The use of benthic macroinvertebrate community to evaluate the environment of Cirata Reservoir, in West Java, Indonesia

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Abstract. Macroinvertebrate community reflects the condition of a freshwater ecosystem. This study examined the community structure of macroinvertebrates and the water quality based on the existence of the Family in the Cirata reservoir. Moreover, to understand its response to several environmental variables. Cirata reservoir is a part of the cascade reservoir which has been known significantly loaded with organic material. The data of Environment variables, macroinvertebrates, and sediment samples were collected in November 2017 from five sites of the reservoir. The sites were chosen between floating net cages and the outlet, which the first site was the nearest and the fifth site was the farthest from the cages. Macroinvertebrates were collected and identified based on standard guidance. Ekman grab was used for collecting the sediment samples from the depth of 1.5 to 5 m with three times repetition in each site. The environmental variables including pH, dissolved oxygen (DO), turbidity, total dissolved solid, oxidation-reduction potential, and conductivity were recorded on the spot using Water Quality Checker. Meanwhile, Total Organic Matter (TOM) of sediment were analysed in Research Center for Limnology LIPI. The relationship between environmental variables and macroinvertebrate were evaluated using Canonical Correspondence Analysis (CCA). Eighteen taxa comprising four orders were identified. The community is grouped into four categories, Chironomids (81.65%), Non-Chironomids (Culliculidae, Odonata) (1.01%), Gastropods (4.13%), and Annelids (13.21%). The finding shows that polluted-tolerant groups are dominantly found in Cirata which consists of Chironomids and Annelids. Moreover, the diversity of macroinvertebrate was ranged moderate to low between 1.75 to 3.282. While the abundance ranged between 600 to 1889 ind/m2 in each site. However, the ordination of CCA described that TOM tended to be related to the existence of the non-Chironomids group, On the contrary, other parameters such as pH, DO, and temperature influenced the presence of the Chironomids, Annelids (worm), and Gastropods.

1. Introduction
Several pollutants have polluted Cirata Reservoir. One of the major causes of this problem comes from the fishery activity. The reservoir has been used as Fishery (floating net cage system) since 1988 [1]. The amount of floating net cages increased rapidly in the last decade. It was around 3000 units in 1988, and then it rose significantly to 51,000 units in 2008, 77,000 units in 2014 [2], then 98,000 in 2018 [3]. The residues that were dumped from this activity are around 325,712 tons in 2007 [2]. It dropped the water quality of Cirata Reservoir. It impacted the ecosystem, including benthic invertebrate that lives in the bottom of the reservoir. Benthic macroinvertebrate community is a
bioindicator for freshwater ecosystems to confer the ecosystem condition. Some of them have been known as a tolerant group, such as worms (Tubificid) and Chironomid which tolerant to the low concentration of dissolved oxygen (1-2 mg/L for Tubificid and 2-3 mg/L for Chironomids) [4].

On the other hand, a problem comes from sedimentation. The volume of sediment in Cirata was around 14,000 x 10^6 m^3 in 2000, and then it rose to 80,000 x 10^6 m^3 in 2007. Cirata has been loaded by suspended sediment 2.32 – 2169 mg/L from several inlets, for example Cimeta River, Cibalagung River, Cikundul River and Cisokan river [5]. Furthermore, an increase of suspended sediment, particularly fine sediment, impacted benthic macroinvertebrates by reduced the abundance, diversity, number of taxa, and biomass which can change the community structure [6]. These also reduced the metabolic rate of the filter feeder group [6].

Cirata reservoir is one part of the cascades reservoir in the Citarum River watershed. The other two are Saguling and Jatiluhur reservoir. It located in West Java. Cirata reservoir has been established since 1988 [7]. Though Cirata has a primary function as a hydroelectricity power plant, this reservoir has also been used for fishery, irrigation, transportation, and tourism. The reservoir covers 603,200 Ha of the catchment area with a volume around 2165 x 10^6 m^3. The depth average is about 34.9 m and the width is about 6200 Ha [8]. Some reports showed that the water quality condition in Cirata reservoir has declined due to the pollutants including heavy metals [9,10]. The stability of oxygen dropped drastically over the 5 m depth, particularly in the zone near to fishery cage [1]. Due to this condition, current condition of Cirata water quality needs to be investigated. Benthic macroinvertebrate community as an indicator that has been applied to measure the degree of pollution by using the Family level of this community. It then can be used to calculate the Family Biotic Index (FBI), which implies the Tolerance value. The water quality will be categorized based on the score of FBI to classify the degree of pollution [4].

