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The diversity of plankton as bioindicators in Kakap River Estuary, West Kalimantan

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ABSTRACT

Kakap River Estuary plays an essential role in the life organisms, but it is vulnerable to environmental changes and pollution caused by human activities. This study aims to assess the presence of plankton species, their abundance and diversity as aquatic ecological bio-indicators in Kakap River Estuary. Plankton and water samples were taken for three months, with a frequency of one sample per month, viz. in March, April and June 2020 from four sampling stations in Kakap River Estuary, West Kalimantan. A total of 34 species of plankton were observed from all sampling sites, and identified to belong to 18 classes. Chlorophyceae had the highest relative abundance among the phytoplanktons (40.10%), followed by Bacillariophyceae (21.86%) and Cyanophyceae (19.28%). Oscillatoria sp. and Hydrodictyon sp. were the most dominant phytoplankton species. There were 8 classes of zooplankton identified from all sampling stations throughout the research period. Hexanauplia had the highest relative abundance among the zooplanktons (36.56%) followed by Euglenophyceae (24.37%). The plankton diversity index (H ') values ranged between 2.33 -3.11. The plankton evenness index value ranged from 0.79 to 0.89 which indicates high plankton evenness at all samping stations, and this is supported by a low dominance index value at all stations ranging from 0.06-0.16. Station 1 had high Shannon-Wienner diversity index score, while for station 2, 3, 4, their scores were in the moderate level. Overall. the diversity index of the plankton from all sampling sites indicated that the quality of the water had no pollution to light pollution level.

Introduction

Human activities affect the quality of water bodies including lakes, seas, rivers and estuaries (El-Zeiny and El Kafrawi 2017; Fadillah *et al.,* 2017). The estuary is a transitional zone between land water bodies (rivers, streams) and the ocean where the mixing of freshwater and saltwater occurs, or a, giving this area unique characteristics (Hakiki *et al.*, 2017). Estuaries are also a productive area, due to the increased input of organic matter from the land and upstream rivers. Estuaries also play an important role in the life of aquatic organisms, namely as a source of nutrients, as habitat and shelter for various biota, areas of food source, spawning grounds, and also as nursery ground for a number of shrimp and migratory fish species. Furthermore, estuaries are also a habitat for plankton and nekton. Estuaries are very dynamic areas that are vulnerable to environmental changes and pollution caused by human activities, including through the disposal of waste which can come from domestic area, industrial, and other public places (Suoth and Nazir, 2016). This condition is also present in the Kakap River Estuary.

The estuary of Kakap River is located in Sungai Kakap District, Kubu Raya Regency, West Kalimantan. In this area, there are not only domestic activities going on. Due to the existence of a fishing port, there are also capture fisheries activities and a fish processing industry. Currently, the Kakap River Estuary seems to have been polluted by domestic waste, market waste, and fish waste. This condition can cause disruption of the ecosystem which then affects the life of the biota living in it, including plankton.

Generally, water quality can be observed and measured by a variety of physical, chemical and biological methods. Examples of the biological

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methods used to study water quality includes the collection, counting and identification of aquatic organisms, such as plankton. Plankton is a group of aquatic biota aquatic, which includes both phytoplankton and zooplankton, whose movements are influenced by currents (Kutama *et al.,* 2014). This biota can provide information on water condition, one of which is as an indicator of pollution (Igwe *et al*., 2019; Krupa *et al.,* 2020). Research on the use of phytoplankton as a bioindicator has been conducted by Fatmayanti *et al*., (2019), Yusuf (2020), and Zhu *et al.* (2021), while research on the use of zooplankton as a bioindicator has been conducted by Neto *et al.* (2014). This study aims to assess the presence of plankton species, their abundance and diversity as aquatic ecological bio-indicators in Kakap River Estuary.

