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Bioassessment of river water pollution using benthic macroinvertebrates as bioindicators

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Abstract. Benthic macroinvertebrates are indicators that provide an integrated assessment of the health of water bodies and potentially identify water quality deterioration prior to detection by physicochemistry. The research was caried out using a survey method by sampling the macroinvertebrates that lived around the watershed. The sampling was performed by kicking and jabbing techniques. The obtained macroinvertebrate samples were sorted and stored for identification and evaluation of the types of macroinvertebrate, habitats, and the quality and pollution level of water using the Family Biotic Index. The results showed that the types of macroinvertebrates that were found consisted of 21 species including Sericosmatidae, Lepidasmatidae, Glossosomatidae, Psychomydiidae, Perlidae, Perladidae, Gomphidae, Lepthoblebiidae, Caenidae, Heptageniidae, Elmidae, Simuliidae, Tipulidae, Chironomous thummiplusmosus, Baetidae, Sphaeriidae, Planariidae, Glossiphoniidae, Nereidae, Physidae, and Lymnaeidae. The Family Biotic Index (FBI) and the Biological Monitoring Working Party (BMWP) scores were 4.75 and 88, respectively. To conclude, the watershed contained slight organic pollution with a medium level of pollution.

1. Introduction

Rivers are open ecosystems that can receive streams or water catchments to affect water quality and those living in the river. The river water quality is influenced by the water supply quality from the catchment area, while the water supply quality from the catchment area is related to its human activities [1]. Various types of river utilization activities, such as agriculture, household needs, and industries can make river water has a very strategic role in the lives of humans and other living things. The river water environment consists of abiotic and biotic components that interact through the nutrient cycle and energy flow [2]. If the interaction between the two is disrupted, a change will occur that causes the aquatic ecosystem to become unbalanced [3].

The river has dynamic properties, but the utilization can potentially reduce the value of the benefits of the river itself and create other impacts that can endanger the environment widely. This change can reduce the important materials in the water so that it disturbs the aquatic ecosystem. Disposal of garbage into river bodies can cause changes and damage, both directly and indirectly, to these resources. The direct consequences include the death of fish in rivers, damage to agriculture and fisheries around landfills, or change in the color of river water handled that cannot be used for human needs. The indirect result is damage to river ecosystems, such as the decline in productivity and diversity of aquatic indicator species. For the large species richness or health of the ecosystem, the indicator species can be used as an indirect measurement [4]. In tropical countries, benthic macroinvertebrates are closely related to the water quality degradation in which their community diversity is in line with the polluted aquatic environment [5]. The benthic can identify the cause of water quality deterioration in streams [6].

Globally, the abundance and diversity of aquatic macroinvertebrates have been used to determine the ecological condition of river bodies [7]. Benthic macroinvertebrate is one of the best biological water quality indicators [8] because of its resistance to the ecological variability [9]. Benthic could monitor the problem in the ecosystem through behavioral or physiological processes. It could also recognize pollutants in an ecosystem and the extent to which the problem may exist [10]. Hence, Some kinds of benthic macroinvertebrates can be used as organic pollution indicators. The advantage of using benthic macroinvertebrates as pollution indicators is due to their long-lives, which are settled in a particular area and have limited mobility [5] so that their presence is very sensitive to exposure to pollutants [11]. In this study, water quality testing was carried out in Coban Sewu watershed, Batu City, to analyze the diversity of benthic macroinvertebrate species and water quality in the watershed. The purpose of this study was to study the macroinvertebrate species lived in Coban Sewu watershed and to analyze the quality of its watershed.

2. Materials and methods

2.1. Study site

Coban Sewu watershed is in Bendosari Village, Pujon District, Malang Regency, with the coordinates of 7^{o} 51' 59.01" S; 112^{o} 25' 24.04"E and an altitude of 874 m above sea level. The watershed is in a rural area. Based on the structural geology, the location was a fracture that becomes a waterfall. The fracture was indicated by the presence of upright cliffs and scratches on the wall allegedly that the fracture occurred was a normal fracture.

