

Trophic Level Analysis of Eretan Coastal Waters, Indramayu Regency, West Java Province

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Abstract

The coastal waters of Eretan located in the north of Indramayu Regency are used as fishing grounds by local fishermen. The condition of water input, especially from the surrounding river waters, namely the Cimanuk River, Cipunagara River, and Perawan River, is thought to affect the condition of coastal waters. This study aims to analyze the trophic level based on water quality conditions. Data collection on the quality of the aquatic environment was carried out in three locations with purposive sampling considerations, namely the Cipunagara estuary, the Perawan estuary, and the Cimanuk estuary. Sampling was carried out in two different seasons, namely the dry season and the rainy season. The method used in the analysis is the TRIX Index based on nutrients, phosphate, chlorophyll- α , and DO saturation. Meanwhile, water quality parameters at each location were analyzed using principal component analysis (PCA). The results of the study showed that the main water quality parameters tended to differ in each season. The trophic level at the three locations had values between 4.99 and 8.59, so they had mesotrophic to hypertrophic status. This shows that coastal water conditions need to be managed so that water conditions are more stable.

Keyword : Thropic Level, Eretan Coastal, Water Quality

INTRODUCTION

The coastal waters of the Eretan region, which are strategically situated along the expansive Java Sea, are renowned for their exceptionally dynamic and diverse coastal ecosystems that are significantly shaped by a multitude of factors including riverine inputs, intricate tidal patterns, and the myriad of human activities that take place in the vicinity (Aguilera *et al.*, 2022). This specific area is located within the administrative boundaries of the Indramayu Regency, which is an integral part of the northern coastline of Java, and it presents a unique geographical characteristic that is typified by a flat and low-lying topography that is commonly observed in coastal zones throughout the Java region. Moreover, the landscape of this area is interspersed with several rivers and estuaries, such as the Cipunagara, Cimanuk, and Perawan rivers, which play a crucial role in significantly influencing the quality of the water and the processes of sediment transport within the coastal environment.

Within these rich waters, a plethora of diverse ecosystems can be found, which include but are not limited to, extensive mangrove forests, lush seagrass beds, and vital estuarine habitats that are essential in supporting a wide array of marine biodiversity and serve as critical breeding and nursery grounds for numerous aquatic species (Atkins *et al.*, 2011). Additionally, this coastal region serves as a hotspot for small-scale fishing activities, which are pivotal in sustaining the livelihoods of local communities, as these waters are teeming with abundant species of fish, shrimp, and crabs that contribute to both food security and economic stability in the area.

The economy of this region is heavily dependent on various marine-based activities, including fishing and shrimp farming, which are integral components of the local economic framework. Furthermore, the river systems that traverse the area, notably the Cimanuk and Cipunagara rivers, contribute significantly to the agricultural productivity of the region; however, it

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is crucial to recognize that the runoff from agricultural practices can adversely affect the quality of the coastal waters (Wang *et al.*, 2023). Despite being somewhat limited in scope, there exists a considerable potential for eco-tourism development in the Eretan region, primarily due to its stunning natural beauty as well as its proximity to significant cultural and historical sites located within Indramayu.

Nonetheless, the region grapples with increasing nutrient loads that originate from agricultural runoff, industrial discharges, and domestic waste, which collectively have a detrimental impact on water quality and can lead to the phenomenon of eutrophication in specific areas. Similar to many regions along the northern coast of Java, the Eretan coastline is confronted with formidable challenges associated with erosion, which is further exacerbated by the dual threats of land subsidence and rising sea levels that pose significant risks to the coastal environment (Abdyralieva & Totubaeva 2024). Moreover, the mangroves and other essential coastal ecosystems are currently under considerable pressure

stemming from deforestation activities and the conversion of land for various developmental purposes, which jeopardizes their ecological integrity and the myriad of ecosystem services they provide.

This study aims to analyze the trophic level of Eretan coastal waters, Indramayu, West Java. Meanwhile, the benefit of this research is to provide information regarding the actual conditions of Eretan coastal waters, related to the trophic state of the waters.

