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The Effect of Dams on the Distribution of Functional Feeding Groups in Benthic Macroinvertebrates (Case Study: Rivers Connected to Jatiluhur Reservoir, Curug Klari Dam, and Walahar Dam)

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Abstract

Human development and activities are significantly affecting water quality, including the life of organisms such as macrofauna and benthic macroinvertebrates. To meet human needs, the construction of reservoirs and dams is being carried out, which inevitably alters natural conditions and the presence of other organism. Therefore, this study aimed to analyze the relationship between water quality parameters and sediment characteristics in river channels affected by the presence of reservoirs and dams on the distribution of benthic macroinvertebrates classified into functional feeding groups (FFG). During the analysis, FFG was used to understand the dynamics of food in aquatic ecosystems and its changes based on the distribution of benthic macroinvertebrates. The investigation was conducted from July to September 2023, in the central and lower parts of the Citarum River, located in West Java Province, Indonesia, specifically around Jatiluhur Reservoir in Purwakarta Regency for the Central part and Curug Klari Dam and Walahar Dam in Karawang Regency for the Lower part. Field data collection comprised the sampling of water, sediment, and benthic macroinvertebrates. Data analysis was based on the calculation of benthic macroinvertebrate community structure, pollution indices, Biological Monitoring Working Party - Average Score per Taxon (BMWP-ASPT) biotic index, Pearson correlation, Principal Component Analysis (PCA), and Hierarchical Cluster Analysis (HCA). The results showed that FFG distribution was dominated by gathering-collectors (72%), scrapers (22%), predators (6%), and filtering-collectors (0.06%). The pollution index (PI) indicated that the water quality in the central part of the Citarum River was mild, while the lower part was moderately polluted. Based on the biotic index (BMWP-ASPT), the water quality was categorized as poor and heavily to very densely polluted part. The correlation between PI and BMWP-ASPT showed a very strong relationship according to Pearson correlation (r = -0.96). PCA analysis indicated a positive correlation between predators and gatherers in moderately polluted conditions at the Jatiluhur Reservoir location. At the Curug Klari and Walahar Dams, characterized by lightly polluted conditions, there was a positive correlation between filtering and scrapers. HCA calculations showed that the conditions in the Central part (Jatiluhur Reservoir) varied from the Lower part (Curug Klari and Walahar Dams) of the Citarum River.

Keywords: *benthic macroinvertebrates, citarum river, feeding group, HCA, PCA.*

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1. Introduction

Rivers are water ecosystems whose quality can be influenced by various anthropogenic factors. The Citarum River is the largest river in West Java, with a river area of ±6614 km^2 and river length ±297 km. The geographical location of the Citarum River is 106° 51" 36"–107° 51' E and 7° 19'–6° 24' S. The river was divided into three parts: the upper part of the river, which is at the top of the Mountain of Wayang to the end of

Saguling; the middle part of Citarum, which lies between the three waters dams of Sagulling, Cirata, and Jatiluhur; and the downstream (hilir) Citarum which lies from Jatiluhur Dam to Muara Gembong, Java Sea).
The construction of river-flow barriers, such as hydroelectric power dam and the construction of reservoirs, has many serious consequences for the aquatic environment (Gracey et.al., 2016). The decline in water quality caused by excessive release of sediment, pollution from hazardous substances, and domestic wastewater is the most significant impact of the dam (Alla dan Liu, 2021). The presence of the dam can also alter the thermal patterns and flow of the river, which in turn can affect the history of the life of the beetle (Brittain dan Saltveit, 1989; White et.al., 2017).
Benthic macroinvertebrates are well-established bioindicators for assessing aquatic ecosystem health due to their environmental sensitivity (Rosenberg et al., 1986; Smith et al., 1999). Such biological monitoring is frequently more effective than assessments based only on physicochemical parameters (Merritt et al., 1996; Addo-Bediako, 2021). While early research emphasized community structure and species diversity, recent work has shifted towards a functional approach (Brown et al., 2018). This method, which examines the ecological roles of organisms, offers a more comprehensive and simplified means of evaluating ecosystem structure and function (Mouton et al., 2020; Liu et al., 2014). This approach is founded on the concepts of functional feeding groups (FFGs)—classifying organisms by their food acquisition adaptations—and functional diversity, which quantifies the range and value of species traits in a community (Baker et al., 2021; Wang et al., 2019). The importance of functional diversity lies in its capacity to predict links between ecological processes and to mirror how biological communities affect ecosystem function (Mason et al., 2005). The arrangement of these traits is shaped by hierarchical habitat filters that select for organisms possessing traits suited to local conditions (Poff and Ward, 1990; Statzner et al., 2001). Consequently, variations in FFG composition and functional diversity serve as effective tools for diagnosing the mechanisms behind environmental change (Zhong et al., 2020; Li et al., 2022). Macroinvertebrates can be classified into five functional feeding groups (FFGs) according to the way they obtain food. Furthermore, the various food sources used by macroinvertebrates consist of: rough detritus, mainly composed of leaves that sprinkle from river vegetation (shredder); epiletic layers that grow on the surface of the substrate (scrapers); fine particulate organic matters (FPOMs), either dotted on the substratum (gathering) or suspended in a water column (filters); and finally live animals (predators) (Cummins, 2018). Functional feeding groups in thin macroinvertebrates can reflect the impact of habitat changes. It also reveals community structure and habitat adaptation characteristics (Bohan et al. 2017). Therefore, in recent years, FFG has been widely used by researchers to evaluate river ecosystem quality (Bohan et al. 2017; Zhu et al. 2020).
According to Imansyah (2012), each Jatiluhur Dam holds ±3,000 million cubic meters of water. The covered water is used for a variety of purposes, including irrigation, raw water sources in major cities, and power plants in Java-Bali. According to Astuti et al. (2022), Jatiluhur Dam has eutrophic-hypertrophied trophic status. Elevated concentrations of chlorophyll-a and total phosphate indicate nutrient enrichment of the water body The Curug Dam serves as a divider dam that supplies water for irrigation, raw water, and power plants. The Walahar Dam serves to control water drainage and air circulation while irrigating surface areas in Karawang. This research aims to find out the distribution of functional feeding groups of macroinvertebrates benthically related to their habitat conditions. The research location is Jatiluhur Dam, Klari Dam, and Walahar Dam in the downstream section of the Citarum River.