2.2. Macroinvertebrate sampling

The bioassessment was conducted in Coban Sewu watershed in January 2017. This research was implemented based on a study methodology for the results of monitoring of Coban Sewu watershed. The sampling of macroinvertebrates was done using a purposive random sampling method. This sampling was performed using the kicking and jabbing method (Figure 1a).

The sampling tools included D-net (500 µm mesh), a sample bottle, tweezers, a white tray, a sieve bucket (0.5 mm mesh), a label sheet, and a waterproof marker pen. Meanwhile, the laboratory analysis tools included a petri dish, a microscope, and 96% alcohol. The data collection procedures were divided into two stages. The first was the macroinvertebrates sampling at the field, and the second was the macroinvertebrates identification in the laboratory.

The macroinvertebrates sampling was conducted based on Stark *et al*. [12]. The sampling procedure began at the downstream end and continued to the upstream. The natural flow area of the substrate was selected because it would point organisms into the D-net. When sampling, the D-net was held in the direction against the water current and placed on the streambed. After stepping into the sampling area, the substrate under the feet was disturbed by kicking to release the organism from the bottom of the water, the gravel, and the cobbles. Afterward, the D-net was jabbed into the bottom of the watershed to collect organisms near the bottom and to further disturb the macroinvertebrates. The disturbed area should extend no further than 0.5 meters upstream from the net. The material from the D-net should be removed into the white tray if the D-net had begun to be clogged (Figure 1b). This treatment was repeated at several different locations within a 50 m stream reach and covered a total area of riffle habitat. The D-net was turned outward to move the sample into the sample container. Any unwanted leaves, sticks, and stones were removed that might not fit into the sample container or would reduce the effectiveness of the preservative (Figure 1c). The organisms were transferred to a half full of water in a white tray as the sample container

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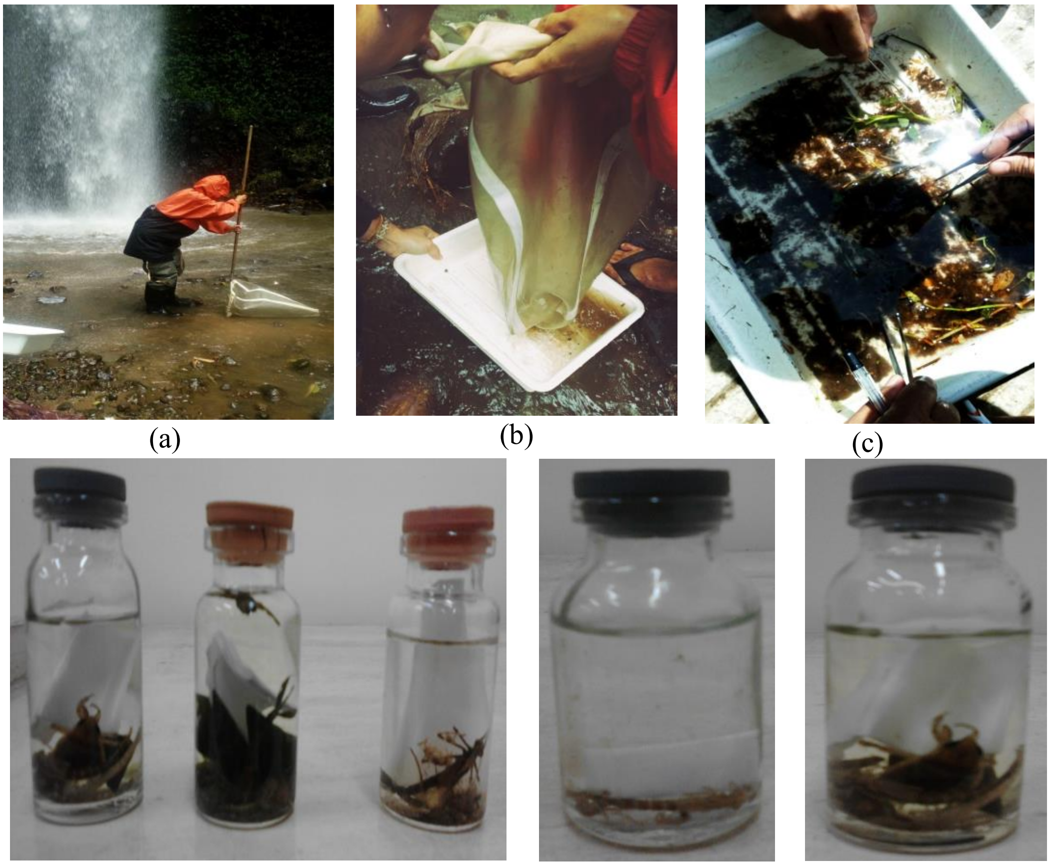
(Figure 1d). The side of the sample bottle was stuck by a sticker that recorded the replicate number, date, and code/name. The macroinvertebrates were preserved using 96% alcohol.



