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Estuary and Marine Waters Characteristics of the Sungai Nibung Village Coastal Waters, Kubu Raya, West Kalimantan

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ABSTRACT

Sungai Nibung Village is a KKPP3K (Coastal Waters and Small Islands Conservation Area) in Kubu Raya District. This community features an abundance of diverse natural resources, such as crab, fish, shrimp, squid, octopus, and finless dolphins. This indigenous biota is sustained by fertility and high water quality. Water fertility reveals high nutrient concentration and identifies phytoplankton as primary producers. Water contains nutrients in the form of nitrates and phosphates. Phytoplankton and other aquatic species require these nutrients to survive. The concentration of chlorophyll-a, the primary pigment of phytoplankton, which has a role in photosynthesis, can also be used to estimate the trophic state of waterways. The fertility of Sungai Nibung Village waters in the sea (Station I and II), estuary (Station III), and river (Station IV and V) has been assessed. Nitrate and phosphate levels in water samples were assessed in line with SNI 06-2480-1991 and SNI 06-6989.31.2005, respectively. The chlorophyll-a was evaluated using the trichromatic method with a UV-Vis spectrophotometer at 664, 647, and 630 nm. Sungai Nibung Village's waters include 0.9−1.5 mg/L nitrate and 2.06−2.19 mg/L phosphate. Chlorophyll-a levels range from 2−5 µg/L, placing them in the low category.

Keywords: chlorophyl-a, Sungai Nibung Village, nitrate, phosphate

INTRODUCTION

Sungai Nibung Village, located in Teluk Pakedai Subdistrict, Kubu Raya Regency, West Kalimantan, is one of the Coastal and Small Islands Water Conservation Areas (KKPP3K) designated by West Kalimantan Provincial Regulation No. 1 of 2019. The town and local community manage this region using blue economy principles, which emphasize the sustainable use of natural resources. The richness and diversity of fish species demonstrate how effective management can improve community welfare and conservation (Ammas 2020, Magfiroh *et al.* 2020). The coastal ecosystem of the village contains a diverse range of natural resources (Safitri *et al.* 2023). These seas are home to a diverse biota, including dolphins, porpoises, turtles, crabs, fish, shrimp, octopus, and squid. The village also features a mangrove region with rich biota, including gastropods, bivalves, proboscis monkeys, langurs, and other bird species (BPSPL Pontianak 2019). The diversity and quantity of these creatures are aided by the comparatively high quality and fertility of the waters.

Water fertility is governed by the availability of critical nutrients like nitrogen (N) and phosphorus (P), particularly nitrates and phosphates, which are essential for the growth and development of aquatic creatures and phytoplankton. The presence of these nutrients affects biogeochemical processes and primary productivity in water (Howarth *et al.* 2021, Wisha *et al.* 2018). Nutrients can come from natural processes like plant and animal decomposition (Patty 2015), or from human activities like runoff from land, erosion, leaching from agricultural land, and domestic waste flowing through rivers to estuaries and the sea (Guignard *et al.* 2017, Nataniel *et al.* 2022, Simanjuntak 2012).

Sufficient food availability enhances the quantity of phytoplankton, which are primary producers in aquatic bodies. Phytoplankton produces oxygen and organic matter through photosynthesis (Boyd 2000, Kim *et al.* 2018, Sofyan & Zainuri 2021), and they are an important functional component in aquatic biogeochemical cycles (Bouman *et al.* 2018). The number of phytoplankton can be determined by the concentration of chlorophyll-a, the principal pigment in photosynthesis. Thus, chlorophyll-a level frequently implies primary productivity in aquatic environments (Febbrianna *et al.* 2017, Li *et al.* 2024).

Nutrient content and phytoplankton abundance not only represent water body fertility but also act as key indices of ecological health (Enawgaw & Lemma 2018, Sari *et al.* 2019, Insani *et al.* 2021). As a result, understanding the dynamics of these two parameters is critical for long-term aquatic resource management. However, baseline data on the fertility conditions of the

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waterways in Sungai Nibung Village are currently missing, as is information on their link with biodiversity and the effects of human activities such as agriculture and residential waste. This study is critical in providing baseline data for sustainable and blue economy-based conservation area management.

METHODS

Primary productivity was assessed using nitrate, phosphate, chlorophyll-a, and phytoplankton abundance in the river, estuary, and sea in Sungai Nibung Village, Teluk Pakedai Subdistrict, Kubu Raya Regency, West Kalimantan. Figure 1 depicts five research stations: I, II, and III (estuary), as well as IV and V (sea). The stations were identified using purposive sampling on August 19, 2023; water samples were collected from the surface layer using a water sampler. Sampling was only done once during low tide. Water samples for nitrate and phosphate analysis were maintained in a cold box with ice as a coolant and then transported to the laboratory (APHA) 2017, Pahlewi & Sakinah 2020, Wahyuni *et al.* 2021).