2. Methodology

2.1 Study area

Figure 1 and Table 1 are showing the location of the research is in the middle of Jatiluhur Dam, which is in Central Part, and at Curug Klari Dam and Walahar Dam, which are in the downstream section of the Citarum River (Figure 1). The time of research at Jatiluhur outlet was in July-September of 2022 (Ilmi.,2023).

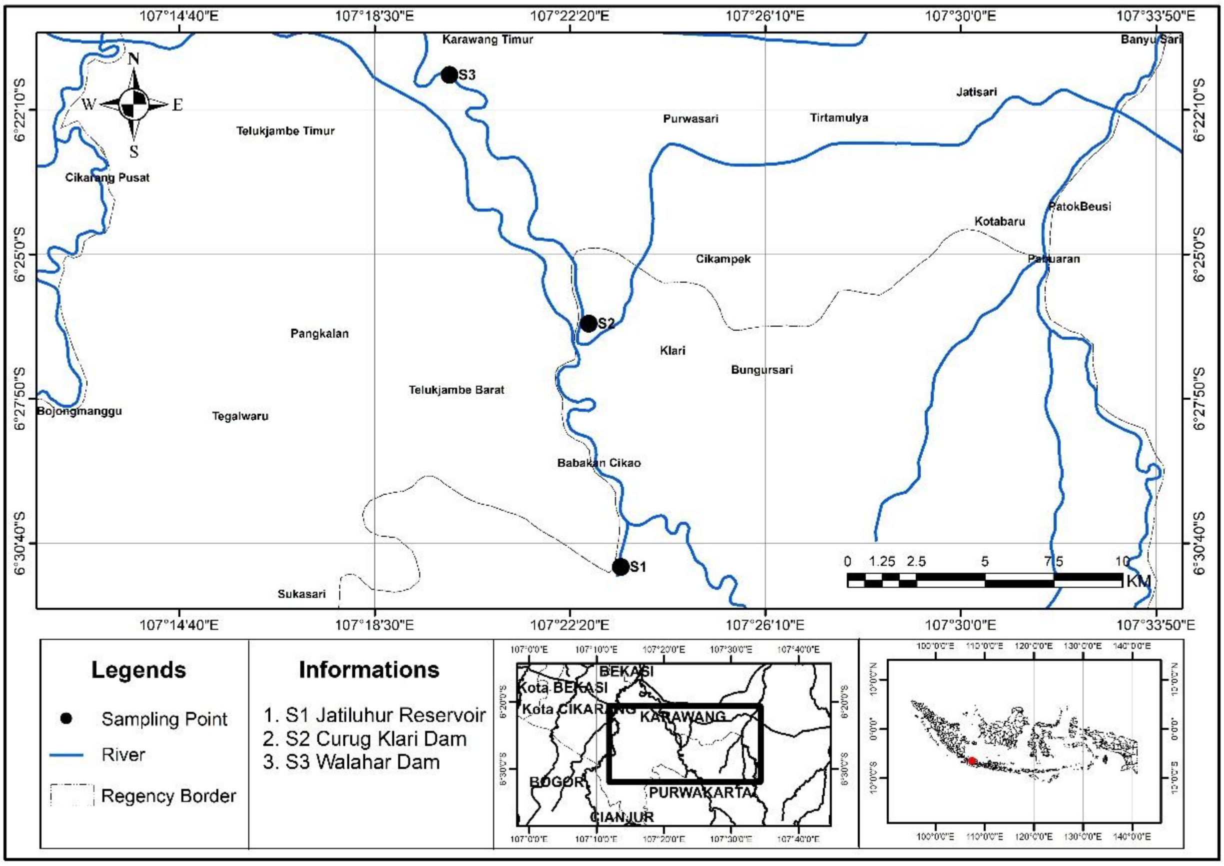

Figure 1. Sampling location

Table 1. Description of sampling location

Station	Coordinat	Characteristics	Description
S1-Jatiluhur Reservoir	6°31'8.21"S 107°23'19.98"E	Width 5 m Velocity 0,47 m/s	Rural area ± 300 m from Outlet Dungeon Jatiluhur ±20–40 m of vegetation along the river's edge and very little human activity on the banks of a river
S2-Curug Klari Dam	6°26'21.98"S 107°22'42.14"E	Width 7 m Velocity 0,3 m/s	Plantation area ±400 m from Outlet Curug Dam Klari, there is a bridge to cross the river, dense vegetation on the banks
S3-Walahar Dam	6°21'29.22"S 107°19'58.33"E	Width 3,7 m Velocity 0,3 m/s	Plantation area ±1500 m from the Walahar Dam Outlet, there is a bridge to cross the river, dense vegetation on the bank