Materials and Methods

Location and time of research

The research was conducted monthly for three months, viz. in March, April and June 2020 at the Kakap River Estuary, Kubu Raya Regency, West Kalimantan (Figure 1). The tools and materials used in this study were as follows: plankton net (mesh size 25µm), dropper pipette, label, flacon bottle, camera, Secchi disk, thermometer, pH indicator, refractometer, ruler, distilled water, DO meter, 1liter water sample bottle, formalin 4%, microscope, Sedgwick Rafter Counting Cell (SRC), and plankton identification books i.e., Davis (1995) and Mizuno (1979).

The data was collected using purposive sampling method, at four stations which were divided based on the characteristics of the potential waste load estimation. Station 1 was located at the estuary with the characteristics of a densely populated location with suspected domestic waste from human activities, station 2 was located in the fish auction market section with the characteristics of a fishing boat port and ship waste, station 3 was located close to the sea in Pekong which is an area for ship anchoring and fish processing. Station 4 was located near the mangroves with the characteristic of the absence of human population. Data collection was divided into 2 categories i.e., primary data and secondary data.

Primary data consists of data on plankton types as well as their abundance. Plankton data collection was carried out by filtering 100 L of water samples using plankton net. The filtered sample was then preserved using 4% formaldehyde and then analyzed in the laboratory. The physical-chemical water analysis method used in Kakap River Estuary is referred to APHA 2012 (Table 1). The physical parameters analyzed included temperature, water color, water odor, transparency, depth, current, Total Dissolved Solid (TDS) and Total Suspended Solid (TSS) while chemical parameters included pH, (Dissolved Oxygen (DO), Biological Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), salinity, alkalinity, and hardness.

Secondary data that was collected include tidal data that was obtained from the Pontianak Maritime Meteorological, Climatological, and Geophysical Agency. In addition, data on the population and education level were collected from Sungai Kakap Village. Interviews were also conducted with several fisherman and people in the village.

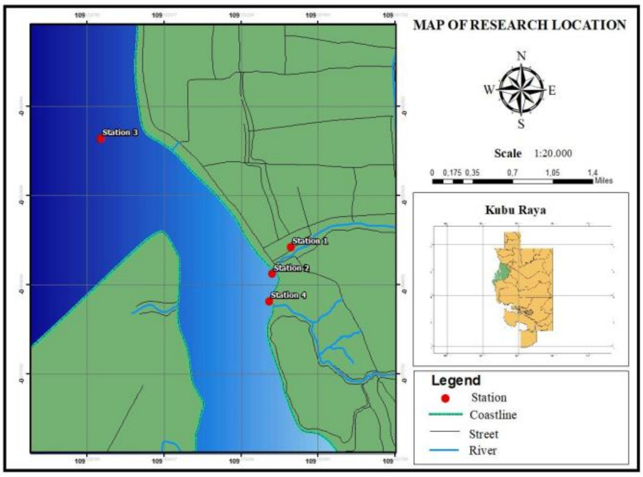

Figure 1. Map of research location.

Table 1. The physical-chemical water parameters measured in Kakap River Estuary.

Parameter	Unit	Method/Measuring Equipment	Note
Temperature	°C	Thermometer	*In-situ*
Water color	-	Visual	*In-situ*
Water odor	-	Sensory analysis	*In-situ*
Transparency	cm	Secchi disk	*In-situ*
Depth	cm	Scaled rope	*In-situ*
Current	m/s	Flow meter	*In-situ*
TDS and TSS	mg/l	Gravimetric method	*Ex-situ*
pH	-	pH meter	*In-situ*
DO	mg/l	DO meter	*In-situ*
BOD_5	mg/l	Titrimetric method	*Ex-situ*
COD	mg/l	Closed reflux method	*Ex-situ*
Salinity	‰	Refractometer	*In-situ*
Alkalinity	mg/l	Titrimetric method	*Ex-situ*
Hardness	mg/l	EDTA titrimetric method	*Ex-situ*

Data analysis

Plankton abundance

The abundance of plankton can be calculated using an SRC using cell/m^3 or ind/m^3units. The formula used was based on Baird *et al.* (2017):

$$N = n \times \frac{Vt}{Vsrc} \times \frac{Asrc}{Aa} \times \frac{1}{Vd}$$

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Description: N = Plankton abundance (cell/m^3 or ind/m^3); n = number of observed plankton; Vd = volume of filtered water sample (m3); Vt = volume of water in the sample bottle (ml); Vsrc = volume of water in the SRC (ml); Asrc = SRC's area of view (1000 mm^2); Aa = area of view (mm^2).