Therefore, the objectives of this research aimed to examine the current condition of benthic macroinvertebrates community structure, including abundance, taxa richness, diversity; the responses of the community to environment variables; and to investigate the current status of water quality according to the family level of macroinvertebrate community.

2. Methods
The research in the Cirata reservoir was conducted by survey method in November 2017 (figure 1). The data and the samples including environmental variables, macroinvertebrate samples, and sediment samples were collected from five sites (CR1, CR2, CR3, CR4, CR5) (figure 2). These sites were chosen between floating net cages and the dam, which the first site was the nearest and the fifth site was the farthest from the cages.

Sediment and benthic macroinvertebrate samples were taken using the Ekman grab. Benthic macroinvertebrate samples were taken three times repetition from the depth of 1.5 to 5 m. The composite samples were preserved using a 10% formaldehyde solution for further use. The preserved samples were rinsed, stored in 70% alcohol solution, and then sorted before identified in the Research Center for Limnology LIPI.

The collected macroinvertebrates were examined using NIKON stereo and OLYMPUS binocular microscope. The macroinvertebrate species were identified following, the identification book of Insect [11], Chironomid [12], and Oligochaete [13,15,15]. Ecological analysis of benthic macroinvertebrates includes taxa richness, abundance, diversity index, and evenness index [4]. The diversity index and the evenness index were calculated by MVSP software 3.22. Family Biotic Index (FBI) of Macroinvertebrates is used to describe the water quality condition. FBI has been known for years as rapid assessment of organic pollution. FBI was calculated by multiplying the tolerance value of each family or higher taxa of, summing the products, and dividing by the total of samples that were founded during sampling [16]. Furthermore, FBI values are used to determine the water quality and the degree of pollution based on Hilsenhoff (1988) classification. FBI can be calculated by using the equation (1) [4].
\[ FBI = \frac{ni \times T}{N} \]  

(1)

Where: \( ni \) = number of individuals; \( T \) = the tolerance value of each family; \( N \) = Total number of individuals within the samples

To find out the environmental conditions around the sampling sites, the water quality parameters were measured in situ for pH, temperature, dissolved oxygen (DO), Conductivity, oxidation-reduction potential (ORP), total dissolved solids (TDS), and Turbidity using HORIBA Water Quality Checker (WQC) and in the laboratory for total organic matter (TOM), total nitrogen (TN), and total phosphate (TP).

Sediment samples were analyzed for particle size and organic matter. The hydrometer method of the American Society of Testing Materials (type 151H ASTM D422) was used, which generated particle-size of sediment [17], according to Stoke’s Law [18]. The grain size of the sediment in the five locations of the study was categorized as silt (fine sediment) based on the Wentworth size scale [19]. Furthermore, total organic matter of deposit was determined based on gravimetric weight change after over-drying the sample at 105°C overnight. The loss on ignition (LOI) method was used to estimate organic matter of sediment [20]. The relationship between environmental variables and macroinvertebrate was evaluated using Canonical Correspondence Analysis (CCA).

![Figure 1. Cirata Reservoir in November 2017](image)
3. Results and Discussion

3.1 Benthic macroinvertebrate structure

3.1.1 Taxa richness, abundance, and comparison of indexes

A total of eighteen benthic macroinvertebrate taxa comprising four classes were identified. It covered 408 individuals during the collection. The community is grouped into four categories, which are Chironomids (81.65%), Non-Chironomids (Culliculidae, Odonata) (1.01%), Gastropods (4.13%), and Annelids (13.21%). The insect was the most abundant group, with a total of around 83% of all of the findings. A total of 11 taxa of Insect had been found, which was dominated by the family of Chironomidae and found with the highest amount in every station. Meanwhile, non-Chironomid insects, Odonata was the least in number.