Source: Study Team P2MI, 2021

2.2 Sampling method

Sampling was conducted in the noon when the weather was clear. Water sampling is done at ±2 liters at each location using a plastic bottle, while sediment samples are taken at the top surface of a sediment of ±1 kg. Macroinvertebrate samplings are taken with Surber Net 25x40 cm^2 with mesh size of 0.5 mm. Five subsamples are collected at a distance of approximately 1 m at each sample-taking site, which is about 20 m away (Wakhid et al., 2021). The samples obtained are placed in the sample bottle and tempered with 70% alcohol. The identification of macrozoobenthos is done in the Biology Laboratory of the Faculty of Mathematics and Natural Sciences of Padjadjaran University. Measurements of the physical and chemical parameters of the water are performed in situ and ex situ. Measured in situ parameters include degrees of acidity (pH), depth (m), speed (m/s), dissolved oxygen (DO), and temperature (℃). Ex situ measurements are made for TSS, COD, nitrates, and phosphate. The water samples were analyzed at the Water Quality Laboratory, Faculty of Civil and Environmental Engineering, Bandung Institute of Technology.

2.3 Data analysis – pollution index

Pollution index (PI) method was used to determine the pollution level of a water quality parameter. The determination of river water quality standards used Class II based on Government Regulation 22/2021. Meanwhile, the determination of water quality status through the pollution index was based on Ministerial Decree 115/2003, with the calculation as follows:

$$IP_j = \sqrt{\frac{\left(\frac{C_i}{L_{ij}}\right)_M^2 + \left(\frac{C_i}{L_{ij}}\right)_R^2}{2}} \qquad (1)$$

Where:

Ipj = Pollution index for indicator j

Ci = Concentration of water quality parameter i

Lij = Concentration parameter i specified in water quality standard j

M = Maximum

R = Average water quality value

The calculation results of the pollution index are based on the following criteria:

0 ≤ IPj ≤ 1.0: Good condition and fulfills quality standards
1.0 < IPj ≤ 5.0: Light Pollution
5.0 < IPj ≤ 10: Moderate Pollution
IPj > 10: Heavy Pollution

The abundance of benthic macroinvertebrates was calculated based on the number of individuals per square unit (ind/m^3). Community structure was used to understand the distribution of benthic macroinvertebrates and their interactions within a biological community, including diversity, uniformity, richness, and dominance indexes calculated using the Shannon-Wiener method. FFG ratio calculations were used to determine the FFG role in the food chain of an ecosystem, calculated using the TDP (Top Down Predator) index, FC (Filtering-Collectors) index, HS (Habitat Stability) index, and AH (Autotrophy-Heterotrophy) index based on Cummins (2018). Moreover, community structure and FFG ratio calculations can be combined or used together to provide a more comprehensive overview of the ecosystem's condition.

2.4 Data analysis – biotic index of BMWP-ASPT

The Biological Monitoring Working Party-Average Score per Taxon (BMWP-ASPT) is an index used to determine the value of a sample by assigning scores between 1 and 10 for each family group based on their sensitivity or tolerance to pollution in aquatic ecosystems (Bartram & Balance, 1996). The Average Score per Taxon (ASPT) is the average score per family obtained by dividing the BMWP score by the number of families in the sample using the Bartram & Balance (1996) calculation technique.

Table 2. Water quality categories based on BMWP and ASPT(E)

Water Quality Category	Total Score BMWP	Score ASPT (E)
Excellent	>120	>5.4
Good, no pollution	101 - 120	4.8 - 5.4
Good, eutrophic, moderate pollution	61 - 100	4.3 - 4.8
Poor, polluted	36 - 60	3.6 - 4.3
Poor, heavy pollution	16 - 35	3.0 - 3.6
Poor, extreme pollution	<15	

Source: BMWP (Alba-Tercedor, 1996:MINAE, 2007), dan ASPT(E) (Ganguly et.al., 2018).

This study calculated the correlation between the pollution index and the BMWP-ASPT Biotic Index using the Pearson's Correlation Coefficient. Factors significantly affecting the data were analyzed using PCA, while

HCA was performed using the Unweighted Pair Group Method with Arithmetic Mean (UPGMA) based on the Bray-Curtis index to show the main differences and similarities between study locations.

3. Result and Discussion

3.1 Environmental parameter conditions

The observations and results of physico-chemical water parameters are presented in Table 3. Based on observations at the three locations, some parameters exceeded the water quality standard for Class II set by Government Regulation No. 22 of 2021. These parameters included total suspended solids (TSS) at location S3, dissolved oxygen (DO) at locations S1 and S3, chemical oxygen demand (COD) at locations S2 and S3, and phosphate at all locations.

