1}$)	34.68	32.11	32.72	33.28	35.23	32.11	37.57	50.31	54.08	59.19
pH	7.46	7.63	7.65	7.55	7.61	7.7	7.49	7.23	7.11	7.01
Dissolved oxygen ($mg \cdot L^{-1}$)	7.5	7.21	7.01	6.96	6.53	6.5	6.3	5.93	5.63	4.82
C-organics (%)	1.93	2.43	2.51	2.23	2.35	2.52	3.05	2.53	3.14	3.26

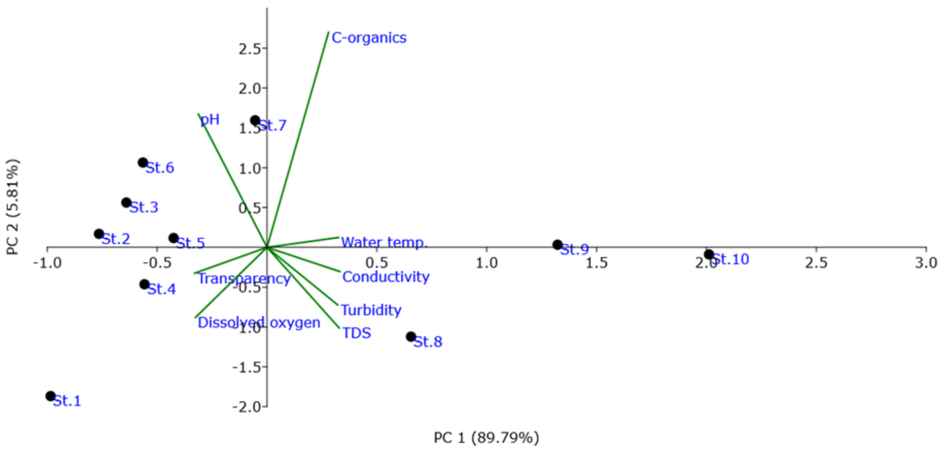

Fig. 2. PCA plots of the first 2 principal components analysis of 8 normalized environmental physicochemical parameters of water quality in Bilah River. Values on the axes indicate the percentages of total variation accounted by each axis

Community assemblage of macroinvertebrates

In total, 27 macroinvertebrate taxa were encountered during 2016 and 2017, including 8 Odonata, 6 Gastropoda, 5 Decapoda, 2 Bivalvia, 2 Plecoptera and each of Coleoptera, Ephemeroptera, Hemiptera, and Trichoptera. The assemblage of macroinvertebrate community from each sampling stations is presented in Figure 3. Station 1 was structured by most of the representative macroinvertebrate group in our study, in which Odonata represented the most abundant group (30.77%). Station 2,3, and 4 were also inhabited by mostly Odonata with the relative abundance of 63.63, 66,67, and 77.78%, respectively. Station 5, 6, 7, and 8 was structured by Decapoda with the relative abundance of 33.33, 42.85, 50, and 75%, while station 9 and 10 was inhabited by the tolerant group, Bivalvia with the relative abundance of 66.67 and 50%, respectively.

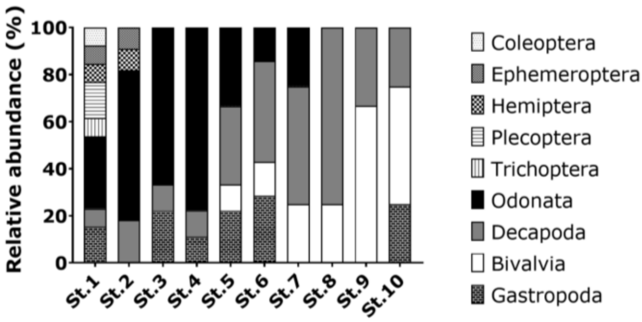

Fig. 3. Relative abundance (%) of macroinvertebrate community among sampling stations in Bilah River

Density of macroinvertebrates

The density from each macroinvertebrate species across sampling stations is presented in Table 2.

