Assessing the ecological status of the Cisadane River’s headwaters using benthic macroinvertebrates

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Abstract. Benthic macroinvertebrates are commonly used in river health biomonitoring. In monitoring program biotic indices are now widely established in water quality monitoring around the world, including in the tropical countries. The aim of this study was to reveal the ecological status of Cisadane River’s headwaters in inside and outside of Mount Halimun-Salak National Park by using benthic macroinvertebrates. The research was conducted in the headwaters of Cisadane River located in Mount Halimun-Salak National Park. Macroinvertebrates were collected from four sites, i.e. inside the park (station 1, 2, 3, and 4) and from two sites outside the park (station 5 and 6). Collections were made twice a month, starting from April to June 2015 by means of Surber sampler (frame area 30x30 cm). A total of 65 genera from 38 families and 11 orders were found in the river. The results showed that based on diversity index, Lincoln Quality Index (LQI), Family Biotic Index (FBI), and Stream Invertebrate Grade Number Average Level 2 (SIGNAL 2), stations located within national park were ecologically better than those outside national park. Rivers with well-preserved riverside vegetation, as in the national park area have greater ecological status.

1. Introduction

The headwaters of Cisadane River are originally from Salak and Gede-Pangrango Mountains and flow into Teluk Naga coastal waters. The river has multiple uses to fulfill agricultural, domestic, and industrial needs [1] and provides economic values to people living in the cities where the river goes through [2].

As an aquatic ecosystem, headwaters of stream is favorable habitat for several benthic macroinvertebrate animals and is mostly dominated by aquatic insects [3, 4] and plays important food source for fish, birds, and other vertebrates [5]. These organisms has been widely used as biological indicators (bio-indicators) to assess the health status of the river [6]. For example, 49 of the 50 states in the United States use benthic macro invertebrate in water quality monitoring [7].

Monitoring of water quality can be done in various ways, such as with the physical and chemical analyses of water and biological analysis. The use of biological materials as bio-indicators in the management of waters is needed, because directly related to the ecological conditions or the health of aquatic ecosystems. Biological measurements provide a comprehensive and integrated assessment of the waters health from time to time [8]. Biota characteristics such as the presence or abundance can be an overview of the status change or an environmental condition. Because of these reasons these biotas
serve as a tool to continuous monitor for the waters. One of the Cisadane River’s headwater is located in Mount Halimun-Salak National Park (MH-SNP).

The aim of this study was to reveal the ecological status of Cisadane River’s headwaters in inside and outside of Mount Halimun-Salak National Park by using benthic macroinvertebrates.

2. Material and methods
The research was conducted in the headwaters of Cisadane River. One of the Cisadane River’s headwater is located in Mount Halimun-Salak National Park. Macroinvertebrates were collected from four sites inside the park (station 1, 2, 3, and 4) and from two sites outside the park (station 5 and 6) (figure 1). Ten replicates of samples were collected at each station. Collections were made twice a month, starting from April to June 2015 using Surber sampler (frame area 30x30 cm) and preserved using 70% alcohol. Macroinvertebrates were identified up to genus level following identification guides [9]. Some environmental characteristics were recorded, i.e. hydrological characteristics, velocity, temperature, dissolved oxygen (DO), and pH. Environmental characteristics were measured in situ at the time of biota sampling. Macroinvertebrate biotic indices were used is diversity index, Lincoln Quality Index (LQI), Family Biotic Index (FBI), and Stream Invertebrate Grade Number Average Level 2 (SIGNAL 2). Dendrogram of grouping stations in Cisadane’s River headwater was used by using Bray-Curtis Index [10]. One-way ANOVA was performed to detect a significant difference in benthic macroinvertebrate diversity between stations inside and stations outside the national park at p= 0.05.

![Figure 1. Map of location and observation stations in the headwaters of Cisadane River, West Java - Indonesia.](image)

2.1. Biotic indices
Biotic indices as numerical estimators of stream health, based on the tolerance or sensitivity of macroinvertebrates to an environmental gradient, are now widely established in monitoring regimes around the world. A few biotic indices have been developed for Southeast Asia, and more generally the tropics [11]. Diversity of species shows the number of organisms present in an area. To determine the species present within a community and the level of diversity can be seen with the diversity index (H') [12]. Evenness index (E) is the composition of individuals of each species contained in a community [12]. This is obtained by comparing the diversity Index to the maximum value of diversity index. If E value approaches 0, means there is a dominance of species. While if E value approaches 1, means number of individuals of each species was same or no dominance.