METHODS AND MATERIALS

The research was conducted in the coastal waters of Eretan, Subang-Indramayu, West Java. The location of water intake was based on three river estuaries around the location, namely the Cipunagara estuary, the Perawan estuary, and the Cimanuk estuary. Water sampling was carried out based on two seasons, namely the dry season and the rainy season which were carried out in October 2024 and February 2025. The detailed research location is presented in **Figure 1**.

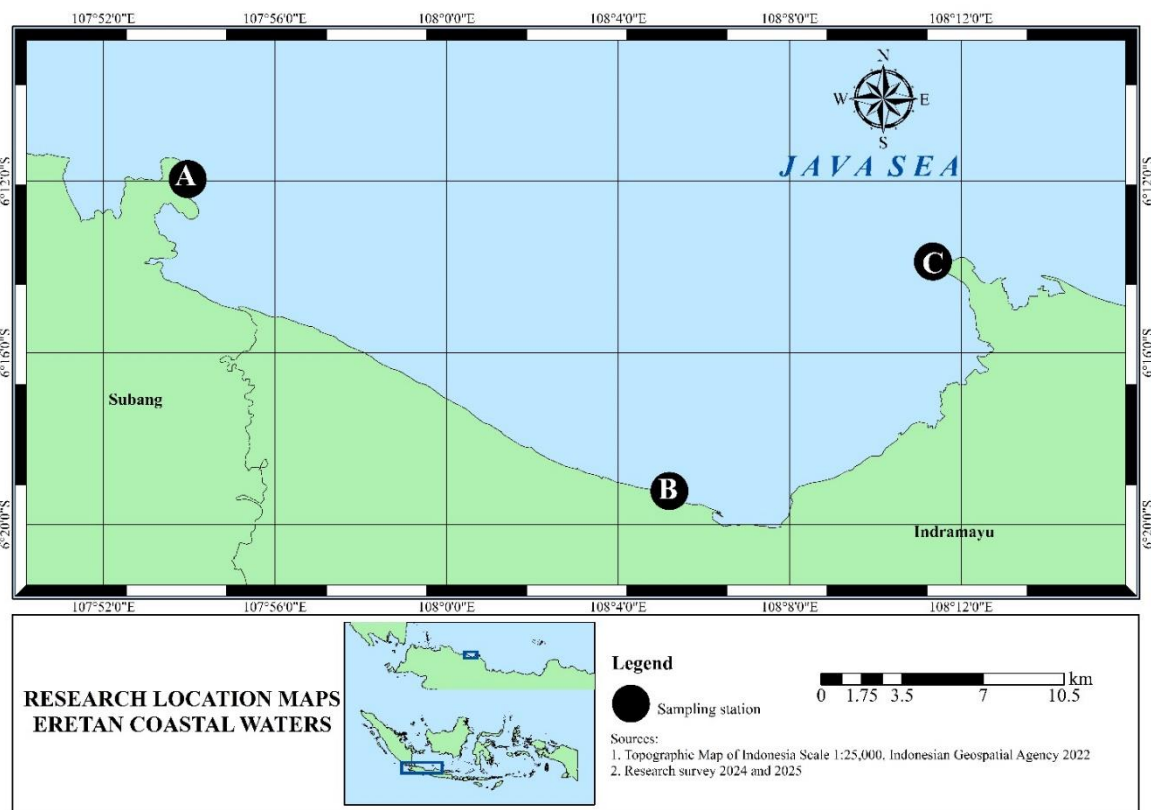


Figure 1. The research location is in the coastal waters of Eretan, Indramayu Regency, West Java Province. Monitoring stations are distinguished based on the river estuaries around the location, namely Cipunagara Estuary (A), Perawan Estuary (B), and Cimanuk Estuary (C).

Data Collection

Water sampling was carried out using the SNI 8995:2021 method concerning water sampling for physical and chemical testing. Sample of seawater was collected from the surface using a Van Dorn Water Sampler with a volume of 2 liters at each sampling station. The water quality measured includes physical, chemical, and biological parameters that are suspected of acting as organic pollutants in the coastal waters of Eretan. Water samples were then tested directly (in situ) and analyzed at the Aquatic Environmental Productivity Laboratory, Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, IPB University. The in situ parameters measured in this study were temperature, salinity, and dissolved oxygen (DO). The water quality parameters observed in this study are presented in Table 1.

