



The Influence of Water Physical Chemical Quality on the Zooplankton Community Structure in the Upstream Citarum River of West Java Province

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Authors' contributions

This work was carried out in collaboration among all authors. Author SSA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors ZH and Sunarto managed the analyses of the study. Author HH managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The Citarum River is the longest river in West Java Province which is used for various human activities to produce a load of waste input into water bodies which cause changes in the physical and chemical parameters of the waters that will affect the life of aquatic organisms that live in it, one of which is zooplankton. Zooplankton can be used as a water bioindicator because it has a high level of sensitivity to pollution, especially in freshwater. The purpose of this research is to determine the physical-chemical quality of the water in the Citarum River and its influence on the structure of the zooplankton community in this environment. The research was carried out from August 2020 until October 2020 with a purposive sampling method. Sampling was carried out at 5 stations with 6 repetitions every 1 week. The parameters observed were physical and chemical parameters of the waters, an abundance of zooplankton, diversity index, and dominance index. The results showed that the composition of zooplankton in the Upstream Citarum River was 15 genus consisting of 2 phyla. The abundance of zooplankton obtained ranged from 21 - 51 individuals/L. The Simpson diversity index (D) obtained a range between 0.59 - 0.73 for the high

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category. The dominance index obtained ranges from 0.27 to 0.41 for the low category. Dissolved oxygen and pH are the parameters that most influence the presence of most of the identified zooplankton orders.

Keywords: Citarum River; water quality; community structure; zooplankton.

1. INTRODUCTION

Citarum River is the largest and longest river in West Java. The upstream Citarum River plays a major role because of the many activities around the watershed (DAS) such as industrial, agricultural, and residential activities which are thought to produce inputs of organic and inorganic materials into the waters. The activities of residents around the river and the excessive discharge of domestic waste into the river will affect the physical, chemical, and life parameters of aquatic organisms that live in it, one of which is zooplankton [1].

Physical and chemical factors that affect the composition of zooplankton include temperature, light transparency, DO, current, and pH. Temperature is a physical factor of waters that can affect the growth rate, distribution, composition, and abundance of plankton in waters [2]. Dissolved oxygen (DO) is a limiting factor for zooplankton life. Dissolved oxygen is needed for the respiration process for most aquatic organisms, one of which is zooplankton [3]. Furthermore, currents also play a direct role in the composition of zooplankton. The composition of zooplankton will increase at fairly weak currents because zooplankton will be carried to the body of water if the water current is too strong [3]. The pH parameter in water can affect the production of zooplankton. This is because each species has a different tolerance for pH so that changes in pH can cause changes in the abundance of plankton in the waters [4].

Zooplankton can be used as a water bioindicator because it has a high level of sensitivity to pollution, especially in freshwaters [5]. Changes in the ecological structure of water (abundance, diversity, uniformity, and dominance) can indicate that the waters have changed conditions [6]. Based on this explanation, it is necessary to study the physical and chemical quality of the abundance of zooplankton in the Upper Citarum River so that it can be used as a basis for determining policies for managing Citarum River waters.

2. MATERIALS AND METHODS

2.1 Period and Place Study

The research was carried out from August 2020 until October 2020 in the Upstream Citarum watershed. The method used is a field survey method with a purposive sampling technique of sampling. The sampling station is divided into 5 stations, namely 1,2,3,4, and 5. The determination of the research station is based on a preliminary survey of the field, namely the determination of the research station and coordinate points with consideration of easy access to the location and land use maps.

The locations of the research stations are as follows:

- Station 1: Cisanti Springs, at the foot of Mount Wayang - South Bandung covering unspoiled water conditions. The surrounding land use is primary forest. The sampling location is located at coordinates -7° 12 '28' 'latitude and 107° 39' 19 " east longitude.
- Station 2: Situ Cisanti, located in Tarumajaya, Kertasari, Bandung as an outlet there Cisanti. The surrounding land use is primary forest. The sampling location is located at coordinates -7° 12 '29' 'latitude and 107° 39' 33 " east longitude.
- Station 3: Wangisagara, located in Wangisagara Village, Majalaya, Bandung, is a part of the river that is indicated to be affected by agricultural waste such as fertilizers, pesticides, and livestock manure. The land use around is a residential area and agricultural land. The sampling location is located at coordinates -7° 4 '54' 'South Latitude and 107° 44' 20 " East Longitude.
- Station 4: Majalaya, the surrounding land use is a settlement. The sampling location is located at coordinates -7° 3 '4' 'latitude and 107° 45' 24 " east longitude.

