Journal of Biotechnology and Natural Science ISSN 2808-2508
Vol. 1, No. 2, December 2021, pp. 88-99

Diversity of Meiofauna in Progo and Opak River Estuaries

[1a]Fauzan Muhammad Ardhi, [2b]Nurul Suwartiningsih*

[1a] Study Program of Biology, Universitas Ahmad Dahlan
[2b] Laboratory of Ecology and Sistematics, Study Program of Biology, Universitas Ahmad Dahlan
[2]nurul.suwartiningsih@uad.ac.id*
* corresponding author

ARTICLE INFO

Article history
Received December 25, 2021
Revised December 30, 2021
Accepted December 31, 2021

Keywords
Bioindicator
Ciliopora
Copepoda
Water ice treatment

ABSTRACT

The Estuaries of Progo and Opak rivers, being the terminus of all rivers flowing through the Special Region of Yogyakarta, are highly susceptible to pollution which results in decreased water quality. The use of meiofauna as a bioindicator to assess water quality in the estuaries of Progo and Opak rivers has never been made. This study aims to determine the diversity of meiofauna at the estuaries of Progo and Opak rivers. Stations and sampling points are determined using purposive sampling method. Extraction is conducted using water ice treatment method. The meiofauna obtained from the sediment screening are then identified, calculated and analyzed to find out the index values of abundance, dominance, diversity, and evenness. The results showed that the highest meiofauna abundance index was 247,333 ind. m^{-2} at the estuary of Progo river station 1 at the time of the first pick-up. While the lowest meiofauna abundance was 13,333 ind. m^{-2} at station 2 of Opak river estuary during the first take. The dominance at the estuaries of Progo and Opak rivers is in the moderate category. The meiofauna diversity in both river estuaries is categorized as low to moderate. Evenness in both estuaries is uneven at several stations. The meiofauna diversity at the estuaries of Progo and Opak rivers is low to moderate, although the water quality still meets the quality standards.

How to Cite: Ardhi, F.M. and Suwartiningsih, N. 2021. Diversity of meiofauna in Progo and Opak river estuary. *Journal of Biotechnology and Natural Science*, 1(2), 88-99

1. Introduction

River estuary is the transition area of clear water and sea water. When flood happens, an estuary functions to flow river water discharge to the sea. However, in the event of tide, when sea water discharge is higher than river discharge, the estuary should be capable of passing such discharge (Werdi & Eryani, 2020). An Estuary would accumulate incoming pollutants along the river flow area (Fajri & Kasry, 2013). As a result, water quality in the estuary may decrease and may lead to other environmental problems with more harmful effect to the health of environment.

Pollutants entering an estuary area are the results of human activities along river flow areas. Such activities as rubbish throwing to rivers, and disposal of domestic, mining, agriculture, and fishery wastes are some of the examples. World Bank's survey (2018) suggested that Yogyakarta is one of the cities with largest amount of plastic wastes in the river flow area compared to other cities. The highest percentage of waste in Yogyakarta consists of plastic wastes 23.8% and organic waste 60.9%. Hence, the estuaries of Progo and Opak rivers, being the terminal points of all rivers flowing through the Special Region of Yogyakarta, are highly susceptible to pollution which results in decreased water quality.

The potential of decreased water quality can be monitored using various methods. One of them is the application of bioindicators. All living organisms such as plants, animals, and microorganisms may be called bioindicators as long as they can be used to monitor the conditions of an ecosystem (Parmar, et. al., 2016). The use of bioindicators to assess water quality in Opak River estuary has been done by Lesnussa (2019) using phytoplanktons. The results show that the water condition of Opak River estuary is polluted, ranging from low to moderate levels.

In addition to phytoplanktons, meiofauna can also be used as bioindicators. Meiofauna are animals in the size of 63-1000 µm (Giere, 2009). Zulkifli (2008) suggested that the use of meiofauna as bioindicators was considered good in the assessment of environmental conditions. A number of studies related to the use of meiofauna as bioindicators have been performed. A study by Gyedu-Ababio (2011) suggested that the structure of Nematode community in Swartkops and Gamtoos river estuaries in East Cape (South Africa) was affected by the existence of metals (Cu, Fe, Pb, Zn) and organic carbons. Alves, et. al., (2013) added that the response of meiofauna was affected by the gradient of estuary (such as dynamics and types of sediment, existence of oxygen, temperature, and speed of flow) as well as by anthropogenic pressure (such as high density of local population, existence of pier, and mining activities). However, the use of meiofauna as bioindicators in Progo and Opak River estuaries has not been made. Based on these backgrounds, the study on the meiofauna diversity in Progo and Opak River estuaries is expected to become supporting data in examining and monitoring water quality of estuary area.

2. Method

This study is categorized as exploratory study conducted from October 2019 to January 2020 to identify diversity of meiofauna in the estuaries of Progo and Opak Rivers Figture 1). In each estuary, three stations are chosen using purposive sampling method with the following criteria: have up and down tides zone, not far from the end of estuary, and can be accessed safely. Station I is the closest to the sea, i.e. at the mouth of the estuary at 100 meter distance from the sea. The distance between one station to the other is 200 meters. In each station, three sampling point are decided at the interval of 1 meter between sampling points. Those three sampling points are in up and down tidal area and are decided using purposive sampling method (Figure 2).