Nitrate levels in water samples were determined using the brusin sulfate method by SNI 06-2480-1991 (Badan Standardisasi Nasional 1991) using a spectrophotometer at 420 nm. SNI 06-6989.31.2005 measured phosphate levels using the spectrophotometric technique with ascorbic acid at a wavelength of 880 nm. (Badan Standardisasi Nasional 2005).

A 1 L water sample was examined for its chlorophyll-a concentration. Before being analyzed in the laboratory, the water sample was stored in a dark container and kept in a cool box with ice cubes. Chlorophyll-a was measured using trichromatic technique. A 500-mL water sample was filtered with Whatman No. 42 filter paper. The filter paper containing the residue was placed in a test tube that had previously been wrapped in aluminum foil. The residue was then mixed with 10 mL of 90% acetone solvent and refrigerated for 24 h. The residue extracted with acetone solvent was centrifuged at 3,500 rpm for 15 min at room temperature. The obtained supernatant was then tested for chlorophyll-a content with a Shimadzu Spectrophotometer at 630, 647, 664, and 750 nm wavelengths. The formula for determining chlorophyll-a content was as follows (APHA 2017):

$$Chlorophyll - a\ (mg/L) = \frac{\left((11{,}85\ x\ \lambda_{664}) - (1{,}54\ x\ \lambda_{647}) - (0{,}08\ x\ \lambda_{630})\right)\ x\ V_e}{V_s\ x\ d}$$

where

λ_{664} : Absorbance at 664 nm – Absorbance at 750 nm
λ_{647} : Absorbance at 647 nm – Absorbance at 750 nm
λ_{630} : Absorbance at 630 nm – Absorbance at 750 nm
Ve : Volume of acetone (10 mL)
Vs : Volume of filtered water sample (500 mL)
d : Width of cuvette (1 cm)

RESULTS AND DISCUSSION

Water Quality

Table 1 shows the water conditions in Sungai Nibung Village, with depth, dissolved oxygen (DO), pH, and salinity as critical criteria for describing the aquatic

Figure 1 Location of estuary and marine waters of Sungai Nibung Village

Table 1 Water conditions in Sungai Nibung Village

Parameter	Station				
	I	II	III	IV	V
Depth (m)	6.3	5.0	7.4	1.2	3.3
DO (mg/L)	2.2	2.9	3.1	3.6	3.7
pH	6.9	7.1	7.2	7.4	7.2
Salinity (‰)	18.7	20.5	21.4	22.6	22.1

ecosystem. The water has physical and chemical properties that are impacted by tidal interactions and low freshwater flow. The dissolved oxygen (DO) values in the estuary and coastal sections range from 2.2 to 3.7 mg/L, which is low. According to Government Regulation No. 22 of 2021 on Environmental Protection and Management, the quality standard for marine life is higher than 5 mg/L. Several studies on DO levels in West Kalimantan estuaries include the Sungai Kapuas Kecil estuary at 2.5−4.2 mg/L (Anggreani *et al.* 2023), the Sungai Kakap estuary at Kubu Raya at 3.9−5.3 mg/L (Sari *et al.* 2021), and the Namhoi estuary at Mempawah Hilir at 7.3−7.7 mg/L (Maulani *et al.* 2024), Teluk Cina, Lemukutan Island 7.9 mg/L (Yunivah *et al.* 2023), Teluk Melanau, Lemukutan Island 5.3−7.5 mg/L (Zainal *et al.* 2023), Kabung Island 7.39−7.42 mg/L (Palias *et al.* 2022), and Pantai Pasir Mayang, Kayong Utara 3.0 mg/L (Saputra *et al.* 2023).

Oceanic seawater is often high in oxygen due to phytoplankton photosynthesis. However, oxygen levels in estuaries are often lower due to the input of organic matter, decomposition activities, and limited mixing of freshwater and seawater. The seawater in Sungai Nibung Village has a higher DO level (3.6−3.7 mg/L) than the estuary (2.2−3.1 mg/L). DO levels drop even lower in the upstream estuary waters. This low DO level could be attributed to poor tidal circulation and restricted freshwater availability. Tidal currents at the Kapuas Sepok Pangkalan estuary of Sungai Nibung Village are quite weak (Kushadiwijayanto 2024). This causes slow vertical and horizontal mixing between the sea and the estuary. This scenario will lead to an increase in organic matter accumulation, with microbes dominating the decomposition process (oxygen consumption) (Bu *et al.* 2021, Catalán *et al.* 2021, Robinson 2019). Eventually, an imbalance between oxygen generation from photosynthesis and oxygen consumption by biological activity develops.