(d)

Figure 1. (a) Kicking and jabbing method; (b) transferring the material from the D-net into the white tray; (c) removal of unwanted material; (d) macroinvertebrates.

2.3. Water quality assessment

Measurement of the water quality assessment was carried out by Family Biotic Index determination, Biological Monitoring Working Party-Scoring System, and water acidity measurement.

2.3.1. Family Biotic Index determination. The assessment of the water was done by using Family Biotic Index (FBI). Biotic indices are based on the idea of pollution tolerance for various benthic. Firstly, the FBI was calculated to determine the score of organisms' pollution tolerance in a sample. The score of family degree pollution tolerance was taken from Hilsenhoff [13]. Secondly, in a given family, the number of organisms were multiplied by the tolerance score for that family. The sum of the product in a sample was then added and divided by the number of organisms within the sample, resulting in THEFBI. The FBI resulted in numerical scores to a specific indicator organisms at a particular taxonomic level. The formula of FBI is shown below:

$$\mathrm{FBI} = \frac{\sum x_i . t_i}{n}$$

(1)

where:

xi = number of individual within a species

ti = tolerance value of species

n = total number of organisms in the sample

Besides, the degree of the water quality is presented in Table 1.

Table 1. Degree of water quality.

Family biotic index	Water quality	Degree of organic pollution
0.00 – 3.75	Excellent	Organic pollution is unlikely
3.76 – 4.25	Very good	Possible for slight organic pollution
4.26 – 5.00	Good	Possible for some organic pollution
5.01 – 5.75	Fair	Substantial pollution is fairly likely
5.76 – 6.50	Fairly poor	Substantial pollution is likely
6.50 – 7.25	Poor	Substantial pollution is very likely
7.26 – 10.00	Very poor	Severe substantial pollution is likely

Source: Hilsenhoff [11]

2.3.2. The scoring system of macroinvertebrates. The macroinvertebrate assessment system for evaluating water quality in Coban Sewu watershed used the Biological Monitoring Working Party-Score System (BMWP) [14]. The BMWP is an index that requires a limited taxonomic precision, effective, and efficient because it was simple and easy to use. It is a procedure used to measure water quality by using a macroinvertebrate as a biological indicator. This method is based on the principle that aquatic invertebrates are different, and they have different tolerance for pollutants. Because of the huge number of taxa, Alba-Tercedor [15] modified Hellawell's BMWP and preserved the original scores. The total score of BMWP was the sum of all scores of each taxon in the study site based on order or family (Table 2). Moreover, taxa that were not included in the Alba-Tercedor [15] would be put a score of 1 [16], and the taxa which were included in Alba-Tercedor [15] table would be put a score based on Table 3.

Table 2. Interpretation of BMWP.

Class	Score of BMWP	Category	Interpretation
	>150	Very good	Very clean water
I	101 – 149	Good	Clean or not significantly altered
II	61 – 100	Questionable	Clean but slightly impacted
III	36 – 60	Moderate	Moderately impacted
IV	16 – 35	Poor	Polluted
V	0 – 15	Very poor	Heavily polluted

Source: Alba-Tercedor [13]

Table 3. Taxa scores of BMWP.