Fig. 1. Locations of sample taking points. Progo River Estuary (Left) and Opak River Estuary (Right). (Source: GPX Virwer With Drive 2020)

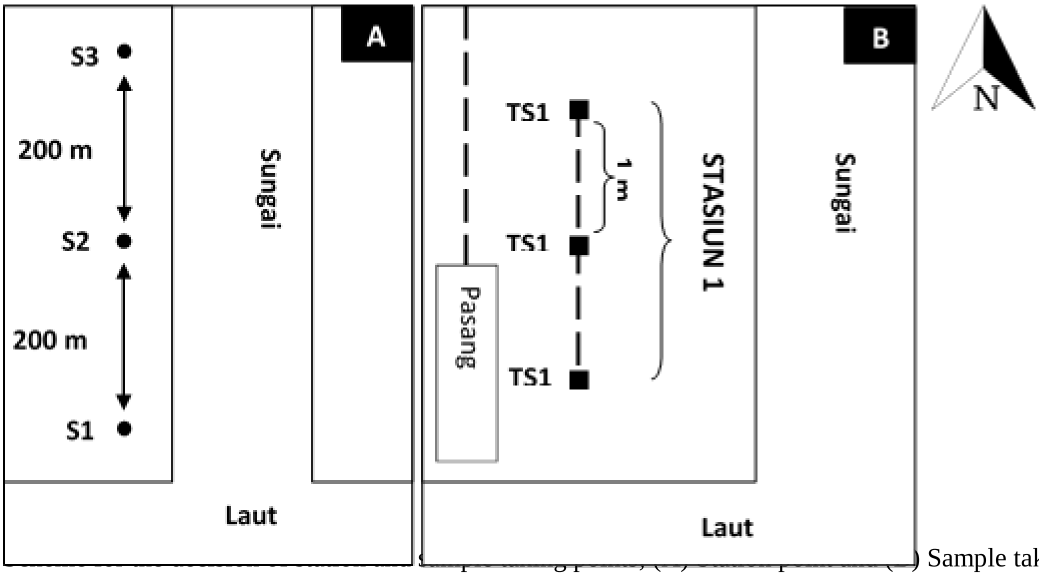

Fig. 2.) Sample taking point

2.1. Taking of Sediment Samples

The taking of sediment samples was conducted from 05.00 to 07.00 WIB (West Indonesia Time) on the consideration that such time would enable the observation of up and down tide area as well as to minimize the effects of temperature on meiofauna. Sediment samples were taken using a corer. The corer was inserted up to 20 cm into the sediment. Each taken sediment sample was immediately put into a separate plastic bag, tightly tied, and labeled to avoid inter-changes. The samples in the plastic bags were then put into a cooling box filled with ice blocks to keep the temperature cold so that bacteria would not grow. The samples were then brought to the Laboratory of Ecology and Systematics of UAD to be proceeded with extraction and identification. The assessment of environmental parameters in this study was made according to Erliyanda, et. al. (2017). The parameters assessed among others were temperature, salinity, levels of Dissolved Oxygen (DO), and pH of river water around the sediment.

2.2. Extraction of Sediment

Meiofauna were extracted from the sediment samples in two phases. In the first phase, extraction was conducted using water ice treatment method (Uhlig, et. al., 1973) (Gambar 3) with modification. This method was aimed at macrofauna and sediment were screened. Ice blocks and estuary water were used since meiofauna were affected by the changes in salinity levels, water flow passing the sediment, and temperature. These factors cause meiofauna to actively move out from the sediment and can be observed when they are still alive (Uhlig, et. al., 1973).

The tools for the first screening consisted of a PVC pipe and nylon mess with pore diameter of 1000 placed on a static stand. A Petri dish already filled with estuary water was placed under the screen with the water surface touching part of the screen (Fig. 3). Once the screen was ready, the sediment was slowly poured into the pipe. A lump of cotton was then placed on the sediment to partition between the sediment and ice. The cotton was spread evenly in such a way that its melts would distribute to all parts of the sediment. Ice blocks were broken down to the size of ± 3 x 3 x 3 cm, spread over cotton, and let melt. Screened materials contained on Petri dishes (P1) and (P2) were subsequently proceeded to the second extraction phase for another screening with lower limit screen size 230 mesh (pore diameter 63 µm). The meiofauna captured in this second screening were then transferred to new Petri dishes by way of pouring with aquadest.