- Station 5: Sapan, located at Jl. Sapan, Gedebage, Bandung covers the area after the confluence of 3 rivers, namely the Citarum River, the Citarik River, and Cikeruh River. The surrounding land uses are residential areas, agriculture, and various industrial activities. The sampling location is located at coordinates $-7^{\circ} 0' 55''$ latitude and $107^{\circ} 43' 31''$ east longitude.

The map of the research location can be seen in Fig. 1.

2.2 Sampling and Measurement

The sampling location was carried out in the Upstream Citarum River. Citarum River is the longest in West Java. The Citarum River originates at Mount Wayang, Kertasari District, Bandung Regency and empties into Muara Gembong, Bekasi Regency [7]. The river is used for various activities that support human life as well as a place for disposal of liquid waste such as domestic waste, industrial waste, and agricultural waste as well as livestock [8]. The waste products that are wasted then enter directly into the water which causes pollution.

The Citarum River is currently one of the most polluted rivers in the world [9].

A sampling of water and zooplankton in this research was carried out in a time series every seven days with six sampling times at five stations. Research activities consist of in-situ research and ex-situ research. In-situ research is taking water samples and measuring water quality, including measurements of temperature, current, light transparency, pH, and DO. Exsitu research is plankton identification, BOD analysis, ammonia measurement from sampling to be analyzed at the Laboratory of Water Resources Management, Faculty of Fisheries and Marine Sciences, Padjadjaran University, Indonesia.

2.3 Sample Analysis

Zooplankton data obtained from the research results were analyzed using comparative descriptive methods at each station while the relationship between water quality and zooplankton abundance was analyzed using CCA (Canonical Correspondence Analysis).