Table 2. Density of macroinvertebrates ($\bar{X}$, ind m^{-2}) from each station at Bilah River, Labuhanbatu regency, North Sumatra, Indonesia

Macroinvertebrates	**Stations**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Coleoptera										
Psephenus texanus	13.29	-	-	-	-	-	-	-	-	-
Ephemeroptera										
Heptagenia diabasi	18.20	8.91	-	-	-	-	-	-	-	-
Hemiptera										
Gerris remiges	2.96	10.09	-	-	-	-	-	-	-	-
Plecoptera										
Neoperla sp.	12.58	-	-	-	-	-	-	-	-	-
Swelstsa sp.	6.00	-	-	-	-	-	-	-	-	-
Trichoptera										
Chimarra sp.	20.58	-	-	-	-	-	-	-	-	-
Odonata										
Aphylla angustifolia	-	15.78	13.33	12.82	-	-	-	-	-	-
Argia sp.	17.71	7.35	5.20	-	2.22	-	-	-	-	-
Calopteryx aequabilis	15.15	15.55	14.95	14.29	13.71	11.00	10.15	-	-	-
Ceriagrion tenellum	-	14.27	13.98	12.87	-	-	-	-	-	-
Epicordulia princeps	9.11	15.95	-	-	-	-	-	-	-	-
Gomphus sp.	17.55	12.82	11.27	-	6.67	-	-	-	-	-
Macrodiplax balteata	-	14.09	14.22	9.55	-	-	-	-	-	-
Macromia illinoiensis	-	-	8.69	8.44	-	-	-	-	-	-
Decapoda										
Macrobrachium lepidactyloides	-	-	-	-	10.07	4.44	4.44	5.40	-	-
Palaemonetes bulgaris	-	-	-	-	6.67	7.22	-	-	-	-
Palaemonetes convexa	13.27	3.33	14.42	8.22	-	-	-	-	-	-
Palaemonetes varians	-	-	-	-	13.33	12.71	11.89	14.00	-	-
Parathelphusa convexa	-	10.51	-	-	-	-	-	6.04	5.00	11.73
Bivalvia										
Corbicula fluminea	-	-	-	-	-	-	-	-	15.84	17.44
Corbicula javanica	-	-	-	-	15.35	15.11	16.55	15.02	17.80	18.40
Gastropoda										
Brotia testudinaria	-	-	-	13.67	12.49	14.22	-	-	-	-
Melanoides tuberculata	-	-	16.38	15.40	-	-	-	-	-	-
Physa gyrina	-	-	-	7.80	12.82	11.44	-	-	-	-
Pleurocera canaliculata	-	-	-	-	-	-	-	-	-	11.42
Pomatiopsis lapidaria	2.22	-	-	-	-	-	-	-	-	-
Thiara scabra	11.51	-	-	-	-	-	-	-	-	-
Grand total	160.13	128.65	112.44	103.06	93.33	76.14	43.03	40.46	38.64	58.99

The highest density of macroinvertebrate was observed from station 1 (160ind·m^{-2}), while the lowest density was observed from station 9 (38.64ind·m^{-2}). In station 1, *Chimarra* sp. was observed as the most abundant species belonging to Trichoptera. *Epicordulia princeps* and other odonatans were the most abundant species in station 2. *Melanoides tuberculata* was the most abundant gastropod in station 3 and 4. *Corbicula javanica* was the most abundant bivalvian species in station 5 to 10, revealing its high tolerance to low water quality. The trend in density pattern was also similar to previous water quality which indicate the different carrying capacity or even pollution state across sampling stations.