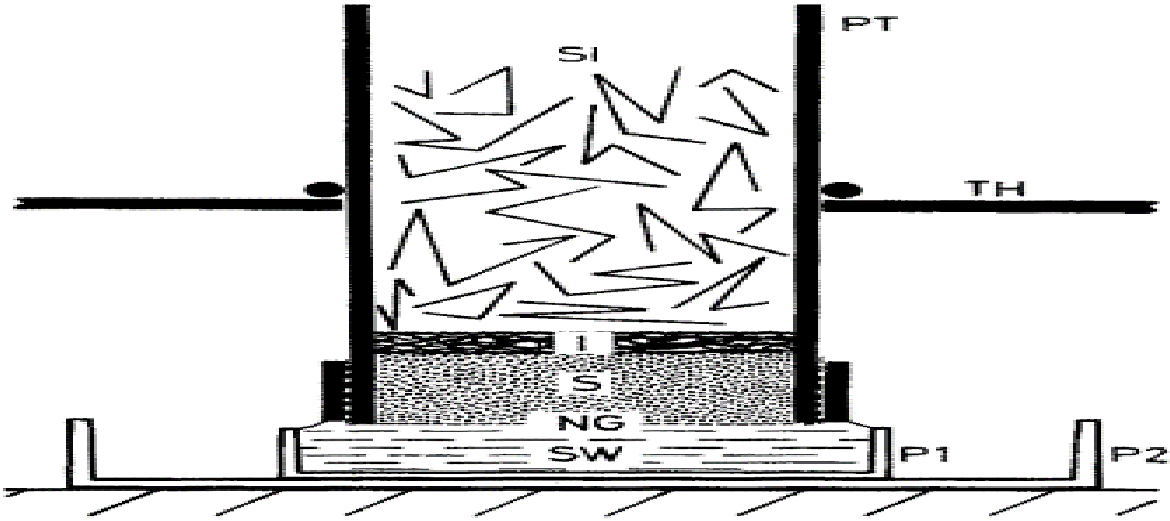

Fig. 3. Screening diagram of *water ice treatment.* I: Partition (cotton), NG: Nylon mesh 1000 µm, P1: Petri dish (diameter 9 cm), P2: Petri dish (diameter 15 cm), PT: PVC Pipe, S: Sediment, SI: Ice blocks, SW: Estuary 2ater, TH: Static stand (Uhlig, et. al., 1973)

2.3. Meiofauna Identification

Meiofauna samples were then examined, identified, and counted under a binocular microscope for analysis. Identification was made based on the book entitled Identification to the Study of Meiofauna (Higgins & Thiel 1988).

2.4. Data Analysis

Data on phylum and number of meiofauna were used to calculate indexes of abundance, Simpson dominance, Shannon-Wiener evenness, and Shannon-Wiener diversity. The formulas applied for the calculation are as follows:

Calculation of meiofauna abundance is calculated based on number of individuals per unit of area.

$$C = \sum_{i=1}^{n} \frac{ni}{A} C = \sum_{i=1}^{n} \frac{ni}{A} \quad \text{or} \quad C = \frac{10000 \times a}{b} C = \frac{10000 \times a}{b} \quad (1)$$

Description:

C : Abundance of meiofauna (ind. m-2)

ni or a : Number of individuals of i (ind)

A or b : Coverage Area of corer conversion from cm2 to m2)

Calculation of dominance using Simpson dominance index with the following formula (Dhahiyat, et al., 2003):

$$D = \sum_{i=1}^{s} (pi^2) D = \sum_{i=1}^{s} (pi^2) \quad (2)$$

Description:

D : Simpson dominance index

Pi : ni/N

ni : number of genus individuals of i

N : total individuals in community

Criteria of dominance according to Faturohman, et. al. (2016)

0,00 < D < 0,30 : Low Dominance

0,30 < D < 0,60 : Moderate Dominance

0,60 < D < 1,00 : High Dominance

Diversity Index of meiofauna is determined using Shannon-Wiener formula as follows (Zulkifli, 2008):

$$H' = -\sum_{i=1}^{n}\left(\frac{ni}{N}\ln\frac{ni}{N}\right)H' = -\sum_{i=1}^{n}\left(\frac{ni}{N}\ln\frac{ni}{N}\right)$$
(3)

Description:

H' : Shannon-Wiener Diversity Index

Ni : Number of phylum individuals of i

N : total individuals in community

Criteria of diversity Index according to Odum (1971) in Rinanda, et. al. (2016):

H' < 1 : Low diversity

1 < H' < 3 : Moderate diversity

H' > 3 : High diversity

Shannon-Wiener index of evenness is determined using the following formula:

$$E = \frac{H'}{H'\,maks}E = \frac{H'}{H'\,maks}$$
(4)

Description:

E : index of evenness

H' : index of Shannon-Wiener diversity

H' maks : total individuals in community

Criteria for index of evenness (E) according to Magurran (1998) in Ahlunnisa, et. al. (2016):

E close to 0: Distribution of individuals anong types is highly uneven

E close to 1: Distribution of individuals anong types is almost even/even

3. Findings and Discussion

3.1. Diversity of Meiofauna in Both Estuaries

Results of examination suggested that the highest abundance of meiofauna at 247,333 ind. m^{-2} existed in Progo River Estuary at station 1 at the first take. Whereas, the lowest abundance of meiofauna of 13,333 ind. m^{-2} was found at station 2 in Opak River Estuary at the first take (Tabel 1). Numbers of meiofauna individuals in Progo and Opak Rivers did not show significant difference based on Man Whitney test.