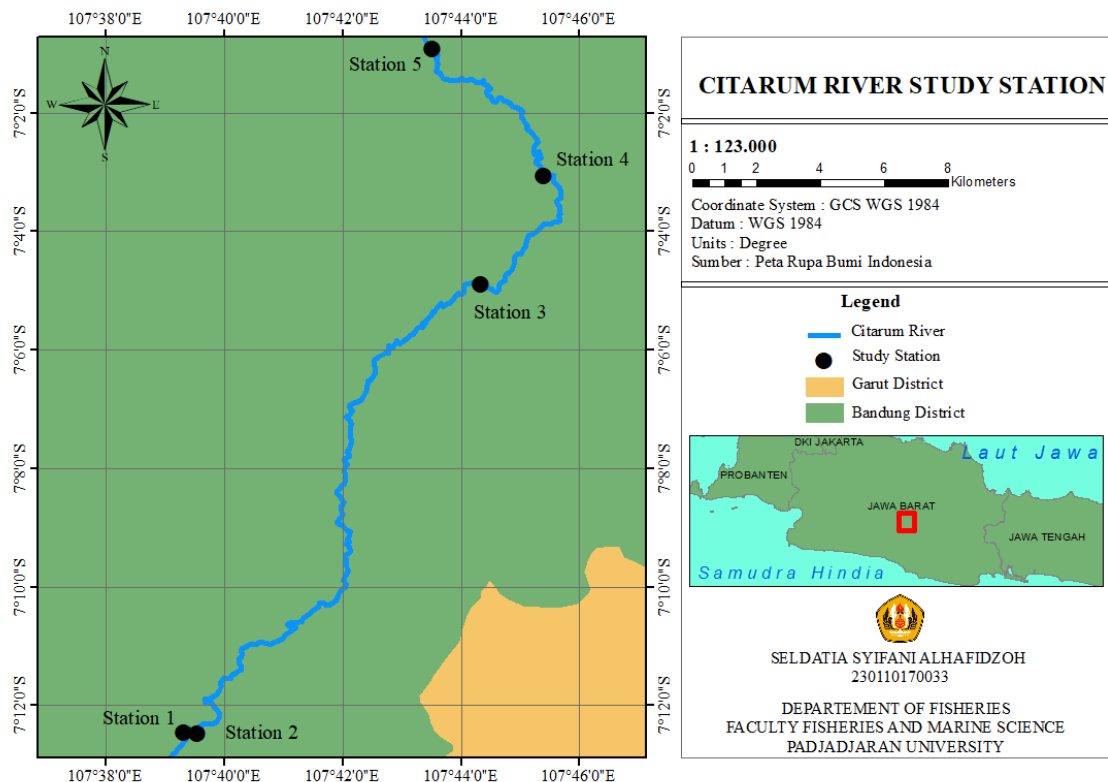


Fig. 1. Research location map

Table 1. Water quality parameters

Parameter	Unit	Method	Observation Location
Physical			
Temperature	°C	Potensiometrik	Citarum River
Light Transparency	cm	Visual	Citarum River
Current	m/s	Potensiometrik	Citarum River
Chemical			
DO	mg/L	Potensiometrik	Citarum River
pH	-	Potensiometrik	Citarum River
BOD	mg/L	Titrimetrik	Laboratory
Ammonia	mg/L	Spektrofotometrik (SNI 06-6989-1.30-2005)	Laboratory
Biology			
Abundance, Diversity and Dominance Zooplankton	ind/L		Laboratory

2.3.1 Abundance plankton abundance

The abundance of plankton is calculated quantitatively, which is based on the abundance expressed in ind / L. Plankton abundance is calculated using a modified Sachlan formula [10]:

$$N = n \times \frac{(vr)}{(vo)} \times \frac{1}{(vs)}$$

Information:

N = Number of Plankton (ind / L)

n = Amount of plankton observed

vr = Volume of plankton filtered (ml)

vo = Observed plankton volume (ml)

vs = Volume of filtered water (l)

2.3.2 Simpsons diversity index (D')

Plankton diversity was analyzed using the Simpsons Diversity Index in [11] which is formulated as follows:

$$D' = 1 - \sum \left(\frac{ni}{n}\right)^2$$

Information:

D' = Simpson s Diversity Index

ni = Number of individuals in the species to-i

N = total number of individuals

The Simpsons Diversity Index value ranges from 0 - 1, the diversity index index is 0, the diversity value is low and the diversity index value is 1, the

diversity value is high. Ecosystem stability is said to be good if it has Simpson's Diversity Variety between 0.6 - 0.8 [12].

2.3.3 Dominance index (C)

The small value of the Uniformity and Diversity Index indicates the high dominance of a species over other species. The Simpson dominance index formula, according to [12], is:

$$C = \sum_{i=1}^n pi^2$$

Information:

C = Dominance Index

Pi = ni / N

ni = number of individuals in one type

N = total number of individuals of all types

The index values range from 0-1 with the following categories:

0 ≤ C ≤ 0.5 = Low Dominance

0.5 ≤ C ≤ 0.75 = Moderate Dominance

0.75 ≤ C ≤ 1.0 = High Dominance

2.3.4 Relations analysis

Data obtained from water quality measurements were analyzed using PAST software (Paleontological statistical software package)

version 3.25. CCA (Canonical Correspondence Analysis) is a multivariate analysis that can explain the relationship between biological communities and environmental parameters in the form of ordination [13]. The results of the CCA analysis are displayed in the form of an ordinate diagram containing the points of the order and environmental variables.

3. RESULTS AND DISCUSSION

3.1 Physical and Chemical Parameters of Waters

The physical and chemical parameters of water during the research are presented in Table 1.

The highest average temperature in the Upstream Citarum River during the research was at station 5 at $26.63^{\circ}\text{C} \pm 1.52$ and the lowest average temperature was at station 1 at $22.7^{\circ}\text{C} \pm 2.20$ with a range between 22.7 to 26.63°C . The temperature difference is due to the condition of the research station which has a different altitude where station 1 is higher because it is located in the Upstream reaches of the Citarum River, which is at an altitude of 1,500 masl, while station 5 is at an altitude of 665 masl. Water temperature is influenced by sunlight intensity, geographic elevation, and surrounding vegetation factors [3]. The temperature range obtained during the research is in the optimal range for zooplankton growth, which is between 15 - 35°C [14].