Based on cluster analysis using Bray-curtis similarity coefficient, there were two distinct groups or habitats in regards of its species assemblage. Group 1 consisted of station 1, 2, 3 and 4 while group 2 consisted of station 5, 6, 7, 8, 9, and 10 (Fig. 4). The most dissimilar species was observed from station 1, as indicated by the presence of Coleoptera, Plecoptera, and Trichoptera. Station 2 was distinct from station 1 due to the numerous Odonata species. Station 3 and 4 were grouped together due to the presence of Odonata, Decapoda, and Gastropoda species. Meanwhile, group 2 was clustered in pairs due to the absence or less number of Odonata, following the presence of Bivalvia, Decapoda, and Gastropoda. Overall, the clustering revealed that each sampling station had different and similar carrying capacity for the macroinvertebrates group.

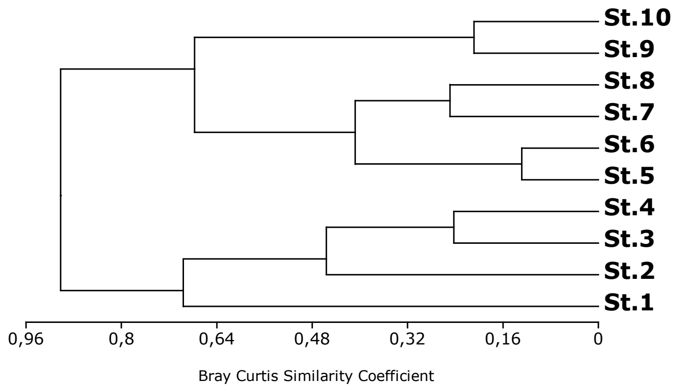

Fig. 4. Dendrogram obtained by UPGMA, using the Bray-Curtis similarity coefficient, by calculating the density matrix of macrozoobenthos from each station at Bilah River, Labuhanbatu, North Sumatra, Indonesia

Ecological analysis of macroinvertebrate community

The ecological implication of macroinvertebrates in Bilah River was determined using three diversity indices and an evenness index (Table 4).

Table 4. Ecological analyses of macrozoobenthos from each station at Bilah River, Labuhanbatu regency, North Sumatra, Indonesia

Parameters	Stations									
	1	2	3	4	5	6	7	8	9	10
Margalef's diversity index (*Dα*)	2.38	2.08	1.71	1.75	1.78	1.39	0.81	0.81	0.55	0.74
Shannon's diversity index (*H'*)	2.44	2.34	2.16	2.17	2.11	1.89	1.30	1.29	0.99	1.36
Simpson's index (*D*)	0.09	0.10	0.12	0.12	0.13	0.16	0.29	0.30	0.40	0.26
Evenness (E_H)	0.88	0.94	0.96	0.97	0.91	0.94	0.92	0.91	0.89	0.98

Both Shannon's (*H'*) and Margalef's (*Dα*) diversity index gave a consistent value within a range of 0.99 to 2.44 and 0.55 to 2.38, respectively. The diversity may be classified as low to moderate level of biodiversity. The Simpson's index (*D*) was ranged between 0.09 and 0.40, in which the higher the value, the lower in biodiversity. The evenness (E_H) index was ranged between 0.91 and 0.98 which indicated an even distribution of species or the absence of dominating species within a sampling station. By looking to its ecological condition along Bilah river, there is an indication of environmental pressure which limit certain species to thrive in the habitats yet supporting the growth of tolerant or insensitive species.

Interaction between abiotic and biotic factors

A multivariate or CCA analysis was performed on both the abundance and physicochemical data set to illustrate any possible relationship between the spatial distribution of macroinvertebrate species and environmental conditions according to the 8 environmental factors measured in this study (Fig. 5). The first two axes accounted for 56.97% of the variance, with axis 1 for 30.88% of the variance and axis 2 for 25.86% of the variance. Dissolved oxygen, transparency, and pH were negatively correlated with conductivity, C-organics, turbidity, TDS, and water temperature.