Taxa	Score
Trichoptera: Sericostomatidae, Odontoceridae, Leptoceridae, Brachycentridae **Plecoptera:** Perlidae **Ephemeroptera:** Leptohyphidae, Leptophlebiidae	10
Trichoptera: Psychomyiidae, Philopotamidae, Glossomatidae, Calamoceratidae **Odonata:** Libellulidae, Gomphidae, Cordulegastridae, Calopterygidae, Coenagrionidae	8
Trichoptera: Polycentropodidae **Plecoptera:** Nemouridae	7
Trichoptera: Hydroptilidae, Hydrobiosidae Crustacea	6
Trichoptera: Hydropsychidae, Helichopsychidae, **Ephemeroptera:** Polymitarcidae Platelminthes, Euthyplociidae	5

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Diptera: Tipulidae, Simuliidae **Coleoptera:** Dryopidae, Elmidae	
Megaloptera: Sialidae, Corydalidae **Ephemeroptera:** Caenidae, Baetidae **Diptera:** Tabanidae, Stratiomyidae, Psychodidae, Limoniidae, Empididae, Dolichopodidae, Dixidae, Chaoboridae, Ceratopogonidae, Anthomyidae **Coleoptera:** Haliplidae, Curculionidae, Chrysomelidae **Arachnida:** Hidracarina	4
Mollusca **Hemiptera:** Vellidae, Pleidae, Notocectidae, Nepidae, Mesovellidae, Naucoridae, Limnocoridae, Hydrometridae, Gerridae, Corixidae, Belostomatidae **Coleoptera:** Notoridae, Hydrophilidae, Helodidae, Gyrinidae, Dytiscidae **Annelida:** Hirudínea	3
Diptera: Thaumaleidae, Muscidae, Ephydridae, Culicidae, Chironomidae	2
Lepidoptera **Diptera:** Sciomyzidae, Syrphidae, Thagionidae **Blattaria:** Blattidae **Annelida:** Oligochaeta	1

Source: Alba-Tercedor [13]

In Indonesia the use of the biotic index to assess water quality was still very limited. Trihadiningrum and Tjondronegoro [17] have succeeded in compiling a classification of macroinvertebrates based on the pollution loads. Biota grouping was based on the highest species abundance found at certain water quality levels. On that basis river, water quality could be divided into 6 pollution levels as shown in Table 4.

Table 4. Indicator of macroinvertebrate pollution level.

Pollution level	Macroinvertebrate indicator
I. Healthy (not polluted)	Planaria, Trichoptera (Glossosomatidae, Lepidosmatidae Sericosmatidae)
II. Fair (polluted)	Coleoptera (Elminthidae), Odonanta (Aeshnidae, Agriidae, Olarycbenatidae, Gomphidae), Trichoptera (Psychomydae, Hydropschydae), Ephemeroptera (Caebidae, Ecdyonuridae, Pseudocloeon, Leptophlebiidae), Plecoptera (Peleididae, Perlidae)
III. Fairly poor (polluted)	Odonanta (Cordulidae, Libellulidae), Crustacea (Gammaridae), Mollusca (Bivalvia, Pulmonata)
IV. Polluted	Hemiptera, Hirudinea (Hirudidae, Glossiphonidae)
V. Poor (polluted)	Syrphidae, Diptera (Chiromonus thummiplumosus), Oligochaeta (ubificidae)
VI. Very poor (polluted)	There were no macroinvertebrates, very tolerant of organic waste which were found on the water surface

Source: Trihadiningrum and Tjondronegoro [17]

3. Results and discussion

The water quality assessment used macroinvertebrates indicators, mainly based on macrobenthic animals, like larvae, insects, worms, and some other types of soft animals that live at the bottom of the waters. From the study result, the macroinvertebrates in Coban Sewu watershed could be identified for 6 classes (Insecta, Mollusca, Rhabditophora, Hirudinea, Polychaeta, and Gastropoda), 12 orders (Trichoptera, Plecoptera, Odonata, Ephemeroptera, Coleoptera, Diptera, Ephemeroptera, Veneroida, Planaria, Rhincobdelae, Phyllodocidae, and Bassomatophora), and 21 families as shown in Table 5. Of the 21 families, the insects had the highest abundance. Sericosmatidae, Lepidasmatidae, and Glossosomatidae are insects that live in a healthy watershed, while Chironomous thummiplusmosus and Baetidae are insects that cause pollution [17].