The highest average flow velocity in the Upstream Citarum River during the research was found at station 5 at $0.31 \text{ m/s} \pm 0.09$ because the station in the Sapan area is a confluence river of three rivers, namely the Citarum River, Citarik River, and Cikeruh River. The lowest average current is at station 2 of $0.04 \text{ m/s} \pm 0.01$ due to the slope of the slope in these waters is quite flat so that the current movement is calmer. Flow velocity is influenced by several river flows that enter the waters and differences in the height and slope of the slopes at each sampling station [15,16]. The average flow in the waters of the Upstream Citarum River is classified as very weak. N use values if current less than 0.1 m/sec classified as very weak current speed, the current speed of 0.1 - 1 m/s classified as current speed and current velocity being $> 1 \text{ m/sec}$ relatively strong flow velocity [17].

The highest average light transparency in the Upstream Citarum River during the research was at station 1 at $152.17 \text{ cm} \pm 2.93$ and the lowest average light transparency was at station 4 at $29.42 \text{ cm} \pm 11.22$. The condition of Station 1 is an unspoiled spring with clear water, in contrast to the condition of Station 4 which has shallow water bottoms in the form of mud and a large number of pollutant loads that enter the water bodies. The low transparency of light is influenced by the movement of water and shallow water conditions, as a result of which the base of the dominant mud rises to the surface and the waters become cloudy so that the mud particles block the penetration of light [18].

The highest BOD value from the measurement results during the research was at station 5 of $4.47 \text{ mg/L} \pm 1.68$. This is due to the presence of organic matter in the waters as a result of human activities in the form of agricultural activities and household waste. The value of BOD in waters can come from waste or residential waste that is not decomposed by microbes that decompose organic matter in the waters [19]. The lowest BOD value is at station 1, which is $1.35 \text{ mg/L} \pm 0.75$, this is because the water conditions at station 1 are still natural without any disturbance to human activities so that the organic matter content is low.

The results of measurements DO range between 6.92 - of 7.65 mg/L , the condition is optimal for plankton life. Phytoplankton and zooplankton can live optimally at DO concentrations above 3 mg/L [17]. The range of DO values is suitable for fisheries according to Indonesian Government Regulation No. 22 of 2021 [20] which ranged from > 3 - 4 mg/L .

The results of pH values at all stations ranged from 6.32 to 6.46 . The figure is normal for a large number of pH waters according to water quality criteria for fisheries by Indonesian Government Regulation 22 of 2021 which is between $6:00$ to $9:00$ [20]. Aquatic organisms, especially plankton, can live in an ideal pH range that is smaller or slightly larger than a pH value of 7 [21].

The highest average ammonia concentration value in the Upstream Citarum River during the research was at station 5, namely $0.0107 \text{ mg/L} \pm 0.0015$, and the lowest average ammonia concentration value was at station 1 of 0.0003 ± 0.0001 which ranges from 0.0003 mg/L - 0.0107 mg/L .

Table 2. Physical and Chemical Parameters in the Upstream Citarum River during Research

Parameter	Unit		Station				
			1	2	3	4	5
Temperature	°C	Average	22.7 ± 2.20	25.02 ± 2.82	25.12 ± 2.81	26.62 ± 2.84	26.63 ± 1.52
		Range	19.8-25.2	21.2-28.1	21.1-29.4	21.6-29.9	23.6-27.6
Current	m / s	Average	0.06 ± 0.03	0.04 ± 0.01	0.21 ± 0.08	0.18 ± 0.14	0.31 ± 0.09
		Range	0.02-0.09	0.02-0.05	0.14-0.25	0.11-0.46	0.23-0.46
Transparency	cm	Average	152.17 ± 2.93	51.08 ± 7.98	39.58 ± 18.39	29.42 ± 11.22	29.71 ± 13.38
		Range	147-155	42.0-59.2	11.7-61.0	9.00-43.50	15.25-49.50
BOD	mg / L	Average	1.35 ± 0.75	3.22 ± 1.00	2.12 ± 1.24	3.59 ± 0.49	4.47 ± 1.68
		Range	0.33-2.27	2.10-4.87	0.33-3.95	2.92-4.22	1.95-6.48
DO	mg / L	Average	7.65 ± 0.78	7.50 ± 1.15	7.48 ± 0.73	6.95 ± 1.10	6.92 ± 0.61
		Range	6.30-8.50	6.20-9.40	6,70-8,60	5,60-8,70	6,10-7,80
pH	-	Average	6.46 ± 0.32	6.38 ± 0.25	6.37 ± 0.23	6.36 ± 0.17	6.32 ± 0.10
		Range	5.95-6.75	6,08-6,82	6,20-6,81	6,07-6,52	6,23-6,45
Ammonia	mg / L	Average	0.0003 ± 0.0001	0.0033 ± 0.0047	0.0013 ± 0.0005	0.0053 ± 0.0005	0.0107 ± 0.0015
		Range	0.0002-0.0005	0.0010- 0.0130	0,0010- 0.0020	0.0050- 0.0060	0.0080- 0.0120