Figure 3 shows the individual number of benthic macroinvertebrates in November 2017. The number of benthic macroinvertebrates were varied in each station, which ranged between 41-128 individual. Overall, the number of invertebrates collected were relatively lower during the research. Chironomidae was the only benthic found in this station. While, the station 4 (CRT4) revealed the most abundant benthic macroinvertebrates. The macroinvertebrate abundance in CRT4 was about 128 ind/m². In contrast with CRT4, the abundance of macroinvertebrate was the smallest in CRT3. However, the distant between CRT1 to CRT2 is about 2 kms’, CRT2 to CRT3 is about 2 kms’, CRT3 to CRT4 is about 2 kms’, and CRT4 to CRT5 is about 3 kms’.

Furthermore, the chart in Figure 4 illustrates the relative abundance of benthic macroinvertebrate in November 2017, which are distributed in 5 stations. The insect, particularly dipteran chironomids were highly represented in every station, particularly 32% in CRT4, 28% in CRT2, and 20% in CRT5. So
far, eight Dipteran-Chironomids have been identified into the level of Genus (*Chironomous, Tanypus, Polypedilum, Microchironomous, Cladopelma, Microspects, Clynotanypus, Procladius*). On the contrary, the other insects, Dipteran-Non-Chironomid, including Culiculidae and Odonata were neither numerically found nor well-distributed. Culiculidae was found in CRT1 and CRT2, whereas Odonata was only found in the CRT4. Moreover, the Gastropods were not observed in CRT5. However, the abundance ranged between 600 to 1889 ind/m² in each station.

**Figure 3.** The Individual number of Benthic Macroinvertebrate in November 2017.

**Figure 4.** Spatial Variations of the Relative Abundance of Benthic Macroinvertebrate in Nov 2017

**Figure 5.** Shanon-wiener index, Evenness Index, and the number of taxa

The other aspects that can be observed are taxa richness, the diversity index, and the evenness index of benthic macroinvertebrate. Based on the finding in Figure 5, we noted that CRT3, CRT4, and CRT2 had more taxa than CRT1 and CRT2. Furthermore, CRT3 was the most varied (with the 13
numbers) in the taxa of macroinvertebrates. In the opposite, CRT5 had the least in the number of taxa (5). Meanwhile, the diversity index was ranged mostly low to moderate between 1.75 to 3.282. It can be seen from Figure 5 that the highest Shanon-wiener index is noted in the station 3 (CRT3), 3.22 and the lowest in the station 4 (CRT4), 1.75. Moreover, the Evenness Index was ranged between 0.488 to 0.877. The highest was in the station four and the lowest was in the station 3 and 5.

3.1.2 Functional feeding group

Functional feeding of the macroinvertebrate has been grouped based on the previous kinds of literature [21]. Insect, particularly Diptera-Chironomidae had been being noted as the most abundant in the observed stations. Most of the members of this group, especially the member subfamily of Chironomini and Tanytarsini, such as Chironomous, Microchironomous, Microspectra, Polypedilium, and Cladopelma have been known as collector gather [22] [4]. This group, particularly Chironomous, eats detritus [23]. All of Tanypodinae in our finding, Tanypus, Clionotanypus, and Procladius have been identified as predators [11]. The last of Diptera- for non Chironomidae group, Culiculidae is noted as Filtering gather [22]. We also found Insect- Odonata that had been known as predators in the ecosystem [22]. We found very small amount of Odonata (0.25%) in Cirata (CRT4). Beside of Chironomidae, the group of worms Oligochaeta has been being noted as Collector gather [4]. We found about 12% of Oligochaeta that had been being distributed in CRT 1-4. This group consists of Naidinae and Tubificinae. Naidinae was found in CRT1, 3, and 4, while Tubificinae was found in CRT2,3, and 4.