LQI method was used to determine the environmental criteria. Organisms that have been identified to the family level, given a score [13], then the scores were summed whole and of the values obtained BMWP. BMWP value divided by the number of taxa to get the value of Average Score Per taxon
The calculation of the value BMWP and ASPT used to determine the value of Overall Quality Rating (OQR). OQR value is used to provide Lincoln Quality Index (LQI) [13]. FBI method was used to determine which organisms are more sensitive to dissolved oxygen content in an aquatic ecosystem impacted by organic matter pollution [14]. Calculations were performed using the multiplication of the value indicator based on relative abundance of organisms with a score of each family. The total amount is divided by the total number of organisms, then the results adjusted to the water quality criteria [15]. SIGNAL 2 was developed for assessing water quality based on the presence of particular benthic macroinvertebrate to indicate the type of physics and chemistry pollution. The calculation is performed by using a weighting factor multiplied by the score of each family, and the multiplication result is summed. The sum of the multiplication is divided by the total number of weighting factors, and the value obtained SIGNAL 2. The value obtained plotted on the graph associated with a number of families [16].

3. **Result and discussion**

3.1. **Diversity, evenness, and Simpson’s dominance indices**

A total of 65 genera from 38 families and 11 orders benthic macro invertebrate were found in the river. The value of diversity (H’), evenness (E), and Simpson’s dominance index (C) in each station in Cisadane’s River headwater can be seen in table 1. The value of diversity index was of relatively high at stations located inside the national park (station 1, 2, 3, and 4) than at stations outside the national park (station 5 and 6). Benthic macroinvertebrate diversity was significantly higher inside the national park than outside the park (ANOVA, p<0.05).

| St 1 | St 2 | St 3 | St 4 | St 5 | St 6 |
|------|------|------|------|------|------|
| Diversity (H’) | 1.00 | 1.05 | 1.04 | 1.02 | 0.53 | 0.61 |
| Evenness (E)   | 0.79 | 0.81 | 0.81 | 0.87 | 0.50 | 0.67 |
| Dominance (C)  | 0.16 | 0.13 | 0.14 | 0.11 | 0.43 | 0.34 |

Riverside conditions at the stations within national parks are mostly forests and located in protected area. Well-preserved riverside vegetation, as in the National Park Area, can prevent soil erosion and nutrient release into adjoining rivers because it stabilizes the river banks. Consequently, rivers with preserved watersheds have greater biodiversity [17]. The diversity index was lower at stations that are outside the national park. The decrease of diversity index was partly due to changes in the composition and balance level of macroinvertebrate taxa abundance [18]. The values of dominance index were relatively higher at stations outside the national park compared with stations located inside the park. This indicates that there are one or a few organisms that dominate at stations outside the national park. Dominance may happen, because only a few types of organisms are able or tolerant to their lives environment [19].

3.2 **LQI, FBI, and SIGNAL 2**

The value of LQI in the headwaters of Cisadane’s River can be seen in table 2. Based on table 2, the value of LQI in rivers located within national park (station 1, 2, 3, and 4), was A + up to A ++. While the stations outside the park (station 5 and 6) the value was A. All of those LQI values were still classified the rivers into the excellent water quality criteria.
Table 2. LQI values of Cisadane’s River headwaters. Determination was in accordance to LQI water quality criteria [13].

|   | OQR | LQI | Water Quality Criteria |
|---|-----|-----|------------------------|
| St 1 | 6.0 | A++ | excellent |
| St 2 | 6.3 | A++ | excellent |
| St 3 | 6.3 | A++ | excellent |
| St 4 | 5.9 | A+  | excellent |
| St 5 | 5.3 | A   | excellent |
| St 6 | 5.1 | A   | excellent |

FBI values of Cisadane’s River headwaters are shown in table 3. According to table 3, the water quality criteria of rivers located within national park (station 1, 2, 3, and 4) were classified as good to excellent. While the river that located outside the park (station 5 and 6) was moderate to quite bad.

Table 3. FBI values of Cisadane’s River headwaters. Determination was in accordance to FBI water quality criteria [15].

|   | FBI | Water quality Criteria |
|---|-----|------------------------|
| St 1 | 4.45 | good |
| St 2 | 4.23 | excellent |
| St 3 | 4.08 | excellent |
| St 4 | 4.44 | good |
| St 5 | 5.67 | moderate |
| St 6 | 5.93 | quite bad |

Figure 2. Graph of SIGNAL 2 scores based on the number of families that are found in the headwaters of Cisadane’s River.

Position of SIGNAL 2’s score of each station based on the number of families is seen in figure 2. As seen in figure 2, the point scattered in quadrants 1 and 3. Stations located within national park (station 1, 2, 3, and 4) are posted in quadrant 1. Quadrant 1 means that the diversity of benthic macroinvertebrate
was high and there was no ecological stress factor in the stations. Quadrant 1 illustrates good water conditions (lack of interference) [16]. While the stations that located outside national park (station 5 and 6) are in quadrant 3. Quadrant 3 indicated those rivers have been contaminated. This quadrant showed that water quality criteria of river was moderate polluted waters [16].

