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Primary Productivity Based on Chlorophyll-a Concentration in the Luk Ulo River Estuary, Kebumen Regency, Central Java

Yunita Rahma Wati[1*], Heti Herawati[2], Nora Akbarsyah[1], Zahidah[2]

[1]Department of Tropical Marine Fisheries, Faculty of Fisheries and Marine Sciences, Universitas Padjadjaran, Indonesia
[2]Department of Fisheries, Faculty of Fisheries and Marine Sciences, Universitas Padjadjaran, Indonesia

*Correspondence Author: yunita21001@mail.unpad.ac.id

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ABSTRACT

The Luk Ulo River estuary is one of the water areas in Kebumen Regency that leads directly to the Indian Ocean. The discharge of waste from river flows that lead into the Luk Ulo River estuary, along with sand and stone mining activities, is believed to be the primary cause of damage to the aquatic ecosystem. Water quality in a water body can affect the primary productivity of the estuary. The objective of this research is to evaluate the primary productivity by analyzing chlorophyll a concentration, which serves as an indicator of the trophic status of the water. This research was conducted from January to February 2025. This research utilizes the method of survey method with a purposive sampling technique. Based on the results of the research, the average chlorophyll a concentration in the Luk Ulo River Estuary ranges from 3.91 to 5.74 mg/m^3. The average value of primary productivity during the study was in the range of 124.96-149.24 mgC/m^3/day, including in less fertile waters, or can be said to be oligotrophic because the average is in the range of 0-200 mgC/m^3/day. The water quality in the Luk Ulo River Estuary generally complies with Class II and III quality standards, as stipulated in Government Regulation No. 22 of 2021 regarding the Implementation of Environmental Protection and Management.

INTRODUCTION

River estuaries are semi-enclosed waters that originate upstream and are freely connected to the sea, so that seawater with high salinity can mix with fresh water in the estuary (Purba *et al*., 2021). This area is the last part of the river before heading to the sea. River and ocean currents tend to converge in the estuary, as the upstream water is held back by seawater before gradually mixing with it (Warman, 2015). This is a factor in the storage of waste in the estuary, so that all the waste that has been received will affect the water quality in the estuary.

The Luk Ulo River Estuary is one of the water areas in Kebumen Regency that flows directly into the Indian Ocean. This estuary originates from the Luk Ulo River, which is located at coordinates between 109˚ 30' 30"-109˚ 52` 30" BT and 07˚ 37' 30"-07˚ 22' 30" LS. Luk Ulo River is the largest watershed in Central Java with an area of 676 km^2 covering three districts namely Kebumen Regency, Banjarnegara Regency, and Wonosobo Regency (Saifudin & Raharjo, 2016).

Rainfall in the upper reaches of Luk Ulo River reaches 2,500-3,250 mm/year, and in the lower reaches less than 2,600 mm/year. According to Sriyono *et al.* (2016), the rainfall supports agricultural activities around the river flow. Generally, the types of agriculture consist of wetland agriculture and dryland agriculture. The Luk Ulo River that crosses Karangsambung Village has sand mining activities that take place continuously (Fitri *et al.,* 2021). This river flow passes through residential areas with various activities that generate waste that flows directly into the river, so that the waste can accumulate in the estuary.

Multi-functional nature causes the Luk Ulo River Estuary to be suspected of having pollution potential. The input of waste from the flow of river bodies that empties into the Luk Ulo River estuary area and the existence of sand and stone mining activities are feared to be the main factors that cause damage to aquatic ecosystems (Arumsari *et al.,* 2023). In addition, sand mining activities can cause degradation and erosion that will affect river water quality (Ikhsan *et al.* 2015 in Arumsari *et al.* (2023). Water quality in a body of water can affect the primary productivity of the estuary (Febbrianna *et al*., 2017).

Aquatic primary production and phytoplankton life can be affected by the influx of nutrients from various human activities through river flow. Chlorophyll concentration and phytoplankton presence have an important impact on the primary productivity of estuarine waters. Therefore, chlorophyll serves as a reliable indicator of water fertility. According to Baktiar *et al.* (2016), various physical and chemical factors that regulate and affect the distribution of chlorophyll a in aquatic environments include light intensity and the availability of nutrients, particularly nitrates and phosphates. Chlorophyll a concentration in waters can describe the fertility status of a water body. At present, information regarding primary productivity based on chlorophyll a concentration in the Luk Ulo River estuary is still lacking. Therefore, this research was undertaken to evaluate the fertility status of the estuary in support of fisheries management development.