The increase in ammonia concentration can be caused by agricultural, plantation, industrial, and residential activities around the area [22]. Based on Government Regulation No. 22 of 2021 [20] concerning Regarding the Implementation of Environmental Protection and Management in connection with the classification and criteria for class II wastewater quality standards, the threshold value for ammonia in waters is 0.5 mg / L this indicates that the value obtained is far below the set threshold.

3.2 Zooplankton Abundance, Diversity Index, and Dominance Index

Zooplankton composition obtained during research in the Upstream Citarum River consists of 2 phyla and 15 genus. The two zooplankton phyla are Arthropoda (7 genus) and Rotifera (8 genus). The abundance of zooplankton obtained from all stations during the research ranged from 21 individuals / L - 51 individuals / L can be seen in Table 3.

The highest abundance of zooplankton obtained during the research was at station 2 at 51 individuals / L and the lowest abundance obtained during the research was at station 1 at 21 individuals / L. The high abundance of zooplankton at station 2 is because this area is part of the outlet of Situ Cisanti where much of the residual content of organic matter which is disposed of in this area is found so that it

produces a lot of nutrients into the waters. This organic material is thought to come from fish feed which is not consumed by the fish so that it dissolves in the water. The large contribution of nutrients to water areas will trigger the growth of plankton [23]. Meanwhile, station 1 is unspoiled waters without any disturbance to human activities so that the abundance at station 1 is still low.

The highest zooplankton abundance is found in the Cyclops genus of 19 ind / L at station 2. Cyclops is part of the Copepoda group which is a zooplankton group that has a wide distribution because it has high adaptability and tolerance to water quality and can live in various types of waters [24]. Copepod types reproduce throughout the year. Therefore, copepods are always found in abundance. Abundance and distribution patterns depend on the availability of food, oxygen, sunlight, and wind [25].

The results of the plankton diversity index obtained from all stations during the research are in the high category, namely the range between 0.59 - 0.73 can be seen in Fig. 2. The Simpsons diversity index value ranges from 0 - 1, if the index value is close to 1, the distribution of an individual's uneven and stable ecosystem is said to be good if it has a Simpson Diversity Index between 0.6 - 0.8 [12]. This shows that the waters of the Upstream Citarum River have a stable community.

Table 3. Zooplankton abundance data (individual / L) during Research

Phylum	Class	Genus	Station				
			I	II	III	IV	V
Arthropods	Maxillopoda	Undila	0	1	0	0	0
		Crustaceans	Cyclops	5	19	2	0
	Tropocyclops		0	2	0	0	2
	Nauplius		3	11	3	1	0
	Diaphanosoma		0	3	0	0	0
	Daphnia		3	1	0	0	3
	Ostracoda	Cypris	0	0	0	1	0
Rotifera		Monogononta	Notholca	1	4	3	4
	Brachionus		0	2	0	0	0
	Euchlanis		0	0	0	1	4
	Asplanchna		2	3	4	9	5
	Trichocerca	0	1	0	1	3	
	Karatella	3	0	0	0	0	
	Eurotatoria	Fillnia	0	0	5	3	0
		Bdelloidea	Rotaria	4	4	7	8
Zooplankton abundance (individual / L)			21	51	24	28	41