Table 1. Data Analysis of Meiofauna in Progo and Opak River Estuaries

Progo River Estuary							
First Take				Second Take			
Analisis	Station			Analysis	Station		
	S1	S2	S3		S1	S2	S3
∑ Species	7	6	4	∑ Species	2	-	-
∑ Individual	371	50	37	∑ Individual	28	-	-
C	247.333	33.333	24.667	C	18.667	-	-
D	0,28	0,42	0,44	D	0,59	-	-
H'	1,40	1,14	1,02	H'	0,60	-	-
E	0,72	0,55	0,37	E	0,43	-	-
Opak River Estuary							

First Take				Second Take			
Analisis	**Station**			**Analysis**	**Station**		
	S1	**S2**	**S3**		**S1**	**S2**	**S3**
∑ Species	7	4	5	∑ Species	4	-	-
∑ Individual	134	20	113	∑ Individual	35	-	-
C	89.333	13.333	75.333	C	23.333	-	-
D	0,30	0,34	0,54	D	0,33	-	-
H’	1,43	1,22	0,97	H’	1,20	-	-
E	0,74	0,88	0,60	E	0,87	-	-

[a] Description: C (index of abundance; D (index of dominance); H’ (index of diversity; E (index of evenness

The number of meiofauna in Progo River Estuary is not significantly different from that of Opak River Estuary. This may be related to the the fact that the characteristics of substrates in these two stations are almost the same, i.e. sandy. Based on the examination, the type of sediments in Progo and Opak River Estuaries are donінated by sand at Station 1 and 2. Sediment at Station 3 in Progo River Estuary starts to mix with mud and had finer sand grains, whereas at Station 3 of Opak River Estuary the sand grains are still coarse although they are in smaller size than the ones at Stations 1 and 2. Coarse sand grains are preferred by meiofauna *mesobenthic* (Giere, 2009). This is also observed from the abundance of Copepoda dan Ciliophora found in Opak and Progo River Estuaries (Table 2 and 3).

There is significant difference in the number of meiofauna individuals between the first and second takes in each of the rivers based on Wilcoxon test. This is due to the fact that, in the second take at Stations 2 and 3 in each of the Estuaries, no meiofauna individuals were found. The absence of meiofauna in the second take may be caused by seasonal change from dry season to rainy season. Rain in the upstream area has the potential to bring in pollutants from the land. Pollutants entering waters may be harmful to the living organisms, including meiofauna (Yusal, *et al*., 2018; Elviana, 2014). The study by Elviana (2014) also suggested that there was no meiofauna at one of the substations due to the pollutants.

Based on the examination, Stations 1 in both Estuaries are areas affected by sea waves. Sea waves would stir sand sediment as the habitat of meiofauna and would cause circulation of organic and non-organic materials. Such circulation may be beneficial to meiofauna, because the sediment would always have nutrients and oxygen required by meiofauna. Station 2 in Progo River Estuary is also an area affected by sea waves since it is perpendicular to the mouth of the estuary. However, the Station 2 of Opak River Estuary is not much affected by sea waves due to the winding shape of the river flow Figure 1).

Station 3 in Opak River has different sediment characteristics from that of Progo River Estuary. Based on examination, sand sediment at Station 3 of Opak River consists of small stones and a few fine sands. This condition leads to larger sediment pores in Opak River Estuary. On the contrary, sand sediment at Station 3 in Progo River Estuary consists of mixture of sand and mud resulting in smaller sediment pores Figure 4). Due to such condition, there is a possibility that certain meiofauna are abundant in this area.

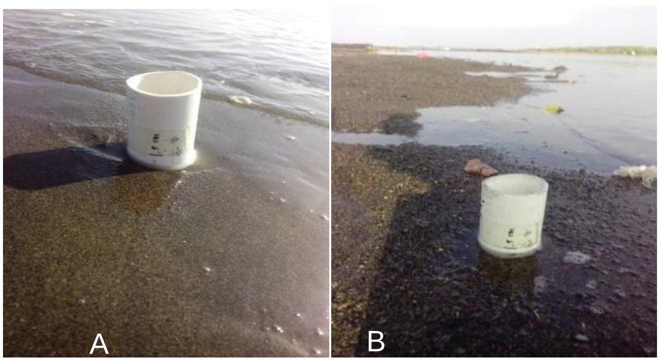

Fig. 4. Substrate condition in both River Estuaries. A. Sediment at Progo Estuary Station (fine and muddy); B. Sediment at Station 3 of Opak River (coarse)

Calculation of index of dominance (Table 1) reveals that most of the stations in both Estuaries have value range of 0.30 < D <0.60. According to Dhahiyat, et. al. (2003), such value suggests that the species dominance in Progo and Opak River Estuaries is at moderate level. This indicates that there are some dominant taxa of meiofauna. Spot with the highest index of dominance was found at Station 1 in the second take in Progo River Estuary at 0.59. The lowest index of dominance was found at Station 1 in Progo River Estuary in the first take at 0.28. The high value of dominance in Progo River Estuary at Station 1 in the second take is due to the discovery of only two types of meiofauna, i.e. Ostracoda dan Turbellaria. Whereas, in the Progo River Estuary at Station 1 in the first take, ten types of meiofauna were discovered (Table 2). The first take resulted in larger number of meiofauna compared to the second take at the same station because the second take was made during rainy season. Rain in the upstream area as well as along river flow area is potential to bring pollutants from land area, so that only certain types of meiofauna survive resulting in relatively high dominance index.