Meanwhile, the group of Gastropods is scrapper [22], which eats microalgae such as periphyton and non-filamentous algae [18]. We also found two taxa of Gastropods in a small amount (3.9%) in Cirata (CRT1-4), Pilla and Filopaludina.

Thus, the grouping of benthic macroinvertebrates based on the functional feeding group indicates that Cirata has been being occupied by collector gather, since Chironomidae (75.9%) and Oligochaeta (12%) were the most dominant groups. Collector gather group is known as a group of deposit feeders. They feed Fine Particulate Organic Matters, which size ranges between 0.05-1 mm [21].

3.2 Macroinvertebrate confer water quality

3.2.1 The current status of water quality

Family Biotic Index (FBI) was calculated to understand the water quality and the degree of pollution based on tolerance index of family or higher taxa macroinvertebrate which was found in Cirata reservoir.

**Table 1.** Groups of macroinvertebrates in each site.

| Sites | Benthic Macroinvertebrates |
|-------|---------------------------|
| CRT1  | Chironomidae, Culiculidae, Ampullaridae, Hirudinea, Naididae |
| CRT2  | Culiculidae, Culiculidae, Ampullaridae, Oligochaeta |
| CRT3  | Chironomidae, Ampullaridae, Naididae, Tubificidae, Oligochaeta, Hirudinea |
| CRT4  | Chironomidae, Odonata, Ampullaridae, Naididae, Tubificidae |
| CRT5  | Chironomidae |

**Table 2.** Family Biotic Index, Water Quality, Pollution Degree (using Hilsenhoff, 1988)

| Sites | FBI | Water quality | Degree of Organic Pollution |
|-------|-----|---------------|----------------------------|
| CRT1  | 8.6 | Very poor     | Severe organic pollution   |
| CRT2  | 7.15| Fairly poor   | Significant organic pollution |
| CRT3  | 7.82| Poor          | Very significant organic pollution |
| CRT4  | 6.45| Fair          | Fairly significant organic pollution |
| CRT5  | 8.14| Very poor     | Severe organic pollution   |
Table 2 shows the status of each site's condition in the Cirata reservoir according to the Family Biotic Index (FBI) of benthic macroinvertebrate. The FBI value was used to determine the level of water quality and degree of organic pollution using Hisselhoff (1988) as guidance [16]. All of the sampling sites showed low water quality. Cirata has been polluted particularly by the organic pollutant. The variation of the FBI score shows different degrees of pollution in each location. CRT1 and CRT5 are almost identical in FBI scores. They are 8.6 and 8.14, respectively. The numbers indicate that the water quality is inferior and severely contaminated by the organic pollutant. Both of CRT1 and CRT5 have the highest score among five other locations. However, this applied biotic indices, particularly in CRT5, was quite doubtful, because the site was the farthest from the net fishery cage, but the score was the second-highest. The condition may also indicate that the pollutant has been widely spread to all of the areas of the reservoir. Meanwhile, FBI score of three locations remained CRT4, CRT2, and CRT3 are 6.45; 7.15; and 7.82, respectively. The count represented Fair to Poor in water quality.

Coincide with the water condition, polluted-tolerant groups were dominantly found in Cirata, which consisted of Chironomids and Anellids (worms). Those two groups are tolerant of the unhealthy freshwater environment, for example in the low concentration of dissolved oxygen (1-2 mg/L for Tubificid and 2-3 mg/L for Chironomids) [4]. Based on the previous review, the worm families had been being noted as the dominant group in nutrient-rich water [24], such as Naididae [25], e.g. Pristina and Nais, and Tubificidae, e.g. Tubifex and Limnodrilus [24]. Dissolved oxygen in Cirata reservoir was generally low (0.32 to 6 mg/L) (table 3), indicating that polluted-tolerant group might be abundant.

