

Ecological health assessment using Macroinvertebrate - based Index of Biotic Integrity (M-IBI): case study Lake Gunung Putri, West Java, Indonesia

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Abstract. Macroinvertebrate - Index of Biotic Integrity (M-IBI) is one of the most widely used to assess the health of the aquatic ecosystem. However, few studies of M-IBI on the lake ecosystem. Lake Gunung Putri, which is one of the small lakes in Bogor Regency, West Java affected anthropogenic activities. We collected macroinvertebrates with an Ekman Grab sampler at five different sampling sites of Lake Gunung Putri in February – April 2019. Metric variability, sensitivity, redundancy, and responsiveness to environmental gradients were tested on 22 candidate metrics of properties of richness, taxonomic composition, tolerance, and functional feeding. The selected metrics were the number of taxa, Shannon-Wiener diversity index, percentage of dominant taxa, and Biological Monitoring Working Party (BMWP). Application of M-IBI in the Lake Gunung Putri ranged between 20 to 4 with represented criteria of good, fair, poor, and very poor condition.

1 Introduction

Situ Gunung Putri lake is one of the natural small lakes located in Gunung Putri District, Bogor Regency, West Java. Commonly, this lake has been used by people around as a fishery, especially for captured fishery which uses fishing rods. Unfortunately, the bloom of water hyacinth is a serious problem in this lake [1]. It indicates the eutrophication condition of the waters due to anthropogenic activities from the environment nearby the lake. In addition, some other sources of pollution such as domestic waste, industry, and agriculture will impact the degradation of the biotic integrity of the ecosystem.

The ecosystem health of the lake can be assessed by a biological approach (bioassessment). Some bioassessment development has been dominated by single indices to describe aquatic ecosystem conditions. Integration of more than one index or metric

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summarized into a single index or multimetric index has been developed on fish by Karr [2]. Application of the multimetric index was adapted to other biotic communities for example macroinvertebrate [3], periphyton [4], and plankton [5]. Benthic macroinvertebrate is the most popular for bioassessment due to the character of its life which is sessile in the bottom of substrates [6], easy to be sampling [7], and has various tolerances to respond to water pollution [8].

The use of multimetric indices integrates biological data and reflects aquatic conditions comprehensively [9,10]. Application of the biotic integrity index for macroinvertebrate involves some aspects such as richness, taxonomic composition, tolerance, and feeding structure [11]. Previous research shows the application of this index for river [12,13] and lake ecosystems [14,15]. However, the development of this index in Indonesia has been limited especially on macroinvertebrate in Situ or the small lake. Therefore, this research aims to assess the ecological condition of Situ Gunung Putri lake based on the Macroinvertebrate-Index of Biotic Integrity as the approach.

2 Materials and Methods

2.1 Collection of macroinvertebrate

This research was conducted at five stations in Situ Gunung Putri lake from February to April 2019 (Figure 1). Macroinvertebrate community samples were collected once every two weeks or six times in total during the research. Samples of this community were taken by using Ekman grab sampler with the size 15 x 15 cm². All of these samples then been processed in the laboratory for filtering and preservation in the formaldehyde solution of 4% - 5%. The next step was sorting and keeping the samples in ethanol at 70% before they were identified to the group they belong to. Furthermore, the identification process was referred to by Jutting [16], Kathman & Brinkhurst [17], and other references. Besides taking the biota, some environmental variables were also measured including physical and chemical parameters. Physical parameters that had been recorded were water depth, Secchi depth, water temperature, and turbidity. Meanwhile, three chemical parameters which had been measured including dissolved oxygen, pH, and chemical oxygen demand (COD).