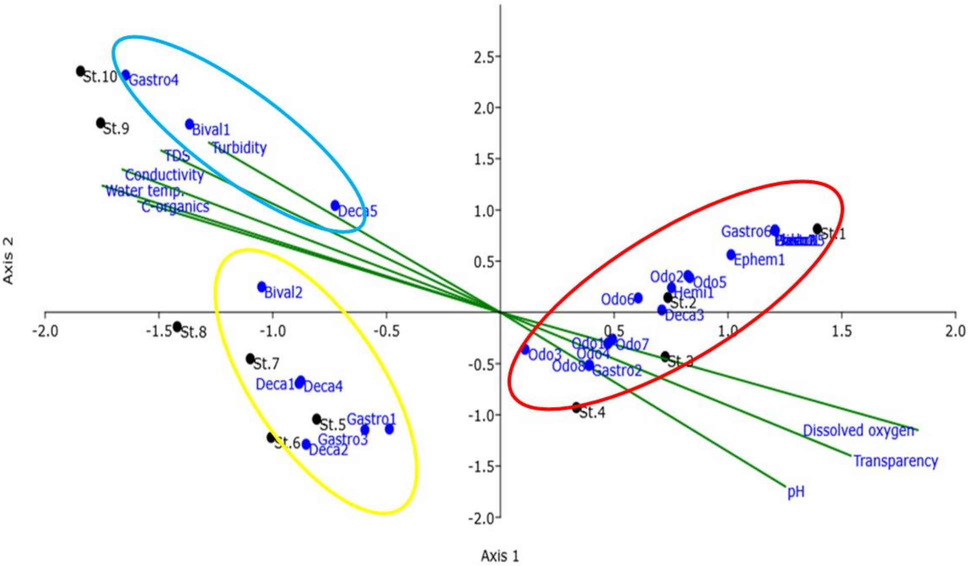

Fig. 5. CCA analysis ordination of environmental variables (green lines) and macrozoobenthos species density data (blue dots) of Bilah River, Labuhanbatu, North Sumatra, Indonesia

The niche from each spesies was presented and grouped closely to the triplot of the environmental factors in respective to its sampling stations. The grouping of macroinvertebrate species with the environmental factors revealed a main accumulation of species in the first and the fourth quadrant, indicating a same niche with the weighted environmental factors (red circle). For example, all Odonata species and common bioindicator insects, e.g Ephem1 (*Heptagenia diabasi*), Pleco1 (*Neoperla* sp.), Pleco2 (*Swelstsa* sp.), Tricho1 (*Chimarra* sp.), were plotted in the first quadrant, indicating a specific preference towards the good environmental conditions. The intermediate environmental conditions were pointed by the grouping of e.g Bival2 (*Corbicula javanica*), Deca1 (*Macrobrachium lepidactyloides*), Gastro1 (*Brotia testudinaria*), etc in yellow circle. Meanwhile, the most suitable environmental factors in contrary to the major macroinvertebrate assemblage were in position with the Bival1 (*Corbicula fluminea*), Gastro4 (*Pleurocera canaliculata*), and Deca5 (*Parathelphusa convexa*), indicating their preference towards the poor environmental conditions (blue circle). Regarding the possible relationship between sampling stations and environmental variables, respective station 1 and 2 were plotted in the first quadrant while station 3 and 4 in the fourth quadrant. Station 5, 6, 7, and 8 were uniformly plotted in the third quadrant while the pair of station 9 and 10 was exclusively plotted in the second quadrant.

Studies on the macroinvertebrates in Bilah River, showed the evidence of direct anthropogenic modifications and disturbances to the riverside. The gradient in trophic status from each sampling stations were affecting the existence of certain macroinvertebrate species. Temperature play role in maintaining the metabolic rate of an aquatic organism, the higher the value the more oxygen consumption by the species. The effect may be detrimental if increased for an extended period of time [20]. However, the rising temperature from the upstream to downstream still indicate the normal condition of a freshwater ecosystem. Transparency is strongly related to the inland or sediment deposit and the depth of a river. The turbidity and TDS are linearly coherent with an increasing value from upstream to dowsntream of the river. The environmental factors may have an effect to the photosynthetic capacity by the phytoplankton and macrophytes in which the higher the value, the lower oxygen production in the stream [21].