Table 3. Results of physical-chemical water and sediment parameter identification

Characteristic	S1-Jatiluhur Reservoir	S2-Curug Klari Dam	S3-Walahar Dam
River width (m)	127	68.42	53.68
Depth (m)	5	6.67	3.67
Flow velocity (m/s)	0.047	0.308	0.258
Temperature (°C)	27.28	27	29
TDS (mg/l)	18	180	321
TSS (mg/l)	14.50	43.33	70.33
DO (mg/l)	2.53	4.63	3.80
COD (mg/l)	22.46	112.02	76.70
pH	6.98	7.60	7.60
Nitrate (mg/l)	0.25	1.34	1.34
Phosphate (mg/l)	2.58	2.00	1.37
Nitrate in sediment (%)	0.4	2.12	1.87
Organic carbon in sediment (%)	58.13	48.82	43.42
Phosphate in sediment (%)	61	167	149
Clay (%)	28	58.03	27.5
Silt (%)	23	41	40.08
Sand (%)	49	0.09	22.53

The results of sediment characteristic identification are shown in Table 3, including sediment analysis for nitrogen content (0.4-2.12%), organic carbon (43.42-58.13%), and phosphate (61-167 mg/kg). Based on the identification of sediment texture, locations S1, S2, and S3 were dominated by sand 49.0%), clay (58.03%), and silt (40.08%), respectively. The movement of sediment is generally affected by the flow velocity and particle size, with smaller particles being more easily carried by the flow. Differences in sedimentation processes affecting sediment particles are due to various physical and chemical characteristics of the water (Rifardi, 2008).

TSS concentration values ranged from 14.5 to 70.33 mg/l, with the highest and lowest obtained at locations S3 and S1, respectively. Furthermore, DO concentration values ranged from 2.53 to 4.63 mg/l, with the highest and lowest obtained at locations S2 and S1, respectively. COD concentration values varied from 22.46 to 112.02 mg/l, with the highest and lowest values obtained at locations S2 and S1, respectively. These variations in the results of water physico-chemical parameter identification were attributed to differences in dam and reservoir utilization as well as land use along the Citarum River.

3.2 Distribution of benthic macroinvertebrates FFG

In this study, the benthic macroinvertebrates found were 1,115 individuals, classified into 20 genera and 17 families, as shown in Table 4. Families found in locations S1 to S3 included Ceratopogonidae, Chironomidae, Naididae, and Thiaridae. However, there was no specific family found at location S1, while location S2 included Gecarcinucidae, Hydrospsychidae, Libellulidae, Lymnaeidae, and Planorbidae. Location S3 had specific genera, namely *Cricotopus sp.* from the Chironomidae family, as well as *Tarebia sp.* and *Thiara sp.* from the Thiaridae family. The highest number of individuals, 458, was found at location S1 in 4 families. This was followed by 314 individuals in 17 families at location S2, and 344 in 15 families at location S3. Based on their abundance, families Naididae and Chironomidae dominated at locations S1 and S2, while Thiaridae and Naididae were predominantly found at location S3.

Table 4. Abundance of benthic macroinvertebrates

Family	Genus	FFG	S1-Jatiluhur Reservoir	S2-Curug Klari Dam	S3-Walahar Dam	Total
Ampullariidae	*Pomacea sp.*	Sc	-	16	5	21
Bithyniidae	*Bithynia sp.*	Gc	-	7	6	13
Ceratopogonidae	*Bezzia sp.*	Pr	34	7	3	45
Chironomidae	*Chironomous sp.*	Gc	172	70	31	273
Chironomidae	*Cricotopus*	Gc	-	0	1	1
Coenagrionidae	*Enallagma sp.*	Pr	-	1	1	2
Gecarcinucidae	*Parathelphusa*	Sc	-	6	0	6
Cylicobdellidae	*Hirudinaria sp.*	Pr	-	1	1	1
Hydropsychidae	*Hydropsyche sp.*	Fc	-	1	0	1
Libellulidae	*Libelulla sp.*	Pr	-	2	0	2
Lumbriculidae	*Lumbricullus sp.*	Gc	-	14	11	25
Lymnaeidae	*Lymnaea sp.*	Sc	-	1	0	1
Naididae	*Tubifex sp.*	Gc	240	96	94	430
Nassariidae	*Anentome*	Pr	-	14	3	17
Palaemonidae	*Palaemonetes sp.*	Gc	-	41	19	60
Planorbidae	*Gyraulus sp.*	Sc	-	1	0	1
Thiaridae	*Melanoides sp.*	Sc	12	12	33	57
Thiaridae	*Tarebia sp.*	Sc	-	0	127	127
Thiaridae	*Thiara sp.*	Sc	-	0	2	2
Viviparidae	*Filopaludina*	Sc	-	23	7	30