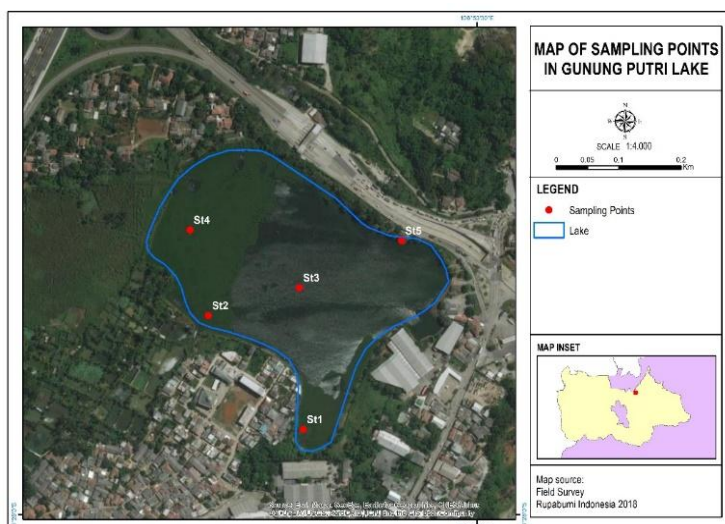


Fig.1. Map showing sampling points in Situ Gunung Putri lake

2.2 Development of M-IBI

2.2.1 Determination of reference site

The reference site (minimally disturbed site) in this study is determined based on the site with the score on the Shannon-Wiener diversity index ($H' \geq 1.5$) modified from Huang [18]. Meanwhile, sites with the value of DO met the water quality standard of 4 mgL^{-1} in Government Regulation of Indonesia No. 22/2021 (class 2) also selected for determined reference site of Situ Gunung Putri lake [19].

2.2.2 Selection of metrics

Totally 22 candidates of metric were selected to arrange M-IBI. These candidates consisted of four aspects which included richness, taxonomic composition, tolerance, and feeding structure. Candidate metrics of macroinvertebrate were calculated using Microsoft excel and PAST 4.03 from the methods by Taowu [14].

- Richness, including the total species abundance, the total number of taxa, the number of Chironomidae taxa, and the number of Mollusc and Crustacea.
- Taxonomic composition, including % of Chironomidae, % of Mollusc and Crustacea, % of Gastropod, % of Pelecypoda, % of Corbicula, Shannon-Wiener Index, and Goodnight-Whitley Index.
- Tolerance and intolerance indices, including the number of intolerant taxa, % of intolerant taxa, % of dominant taxa, Hilsenhoff Biotic Index (HBI), Beck's Biotic Index, and Biological Monitoring Working Party (BMWP).
- Feeding structure, including % of scrapers, % of predators, % of collector-gatherers, % of collector-filterers, and % of shredders.

2.2.2.1 Range and variability

Metric which has a low range (0 to 2) should be deleted in the analysis. Metric with a high variability or coefficient of variation upper 1 ($CV > 1$) should not be analyzed to create the indices [20, 12].

2.2.2.2 Sensitivity

The sensitivity of metric value is determined with Box-Whisker and Plot to show differences between reference site and impaired sites. A metric that does not has overlapping interquartil value between reference and impaired sites will be considered a strong metric in differencing both sites [12].

2.2.2.3 Redundancy

Only one metric will be counted in the next analysis to arrange the indices if there is a redundant metric or who has a high correlation coefficient ($r > 0.8$) [12].

2.2.2.4 Correlation of metrics and environmental variable

Relationships between the selected metrics and environmental variables were also identified using Spearman correlation analysis.

2.2.3 M-IBI calculation

The normalization step had conducted by counting the percentile of each metric, then followed by three-section scoring (1, 3, and 5) in each metric. If the expected metric increase in tandem with the increase of the disturbance or pollution, the value of the lowest metric to the percentile of 50th was given 5 scores, the percentile of 50th and 90th was given 3 scores, while above the percentile of 90th was given 1 score. The value of minimum, maximum, first quartile, second quartile, and third quartile from each metric is determined as the threshold to determine the quartile score. The range of multimetric index value is divided into criteria good, fair, poor, and very poor [14].

3 Results and Discussion

3.1 Macroinvertebrate composition

Benthic macroinvertebrate found in Situ Gunung Putri lake during the observation consist of 26 taxa grouped into 10 families and 4 classes. Those three classes are including Gastropods (16 taxa), Clitellata (8 taxa), Pelecypods (1 taxon), and Insects (1 taxon). Overall, the composition of each class is 92.73 %, 6.78 %, 0.29 %, and 0.20 % in a row.