Indexes of meiofauna diversity in Opak and Progo River Estuaries (Table 1) suggest that the diversity in these two estuaries varies from low to moderate. The lowest diversity value occurs in the Progo Estuary at Station 3. Whereas, the highest diversity value exists in the Opak Estuary at Station 1. According to Ape, et. al., (2018) and Soltwedel (2000), several abiotic and biotic factors would affect meiofauna diversity. Those factors include temperature and salinity. Kotwicki et al. (2014) and Albuquerque, et. al. (2007) also mention that diversity is also affected by the surrounding chemical and physical factors and especially in open and unstable environment such as in intertidal zones.

Indexes of meiofauna evenness in Opak and Progo River Estuaries (Table 1) suggest that meiofauna in both Estuaries are even at most stations. However, tnere are stations with uneven distribution. These atations among others are Station 3 at the first take and station 1 at the second take in Progo River Estuary. Such uneven distribution of meiofauna is probably caused by the difference in substrate conditions at these two stations. This is supported by the discovery of the number of individuals (Table 2).

Table 2. Comparison of meiofauna numbers in Progo River Estuary at the first take and second take

Taxa of Meiofauna	Take	
	First	Second
Ciliophora	22	0
Copepoda sp.1	125	0
Copepoda sp.2	122	0
Copepoda sp.3	23	0
Copepoda sp.4	0	0
Nematoda	8	0
Oligochaeta	1	0
Ostracoda	128	8
Polychaeta	0	0
Turbellaria sp.1	23	20
Turbellaria sp.2	2	0
Turbellaria sp.3	4	0

Based on Table 2, the most type of meiofauna found in Progo River Estuary is Ostracoda dan Copepoda. The Copepoda group were mostly found at station 1 at the first take. This is because Copepoda is able to adapt to estuary environment with changing levels of salinity from unsalted when river water discharge is high to high salinity when high tidal water reaches the estuary, and vice versa. According to Walter and Boxshall (2021), Copepoda may live in relatively wide range of habitats. They can live wherever as long as they are in water. Copepoda can also be found in clear (unsalted) water, even in hypersaline water. With such ability, Copepoda are highly abundant in the nature.

The least meiofauna found were Nematode dan Oligochaeta. Such small amount of these meiofauna may be caused by their adaptation to environmental changes. According to Traunspurger (2009), distribution of Nematode is highly affected by oxygen level. Most Nematodes live in the upper layer of sediment (< 5cm from surface) because this are is rich in oxygen. However, some larger sized species are found in the deeper sediment layer. Nematodes would tend to dig deeper when they are in flowing water area.

Table 3. Comparison of meiofauna numbers in Opak River Estuary at the first take and second take

Taxa of Meiofauna	Opak Estuary	
	First	**Second**
Ciliophora	81	10
Copepoda sp.1	19	2
Copepoda sp.2	0	0
Copepoda sp.3	10	0
Copepoda sp.4	4	0
Nematoda	15	0
Oligochaeta	0	0
Ostracoda	64	16
Polychaeta	1	0
Turbellaria sp.1	50	7
Turbellaria sp.2	0	0
Turbellaria sp.3	23	0

Based on Table 3, the most meiofauna found in Opak River Estuary is Ciliophora with 81 individuals. Whereas the least meiofauna is Polychaeta with 1 individual. According to Yusal, *et. al.* (2018), the high population of Ciliophora in Opak River is also caused by their ability to adapt to pollutants entering the water. Whereas the low population of Polychaeta may be caused by insufficient organic materials. Organic materials are nutrients for Polychaeta (Barus, *et. al*., 2019). However, the sediment in Opak River Estuary which consists of small stones and a little fine sand makes it unable to bond much organic materials (Barus, et. al., 2019). This subsequently results in less nutrients for Polychaeta and ends up in smaller number of Polychaeta. Study by Dafforn, et. al. (2013) also suggests that abundance of Polychaeta is affected by the existence of nutrients in the water.

3.2. Environmental and Water Quality Parameters in Both River Estuaries

Assessment results of environmental parameters in Progo and Opak River Estuaries are shown in Table 4.