Shannon-Wiener diversity index (H ')

The Shannon Wiener diversity index was calculated on the basis of the number of taxa and individual abundance of organisms present in the sample.

$$H' = -\sum_{i=1}^{n} \text{pi} \ln \text{pi}$$

Description: H' = Shannon-Wiener diversity index; Pi = ni/N; ni = number of individual species-ith; N = total number of individuals; H'< 1 = the biota community is unstable; 1<H'<3 = The stability of the biota community is moderate; H'> 3 = the stability of the biota community is in prime condition (stable).

The Shannon-wiener diversity index was also used to determine the pollution level. H' values of 0–1, 1–2, 2–3 and > 3 correlates to heavy, moderate, light and no pollution (Zhu *et al.*, 2021).

Evenness index (E)

According to Michael (1994), this index shows whether or not the distribution pattern of living organisms is evenly distributed. If the index value is relatively high, each type of living organisms present in the waters are evenly distributed even. Evenness index was determined using the following formula:

$$E = \frac{H'}{\text{Hmax}}$$

Description: E = Evenness index; H′ = Shannon-Wiener diversity index; H max = Ln S (S is the number of genera); E = 0-0.5, distribution between species is not even, meaning that the number of individuals of each species is very different. E =0.6-1, The distribution between species is relatively even or the number of individuals of each species is relatively the same

Simpson dominance index (C)

The Simpson dominance index is used to determine the dominance of certain species in the waters with the following formula (Michael, 1994):

$$C = \sum_{i=1}^{n} (pi)^2 = \left(\frac{ni}{N}\right)^2$$

Description: C= Simpson dominance index; ni = number of individual species-ith; N = total number of individuals.

The dominance index values ranged from 0-1. A value close to zero indicates that there is no dominant genus in the community. Otherwise, if a value is close to 1 indicate the dominant genus.

Results

This section reports the total composition, the relative abundance and the community index of the plankton from the four sampling sites through the research period. The total number of plankton species found at the sampling location was 34 species belonging to 18 classes, which consisted of 10 phytoplankton and 8 zooplankton classes. Station 1 had the highest number of species for plankton, meanwhile the lowest number of species was found at station 4 (Figure 2).

The highest abundance was recorded at station 1 and the lowest abundance was at station 4. The abundance of plankton for stations 1,2, 3, and 4were 92,000 cells/m^3 plankton; 47750 cells/m^3 plankton; 36,000 cells/m^3 plankton and 23,750 cells/m^3 plankton respectively (Figure 3).

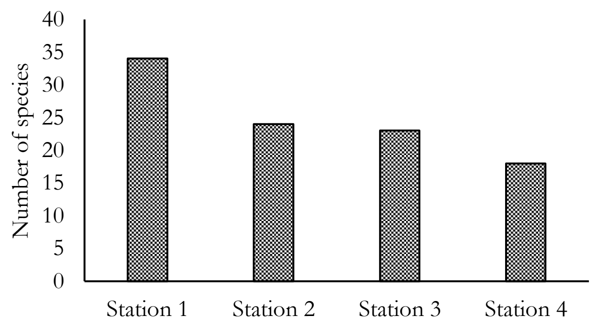

Figure 2. Number of plankton species in Kakap River Estuary.