Rainfall data were obtained based on monitoring results from the Meteorology, Climatology, and Geophysics Agency (BMKG) which can be accessed via https://dataonline.bmkg.go.id/data_iklim. Rainfall data were obtained based on monitoring data from the Kertajati Meteorological Station located in Majalengka Regency, West Java.

Data Analysis

The trophic level of the coastal waters is measured using the trophic index method or TRIX index. This index is used to assess the trophic status of coastal and marine waters (Primpas and Karydis

2011). The parameters used in this index include chlorophyll- α concentration, oxygen saturation, total nitrogen (TN), which consists of nitrate, nitrite, and ammonia, as well as total phosphate (TP). The trophic level status is categorized based on the scale values derived from the equation of Vollenweider *et al.*, (1998) (Table 2).

$$\text{TRIX} = \frac{k}{n} \sum_{i=1}^n \left(\frac{(\text{Log } M - \text{Log } L)}{(\text{Log } U - \text{Log } L)} \right)$$

The TRIX index indicates the fertility level of a water body, which can be determined using the scaling factor (k), typically valued at 10, with a divisor (n) representing the number of observed parameters, which is 4. The next step is to multiply the sum by calculating the difference between the logarithm of the measurement value or average (M) and the lower limit (L), and the difference between the logarithm of the upper limit (U) and the lower limit (L). The TRIX index calculation will yield a value that reflects the TRIX scale based on trophic status.

Rainfall data is analyzed descriptively based on observed values based on the decades that occurred during the research period. Rainfall values exceeding 50 mm are categorized as the rainy season, while if less, it will be categorized as the dry season (Chaudhary *et al.*, 2017). Meanwhile, water quality parameter data were further analyzed based on the sampling location using *Principal Component Analysis* (PCA) to reduce the two data (Jolliffe & Cadima 2016).

Table 1. The water quality measured in the study of the Eretan coastal waters

No	Parameters	Unit	Tools/Method
1	Temperature	°C	Thermometer
2	Salinity	psu	Refractometer
3	Dissolved oxygen (DO)	mg/L	Oxygen meter
4	Nitrate (NO ₃ -)	mg/L	APHA 24 th Edition (2022)
5	Nitrite (NO ₂ -)	mg/L	APHA 24 th Edition (2022)
6	Amoniac (NH ₃ -)	mg/L	APHA 24 th Edition (2022)
7	Ortophospate (PO ₄ -)	mg/L	APHA 24 th Edition (2022)
8	Chlorophyll- α	µg/L	APHA 24 th Edition (2022)

Table 2. The category of trophic status in the TRIX index

TRIX scale	Trophic Status	Level of eutrophication
$0 \leq \text{TRIX} \leq 4$	Ultra-oligotrophic	Low
$4 < \text{TRIX} \leq 5$	Mesotrophic	Moderate
$5 < \text{TRIX} \leq 6$	Eutrophic	High
$6 < \text{TRIX} \leq 10$	Hypertrophic	Very high

RESULT AND DISCUSSION

Rainfall Conditions

Rainfall that occurred during the research period had an average monthly value of 14.80 mm in October 2024 and 134.00 mm in February 2025 (Figure 2). This shows that the sampling at both times represents the dry season and the rainy season. Rainfall can affect water conditions, especially when the rainy season can increase the volume of water input from land to the ocean. This condition can allow natural flushing to occur by carrying pollutants from land to the ocean, so that it can affect the quality of water in coastal areas (Delpla *et al.*, 2023). The impacts that can occur from high rainfall include increased concentrations of water nutrients, changes in salinity concentrations, and increased sedimentation rates (Jia *et al.*, 2021; Zevri *et al.*, 2022).