Table 4. Environmental Parameters in Progo and Opak River Estuaries

River Estuary	Take No.							
	First				**Second**			
	Temp. (°C)	**pH**	**Salinity (‰)**	**DO (mg L^{-1} O_2)**	**Temp. (°C)**	**pH**	**Salinity (‰)**	**DO (mg L^{-1} O_2)**
Progo	30-32	7	0	3,6-7,2	29	7	0-6	5,7-6,5
Average	30,67	7	0	5,33	29	7	2,67	6,07
Opak	24-28	7	4-34	4,5-5,5	28-29	7	0-1	5,2-6,2
Average	25,33	7	24	5,13	28,33	7	0,33	5,8

Examination results of the environmental parameters in Table 4 show that the surface temperature of Progo and Opak River Estuaries is the range of 25,33-30,66 °C. According to Zulkifli (2008), such temperature is classified as normal and can provide optimum support for the life of meiofauna in tropical regions. However, variation in temperature during sample taking can become one of the factors in determining distribution of meiofauna. Giere (2009) describes that some types of meiofauna have specific sensitivity towards temperature changes. They would move farther from or closer to a spot to adapt to the ideal temperature.

Salinity in Progo River Estuary at the first take was 0 ‰ and rose to 0-6 ‰ at the second take. Whereas, salinity at Opak River Estuary was 4-34 ‰ at the first take and lowered to 0-1‰ at the second take (Table 4). The increase of salinity in Progo River Estuary water might be caused by geographical condition of the Estuary. In Progo River Estuary, the sea waves are perpendicular to the mouth of Estuary so that the sea current entering the Estuary is stronger than the current from the river flowing to the sea. This increases salinity of estuary water.

Decrease of salinity in Opak River Estuary might be caused by the rain in the upstream area. During the second sample taking, water discharge in the upstream area was larger than the water entering the river. The other factor might be the geographical condition of Opak River Estuary which is semi-closed and winding in shape. The closed condition of the estuary is caused by the piling up of shore sand in the mouth of estuary due to the accumulation of sand sediments both from the river and the sea (*longshore sedimen transport*) (Wardhana, 2015). Due to this phenomenon, the substrate at the mouth of estuary becomes taller and this prevents sea water from entering further into the river, and hence salinity decreases.

Water pH values in Opak and Progo River Estuaries at the first and second takes were stable at air neutral level (Table 4) even though there was possibe presence of pollutant. Study by Barus, et. al., (2019) in Pulau Payung waters, South Sumatera also shows neutral pH although pollutants are present. According to Giere (2009), survival of meiofauna is not affected by neutral pH. Low pH values may affect meiofauna community. Ricketts, et. al. (2009) suggest that low pH values in water may result in reduced number of individuals and diversity of meiofauna.

Dissolved Oxygen (DO) levels in water have significant effect on meiofauna. Presence of oxygen affects the existence of meiofauna and their habitats. Most meiofauna organisms living in water base (*meiobenthic organism*) require oxygen and wide surface area for their life. However, some species prefer area with less or even without oxygen *hypoxic*) (Giere, 2009). As such, distribution pattern of meiofauna may be related to the presence of oxygen in the sediment and water.

Based on field examination, DO level in Progo River Estuary is in the range of 3,6-7,2 mg L^{-1} O_2 in the first take and 5,7-6,5 mg L^{-1} O_2 in the second take. Whereas in the Opak River Estuary, the DO level is in the range of 4,5-5,5 mg L^{-1} O_2 in the first take and 5,2-6,2 mg L^{-1} O_2 in the second take (Table 4). According to the Regulation by the Governor of Yogyakarta Special Region No. 20 of 2008, the oxygen levels in both rivers are classified as second class water quality standard, i.e. 5 mg L^{-1} O_2 (Regional Body of Environmental Impact Control or Badan Pengendalian Dampak Lingkungan Daerah, 2008). The results of Spearman Correlation Test between meiofauna individuals, temperature, pH, salinity, and DO are presented in Table 5.

Table 5. Spearman Correlation Test between meiofauna individuals, temperature, pH, salinity, and DO

		No. of Individual	Temp.	pH	Salinity	DO
Number of Individual	**Correlation Coefficient**	1.000	-.082	.	.424	-.643*
	Sig. (2-tailed)	.	.799	.	.169	.024
	N	12	12	12	12	12
Temp.	**Correlation Coefficient**	-.082	1.000	.	-.704*	.200
	Sig. (2-tailed)	.799	.	.	.011	.532
	N	12	12	12	12	12
pH	**Correlation Coefficient**	.	.	.	.	.
	Sig. (2-tailed)	.	.	.	.	.

	N	12	12	12	12	12
Salinity	**Correlation Coefficient**	.424	-.704*	.	1.000	-.236
	Sig. (2-tailed)	.169	.011	.	.	.459
	N	12	12	12	12	12
DO	**Correlation Coefficient**	-.643*	.200	.	-.236	1.000
	Sig. (2-tailed)	.024	.532	.	.459	.
	N	12	12	12	12	12

b. *Correlation is significant at the 0.05 level (2-tailed)

Based on Table 5, it is found out that number of individuals is affected by DO (sign. <0,05). Number of individuals is significantly correlated to DO (correlation coefficient of 0,61-0,80). In addition, number of individuals decreases along with increase in DO (negative correlation). This may be caused by the characteristics of meiofauna in both Estuaries which prefer areas with low oxygen levels. Neira, *et. al*. (2001) mentioned that environment with low DO may be beneficial to meiofauna. This is because predators and competitors for meiofauna are less prevalent in low oxygen condition.