LITERATURE REVIEW

Anthropogenic activities that occur in waters can cause input of pollutants that are deposited into the river, so that they flow into the estuary and reach the open sea (Ridarto *et al.,* 2023). A decrease in water quality can affect chlorophyll a concentrations in estuarine waters. This is in accordance with the research of Febbrianna *et al.* (2017) that various human activities can cause the entry of

nutrients through river flow, thus affecting the primary productivity of waters and phytoplankton life. Chlorophyll a is a pigment found in phytoplankton in a body of water that can describe the productivity and quality of these waters (Agirbas *et al.*, 2017).

Water quality plays a major role in the habitat or living space of many marine biota that play an important role in human life. Changes in water quality have an impact focusing on chlorophyll a concentration, the dominant photosynthetic pigment in phytoplankton (Maslukah *et al.,* 2022). Phosphate and nitrate are nutrients that contribute significantly to the growth and metabolism of phytoplankton and are indicators to evaluate the quality and fertility of waters. The content of nutrients (nitrate and phosphate) obtained from the decomposition process spurs phytoplankton growth, and increases chlorophyll a concentration (Swayati *et al.*, 2015).

Phytoplankton abundance in a body of water can function as a bioindicator for assessing water quality (Alfat'hani *et al.,* 2020). The amount of chlorophyll a in a certain volume of seawater is a measure of plant biomass (phytoplankton) contained in these waters, and chlorophyll a is one of the key parameters that indicate the primary productivity of an aquatic ecosystem (Yuliana & Mutmainnah, 2018). So far, data on primary productivity in the Luk Ulo River estuary, based on chlorophyll a levels, remains limited. Accordingly, conducting this research is essential to obtain information on the fertility status of the Luk Ulo River estuary, which can support the formulation of effective fisheries management strategies.

METHOD

The research was carried out from January to February 2025. Chlorophyll a concentration was analyzed at the Research Laboratory of Jenderal Soedirman University, while Biochemical Oxygen Demand (BOD), Nitrate, and Phosphate were analyzed at the UPTD Environmental Laboratory of Kebumen Regency.

Sampling Procedures

Sampling in this research was conducted using a survey method employing purposive sampling, applied to estuarine waters based on different stations (Karima *et al.,* 2024). Determination of sampling locations based on consideration of organic inputs and regional conditions that are thought to affect primary productivity in the estuary. The stations include estuary openings that lead directly to the sea, watersheds with agricultural activities and community activities, and watersheds with sand and stone mining activities. Water samples were taken in a composite of 1000 ml for the chlorophyll a test and 1000 ml for the nitrate, phosphate, and BOD tests. Samples were taken compositely, namely by taking 3 sample points at each station transversely covering the left bank, center, and right bank of the river, and

then combined into one. The location of the sampling research can be seen in Figure 1. Map of Research Location at Luk Ulo River Estuary, Kebumen Regency