Water Quality Parameter Conditions

Water quality parameters observed during the study showed varying tendencies based on both sampling location and season. The surface water temperature exhibited varying conditions across different estuaries: Perawan Estuary (29.8–30.0 °C), Cimanuk Estuary (28.1–30.5 °C), and Cipunagara Estuary (30.4–32.9 °C) (Figure 3a). The temperature fluctuations between observation seasons at each site ranged from 0.2 to 2.5 °C. Consistently, the highest temperatures were recorded during the dry season, while the lowest

temperatures occurred during the rainy season. The sea surface temperature showed a high change in the Cipunagara estuary with a difference of 2.5 °C, reaching the highest temperature at 32.9 °C. High salinity changes occurred in the Perawan estuary with a range of 5–33 psu (Figure 3b). In terms of seasonal changes, the salinity condition at the Cipunagara Estuary remained relatively stable at approximately 29 psu. However, both the Cimanuk and Perawan estuaries exhibited a declining trend in salinity from the dry season to the rainy season. The salinity at the Cimanuk Estuary decreased from 34 to 22 psu, whereas a more drastic decline was observed at the Perawan Estuary, where salinity dropped from 33 to 5 psu. Dissolved oxygen observed at all three locations showed significant changes to the season. Low dissolved oxygen, which was less than 5 mg/L, occurred during the rainy season, while during the dry season, dissolved oxygen increased at all three locations, even exceeding 5 mg/L (Figure 3c). The range of dissolved oxygen reduction was observed as follows: Perawan Estuary (5.7–3.8 mg/L), Cimanuk Estuary (5.9–3.7 mg/L), and Cipunagara Estuary (6.6–2.9 mg/L). The concentration of dissolved oxygen parameters was influenced by temperature and salinity. High temperatures caused dissolved oxygen to decrease, while high salinity decreased dissolved oxygen. This condition is thought to have an impact on the productivity of waters and marine ecosystems. (Mandal & Ray 2022).

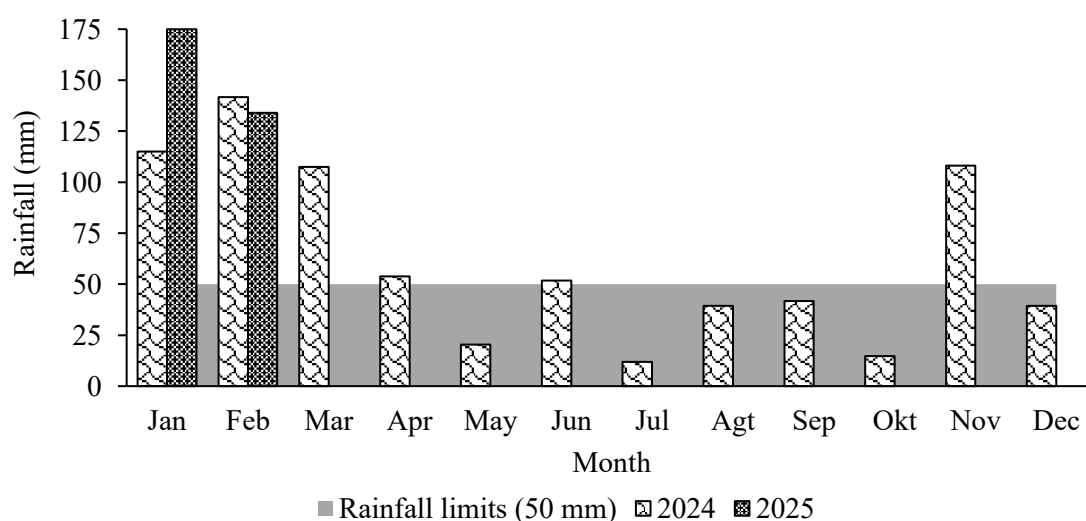


Figure 2. Monthly rainfall that occurred in the coastal waters of Eretan. Data obtained from the Meteorology, Climatology, and Geophysics Agency (BMKG) through the Kertajati Meteorology Station, Majalengka, West Java, accessed in April 2025.