According to research by Sudarso and Wardiatno (2015), chironomid Diptera larvae can be found in nearly every type of habitat, including rivers that have been severely disturbed and those that have not. Because it shows logistic growth at high BOD levels (Djarwanti et al., 2000; Robson, 2002; Chotimah et al., 2011; Dasgupta & Yildiz, 2016), which can indicate an ecological status ranging from slightly polluted to moderately polluted, Chironomus sp. is tolerant to organic pollution. The ability of *Chironomus* sp. to grow in environments with high organic content corresponds with this study, indicating a strong relationship between organic values and nitrate. Furthermore, the larvae of *Diptera chironomid* are found in almost every undisturbed river habitat, indicating the higher resistance of *Chironomus* sp. to organic pollution (Sudarso & Wardiatno, 2015). Additionally, Tubifex sp. was found in sandy habitats, associated with TSS and nitrate parameters.. *Tubifex* sp. is commonly found in lakes, ponds, swamps, and flowing pools, while some species also inhabit fast-flowing river areas. Furthermore, Tubifex sp. is usually found in soft sediments including coarse detritus, vegetation, rough substrates, and highly polluted water rich in organic matter.

The distribution of FFG at the study locations was dominated by gathering collectors (gc) with 72%, followed by 22% scrapers (sc), 6% predators (pr), and 0% filtering collectors (Fc). Changes in FFG dominance could be observed at each location, with a significant decrease in the number of gatherers from location S1 to location S3. However, the number of scrapers increased from location S1 to location S3 due to changes in sediment conditions supporting the life of benthic, as shown in Figure 3.

The river's condition, which restricted the supply of coarse particulate organic matter (CPOM) from the riparian zone and, as a result, the production of fine particulate organic matter (FPOM), which shredders generate and which supports the larger stream food web, was the reason for the low number of shredders in this study. Because filtering collectors rely on the availability of FPOM [R1] carried in the current (FC), the fluctuation in results may also result in a low FFG of FC in this study (Cummins et al. 2022). Shredders are typically found more in forested environments, due to the abundance of CPOM (Encalada et al., 2010; Wakhid et al., 2021). The majority of the riverbanks in this study are urban and agricultural land. Additionally, a previous study conducted in the headwaters of rivers in Malaysia by Shafie et al. (2017) showed that shredders were more commonly found.

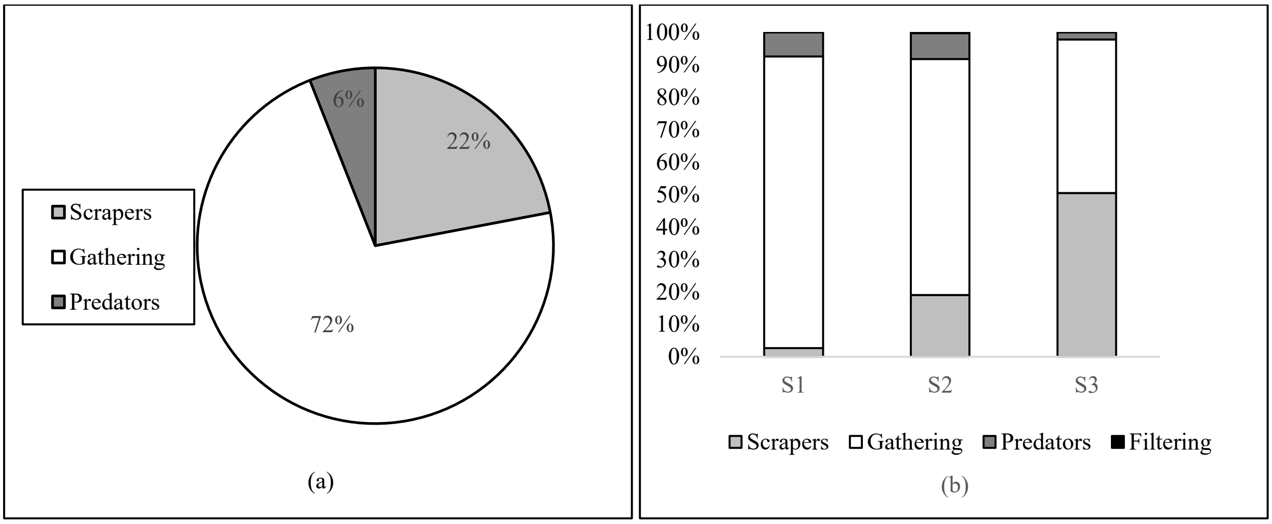

Figure 3. Distribution of FFG at the study locations (a) and at each location (b)

3.3 Benthic macroinvertebrate community structure

Based on the calculation of the Diversity Index, the values at the three locations ranged from 0.99 to 2.07. The lowest value was observed at location S1, falling into the Low Diversity category and the highest value was found at location S2 in the Moderate Diversity category. The calculated Richness Index values ranged from 0.49 to 2.78, with the lowest and highest values at locations S1 and S2, respectively, placing all locations in the Low Richness category. Furthermore, the calculated Evenness Index values ranged from 0.66 to 0.73, with the lowest values at locations S3 and the highest at location S2, grouping all locations into the High Evenness and Stable Community category. Based on the Dominance Index (C) calculations, values at the three locations ranged from 0.18 to 0.42, with the lowest value at location S2 and the highest at location S1, placing all locations in the Low Dominance category.