Salinity changes between Stations I and III at the mouth of Sungai Nibung Village show that seawater has the dominant effect. Station I, located at the estuary's upper reaches, has a salinity of 18.7‰, increasing downstream to 21.4‰. It suggests that this location is a tidal channel with a high concentration of seawater mass that extends to the estuary's upper levels. Although the locals refer to this area as a river, it is defined as a tidal estuary with tide-shaped morphology rather than a river with freshwater flow. The watershed area's limited freshwater supply contributes to the high salinity dominance. The vegetation surrounding the estuary is considered a catchment region because it can store rainwater, hold runoff, decrease surface flow, and reduce erosion and sedimentation (Fadhlan *et al.* 2024). Mangrove regions dominate the vegetation along the estuary in Sungai Nibung Village, with an estimated 8,000 hectares (Yustina 2024), resulting in a narrow catchment area. As a result, the amount of freshwater coming into the estuary is limited, and it is unable to balance the dominance of seawater, resulting in high salinity even in the estuary's upper reaches.

The village's water has a neutral pH of 6.98 to 7.39. The range of 7−8.5 is still appropriate for aquatic life (Effendi 2003). In general, pH influences the acidity and alkalinity of water, which is critical in a variety of biogeochemical processes (Haddout *et al.* 2022). pH values of various estuaries in West Kalimantan have been documented, including the Sungai Kapuas estuary with a pH value of 6.26 (Sari *et al.* 2024), the Sungai Mempawah estuary with a pH range of 6.50−7.98 (Rhediyanto *et al.* 2023), and the pH of the Sungai Kakap estuary with a pH range of 7.39−8.12 (Sari *et al.* 2021). The pH of surface water can impact aquatic species' respiratory cycles (Kleinhappel *et al.* 2019) and create harmful effects when combined with chemicals or metals like sulfur dioxide and aluminum (Ramadan 2004). Human activities such as land use changes, anthropogenic waste, deforestation, agricultural operations, and mining in river upper reaches all contribute to a drop in water pH, particularly in estuaries (Duarte *et al.* 2013). Furthermore, eutrophication can cause acidification by enriching nutrients, increasing the buildup of organic matter and creating acidic chemicals, particularly during certain seasons (Raven *et al.* 2020).

The pH of seawater at Stations IV and V ranged from 7.2 to 7.4. This spectrum is also appropriate for aquatic life. The pH value in various coastal waters in West Kalimantan is as follows: Pantai Mutiara Ketapang 6.8−6.9 (Dahliana *et al.* 2023), Teluk Cina, Lemukutan Island 8.2 (Yunivah *et al.* 2023), Pantai Pasir Mayang 7.0−7.9 (Saputra *et al.* 2023), and Kabung Island 7.39−7.41 (Palias *et al.* 2022). Seawater's pH values are higher due to the preponderance of carbonate ions, making the water more alkaline. Estuaries, on the other hand, have lower pH levels because they continue to be influenced by land-based organic matter and carbon dioxide inputs (Sembiring *et al.* 2012). The sea's high salt content and bicarbonate ions increase alkalinity, neutralizing the influx of organic acids.

Water Fertility

The water column contains nutrients such as nitrate and phosphate. Sungai Nibung Village's water contains relatively high quantities of these two nutrients. The quality criteria based on Minister of Environment Regulation No. 51 of 2004 indicate that nutrient concentrations in water should be 0.008 mg/L for nitrate and 0.015 mg/L for phosphate.