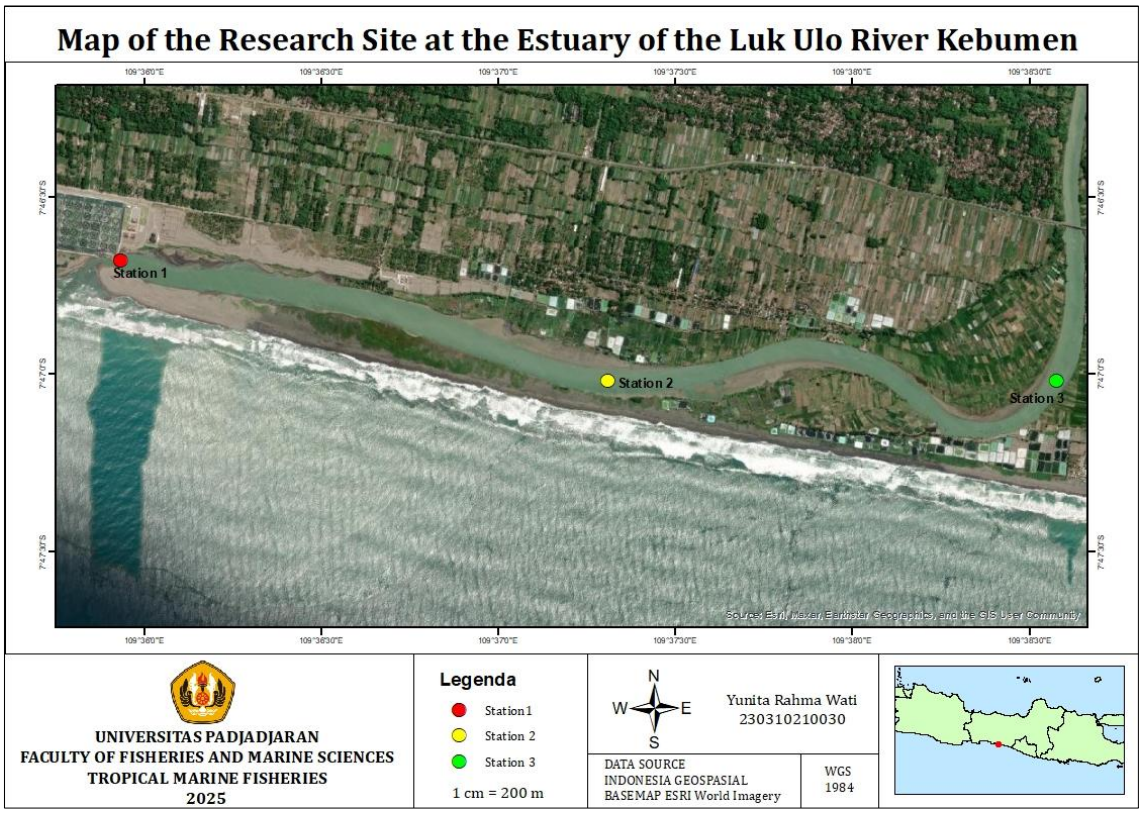


Figure 1. Map of Research Location at Luk Ulo River Estuary, Kebumen Regency

Data Analysis

Chlorophyll-a

Concentration calculation of chlorophyll a concentration value refers to Wetzel and Likens (1991) in (Zahidah, 2017)as follows:

$$\text{Chlorophyll-a} = \text{Ca}\ (\frac{v}{V.L})$$

Description:

Ca = 11.6 D665 -1.31 D645 - 0.14 D630

v = Volume of acetone (mL)

V = Volume of filtered water (L)

L = Length of cuvet (cm)

Classification of water fertility based on chlorophyll-a concentration refers to Bohlen and Boynton (1966) in the Chesapeake Bay Program (1997). The criteria for water fertility based on chlorophyll a concentration are as follows

<1 mg/m3 = Oligotrophic

≥1-15 mg/m3 = Mesotrophic

≥15-30 mg/m3 = Eutrophic

≥30 mg/m3 = Hypertrophic

Primary Productivity of Waters

The chlorophyll a values obtained were converted into primary productivity using the formula (Beveridge 1984 in Permanasaria *et al.,* 2017).

$$PP = 56.5 \text{ (Chlorophyll-a)}^{0,61}$$

The classification of water fertility level according to Triyatmo *et al.* (1997) in Cahyani *et al.* (2020), namely 0-200 mgC/m3/day including less fertile (oligotrophic), 200-750 mgC/m3/day including medium water fertility (mesotrophic), and more than 750 mgC/m3/day including very fertile (eutrophic).

RESULT AND DISCUSSION

Water Quality

As indicated by the research results, the average temperature value is in the range of 27.23-27.73°C. The highest average value is at station 2 and the lowest average is at station 3. The difference in temperature at each station is due to differences in time in field measurements. Variations in water temperature significantly influence phytoplankton abundance. This is consistent with the view of Felixtha *et al.* (2021), who stated that an increase in water temperature can lead to an accelerated growth rate of phytoplankton. Phytoplankton can photosynthesize at a temperature range of 10-40°C, with the optimum temperature for photosynthesis ranging from 20-30°C. So it can be interpreted that the Luk Ulo River Estuary has a good temperature for photosynthesis.

The average value of light transparency of the Luk Ulo River estuary is in the range of 38.81-41.04 cm. Station 3 has the lowest average value due to sand mining activities that cause turbidity in the waters. This aligns with the view of Herawati *et al.* (2024), who stated that reduced light transparency in aquatic environments is due to suspended inorganic materials, such as sand and mud particles, which contribute to water turbidity. Light transparency in waters can describe the ongoing photosynthesis process in the water column (Nuzapril *et al.,* 2019). According to Yusal *et al.* (2025), brightness indicates the level of water fertility. Brightness which is in the range of < 3 m is classified as eutrophic waters. Based on this statement, the Luk Ulo River Estuary is classified as eutrophic waters.