Most insects have limited tolerances against high turbidity which explain the absence of certain taxa in our study, especially from Ephemeroptera, Plecoptera, and Trichoptera. Based on our study, notable bioindicator taxa may be proposed for future biomonitoring purpose by considering the favorable environmental conditions as showed from the multivariate analyses. The pH was relatively consistent in this study while DO was observed to decrease along the stream of Bilah River. The oxygen depletion may be the consequences of human disturbance to the insufficient sunlight for the photosynthetic agents, leading to disruption of oxygen exchange in the waterbodies [22].

C-organics content is an important source of foods for the benthic macrofauna in which the overavailability may lead to a reduced biodiversity and species richness. The present study revealed that the most tolerant macroinvertebrate taxa existed the downstream of Bilah River were dominated by the Decapoda, Bivalvia, and Gastropoda. The taxa have been regarded as pollution-tolerant group which commonly used as bioindicator in moderate to heavy-contaminated sites [23, 24]. The high organic content in the sediment will cause oxygen depletion and accumulation of toxin by-products (ammonia and sulphide), which threaten the life of an aquatic organism [25].

Three major taxa found in this study were Odonata, Decapoda, and Bivalvia with the considerable high abundance in Bilah River. Odonata is the most speciose group found in this study with the genera e.g *Aphylla, Argia, Calopteryx, Ceriagrion, Epicordulia, Gomphus, Macrodiplax*, and *Macromia*. The Odonata assemblage contributed to the highest diversity index from station 1 to 7 in this study. Odonata is known an intermediate insect group, capable of living in the moderate polluted level of aquatic habitats. The group can survive in waters contaminated with organic matters while the tolerance may differ across species [26]. Furthermore, Odonata larvae may incorporate some heavy metals in their bodies as an indication of pollution from industrial waste in wetlands [27].

Decapoda is the second abundant group in this study with the genera found e.g *Macrobrachium*, *Palaemonetes*, and *Parathelphusa*. The Decapoda species may also be a suitable bioindicator in our study as previously reported. Three species of *Macrobrachium,* namely *M. formosense, M. japonicum,* and *M. australe* were more easily found in the upstream of Tanshui River, China with dominant species of *M. aspcrulum* [28]. In addition, the species *P. australis* was able to tolerate the polycyclic aromatic hydrocarbon and other xenobiotics [29]. Furthermore, *P. argentinus* was monitored *in situ* at Ctalamochita River Basin, revealing its tolerance to pollutant mixture of heavy metals and may adjust its presence based on the abiotic changes in the environment [30].

Bivalvia is the most abundant group commonly in the heavy polluted sites during a biomonitoring study. Some species are also attributed directly to the ecosystem health concering the density at that contaminated sites. In our study we only found a genus, namely *Corbicula* which have been reported as filter-feeder and notable bioindicator in freshwater environments [31]. The bivalvian species, *Corbicula fluminea* was also reported being able to withstand the hypoxia condition and high temperature due to its adjusted physiological condition [32]. To date, the species *C. fluminea* is promoted as a widely used bioindicator species in identification and assessment of freshwater toxicity, ranging from ammonia, metal ions, and organic pollutants [33]. The occurrence of both bivalvian species in this study ensured that the downstream stations were relatively polluted by the human disturbances along the Bilah River. The clam species are then known to rapidly colonize the contaminated sites due to its high tolerance to toxic substances.

In generic terms, the diversity indices may be used to indicate the environmental conditions of a habitat. The lowest to moderate diversity of aquatic organisms depicted from its diversity index may indicate the pollution and disturbances in the environment. A moderate pollution was identified to the majority of sampling stations ($1<H'<3$) while only station 9 showed an indication of high pollution ($H'<1$). Wilhm and Dorris set the highest threshold of diversity ($H'>4$) which indicate a healthy or unpolluted water bodies [34]. The accompanying evenness index indicate the unequal distribution of individuals within a species. The higher value of Simpson's index may indicate the increase in pollution load by the increasing number of tolerant individuals among species towards the rising level of pollution in certain sites [35].