Based on the macroinvertebrate families, the FBI calculation resulted in a value of 4.75 which means that Coban Sewu watershed was in a quite good category that contained slight organic pollution with a medium level of pollution. The dominance order of Trichoptera and Diptera in the watershed was an early signal of an increase in waste input of anthropogenic to the waters [18]. It reflected that the form of domestic and agricultural waste [19] and the human activities along the watershed caused disturbance [20]. The BMWP macroinvertebrate scoring at Coban Sewu watershed is shown in Table 6, whereas the water quality assessment based on Trihadiningrum & Tjondronegoro [17] is shown in Table 7.

Table 5. The macroinvertebrate community in Coban Sewu watershed.

Class	Order	Family
Insecta	Trichoptera	Sericosmatidae, Lepidasmatidae, Glossosomatidae, Psychomydiidae
	Plecoptera	Perlidae, Perladidae
	Odonata	Gomphidae
	Ephemeroptera	Lepthoblebiidae, Caenidae, Heptageniidae
	Coleoptera	Elmidae
	Diptera	Simuliidae, Tipulidae, Chironomous thummiplusmosus
	Ephemeroptera	Baetidae
Mollusca	Veneroida	Sphaeriidae
Rhabditophora	Planaria	Planariidae
Hirudinea	Rhincobdelae	Glossiphoniidae
Polychaeta	Phyllodocidae	Nereidae
Gastropoda	Bassomatophora	Physidae, Lymnaeidae

Table 6. The macroinvertebrate scoring at Coban Sewu watershed.

Macroinvertebrate (order:family)	Score
Trichoptera: Sericosmatidae	10
Trichoptera: Lepidasmatidae	1
Trichoptera: Glossosomatidae	8
Trichoptera: Psychomydiidae	8
Plecoptera: Perlidae	10
Plecoptera: Perladidae	1
Odonata: Gomphidae	8
Ephemeroptera: Lepthoblebiidae	10
Ephemeroptera: Caenidae	4
Ephemeroptera: Heptageniidae	1
Coleoptera: Elmidae	5
Diptera: Simuliidae	5
Diptera: Tipulidae	5

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Diptera: Chironomous thummiplusmosus	2
Ephemeroptera: Baetidae	4
Veneroida: Sphaeriidae	1
Planaria: Planariidae	1
Rhincobdelae: Glossiphoniidae	1
Phyllodocidae: Nereidae	1
Bassomatophora: Physidae	1
Bassomatophora: Lymnaeidae	1
Total	88

The determination of organic content in the ecosystem was calculated by the BMWP score. Based on Table 6, the BMWP score in this study was 88. In line with the FBI, it showed that the watershed was clean but slightly impacted (questionable category). Pollution in this level was organic content pollution, which was possible caused by the side by side location with agricultural activities and forest [21] and the disposal of household waste. The existence of agricultural practices has a very strong influence on macroinvertebrate diversity. Water from the agricultural land that flew through this river allowed organic pollution to occur. But this still requires further research on how agricultural land contributes to this organic pollution. The lower the BMPW score, the lower is the level of sensitivity of macroinvertebrate to adapt to the environment, and vice versa [22]. In this case, the macroinvertebrate families that caused the most organic pollution were Chironomous thummiplusmosus, Lymnaeidae, Physidae, Nereidae, and Baetidae (Table 7). Chironomidae were very tolerant of organic pollution, settled in tender bottom sediment [23], and had individual resistance to disturbed water conditions [24]. The presence of Chironomidae in the waters indicates human influence on the habitat of the river [25]. Besides, the more Chironomidae populations that are found in the water indicates that there has been organic waste that is released in the river. If the watershed continues to be used by the public without any environmental monitoring, the water quality will have a serious level of pollution.