4. Conclusion

Abundance of meiofauna was the highest at 247.333 ind. m-2 in Progo River Estuary at Station 1 in the first take. Whereas the lowest abundance of 13.333 ind. m-2 was found at station 2 in Opak River Estuary in the first take. Dominance in Progo and Opak River Estuary are in moderate level. Diversities of meiofauna in both Estuaries are in low to moderate levels. Evenness in both Estuaries is classified uneven in several stations. Assessment of environmental parameters such as the contents of organic materials in the sediment is required to identify specific factors which cause abundance of meiofauna. Further study is required to identify the characteristics of each taxa of meiofauna up to the species level. Data on diversity of meiofauna may be used as one of bioindicators for the DO level and the presence of organic matter pollutants in water.

REFERENCES

Ahlunnisa, H. A. N., Zuhud, E. A. M., and Yanto, D. A. N. (2016). Keanekaragaman spesies tumbuhan di areal. 21(1), 91-98. (Plant Species Diversity in area 21(1), 91-98)

Albuquerque, E. F., Pinto, A. P. B., Perez, A. d'Alcântara de Q., and Veloso, V. G. (2007). Spatial and temporal changes in interstitial meiofauna on a sandy ocean beach of South America. *Brazilian Journal of Oceanography*, 55(2), 121-131. https://doi.org/10.1590/S1679-87592007000200005

Alves, A. S., Adão, H., Ferrero, T. J., Marques, J. C., Costa, M. J., and Patrício, J. (2013). Benthic meiofauna as indicator of ecological changes in estuarine ecosystems: The use of nematodes in ecological quality assessment. *Ecological Indicators*, 24(10), 462-475. https://doi.org/10.1016/j.ecolind.2012.07.013

Ape, F., Sarà, G., Airoldi, L., Mancuso, F. P., and Mirto, S. (2018). Influence of environmental factors and biogenic habitats on intertidal meiofauna. *Hydrobiologia,* 807(1), 349-366. https://doi.org/10.1007/s10750-017-3410-1

Badan Pengendalian Dampak Lingkungan Daerah. (2008). Peraturan Gubernur Daerah Istimewa Yogyakarta Nomor 20 Tahun 2008. Yogyakarta.

Regional Body for Environmental Impact Control (2008). Regulation of The Governor of Yogyakarta Special Region No. 20 of 2008. Yogyakarta.

Barus, B. S., Aryawati, R., Putri, W. A. E., Nurjuliasti, E., Diansyah, G., and Sitorus, E. (2019). Hubungan n-total dan c-organik sedimen dengan makrozoobentos di perairan Pulau Payung, Banyuasin, Sumatera Selatan. *Jurnal Kelautan Tropis*, 22(2), 147. (Correlation of n-total and c-organic of sediment to macrozoobenthos in Pulau Payung waters, Banyuasin, South Sumatera. Jurnal Kelautan Tropis, 22(2), 147) https://doi.org/10.14710/jkt.v22i2.3770

Dafforn, K. A., Kelaher, B. P., Simpson, S. L., Coleman, M. A., Hutchings, P. A., Clark, G. F., … Johnston, E. L. (2013). Polychaete richness and abundance enhanced in anthropogenically modified estuaries despite high concentrations of toxic contaminants. *PLoS ONE*, 8(9). https://doi.org/10.1371/journal.pone.0077018

Dhahiyat, Y., Sinuhaji, D., and Hamdani, H. (2003). Struktur komunitas ikan karang di daerah transplantasi karang Pulau Pari, Kepulauan Seribu. *Jurnal Iktiologi*, 3(2), 87-94. (Coral fish community structure in coral transplant area of Pari Island, Kepulauan Seribu. Jurnal Iktiologi, 3(2), 87-94.)

Elviana, S. (2014). Kepadatan dan keanekaragaman meiofauna di perairan Tallo, Makasar. Agricola, 4(2), 68-78. (Meiofauna density and diversity in Tallo waters, Makassar. Agricola, 4(2), 68-78.)

Erliyanda, Sarong, M. A., and Octavina, C. (2017). Kepadatan dan keanekaragaman meiofauna di perairan Sungai Meureudu Kecamatan Meureudu Kabupaten Pidie Jaya. *Jurnal Ilmiah Mahasiswa Kelautan Dan Perikanan Unsyiah*, 2(1), 26-32. (Meiofauna density and diversity in Meureudu River, Meureudu District, Pidie Jaya Regency. Jurnal Ilmiah Mahasiswa Kelautan Dan Perikanan Unsyiah, 2(1), 26-32.)

Fajri, N. El, and Kasry, A. (2013). Kualitas perairan muara Sungai Siak ditinjau dari sifat fisik-kimia dan makrozoobentos. *Berkala Perikanan Terubuk*, 41(1), 37-52. (Quality of waters in Siak River Estuary based on physical-chemical characteristics and macrozoobenthos. Berkala Perikanan Terubuk, 41(1), 37-52.)