Data of species abundances and environmental factos were processed through Canonical Correspondence Analysis (CCA) with the advantages of readily graphical presentation, where species and environmental factors being plotted to two axis based on the ordination [36]. As confirmed from the CCA, all of the 27 macroinvertebrate species recorded in this study had a preference towards at least one of the environmental conditions. The sampling station 1–4, representing a moderately polluted habitat with supporting environmental factors such as transparency, pH, and dissolved oxygen. At least 10 species occurred with the highest abundances, whereby the specialized species to those sites are *Aphylla angustifolia*, *Argia* sp., *Calopteryx aequabilis*, *Chimarra* sp., *Epicordulia princeps*, *Gomphus* sp. *Melanoides tuberculata*, and *Palaemonetes convexa.* Most of the abundant macroinvertebrate species are known as bioindicators of mild to good environmental conditions. The sampling station 5–8, representing the progressive lower quality of water bodies, were inhabited abundantly by at least 6 macroinvertebrate species, such as *Brotia testudinaria*, *Calopterys aquabilis*, *Corbicula javanica*, *Melanoides tuberculata*, *Palaemonetes convexa*, and *Physa gyrina*. Lastly, the station 9 and 10 representing the worst water quality dominated by the abundant *Corbicula fluminea* and *C. javanica*. By looking to our result, future considerations may be made during an restoration attempt in Bilah River, especially by monitoring the abundant and native macroinvertebrate species which lived in the poor environmental gradients or the downstream part of the river. Local monitoring in other freshwater region of North Sumatra is also required since there are still many unreported impacts of human population to the natural state of the rivers as revealed in previous study [37].

Conclusions

Based on the diversity index, all sampling stations were regarded as moderate to highly polluted habitats. The habitat characteristics of 10 sampling stations representing the actual conditions in Bilah River, was clustered into 3 clusters based on CCA or multivariate analysis. The upstream, belonging to station 1-4 shows a highly abundant of bioindicator macroinvertebrate species (Odonata, Ephemeroptera, Plecoptera, and Trichoptera), station 5-10 shows a species distribution among orders Gastropoda, Decapoda, and Bivalvia with the poorest water quality in station 9. The downstream stations were characterized by the increasing turbidity, TDS, and a reduced dissolved oxygen. The Bilah River is then affected by the anthropogenic activities such as the sand-mining and other activities.

References

[1] J. Heisler, P.M. Glibert, J.M. Burkholder, D.M. Anderson, W. Cochlan, W.C. Dennison, Q. Dortch, C.J. Gobler, E. Humphries, A. Lewitus, R. Magnien, H.G. Marshall, K. Sellner, D.A. Stockwell, D.K. Stoecker, M. Suddleson, *Eutrophication and harmful algal blooms: a scientific consensus*, **Harmful Algae, 8**(1), 2008, pp. 3-13.

[2] V.H. Smith, S.B. Joye, R.W. Howarth, *Eutrophication of freshwater and marine ecosystems*, **Limnology and Oceanography, 51**, 2006, pp. 351-355.

[3] Y. Lu, H. Xu, Y. Wang, Y. Yang, *Evaluation of water environmental carrying capacity of city in Huaihe River Basin based on the AHP method: a case in Huai'an city*, **Water Resources and Industry, 18**, 2017, pp. 71-77.

[4] M.C. Acreman, A.J.D. Ferguson, *Environmental flows and the European Water Framework Directive,* **Freshwater Biology, 55**, 2010, pp. 32-48.

[5] T. Garg, S.E. Hamilton, J.P. Hochard, E.P. Kresch, J. Talbot, *(Not so) gently down the stream: river pollution and health in Indonesia,* **Journal of Environmental Economics and Management, 92**, 2018, pp. 35-53.