The calculated average of water pH throughout the study was in the range of 7.58-7.78. The highest average pH value was recorded at Station 2, whereas the lowest average was observed at Station 3. The overall average pH at each station still meets the quality standards based on Government Regulation Number 22 of 2021 class II and class III, which ranges from 6-9. Biochemical Oxygen Demand (BOD) during the study was in the range of 4.29-5.47 mg/L. The highest average value of BOD is found at station 3 while the lowest average value of BOD is at station

1. The high average value of BOD at station 3 is influenced by sand mining activities. This is in line with the perspective of Gusri *et al.* (2024) who state that sand mining activities can significantly increase the circulation and concentration of organic matter in water.

Dissolved Oxygen during the study was in the range of 6.44-7.28 mg/L. The highest average value of BOD is found at station 1. The high dissolved oxygen at station 1 is due to the current from the sea. This is reinforced by the statement of Madyawan *et al.* (2020) who stated that the high movement of water masses causes oxygen diffusion from the air. The low dissolved oxygen value at station 3 was caused by turbidity due to sand mining activities.

Nitrate concentrations observed during the study ranged from 0.64 to 0.82 mg/L. The highest average nitrate level was recorded at station 2, whereas the lowest was observed at station 1. The lower nitrate value at the station towards the open sea is influenced by salinity. This agrees with the perspective of Arnando *et al.* (2022) who stated that the high and low salinity in the waters affects nitrate levels, because the higher the salinity, the more it affects the activity of nitrosomonas bacteria in the nitrification process and so on. The highest mean value of phosphate is at stations 2 and 3 with a value of 0.11 mg/L with a standard deviation of 0.05. In this study, the station that leads directly to the open sea has a lower average value of phosphate compared to other stations. This agrees with the perspective of Arnando *et al.* (2022) who stated that the more protruding the waters towards the sea, the phosphate content decreases. The measurement results of physical and chemical parameters in the Luk Ulo River Estuary throughout the study period are shown in Table 1. Results of Physical and Chemical Parameters at the Time of Research.

Table 1. Results of Physical and Chemical Parameters at the Time of Research.

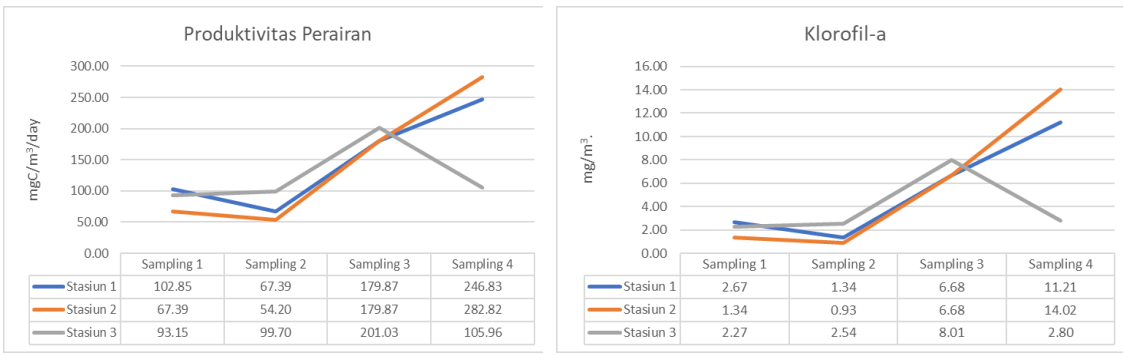
Parameters		Water Quality Value		
		Station 1	Station 2	Station 3
Temperature	R	26.23 - 29.30	26.77 - 28.90	25.65 - 29.00
	A	27.48 ± 1.49	27.73 ± 0.88	27.23 ± 1.59
Light Transparency	R	20.50 - 60.67	16.00 - 70.17	12.50 - 59.50
	A	41.04 ± 21.49	39.21 ± 23.95	38.81 ± 19.60
pH	R	6.00 - 8.66	7.35 - 8.60	5.84 - 8.69
	A	7.68 ± 1.17	7.78 ± 0.56	7.58 ± 1.22
BOD	R	2.82 - 6.05	1.51 - 9.17	2.72 - 7.56
	A	4.29 ± 1.42	5.33 ± 3.43	5.47 ± 2.47
DO	R	5.05 - 9.45	4.92 - 8.40	4.33 - 8.95
	A	7.28 ± 1.85	7.03 ± 1.49	6.44 ± 1.91
Nitrate	R	0.04 - 1.02	0.76 - 0.94	0.60 - 1.10
	A	0.64 ± 0.42	0.82 ± 0.08	0.81 ± 0.21
Phosphate	R	0.04 - 0.13	0.06 - 0.18	0.07 - 0.18