Table 5. Results of community structure calculation at the study locations

Community Structure Index	S1-Jatiluhur Reservoir	S2-Curug Klari Dam	S3-Walahar Dam
Diversity (H')	0.99	2.07	1.80
Richness (R)	0.49	2.78	1.88
Evenness (E)	0.72	0.73	0.72
Dominance (C)	0.42	0.18	0.23

According to Melo et al. (2020), different land uses alter habitat conditions, water quality, and benthic invertebrate assemblages. Furthermore, variations in diversity at each station can be attributed to fluctuating water depth and flow velocity depending on dam operations (Ryder et al., 2015; Liro et al., 2022). Liro et al. (2022) stated that river depth and flow velocity could be temporarily disturbed by water level fluctuations due to artificial dam operations.

Abidin (2018) stated that a high diversity index (H') indicated a region with elevated productivity and nutrient content. According to Arfiati et al. (2019), a high evenness index signifies that the benthic macroinvertebrates found have a uniform and widespread composition, indicating a stable community with diverse ecosystems without specific dominant species. A low dominance index indicates organisms living in a healthy environment. This is consistent with the idea proposed by Thukral et al. (2019), where diversity values correlated negatively with increasing dominance values. Diversity or biotic indices could be used to assess habitat diversity changes caused by allochthonous disturbances and pollutants.

3.4 Functional feeding group surrogate ratio

This study calculated the Habitat Stability (HS) index at all locations, while the Filtering Collector (FC) index was only calculated at location S2. Meanwhile, location 3 has a value above 0.50 for the HS index due to the presence of more evenly distributed FFG compared to other locations. An HS index higher than 0.50 indicates that the location is stable for erosion and attachment, with more individuals foraging and attaching compared to unstable substrate movement (Cummins, 2018). Based on the Filtering-Collector (FC) index calculation, location S2 has an FC index value of 0.003. Cummins (2018) stated that an FFG ratio above 0.50 indicated the burden of fine particulate organic matter (FPOM) suspended is greater than stored (entrained) FPOM. The FC ratio at location S2 is lower than 0.50, indicating that the food available for FPOM collectors has lower density and/or quality compared to FPOM storage.

Table 6. Functional feeding group index

FFG Surrogates	S1-Jatiluhur Reservoir	S2-Curug Klari Dam	S3-Walahar Dam	Threshold*
HS Index	0,03	0,26	1,07	>0.50
FC Index	-	0,003	-	>0.50
TDP Index	0,07	0,08	0,02	0.1-0.2
AH Index	0,03	0,26	1,07	>0.75

The variation in results can also lead to a low FFG of FC in this study, as filtering collectors depend on the availability of organic matters carried in the current (FC) Similarly, Morse et al. (2019) stated that filter feeders are commonly found in fast-flowing water to efficiently obtain organic matter. The autotroph-heterotroph index at locations S1 and S2 shows values below 0.50, while location S3 has a value of 1.07. This indicates that all locations have conditions where the productivity in the river flow is lower than the plants on the riverbank (Cummins 2018). The dominance of heterotrophy over autotrophic production can be associated with extensive pollution by organic waste, resulting in a higher number of collectors compared to scrapers (Masese et al. 2014). Therefore, inappropriate FFG replacement ratios could indicate a disturbed ecosystem. In this study, most FFG replacement ratios did not reach the threshold, indicating that FFG has an imbalanced ratio among FFG types. However, only location S3 showed FFG replacement ratios reaching the threshold. The study confirmed that functional diversity effectively displays different functional features and indicates how those traits react to environmental interference (Zhong et al., 2020). The functional diversity indices demonstrated clear responses to environmental stressors, reinforcing that they are powerful tools for reflecting changes in community organization (Li et al., 2022). A low functional richness (FRic) value, for example, was attributed to an incomplete utilization of available resources, suggesting that species capable of exploiting those resources had disappeared, thereby reducing the community's resilience to environmental fluctuations and its ability to resist invasion (Erasmus et al., 2021; Mouton et al., 2020). This underscores the importance of functional traits in showing how communities respond to external pressure (Lavorel et al., 1997).

3.5 Relationship between the pollution index and biotic index

The results of pollution and biotic index calculations at the study locations are shown in Figure 4, where the values of the pollution index range from 4.0 to 5.65. The highest value is at location S1, indicating Moderate Pollution, while the lowest is at location S3, representing Light Pollution. The calculated BMWP-ASPT biotic index ranges from 2.00 to 4.02, with the lowest value at location S1, categorized as Poor and Extreme Pollution, and the highest value at location S3, categorized as Poor and Light Pollution. The correlation calculation between the pollution index and the BMWP-ASPT Biotic Index shows a very strong negative relationship, with a value of -0.96.