[6] B.A. Badea, A. Gagyi-Palffy, L.C. Stoian, G. Stan, *Preliminary studies of quality assessment of aquatic environments from Cluj suburban areas, based on some invertebrates bioindicators and chemical indicators*, **AACL Bioflux, 3**(1), 2010, pp. 35-41.

[7] K. Kubosova, K. Brabec, J. Jarkovsky, V. Syrovatka, *Selection of indicative taxa for river habitats: a case study on benthic macroinvertebrates using indicator species analysis and the random forest methods*, **Hydrobiologia, 651**, 2010, pp. 101-114.

[8] J.C. Morse, Y.J. Bae, G. Munkhjargal, N. Sangpradub, K. Tanida, T.S. Vshivkova, B. Wang, L. Yang, C.M. Yule, *Freshwater biomonitoring with macroinvertebrates in East Asia*, **Frontiers in Ecology and the Environment, 5**(1), 2007, pp. 33-42.

[9] R.C. Sharma, J.S. Rawat, *Monitoring of aquatic macroinvertebrates as bioindicator for assessing the health of wetlands: a case study in the Central Himalaya, India*, **Ecological Indicators, 9**, 2009, pp. 118-128.

[10] K. Sirisinthuwanich, N. Sangpradub, C. Hanjavanit, *Development of biotic index to assess the Phong and Cheon Rivers' healths based on benthic macroinvertebrates in Northeastern Thailand*, **AACL Bioflux, 9**(3), 2016, pp. 680-694.

[11] A. Harahap, T.A. Barus, M.B. Mulya, S. Ilyas, *Macrozoobenthos diversity as bioindicator of water quality in the Bilah River, Rantauprapat*, **Journal of Physics: Conference Series, 1116**(5), 2018, Article Number: 052026.

[12] J.W.S.S. van Benthem, *Systematic studies on the non-marine Mollusca of the Indo-Australian archipelago, IV, Critical revision of the freshwater bivalves of Java*, **Treubia, 22**, 1953, pp. 19-73.

[13] J.W.S.S. van Benthem, *Systematic studies on the non-marine Mollusca of the Indo-Australian archipelago, V, Critical revision of the Javanese freshwater gastropoda*, **Treubia, 23**, 1956, pp. 259-477.

[14] W.T. Edmondson, **Fresh-water Biology**, John Wiley & Sons, Inc., New York, 1959.

[15] R.W. Pennak, **Fresh-water Invertebrates of United States**, John Wiley & Sons, Inc., New York, 1978.

[16] R.T. Abbott, S.P. Dance, **Compendium of Seashells: A Full-color Guide to More Than 4,200 of the World's Marine Shells**, E. P. Dutton, United States, 1982.

[17] W.L. Kovach, **MVSP – A Multivariate Statistical Package for Windows, ver. 3.1**., Kovach Computing Service, Wales, 2007.

[18] K.R. Clarke, *Non-parametric multivariate analyses of changes in community structure*, **Austral Ecology, 18**, 1993, pp. 117-143.

[19] Ø. Hammer, D.A.T. Harper, P.D. Ryan, *PAST: Paleontological Statistics Software Package for education and data analysis*, **Paleontologia Electronica 4**(1), 2001, pp. 1-9.

[20] J. Hellawell, **Biological Indicators of Freshwater Pollution and Environmental Management**, Elsevier Applied Sciences, London, 1986.

[21] W. Teng, W. Guoxiang, L. Qiang, *Effects of water turbidity on the photosynthetic characteristics of Myriophyllum spicatum,* **Asian Journal of Plant Sciences, 6**, 2007, pp. 773-780.

[22] J.M. Schurr, J. Ruchti, *Kinetics of oxygen exchange, photosynthesis, and respiration in rivers determined from time-delayed correlations between sunlight and dissolved oxygen,* **Schweizerische Zeitschrift für Hydrologie, 37**, 1975, pp. 144-174.