3.2 Development of M-IBI

3.2.1 Determination of reference site

Table 1 shows the values of physicochemical parameters observed in Situ Gunung Putri lake. Station 1 was determined as the reference site in this study, with a dissolved oxygen content of 5.70 mgL⁻¹ (>4 mgL⁻¹). The Shannon-Wiener diversity index at the site was 1.65 (>1.5).

Table 1. Physicochemical parameters of Situ Gunung Putri lake

Parameters	St1	St2	St3	St4	St5
Water depth (m)	0.48±9.90	0.95±5.00	1.39±25.00	0.78±7.00	1.20±14.14
Secchi depth (m)	0.38±8.59	0.56±15.98	0.56±6.00	0.63±7.00	0.63±9.09
Water temperature (°C)	29.37±0.66	28.38±0.56	27.98±0.54	27.98±0.61	28.07±0.58
Turbidity (NTU)	25.71±10.09	25.11±22.00	26.96±22.38	20.46±14.98	16.44±5.25
pH	7.20±0.30	6.86±0.34	7.04±0.33	7.01±0.22	7.05±0.32
DO (mgL ⁻¹)	5.70±2.55	2.81±1.38	3.96±3.73	3.06±2.69	1.92±1.10
COD (mgL ⁻¹)	47.73±5.08	41.21±8.32	39.64±7.33	38.78±7.41	39.64±8.85

3.2.2 Range and variability of metrics

Metrics which has a narrow range in score, can be eliminated in the analysis, for instance, 0 to 2. About 10 metrics had been eliminated in this step, for example the number of Chironomidae taxa, % of Chironomidae, % of Pelecypods, % of Corbicula, the number of intolerant taxa, % of intolerant taxa, Beck's Biotic Index, % of predators, % of collector-filterers, and % of shredders. Meanwhile, the remaining 12 metrics did not eliminate in the variability analysis because they did not show high variability. Therefore, this would be continued to the analysis of metrics sensitivity.

3.2.3 Sensitivity and redundancy

The sensitivity of the metrics score had been determined with Box-Whisker and Plot to show the strength of different reference and impaired sites. Metrics without overlap interquartile score of reference site and impaired sites will be determined as the sensitive metrics [12]. Box-Whisker and Plot had been performed to test the sensitivity of 12 remaining matrices, for instance the total taxa abundance, the total number of taxa, the number of Mollusc and Crustacea, % of Mollusc and Crustacea, % of Gastropods, Shannon-Wiener Index, Goodnight-Whitley Index, % of dominant taxa, HBI, BMWP, % of scrapers and % of collector-gatherers.

Figure 2 shows that there are 4 sensitive metrics to differentiate reference and impaired sites which include the total number of taxa, percent of dominant taxa, Shannon-Wiener index, and BMWP. Those four metrics did not show redundancy (coefficient of correlation >0.8), therefore, this will be used in the next analysis.