Table 7. Classification of macroinvertebrates in Coban Sewu watershed.

not polluted	fair	fairly poor	polluted	very poor
Sericosmatidae, Lepidasmatidae, Glossosomatidae, Planariidae	Perlidae, Perladidae, Gomphidae, Psychomydiidae, Lepthoblebiidae, Heptageniidae, Elmidae	Sphaeriidae, Caenidae, Simuliidae, Tipulidae	Glossiphonidae	Chironomous thummiplusmosus, Lymnaeidae, Physidae, Nereidae, Baetidae

In addition, the results of measuring water quality biologically make it possible to monitor all changes in variables related to aquatic life and ecological conditions. It does not require a lot of chemicals so that its application is practical and inexpensive. Wang [26] stated that pH values of <5 and> 9 are unfavorable conditions for most macrobenthos organisms. For macroinvertebrate, the effect of pH is concerned to stress decreasing. Macroinvertebrate diversity decreases slightly when the pH is above six [27]. Based on the measurement, the watershed had an average pH of 7.1. In conclusion, it showed that the watershed was quite normal.

4. Conclusion

The macroinvertebrates lived around Coban Sewu watershed consisted of 6 classes (Insecta, Mollusca, Rhabditophora, Hirudinea, Polychaeta, Gastropoda), 12 orders (Trichoptera, Plecoptera, Odonata, Ephemeroptera, Coleoptera, Diptera, Ephemeroptera, Veneroida, Planaria, Rhincobdelae, Phyllodocidae, and Bassomatophora), and 21 families (Sericosmatidae, Lepidasmatidae, Glossosomatidae, Psychomydiidae, Perlidae, Perladidae, Gomphidae, Lepthoblebiidae, Caenidae, Heptageniidae, Elmidae, Simuliidae, Tipulidae, Chironomous thummiplusmosus, Baetidae, Sphaeriidae, Planariidae, Glossiphoniidae, Nereidae, Physidae, and Lymnaeidae). The Family

Biotic Index (FBI) was 4.75, meaning that Coban Sewu watershed contained slight organic pollution with a medium level of pollution. The Biological Monitoring Working Party (BMWP) score was 88, meaning that it was clean but slightly impacted (questionable category). Last, the macroinvertebrate families that caused the most organic pollution were Chironomous thummiplusmosus, Lymnaeidae, Physidae, Nereidae, and Baetidae.

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References

[1] Hamid A, Bhat S U and Jehangir A 2020 Local determinants influencing stream water quality *Appl. Water Sci.* **10** 24
[2] Park H K, Byeon M S, Choi M J, Yun S H, Jeon N H, You K A and Lee H J 2018 Water quality improvement through the interaction of biotic and abiotic variables within the rhizospheric zone of an artificial floating vegetation Island *J. Freshw. Ecol.* **33(1)** 57-72
[3] Setyobudiarso H and Yuwono E 2018 Analysis of biodiversity and quality of Metro River in Malang City (plankton and bentos bioindicator study) *J. Sci. Appl. Eng.* **1(1)** 1-19
[4] Teillard F *et al.* 2016 *A Review of Indicators and Methods to Assess Biodiversity* (Rome: Livestock Environmental Assessment and Performance (LEAP) Partnership) p 128
[5] Huong N T T, Duc P A and Van Mien P 2017 Changes of benthic macroinvertebrates in Thi Vai River and Cai Mep Estuaries under polluted conditions with industrial wastewater *Geosci. Eng.* **LXIII(2)** 19-25
[6] Kenney M A, Sutton-Grier A E, Smith R F and Gresens S E 2010 Benthic macroinvertebrates as indicators of water quality: The intersection of science and policy *Terr. Arthropod Rev.* **2(2)** 99–128
[7] Edegbene A O, Arimoro F O, Odoh O and Ogidiaka E 2015 Effect of anthropogenicity on the composition and diversity of aquatic insects of a municipal river in North Central Nigeria *Biosci. Res. Today's World* **1(1)** 55-66
[8] Duran M 2006 Monitoring water quality using benthic macroinvertebrates and physicochemical parameters of Behzat Stream in Turkey *Polish J. Environ. Stud.* **15(5)** 709-17
[9] Parmar T K, Rawtani D and Agrawal Y K 2016 Bioindicators: the natural indicator of environmental pollution *Front. Life Sci.* **9**
[10] Hussen A C, Retnaningdyah C L, Hakim L and Soemarno 2019 Evaluation of water quality of Coban Rondo Waterfall based on benthic macroinvertebrates as bioindicator *Resour. Environ.* **9(2)** 27–35
[11] Ojija F and Laizer H 2016 Macro invertebrates as bio indicators of water quality in Nzovwe Stream in Mbeya Tanzania *Int. J. Sci. Technol. Res.* **5(6)** 211-22
[12] Stark J D, Boothroyd I K G, Harding J S, Maxted J R and Scarsbrook M R 2001 *Protocols for Sampling Macroinvertebrates in Wadeable Streams* Sustainable Management Fund Project No. 5103
[13] Hilsenhoff W L 1988 Rapid field assessment of organic pollution with a family-level biotic index *J. North Am. Benthol. Soc.* **7(1)** 65-68
[14] Hellawell J M 1978 *Biological Surveillance of Rivers* (London: Water Research Centre. Medmenham and Stevenage) p 332
[15] Alba-Tercedor J 1996 Macroinvertebrados acuaticos e calidad de las aguas de los rios in *IV Simposio del Agua en Andalucía (SIAGA '96)* **2** 203-13
[16] Uherek C B and Gouveia F B P 2014 Biological monitoring using macroinvertebrates as bioindicators of water quality of maroaga stream in the Maroaga cave system, Presidente Figueiredo, Amazon, Brazil *Int. J. Ecol.* 1–2
[17] Trihadiningrum Y and Tjondronegoro I 1998 Makroinvertebrata sebagai bioindikator