**Table 3. Environmental variables in each site**

| Sites | Temp (°C) | pH | DO (mg/L) | Turb (NTU) | TDS (mg/L) | ORP (mv/sec) | Cond (mg/L) | TOM (%) | Diameter of particle (µm) | Distant to the cage (km) |
|-------|----------|----|-----------|------------|------------|--------------|-------------|---------|--------------------------|------------------------|
| CR 1  | 29.96    | 7.37 | 0.32      | 23.1       | 0.082      | 180          | 0.126       | 3.58    | 4.94                     | 0                      |
| CR 2  | 25.90    | 7.56 | 4.58      | 21.7       | 0.081      | 115          | 0.125       | 5.34    | 50.5                     | 0.75                   |
| CR 3  | 29.89    | 7.59 | 5.54      | 32.7       | 0.08       | 120          | 0.123       | 2.45    | 56.2                     | 1.5                    |
| CR 4  | 29.87    | 7.85 | 6.59      | 70.4       | 0.082      | 131          | 0.127       | 2.27    | 51.2                     | 2.5                    |
| CR 5  | 29.69    | 7.62 | 4.96      | 37.3       | 0.079      | 122          | 0.122       | 2.26    | 54.6                     | 3.5                    |

Table 3 illustrates the water quality for some parameters in the locations. In Cirata, DO, and conductivity showed a low range of concentrations. The DO levels were deficient and near to zero in CRT1. Organic matter decomposition may contribute to the low level of DO, but in some cases can happen because of natural conditions [26]. However, benthic macroinvertebrate included Chironomidae, Culiculidae, Gastropod, Hirudinea, and Tubificidae were found at the location. The groups are known to have tolerance to the low dissolved oxygen. Some Chironomidae can be tolerant (moderately to extremely tolerant) to low DO, such as Chironomus and Polyphemus [26,27]. Meanwhile, the organic matter particularly for TOM in every location is generally low. Further spatial and temporal studies are needed to monitor and understand Cirata reservoir in a more extended period as well as to know how the dynamics benthic macroinvertebrate confer the water quality.
3.2.2 Canonical correspondence analysis of macroinvertebrate-environmental variables

Based on the measurement, the sediment size ranged between 49.4-56.2 µm. However, fine sediment is not ideal microhabitat for benthic macroinvertebrate [4]; perhaps this is one reason which caused the community was low in diversity and abundance. Only particular benthic macroinvertebrate could be found there. Previous research examined that sedimentation change the suitability of the substrate for some taxa of benthic macroinvertebrate [6]. Moreover, the deposition increases macroinvertebrate drift and affect their respiration and feeding activities in the lake [6]. Deposition had been known as the other problem in Cirata. Based on the previous study, the sedimentation happened because of the sedimentation in the river that flew to the reservoir. Study of sedimentation had been conducted in several inlet rivers, such as Cisokan, Cibalagung, Cimeta, and Cikundul; however, the highest sediment suspension and the sediment rate came from Cibalagung River [5].

Figure 6 illustrates the ordination of Canonical Correspondence Analysis. This chart describes the correlation of the water quality with the benthic macroinvertebrates in the Cirata reservoir. TOM and sediment size tend to be related to the existence of non-Chironomids group (Culiculidae, Odonata). On the contrary, other parameters such as pH, DO, and water temperature tends to relate to the existence of the Chironomids, Annelids, and Gastropods.

![CCA joint plot](image)

**Figure 6.** Canonical Correspondence Analysis of water quality and macroinvertebrates

4. Conclusions
The structure of the benthic macroinvertebrate community consists of aquatic Insects, Gastropods, and Annelids (worms), which ranged in low diversity and abundance. According to the finding, water quality status was grouped into fair to inferior condition, which the degree of pollution from neutral to severe by organic pollutants and it can be seen from the group of benthic macroinvertebrates which mostly dominated by polluted-tolerant group (Worms and Chironomids).

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Acknowledgments
Authors wishing to acknowledge to Research Center for Limnology of Indonesian Institute of Sciences for the financial support of this research. We also would like to thank Dr. Lukman for the encouragement and help. Finally, we also would like to thank the technical staff Mr. Ira Akhdiana, Ms. Mey Ristanti, and Ms. Eva Nafisyah who helped the research.

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