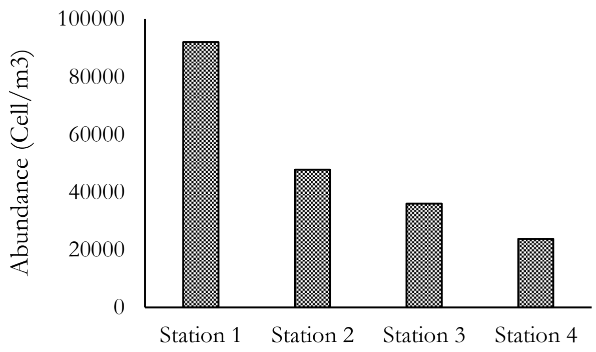

Figure 3. The abundance of plankton in Kakap River Estuary.

In this study, a total of 10 phytoplankton classes were recorded from all sampling stations. Chlorophyceae had the highest relative abundance among the phytoplanktons (40.10%), followed by Bacillariophyceae (21.86%) and Cyanophyceae (19.28%) (Figure 4). The dominant phytoplankton species were *Oscillatoria* sp. (Cyanophyceae) at

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stations 1, 4 and *Hydrodictyon* sp. (Chlorophyceae) at stations 2, 3. Meanwhile, *Navicula* sp. is one of the most abundant Bacillariophyceca that occurred at all sampling stations.

There were 8 zooplankton classes sampled from all sampling stations throughout the research period. Hexanauplia had the highest relative abundance of the zooplankton (36.56%) followed by Euglenophyceae (24.37%) (Figure 5).

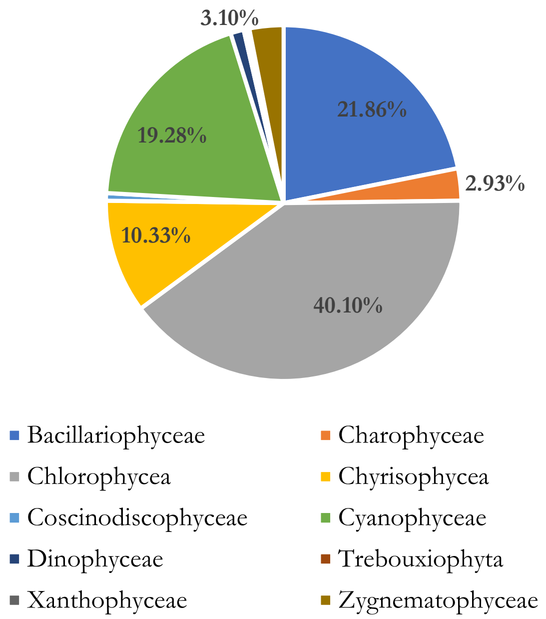

Figure 4. The relative abundance of phytoplankton in Kakap River estuary.

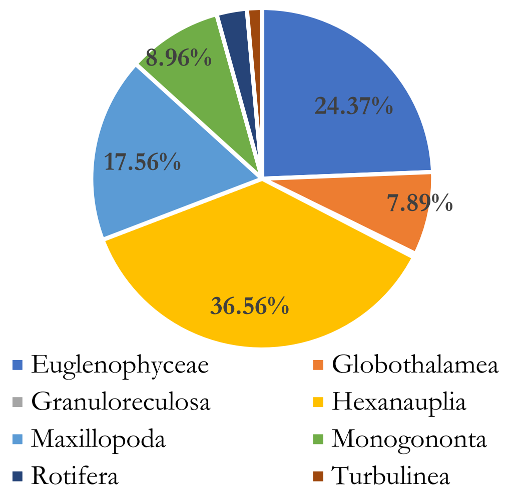

Figure 5. The relative abundance of zooplankton in Kakap River Estuary.

The plankton diversity index (H') values ranged between 2.33-3.11 (Figure 6). Station 1 had a high level of Shannon-Wienner diversity index, which means the plankton community was stable, while for station 2, 3, and 4 it was at the moderate level. Referring to Zhu *et al.* (2021), the plankton diversity index at station 1 which scored higher than 3, indicates that the water was not polluted, while other stations that have a diversity index between 2 and 3 indicates light pollution levels. The plankton evenness index value ranges from 0.79 to 0.89 which indicates high level of plankton distribution evenness at all stations, and this is supported by a low dominance index value at all stations ranging from 0.06-0.16.