Based on these three indices (LQI, FBI, and SIGNAL 2), the river was located within national park tend to have better water quality than the river was located outside national park. FBI is more advisable to use, as the index is known to be more specific in the assessment of the sensitivity of aquatic organisms to environmental conditions [20].

3.3 Grouping stations based on biological index
The level of similarity from the four biological indexes (Diversity index, LQI, FBI, and SIGNAL 2) was calculated and made groupings. Dendrogram of grouping station based on biological indices can be seen in figure 3.

![Dendrogram of grouping stations based on biology indices in the headwaters of Cisadane’s River](image)

**Figure 3.** Dendrogram of grouping stations based on biology indices in the headwaters of Cisadane’s River

At the similarity level of 98.18%, grouping stations are divided into two groups. Group 1 consisted of Stations 1, 2, 3, and 4 (located within national park). While the second group consisted of station 5 and 6 (located outside of national park). Some factors that affect the groupings are the type of families, number of families, and the abundance of benthic macroinvertebrate. In addition, at the similarity level of 92.12%, the sixth station is still in the same group. This is because the entire station was still on the order of 1-3 river, which means the sixth station is still part of headwaters [21].

3.4 Environmental characteristics
Benthic macroinvertebrates are affected by changes in the environmental characteristics of rivers such as width, depth, type of substratum, water velocity, and physicochemical variables [22]. The results of environmental characteristics measured in Cisadane’s River headwaters given in table 4.

The velocity at four stations which located within national park was quite high, in contrast to that of the two stations outside the park. It is influenced by differences in gradient/slope of the river [23]. The water temperature at stations within national park area tended to be low, while outside were higher. This was presumably because stations within national park area were of higher elevation, canopy coverage was high, and with 100% green area coverage. In contrast, stations outside national park area were of lower elevation, canopy coverage was low, and with 16-55% green area coverage.
Table 4. Environmental characteristics of Cisadane’s River headwaters

| Parameter          | Unit | St 1  | St 2  | St 3  | St 4  | St 5  | St 6  |
|--------------------|------|-------|-------|-------|-------|-------|-------|
| River width        | m    | 1.7   | 3.1   | 2.9   | 2.5   | 11.4  | 7.0   |
| River body width   | m    | 2.7   | 4.3   | 3.7   | 3.0   | 14.0  | 13.2  |
| Depth              | cm   | 20.7  | 19.4  | 20.3  | 19.2  | 18.1  | 18.5  |
| Altitude           | m    | 1168  | 1090  | 1075  | 1020  | 717   | 584   |
| Canopy coverage    | %    | 90-100| 60-80 | 40-60 | 0-20  | 0-10  | 0-10  |
| Green area coverage| % (right) | 100 | 100 | 100 | 100 | 55 | 16 |
|                    | % (left) | 100 | 100 | 100 | 100 | 20 | 27 |
| Velocity           | m/s  | 0.45  | 0.43  | 0.37  | 0.38  | 0.22  | 0.28  |
| Temperature        | °C   | 20.08 | 20.33 | 20.48 | 22.57 | 24.15 | 27.78 |
| DO                 | mg/L | 7.08  | 6.53  | 6.70  | 5.67  | 5.18  | 4.80  |

Dissolved oxygen of the stations inside the national park area tend to be high, while those outside the park were lower. This is influenced by the low water temperature, causing the oxygen solubility is high. Besides that, the high velocity also increases oxygen in the waters through diffusion [24]. Benthic macroinvertebrate mostly dominated by aquatic insect prefers a cold and clean river with high dissolved oxygen concentration [25, 26]. Environmental characteristics stations located within the national park more support benthic macroinvertebrates that live in these waters. This is suitable with the results of the four indices and grouping stations based on these indices.

4. Conclusion

The value of diversity index in rivers located within national park has a range of 1-1.05, while in outside the park has a range 0.53-0.61. LQI value in rivers located within national park was A + up to A ++, while in outside the park the value was A. the water quality criteria of rivers located within national park were classified as good to excellent. While the river that located outside the park was moderate to quite bad. Based on graph of SIGNAL 2, river located within national park are posted in quadrant 1 (good water condition). While the river that located outside the park are posted in quadrant 3 (moderate polluted waters). The results showed that based on diversity index, LQI (Lincoln Quality Index), FBI (Family Biotic Index), and SIGNAL 2 (Stream Invertebrate Grade Number Average Level 2), stations located within national park were ecologically better than those outside national park. Rivers with well-preserved riverside vegetation, as in the national park area have greater ecological status.

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