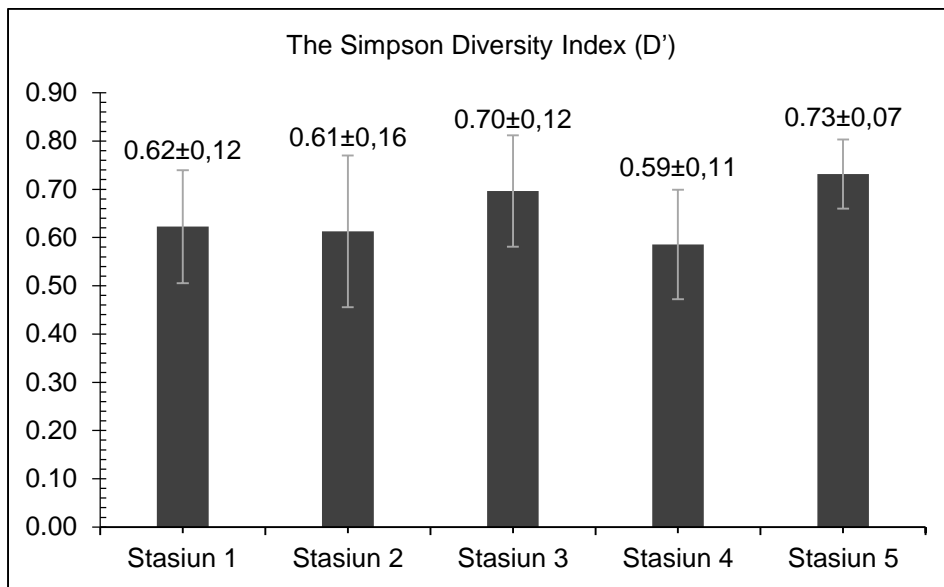


Fig. 2. The simpson diversity index (D') zooplankton during the research

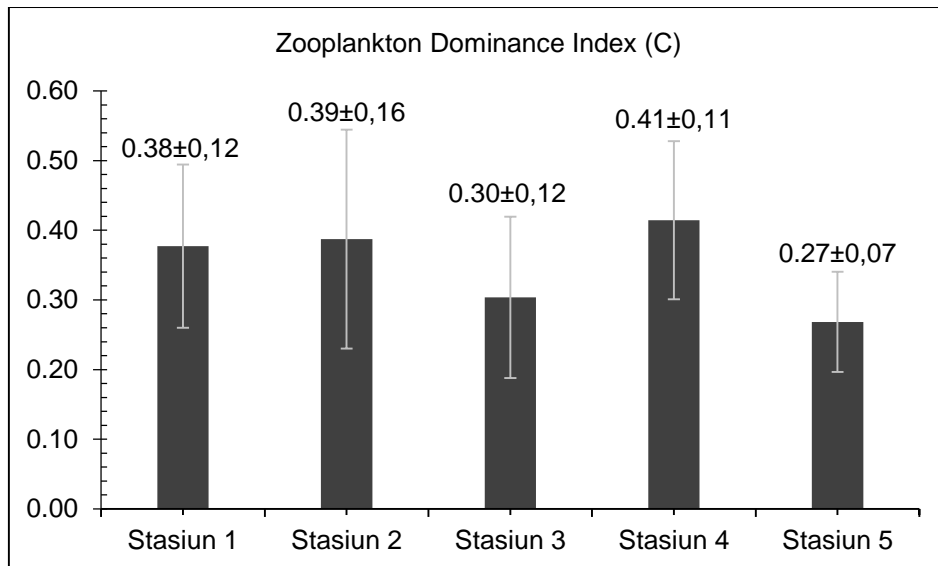


Fig. 3. Zooplankton dominance index (C) during research

The results of the zooplankton dominance index during research in the Upstream Citarum River are in a low category, ranging from 0.27 to 0.41, which can be seen in Fig. 3. By Odum's [12] statement that the dominance index value ranges from 0-1 with 3 categories including low dominance if the index value ranges from $0 \leq C \leq 0.5$, moderate dominance if the index value ranges from $0.5 \leq C \leq 0.75$, and high dominance if the index value ranges from $0.75 \leq C \leq 1.0$. This shows that the index value obtained indicates that there is no tendency for species to dominate in the community [26].

3.3 Relations of Aquatic Physical and Chemical Parameters with Zooplankton Abundance

Based on Table 4, the three orders correlate with DO and pH parameters in the same ordinate. The Copepod Order is the order with the strongest correlation with DO compared to other orders in the same ordinate. This can be seen in Fig. 4 marked with the point of the Copepod order closest to the DO triplot line.