ISBN : 978-602-53575-1-0

pencemaran badan air tawar di Indonesia: Siapkah kita? *Lingkung. Pembang.* **18(1)** 45-60

[18] Masese F O, Muchiri M, and Raburu P O 2009 Macroinvertebrate assemblages as biological indicators of water quality in the Moiben River, Kenya *African J. Aquat. Sci.* **34(1)** 15-26

[19] Rachman H, Priyono A and Usli D A N Y 2016 Macrozoobenthos as bioindicator of river water quality in Ciliwung Hulu Sub watershed *Media Konserv.* **21(3)** 261-9

[20] Jomo B S, Omondi R, Getabu A and Orwa P 2019 Spatial variation in diversity, distribution, and abundance of macroinvertebrates and their response to physicochemical parameters in River Nyakomisaro, kisii-Kenya *J. Trop. Hydrobiol. Fish.* **1(1)** 023-30

[21] Yu J and Wu J 2018 The Sustainability of agricultural development in China: The agriculture–environment nexus *Sustainability* **10** 1776

[22] Oktariani A, Kusratmoko E and Kuswantoro 2018 Assessment of water quality in cilutung watershed in *E3S Web of Conf.* 3rd Int. Conf. on Energy, Environmental and Information System, ICENIS August 14-15 2018 Semarang, Indonesia vol 73 (France: edpscience) pp 06004

[23] Sirisinthuwanich K, Sangpradub N and Hanjavanit C 2017 Impact of anthropogenic disturbance on benthic macroinvertebrate assemblages in the Phong river, Northeastern Thailand *AACL Bioflux* **10(2)** 421–34

[24] Ferrington L C 2008 Global diversity of non-biting midges (Chironomidae; Insecta-Diptera) in freshwater *Hydrobiologia* **595(1)** 447–55, 2008

[25] Restello R M, Biasi C, De Moraes P F M B, Gabriel G and Hepp L U 2014 Composition and diversity of the Chironomidae in subtropical streams: effects of environmental predictors and temporal analysis *Acta Limnol. Bras.* **26(2)** 215–26

[26] Wang Z, Zhang Z, Zhang J, Zhang Y, Liu H and Yan S 2012 Large-scale utilization of water hyacinth for nutrient removal in Lake Dianchi in China: The effects on the water quality, macrozoobenthos and zooplankton *Chemosphere* **89(10)** 1255–61

[27] Basyuni M, Gultom K, Fitri A, Susetya I E, Wati R, Slamet B, Sulistyono N, Yusriani E, Balke T and Bunting P 2018 Diversity and habitat characteristics of macrozoobenthos in the mangrove forest of Lubuk Kertang Village, North Sumatra, Indonesia *Biodiversitas* **19(1)** 311–17