[23] J.F. Elder, J.J. Collins, *Freshwater molluscs as indicators of bioavailability and toxicity of metals in surface-water systems,* **Reviews of Environmental Contamination and Toxicology, 122**, 1991, pp. 37-39.

[24] F.J. Correa-Araneda, A. Contreras, P.D.L. Rios, *Amphipoda and Decapoda as potential bioindicators of water quality in an urban stream (38°S, Temuco, Chile),* **Crustaceana, 83**(8), 2010, pp. 897-902.

[25] J.L. Hyland, L. Balthis, I. Karakassis, P. Magni, A. Petrov, J.P. Shine, O. Vestergaard, R.M. Warwick, *Organic carbon content of sediments as an indicator of stress in the marine benthos,* **Marine Ecology Progress Series, 295**, 2005, pp. 91-103.

[26] F. Patang, A. Soegianto, S. Hariyanto, *Benthic macroinvertebrates diversity as bioindicator of water quality of some rivers in East Kalimantan Indonesia*, **International Journal of Ecology, 2018**, 2018, pp. 1-12.

[27] H. Nasirian, K.N. Irvine, *Odonata larvae as a bioindicator of metal contamination in aquatic environments: Application to ecologically important wetlands in Iran,* **Environmental Monitoring and Assessment, 189**(436), 2017, pp. 1-18.

[28] S.S. Young, H.N. Yang, D.J. Huang, S.M. Liu, Y.H. Huang, C.T. Chiang, J.W. Liu, *Using benthic macroinvertebrate and fish communities as bioindicators of the Tanshui River Basin around the greater Taipei Area – Multivariate analysis of spatial variation related to levels of water pollution,* **International Journal of Environmental Research and Public Health, 11**(7), 2014, pp. 7116-7143.

[29] D. Webb, *Freshwater shrimp (Palaemonetes australis) as a potential bioindicator of crustacean health,* **Environmental Monitoring and Assessment, 178**, 2010, pp. 537-544.

[30] L. Bertrand, M.V. Monferran, C. Mouneyrac, M.V. Ame, *Native crustacean species as a bioindicator of freshwater ecosystem pollution: A multivariate and integrative study of multi-biomarker response in active river monitoring,* **Chemosphere, 206**, 2018, pp. 265-277.

[31] F.G. Doherty, *The Asiatic clam, Corbicula spp. as a biological monitor in freshwater environments,* **Environmental Monitoring and Assessment, 15**, 1990, pp. 143-181.

[32] P.D. Johnson, R.F. McMahon, *Effects of temperature and chronic hypoxia on survivorship of the zebra mussel (Dresseina polymorpha) and Asian clam (Corbicula flumniea),* **Canadian Journal of Fisheries and Aquatic Sciences, 55**, 1998, pp. 1564-1572.

[33] X. Guo, C. Feng, *Biological toxicity response of Asian clam (Corbicula fluminea) to pollutants in surface water and sediment,* **Science of the Total Environmenet**, **631-632**, 2018, pp. 56-70.

[34] J.L. Wilhm, T.C. Dorris, *Biological parameters of water quality criteria,* **BioScience, 18**, 1968, pp. 477-481.

[35] B. Padmanabha, S.L. Belagali, *Diversity indices of rotifers for the assessment of pollution in the lakes of Mysore city, India*, **Pollution Research**, **26**(1), 2007, pp. 65-68.
[36] C.J.F. Ter Braak, *Canonical community ordination. Part I. Basic theory and linear methods*, **Écoscience, 1**(2), 1994, pp. 127-140.
[37] A. Harahap, P. Hrp, N.K.A.R. Dewi, *Macrozoobenthos diversity as anbioindicator of the water quality in the Sungai Kualuh Labuhanbatu Utara*, **International Journal of Scientific & Technology Research, 9**(4), 2020, pp. 179-183.

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