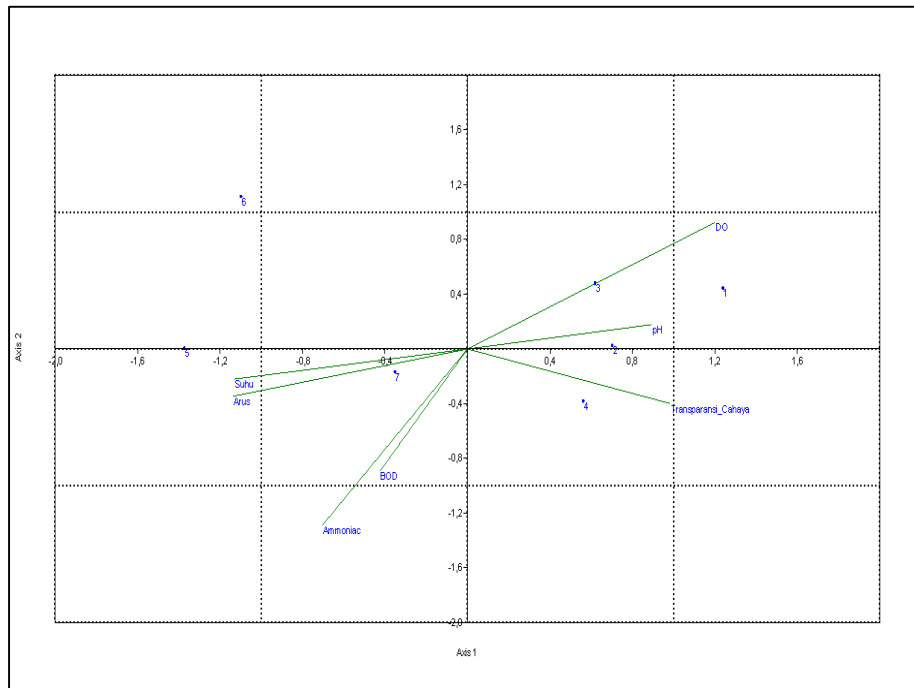


Fig. 4. Canonical correspondence analysis (CCA) diagram of zooplankton order with water quality parameters

1 = *Misophrioida*. 2 = *Cyclopoida*. 3 = *Copepoda*. 4 = *Cladocera*. 5 = *Podocopida*.
6 = *Flosculariaceae*. 7 = *Ploima*

Table 4. Correlation of Zooplankton order with environmental parameters

Order of Zooplankton	Parameter
Misophrioida	DO, pH
Cyclopoida	
Copepod	
Cladocera	Light-Transparency
Podocopida	BOD, Ammonia, Temperature, Flow
Ploima	
Flosculariaceae	Does not have a strong correlation with certain parameters

Two orders are correlated with parameters of temperature, current, BOD, and ammonia in the same ordinate, namely Podocopida order and Ploima order. The Ploima Order is the order that is most strongly correlated with the current compared to other orders in the same ordinate. It is indicated by the point of the Ploima order closest to the triplot line of the current. Furthermore, 1 zooplankton order that was identified, namely the Cladocera order, showed that this order was slightly correlated with light transparency. Meanwhile, the order Flosculariaceae did not have a strong correlation with the environmental parameters tested. The correlation of a parameter with an identified order indicates that the zooplankton of an order is influenced by its presence with certain water quality parameters.

Table 4 also shows that most of the orders identified during the study were more influenced by DO and pH. Meanwhile, several orders that do not have a strong correlation with certain parameters show that the zooplankton in that order is zooplankton that are tolerant of various water conditions.

4. CONCLUSION

Based on the research results, it can be concluded that the water quality is based on Government Regulation No. 22 of 2021 concerning Regarding the Implementation of Environmental Protection and Management in the Upstream Citarum River is included in the category II and III class which can be used for fishing activities and life support for zooplankton.

Zooplankton can be used as a water bioindicator because it has a high level of sensitivity to pollution, especially in freshwaters. The composition of zooplankton is closely related to changes in the aquatic environment in the form of physical and chemical including temperature, light transparency, DO, currents and pH. The results of research on the zooplankton community of the Upstream Citarum River in August - October 2020 amounted to 15 genus consisting of 2 phyla. The abundance of zooplankton obtained ranged from 21 - 51 individuals / L. The highest abundance of the genus during the research was cyclops, part of the Copepod group, which has a wide distribution because of its high adaptability and tolerance to water quality. Simpson's diversity index (D) is high with a range between 0.59 - 0.73. The dominance index obtained was classified as low with a range between 0.27 - 0.41. Dissolved oxygen and pH are the parameters that most influence the presence of most of the identified zooplankton orders.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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