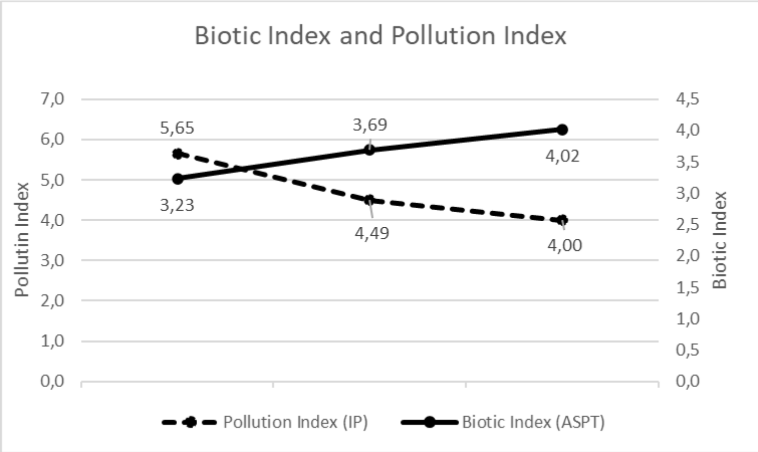

Figure 4. Pollution index (blue) and biotic index (yellow).

3.6 Relationship relationship between physicochemical water parameters and FFG

The condition of physicochemical water parameters affects the FFG of macrozoobenthos that can inhabit a specific location. Therefore, it is essential to examine the relationship between the two parameters using PCA, as shown in Figure 5. At location S1, there is a strong correlation with predator and gatherer FFG types, sediment phosphate, and carbon values as environmental variables. At location S2, there is a strong correlation with filtering FFG. Meanwhile, at location S3, there is a strong correlation with the scraper FFG, temperature, TSS, and TDS as environmental variables.

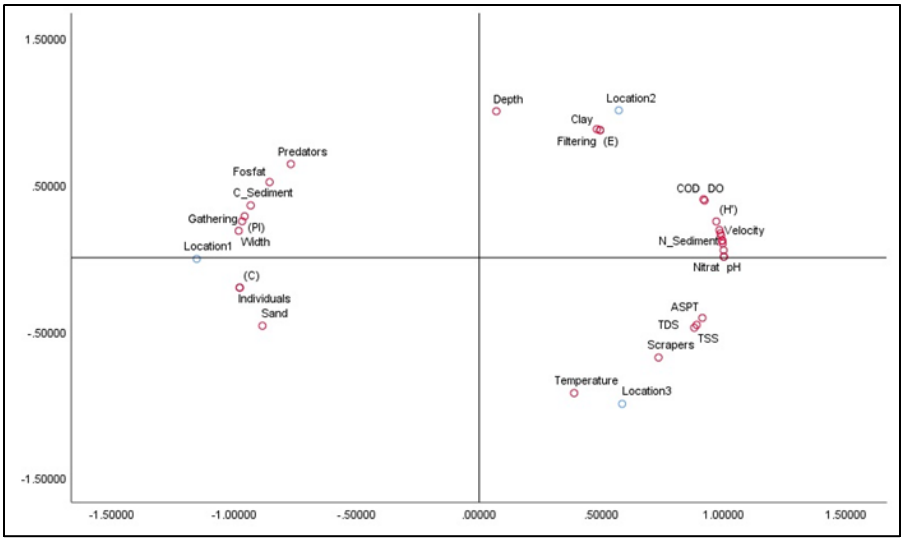

Figure 5. Biplot between physico-chemical parameters and sediment conditions with FFG.

Based on the Pearson correlation in Table 8 and Figure 6, there is a relationship between sediment conditions and FFG. The scraper FFG type has a strong positive correlation with silt sediment (r =0 .70), indicating that the presence of scrapers increases with more silt in the sediment. Furthermore, the gathering FFG type has a strong positive correlation with sand sediment (r = -0.74) and a very strong negative relationship with silt sediment (r = -0.95). This indicates that the presence of gathering collectors increases when the sediment contains more sand and less silt. Predators FFG type has a strong negative correlation with silt sediment (r = -0.74), indicating that the presence of predators FFG decrease when the sediment condition has more silt. Regarding filtering FFG type, a perfect correlation with clay (r = 1.00) is observed because of its presence was only recorded at location S2, with an abundance of 1 ind/m^3.

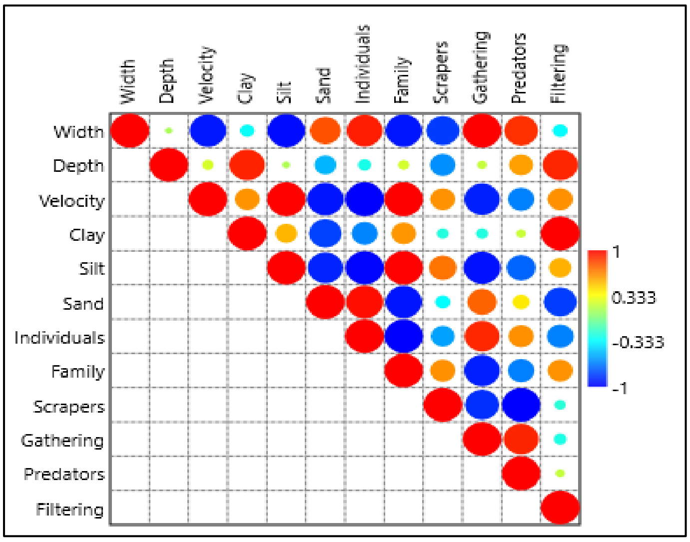

Figure 6. Regression between sediment and FFG.