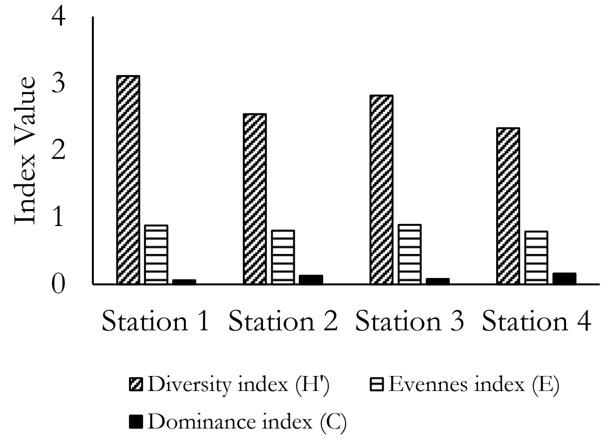

Figure 6. Plankton diversity index (H'), evenness index (E), and dominance index (C) in Kakap River Estuary

Table 2. Physico-chemical parameters of the Kakap River estuary.

Parameters	Station 1	Station 2	Station 3	Station 4
Temperature (°C)	32	30	30	29
Transparency (cm)	34	36	28	41
Depth (cm)	266	238	433	421
Salinity (‰)	5	5	5	5
pH	6	6	6	6
Water color	Brown	Brown	Brown	Brown
Water odor	A little sewage smell	Sewage smell	Sewage smell	A little sewage smell
DO (mg/l)	6	5.31	4.7	5.8
Velocity (m/s)	0.46	0.23	0.3	0.25
BOD_5(mg/l)	5.87	5.69	4.16	5.18
TSS (mg/l)	7	12	26	6
TDS (mg/l)	19.6	20.8	23.10	17.9
Alkalinity (mg/l)	35.26	30.62	33.71	34.60
Hardness (mg/l)	69.69	70.76	83.69	80.14

Observation on the water quality among all sampling sites showed various result. (Table 2). The results of water quality observations through the research periods showed that the water is still suitable for fisheries. Meanwhile in reference to Lee (1978), the waters of the Kakap River estuary would be classified to have light to moderate pollution levels by referring to the DO and BOD values. A water body is classified as lightly polluted if DO value ranges from 4.5-6.5 and BOD is 3-4.9, while it is moderately polluted if the DO is 2.0-4.4 and BOD ranges from 5.-15.

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Discussion

Generally, water quality is detected and determined using a variety of physical, chemical and biological methods. Physico-chemical observation results of Kakap River estuary showed that the waters are still suitable with standard quality value category of class 3 (fisheries purposes) based on PP RI No. 22 (2021). Referring to Lee (1978), the Kakap River had a light to moderate pollution level. Analysis of plankton diversity had been conducted to support and complement the interpretation of the results obtained from physico-chemical analysis. As aquatic organisms, plankton has many advantages for biological models, namely being able to indicate the level of ecological instability and pollution levels.

The plankton diversity in Kakap River estuary varied between all sampling stations. This is influenced by the conditions of the aquatic environment and land use. Station 1 had a high number of species, abundance and diversity level of plankton which indicates that the waters have a good ecological status. DO at station 1 was higher than the other stations, and there was also nutrient input from the discharge of organic matter into the waters, as a result the diversity of species and abundance of plankton at this location is high. The presence of these nutrients affected the growth of plankton in the waters (Mahlil *et al.,* 2018). Runoff from settlements contains a lot of nutrients that enter the water body and are used for plankton growth. Even though BOD value is quite high at this station, it has not disturbed the ecological condition and still suitable with the quality standard value based on PP RI No. 22 (2021).