Parameters		Water Quality Value		
		Station 1	Station 2	Station 3
	A	0.09 ± 0.040	0.11 ± 0.047	0.11 ± 0.050

Source: Processed Data (2025) Description: R = Range; A = Average

Chlorophyll-a Concentration and Primary Productivity

Chlorophyll a in waters is one of the parameters of water fertility because it has an important role in primary productivity (Zhang and Han, 2015 in Widiaratih *et al.,* 2022)**.** The level of primary productivity reflects the ability to produce plant biomass and oxygen supply in waters (Sofyan & Zainuri, 2021). In this study, the analytical results of mean chlorophyll a levels and primary productivity in the Luk Ulo River Estuary are illustrated in Figure 2



(a) (b)

Figure 2. Primary Productivity (a) and Chlorophyll a (b) of Luk Ulo River Estuary
Source: Processed Data (2025)

The average chlorophyll a concentration during the study ranged from 3.91 to 5.74 mg/m^3. The highest average chlorophyll a concentration was found at station 2, measuring 5.74 mg/m^3, whereas station 3 exhibited the lowest average concentration at 3.91 mg/m^3. The increased chlorophyll a concentration at station 2 is attributed to the input of organic matter from nearby agricultural activities. This agrees with the perspective of Maslukah *et al.* (2017) who stated that the high value of chlorophyll a in waters is influenced by the presence of high nutrient inputs as well. High and low chlorophyll a in waters will affect the primary productivity of these waters. Based on the chlorophyll a concentration that refers to the Chesapeake Bay Program (1997) in Zulhaniarta *et al.* (2015), the waters of the Luk Ulo River Estuary are included in medium or mesotrophic waters because they have values between 1-15 mg/m^3.

The average primary productivity during the study ranged from 124.96 to 149.24 mgC/m^3/day. The highest average value of primary productivity was at station 1 while the lowest average value of primary productivity was at station 3.

The high value of productivity at this station was influenced by the relatively high concentration of chlorophyll a at each sampling, besides that the transparency of light at the station had the highest average compared to other stations. This is reinforced by the statement of Febbrianna *et al.* (2017) who stated that the high and low value of water productivity is influenced by the entry of sunlight intensity in the waters. The low value of primary productivity at this station was caused by sand mining activities which resulted in turbidity at the station. Turbidity in the waters can affect the entry of light into the waters and affect the life of phytoplankton. This is reinforced by the opinion of Irawati *et al*. (2013) in *Bawu et al.,* (2023) who stated that high turbidity in the waters affects the transparency of light into the waters which can reduce primary productivity.

Based on the overall average value of primary productivity in this study is classified in less fertile waters or can be said to be oligotrophic. According to Triyatmo *et al.* (1997) in Cahyani *et al.* (2020) the level of water fertility ranging from 0-200 mgC/m^3/day is included in the less fertile waters (oligotrophic). The low value of primary productivity is because this research was conducted during January to February which is included in the west season. The western season is accompanied by high rainfall and strong winds causing the water temperature to drop due to low incoming sunlight (Patty *et al.,* 2019). According to Alhaq *et al.* (2021) the brightness of the waters has a positive relationship directly proportional to the concentration of chlorophyll a, this is because autotrophic organisms need sunlight in photosynthesis.

CONCLUSION

1. Chlorophyll a concentration during the study ranged from 3.91-5.74 mg/m^3. Based on the chlorophyll a concentration that refers to the Chesapeake Bay Program, the waters of the Luk Ulo River Estuary are included in medium or mesotrophic waters because they have values between 1-15 mg/m^3.
2. The value of primary productivity in the Luk Ulo River estuary during the study ranged from 0-200 mgC/m^3/day including in less fertile waters or can be said to be oligotrophic.
3. Water quality in the Luk Ulo River Estuary generally meets the requirements of class II and III quality standards, but there is one parameter, namely BOD, which exceeds the class II quality standards referring to Government Regulation Number 22 of 21 concerning the Implementation of Environmental Protection and Management. BOD values that exceed class II quality standards are still in the safe category to support the survival of fish resources.

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