Faturohman, I., Sunarto, and Nurruhwati, I. (2016). Korelasi kelimpahan plankton dengan suhu perairan laut di sekitar PLTU Cirebon. *Jurnal Perikanan Kelautan*, 7(1), 115-122. (Correlation between abundance of planktons to sea water temperature around Cirebon Steam Power Plant. Jurnal Perikanan Kelautan, 7(1), 115-122.)

Giere, O. (2009). *Meiobenthology: The Microscopic Motile Fauna of Aquatic Sediments* (2nd ed.).

Gyedu-Ababio, T. K. (2011). Pollution status of two river estuaries in the Eastern Cape, South Africa, based on benthic meiofauna analyses. *Journal of Water Resource and Protection*, 03(07), 473-486. https://doi.org/10.4236/jwarp.2011.37057

Kotwicki, L., Deidun, A., Grzelak, K., and Gianni, F. (2014). A preliminary comparative assessment of the meiofaunal communities of Maltese pocket sandy beaches. *Estuarine, Coastal and Shelf Science*, 150(PA), 111-119. https:// doi.org /10.1016 /j.ecss.2013.12.008

Lesnussa, J. (2019). Struktur komunitas fitoplankton sebagai bioindikator kualitas air di muara sungai opak Kabupaten Bantul Yogyakarta. Universitas Kristen Duta Wacana. (Structure of phytoplankton community as bioindicators for water quality in Opak River Estuary, Bantul Regency. Universitas Kristen Duta Wacana.)

Neira, C., Sellanes, J., Levin, L. A., and Arntz, W. E. (2001). Meiofaunal distributions on the Peru Margin: Relationship to oxygen and organic matter availability. *Deep-Sea Research Part I:*, 48(11), 2453-2472. https://doi.org/10.1016/S0967-0637(01)00018-8

Parmar, T. K., Rawtani, D., and Agrawal, Y. K. (2016). Bioindicators: the natural indicator of environmental pollution. *Frontiers in Life Science*, 9(2), 110-118. https://doi.org/10.1080/21553769.2016.1162753

Ricketts, E. R., Kennett, J. P., Hill, T. M., and Barry, J. P. (2009). Effects of carbon dioxide sequestration on California margin deep-sea foraminiferal assemblages. *Marine Micropaleontology*, 72(3-4), 165-175. https://doi.org/10.1016/j.marmicro.2009.04.005

Rinanda, A., Diba, F., and Wahdina. (2016). Studi keanekaragaman jenis kupu-kupu di DAS mendalam Taman Nasional Betung Kerihun Danau Sentarum Kabupaten Kapuas Hulu Provinsi Kalimantan Barat. *Jurnal Hutan Lestari*, 4(4), 437-445. (Study on diversity of butterflies in river flow area of National Park of Betung Kerihun Danau Sentarum Kabupaten Kapuas Hulu Provinsi Kalimantan Barat. Jurnal Hutan Lestari, 4(4), 437-445.)

Soltwedel, T. (2000). Metazoan meiobenthos along continental margins: a review. *Progress in Oceanography*, 46(1), 59-84. https://doi.org/10.1016/S0079-6611(00)00030-6

Traunspurger, W. (2009). *Nematoda*. In G. E. Likens (Ed.), *Encyclopedia of Inland Waters* (pp. 372-383). https://doi.org/10.1016/B978-012370626-3.00181-2

Uhlig, G., Thiel, H., and Gray, J. S. (1973). The quantitative separation of meiofauna. *Helgoländer Wissenschaftliche Meeresuntersuchungen*, 25(1), 173-195. https:// doi.org /10.1007 /BF01609968

Walter, T. C., and Boxshall, G. (2021). *World of Copepods Database*.

Wardhana, P. N. (2015). Analisis transpor sedimen sungai opak dengan menggunakan program hec-ras 4.1.0. *Jurnal Teknisia*, XX(1), 22-31. (Sediment Transport Analysis of Opak River using program of hec-ras 4.1.0. Jurnal Teknisia, XX(1), 22-31m)

Werdi, N. M. K., and Eryani, I. G. A. P. (2020). Alternatif perencanaan jetty di Muara Tukad. Paduraksa, 9(1), 102-113. (Alternative jetty planning at Muara Tukad. Paduraksa, 9(1), 102-113.) https://doi.org/10.22225/pd.9.1.1678.102-113

World Bank Group. (2018). Indonesia - Marine debris hotspot rapid assessment : synthesis report. In Public Disclosure Authorized (No. 126686). Washington, D. C.

Yusal, M. S., Marfai, M. A., Hadisusanto, S., and Khakhim, N. (2018). Analisis ekologis meiofauna sebagai bioindikator di pesisir Pantai Losari Makassar. *Jurnal Bionature*, 19(1), 15-22. (Ecological Analysis of meiofauna as bioindicators in coastal Pantai Losari Makassar. Jurnal Bionature, 19(1), 15-22.https://doi.org/10.35580/bionature.v19i1.7308

Zulkifli. (2008). *Dinamika Komunitas Meiofauna Interstisial di Perairan Selat Dompak Kepulauan Riau*. Institut Pertanian Bogor. (Dynamics of Meiofauna community in Dompak Strait, Kepulauan Riau. Institut Pertanian Bogor.)