Table 7. Correlation of sediment conditions with FFG

Correlations	Width	Depth	Velocity	Clay	Silt	Sand	Inds	Family	Scrapers	Gathering	Predators	Filtering
Width	-	0.93	0.22	0.80	0.15	0.42	0.25	0.21	0.36	0.04	0.32	0.79
Depth	0.11	-	0.86	0.28	0.92	0.65	0.82	0.86	0.57	0.88	0.60	0.28
Velocity	-0.94	0.23	-	0.58	0.07	0.21	0.03	0.00	0.58	0.26	0.54	0.57
Clay	-0.31	0.91	0.61	-	0.65	0.37	0.55	0.58	0.84	0.84	0.88	0.01
Silt	-0.97	0.12	0.99	0.53	-	0.27	0.10	0.06	0.51	0.19	0.47	0.64
Sand	0.79	-0.52	-0.95	-0.83	-0.91	-	0.18	0.21	0.78	0.47	0.75	0.36
Inds	0.93	-0.27	-1.00	-0.65	-0.99	0.96	-	0.04	0.61	0.29	0.57	0.54
Family	-0.94	0.22	1.00	0.61	1.00	-0.95	-1.00	-	0.57	0.26	0.54	0.58
Scrapers	-0.85	-0.63	0.62	-0.24	0.70	-0.33	-0.58	0.62	-	0.32	0.04	0.85
Gathering	1.00	0.18	-0.92	-0.25	-0.95	0.74	0.90	-0.92	-0.88	-	0.28	0.83
Predators	0.87	0.58	-0.66	0.19	-0.74	0.39	0.62	-0.67	-1.00	0.90	-	0.89
Filtering	-0.33	0.90	0.62	1.00	0.54	-0.84	-0.66	0.62	-0.23	-0.26	0.17	-

3.7 Hierarchical cluster analysis (HCA)

Based on the HCA using the Unweighted Pair Group Method with Arithmetic Mean (UPGMA) method with the Bray-Curtis index, there is a similarity in environmental conditions and benthic macroinvertebrate distribution at the study locations. Figure 7(a) shows the similarity of environmental conditions between locations S2 and S3, which differ from location S1. Similarly, Figure 7(b) indicates the distribution of benthic macroinvertebrates.

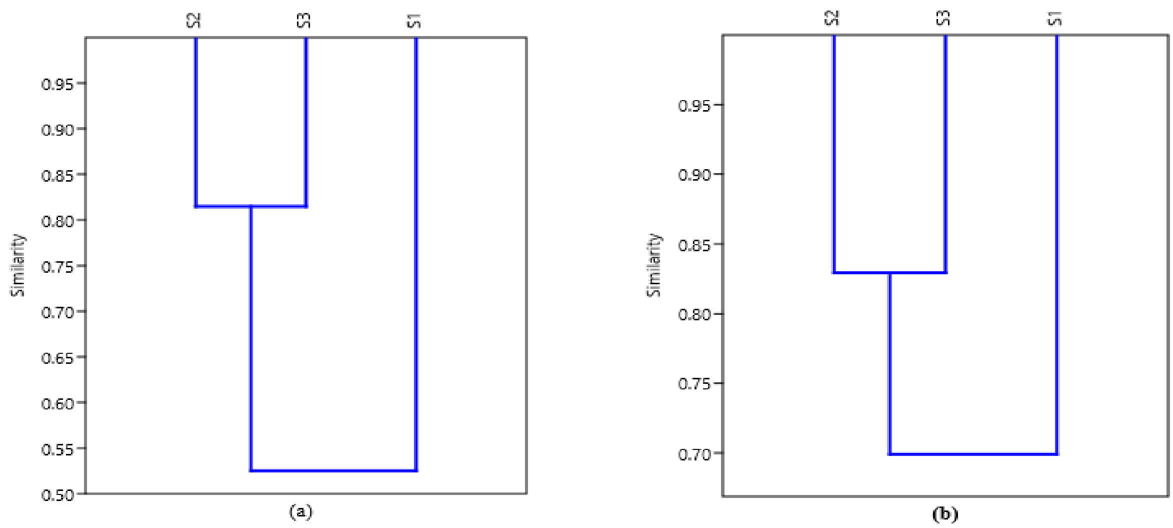

Figure 7. HCA based on environmental: (a) with benthic macroinvertebrates and (b) with the study location.

4. Conclusion

This study emphasizes how community structure and functional feeding group (FFG) surrogate ratios show how changes in water physico-chemical parameters and macrozoobenthos distribution are directly related to ecosystem circumstances. Benthic macroinvertebrate assemblages at the study locations showed distinct geographical differences, according to water quality assessments utilizing pollution and biotic indicators (BMWP-ASPT). The presence of dams and reservoirs had a significant impact on the composition of benthic communities, according to multivariate analyses (PCA and HCA). This was especially true in the central segment of the Citarum River (Jatiluhur Reservoir), whereas the lower segments (Klari Dams and Walahar Dams) showed ecological similarities. These results highlight the ecological effects of hydrological changes and imply that benthic biodiversity may be impacted by habitat structural changes brought about by dams. This necessitates focused monitoring and adaptive management tactics that take site-specific ecological responses into account.

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