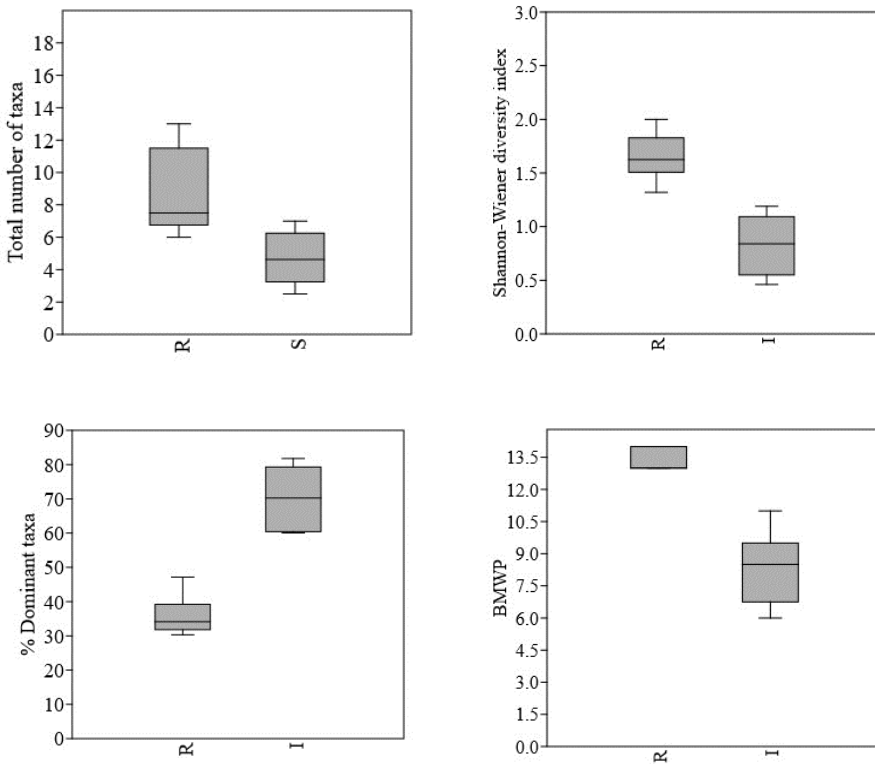


Fig.2. Box-Whisker and Plot showing discriminatory capability of each of the four selected metrics

3.2.4 Correlation of metrics and environmental variable

Correlation of the four remaining metrics and selected environmental variables, which showed significant differences between the impaired sites and reference site including water depth, Secchi depth, water temperature, and dissolved oxygen. The result of the Spearman

correlation shows that the number of taxa, Shannon-Wiener index, and BMWP positively correlated with dissolved oxygen and water temperature. While they have a negative correlation with water depth and Secchi depth. On the other hand, the metrics of the percent of dominant taxa shows the opposite correlation.

3.2.5 M-IBI calculation

The score criteria of the four metrics had been formulated based on the range score of metrics in developing M-IBI. Each range metrics score is divided into three scores (1-3-5) in tandem with the rise of disturbances or pollution. The merger of four selected metrics into a single index or the multimetric index resulted in the range score, which is determined based on the number of minimum and maximum scores from those four metrics (Table 2). The result shows that the score range between 4 to 20, divided into four criteria. The range score of the multimetric index is divided into four criteria of water quality, they are good (17-20), fair (13-16), poor (9-12), and very poor (4-8).

Table 2. Descriptive statistics of the selected metrics at the reference sites and their scoring criteria

Metrics	Descriptive Statistics					Score		
	Min.	10 th percentile	50 th percentile	90 th percentile	Max.	5	3	1
Total number of taxa	6	7	7	12	13	>7	7	<7
Shannon-Wiener index	1.32	1.44	1.62	1.88	2.00	>1.62	1.44-1.62	<1.44
% Dominant taxa	30.33	31.31	33.89	36.01	47.14	<33.89	33.89-36.01	>36.01
BMWP	13	13	13	14	14	>13	13	<13

The result of developing the M-IBI in Situ Gunung Putri lake shows that only four metrics suit to be applied, are the total number of taxa, percent of dominant taxa, Shannon-Wiener index, and BMWP. Those four can describe the level of ecology disturbances in Situ Gunung Putri due to anthropogenic activities. The application of those indexes in this study resulted from criteria of ecology condition in Situ Gunung Putri lake, they are good to very poor condition (station 1), poor to very poor (station 2), and very poor (station 3, 4, and 5).

The total number of taxa and the Shannon-Wiener Index is part of the macroinvertebrate multimetric system in the lake ecosystem that was studied by Burton [21] and Shah [22]. Metrics of percent of dominant taxa is also studied by Lewis [23] and Wesolek et al. [24]. Meanwhile, BMWP has been studied by O’Toole et al. [25]. Ndatimana [26] stated that the application of a M-IBI is an important tool that is adopted by developing countries for lakes ecosystem management in tandem with the rise of anthropogenic stressors. Indexes that resulted might have variations in the number and type of metrics based on the local biota and environmental variables responsive to the disturbances [27].

4 Conclusion

The application of the M-IBI in Situ Gunung Putri lake shows that four metrics which sensitive in determining reference site and impaired site are the total number of taxa, percent of dominant taxa, Shannon-Wiener diversity index, and BMWP. The index resulting from the analysis shows that the ecology health of Situ Gunung Putri lake is from very poor to good, with a range of scores from 4 to 20.

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