The use of species diversity indices (the Shannon-Wiener index) showed that with the increasing pollution, the diversity of communities decreases (Vallina *et al*., 2017). Based on the Shannon-Wiener diversity index, the plankton communities at stations 2, 3 and 4 were classified as moderate, which indicates the degree of light pollution, referring to Zhu *et al.* (2021). Stations 2 and 3, which are located as fishing ports and produce ship waste, may affect the presence of plankton at that location. Boat waste such as oil spill will affect the water quality needed for plankton growth, as seen from the descriptive observations of the two stations having a lower DO range when compared to stations 1 and 4. While station 4 is located near the mangroves with the characteristic absence of human population. This caused the low number of plankton species at station 4 due to the low organic matter presence at this station (Table 2). Low transparency will inhibit phytoplankton to carry out photosynthesis (Avila-Alonso *et al*., 2016). Conversely, high transparency increases the solar radiation intensity that can be absorbed by phytoplankton. An increase of solar radiation intensity has positive effect on photosynthesis and other metabolic activities with a subsequent increase in phytoplankton population abundance (Tanimu *et al*., 2011).

According to Kutama *et al.* (2014), the composition and abundance of plankton in a water body clearly indicates the health status of the water body. Planktons show different responses to different environmental conditions. In the present study, the three dominant phytoplankton classes are Chloropyceae, Bacillariophyceae and Cyanophyceae. These three phytoplankton classes were also found to dominate in several studies (Gulecal and Temel, 2014; Cao *et al.,* 2016; Zhu *et al*., 2021). Chlorophyceae class (40.10%) was found to be the most abundant compared to others. This is because green algae (Chlorophyceae) is the most diverse algae class with a high reproductive abilities compared to those found in any other algal divisions (Adesalu, 2016). Bacillariophyceae (diatoms) tend to dominate in fast-flowing waters and as benthic algae. This is related to their ability to withstand the high current velocity and water-level fluctuations (Trabert *et al.* 2020). The dominance of diatoms could be owing to the fact that they can tolerate widely dynamic hydrographical conditions. According Dembowska *et al.* (2018), the predominance of diatoms population is an indication of eutrophic state of waters. Among the diatoms recorded in Kakap River estuary, *Navicula* sp. is pollution indicator belonging to Bacillariophyceae as pointed out by Palmer (1969), similarly with Cyanophyceae which is one of the algae classes that are found in abundance in various habitats (Albrecht *et al*., 2017). At stations 1 and 4, the most dominant phytoplankton species is *Oscillatoria.* This may be related to the DO content, where stations 1 and 4 have a higher DO range than stations 2 and 3. According to Zhu *et al.* (2021), beside NO_2-N, *Oscillatoria* is positively correlated with DO. *Oscilltoria* sp. is also a pollution indicator species belonging to Chlorophyceae as described by Palmer (1980). Meanwhile, the most dominant phytoplankton species at stations 2 and 3 is *Hydrodiction* sp. Occurrence reports of *Hydrodictio*n are often associated to human-caused environmental changes, and their distribution can also be affected by humans (Peres *et al.,* 2016).

The Hexanauplia class is the most abundant zooplankton found in the Kakap River estuary, this class has a high adaptability and can survive in various water conditions (Antuke *et al.,* 2019). The

Euglenophyceae class is also a group whose frequency is often found to be quite high in fresh, brackish and marine waters (Bicudo and Menezes, 2016).

Conclusion

The diversity of plankton is a very important tool to be used as indicator of water quality in the Kakap River estuary. There were 34 species of plankton belonging to 18 classes observed from all sampling sites. The plankton diversity index (H') values ranged between 2.33 -3.11. The plankton evenness index value ranges from 0.79 to 0.89 which indicates high levels of plankton evenness at all stations and is supported by a low dominance index value at all stations ranging from 0.06-0.16. Station 1 had high score for the Shannon-Wiener diversity index, while stations 2, 3, and 4 had moderate scores. Overall, the diversity index of the plankton from all sampling sites confirms that water quality in Kakap River estuary ranged from no pollution to light pollution level.

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