Table 2 shows that nitrate levels in estuary and sea range between 0.9 and 1.5 mg/L. Nitrate and phosphate concentrations vary in West Kalimantan estuaries such as the Sungai Kakap River, which has nitrate levels of 0.1 to 1.6 mg/L and phosphate levels of 0.08 to 3.81 mg/L (Sari *et al.* 2021), and the Sungai Bakau Besar Village estuary, which has nitrate levels of 3−3.5 mg/L and phosphate levels of 2.5−6.0 mg/L (Nuraya *et al.* 2023). Meanwhile, the waters of Teluk Cina, Lemukutan Island, West Kalimantan, had nitrate levels of 2.1 mg/L and phosphate values of 2.9 mg/L (Yunivah *et al.*, 2023). Nitrate and phosphate concentrations in estuaries and marine waters vary due to changes in nutrient inputs, such as runoff from land, organic waste, and sediment diffusion (Patty *et al.* 2015). Additionally, current dynamics, tides, mixing processes, dilution, and phytoplankton utilization rate all influence the distribution of these two nutrients. Nitrate and phosphate concentrations have been shown by Nuraya *et al.* (2023) to influence phytoplankton abundance. In contrast, numerous phytoplankton can reduce nitrate and phosphate concentrations by absorbing them during growth. Nitrate is essential for protein synthesis, while phosphate is an important ingredient for phytoplankton cell metabolism and growth (Paiki *et al.* 2018, Fachrul *et al.* 2005).

Nitrogen and phosphorus exist in numerous forms in aquatic environments, but phytoplankton can only use dissolved forms such as nitrate, nitrite, and orthophosphate (Jones-Lee & Lee 2005). Nitrate is generated via the aerobic oxidation of ammonia to nitrite and nitrate, known as nitrification (Falkowski 2003, Erickson *et al.* 2015, Maslukah *et al.* 2019). Nitrate and phosphate promote photosynthesis in phytoplankton via chemoautotrophic and photoautotrophic pathways, resulting in the production of oxygen and carbohydrates (Falkowski 2003).

The main sources of nitrate in water are agricultural runoff and organic waste. Water-borne nitrogen fertilizers, organic matter breakdown, and nitrogen fixation by microorganisms all play important roles. It is consistent with the findings of Luthfiah *et al.* (2023): the presence of Anabaena, a form of nitrogen-fixing cyanobacteria acts as an indicator of eutrophication due to its capacity to proliferate fast in nutrient-rich waters.

Phosphate sources can come from both natural processes like rock weathering and human activity like detergent use. Phosphate is a major component in detergents. Increased phosphate levels in water can accelerate eutrophication and cause algal blooms, which have the potential to disturb aquatic ecosystem balance and harm aquatic biota (Tungka *et al.* 2016, Gurning *et al.* 2020).

An imbalance in the nitrogen-to-phosphorus (N/P) ratio in water bodies can speed up the growth of phytoplankton, especially if phosphate levels continue to rise while nitrate levels remain within normal limits. Other elements that influence eutrophication include light intensity, temperature, and water column stability.

Chlorophyll-a concentrations in estuaries and marine waters range between 0.002 and 0.005 mg/L. Stations I, II, III, IV, and V have chlorophyll-a levels of 2, 5, 4, 4, and 5 µg/L, respectively. Low chlorophyll-a levels despite high nitrate and phosphate concentrations suggest that phytoplankton are not utilizing nutrients optimally or that other limiting factors exist, such as insufficient light, water stratification, weak currents, or an immature phytoplankton population. Furthermore, high salinity and low dissolved oxygen levels have an impact on aquatic primary productivity. The number of phytoplankton determines the concentration of chlorophyll-a in the water. Chlorophyll-a is the primary pigment in phytoplankton, which contributes to photosynthesis and the production of nutrients in water (Febriyanti *et al.* 2023, Krishnan *et al.* 2020, Stoń-Egiert *et al.* 2024).

CONCLUSION

The estuary and coastline waters of Sungai Nibung Village, Kubu Raya, exhibit different oceanographic characteristics, with depths ranging from 1.2 to 7.4 m. These waters have a comparatively low dissolved oxygen (DO) level, ranging from 2.2 to 3.7 mg/L, and a neutral pH of 6.9 to 7.4. The salinity in the upstream and downstream estuary is quite high (18.7−21.4‰), while in the sea, salinity ranges from 22.1−22.6‰, suggesting the major effect of seawater in the upstream

Table 2 Nitrate, phosphate, and chlorophyll-a content in the water of Sungai Nibung Village

Parameters	Stations				
	I	II	III	IV	V
Nitrate (mg/L)	1.4	0.9	1.5	1.5	1.5
Phosphate (mg/L)	2.06	2.09	2.11	2.07	2.19
Chlorophyll-a (µg/L)	0.005	0.004	0.004	0.005	0.002

part of the estuary. The waters (estuary and sea) are fertile with high nitrate concentrations (0.9−1.5 mg/L) and phosphate concentrations (2.06−2.19 mg/L), but low chlorophyll-a levels (2−5 μg/L). It suggests that phytoplankton nutrient uptake has not yet achieved peak levels, possibly due to constraints in other environmental parameters such as light, currents, or low dissolved oxygen levels.

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