The total nitrogen observed is an accumulation of three nitrogen parameters, namely nitrate, nitrite, and ammonia. Based on this, it shows that the Perawan estuary has the highest total nitrogen concentration (0.757 mg/L) during the rainy season, but its concentration decreases to the lowest during the dry season (Figure 3d). A different pattern was observed in the Cipunagara and Cimanuk estuaries, where total nitrogen concentrations increased during the dry season and declined during the rainy season. The range of total nitrogen concentrations across the three estuaries was as follows: Perawan Estuary (0.494–0.757 mg/L), Cimanuk Estuary (0.277–0.518 mg/L), and Cipunagara Estuary (0.257–0.514 mg/L). The total phosphate concentration shows that there is a very large change in the Cimanuk estuary with a value range of 0.026–0.049 mg/L (Figure 3e). The total phosphate concentration at the Cipunagara Estuary ranged between 0.023–0.029 mg/L. The highest concentrations at both the Cipunagara and Cimanuk estuaries occurred during the dry season, followed by a decline in the rainy season. A contrasting trend was found at the Perawan Estuary, where the highest concentrations were recorded during the rainy season, with values ranging from 0.033 to 0.038 mg/L. The chlorophyll-a concentration observed at the three locations tends to fluctuate, with the highest value shown in the Cimanuk estuary (Figure 3f). During the dry season, the Cimanuk estuary has the highest concentration (11.645 µg/L), while the Perawan estuary has the highest concentration during the rainy season, reaching 8.664 mg/L. The chlorophyll-a concentration at the Cipunagara Estuary was recorded at 1.386 µg/L during the dry season and increased significantly to 4.459 µg/L in the rainy season. These nitrogen (N) and phosphate (P) parameters can determine the level of water fertility because they are indicators in providing the nutritional needs for the life of aquatic organisms so that they can produce optimal production (Hu *et al.*, 2024). The high levels of chlorophyll- α , nitrate, and orthophosphate suggest that the coastal waters are experiencing eutrophication, a process of water pollution that occurs when the levels of minerals and nutrients in the water increase excessively, especially nitrogen and phosphorus (Alves *et al.*, 2013).

Principal Component Analysis (PCA) of Coastal Water Quality Parameters

PCA was used to simplify and identify the

most influential water quality parameters at each estuary location during the dry and rainy seasons. The results showed that different parameters were dominant at different sites depending on the season. In the dry season, the Cipunagara Estuary was mainly influenced by temperature, dissolved oxygen (DO), and nitrite. The Perawan Estuary was characterized by high levels of total phosphate, ammonia, and chlorophyll- α , while the Cimanuk Estuary was primarily affected by nitrate. During this season, salinity and total nitrogen had little impact across all three estuaries (Figure 4a). In contrast, during the rainy season, the dominant parameter at the Perawan Estuary was DO, while the Cipunagara Estuary was more influenced by ammonia, chlorophyll- α , and salinity (Figure 4b). Meanwhile, the Cimanuk Estuary did not show any dominant water quality parameters in the rainy season, and parameters such as temperature, total phosphate, nitrate, nitrite, and total nitrogen were generally not significant at any location during this period. According to PCA principles, parameters that appear farther from the center point (0 axis) on the PCA plot represent the key characteristics of a location (Ibrahim *et al.*, 2023). Based on this, it can be concluded that the Perawan Estuary in the dry season is mainly characterized by high total phosphate, ammonia, and chlorophyll- α levels. In the rainy season, the Cipunagara Estuary is distinguished by nitrate and chlorophyll- α . On the other hand, the Cimanuk Estuary does not exhibit any specific dominant parameters in either season.

Trophic Levels of Coastal Waters

Trophic level analysis using the TRIX index uses four key parameters in the form of oxygen saturation, total nitrogen (N), total phosphate (P), and chlorophyll-a (Vollenweider *et al.*, 1998). The trophic levels in the three locations showed a fluctuating tendency with values of 4.99–8.59 so that they had mesotrophic-hypertrophic status (Figure 5). Seasonal variation plays a significant role in determining the trophic status of the estuaries. During the dry season, the Perawan Estuary exhibits a mesotrophic status, whereas the Cimanuk and Cipunagara Estuaries consistently exhibit a hypertrophic status. However, in the rainy season, the trophic status of the Perawan Estuary shifts to hypertrophic, as indicated by an increase in the TRIX index. In contrast, the hypertrophic condition in the Cimanuk and Cipunagara Estuaries remains unchanged across both seasons.

This indicates that the trophic level in the Perawan River Mouth area is higher than at the other stations. The trophic level of a water body is influenced by the high concentrations of chlorophyll- α , nitrogen, and phosphorus, where river mouths serve as areas of pollutant accumulation from the land, which then accumulate before being flushed into the sea (Ke *et al.*, 2023). This suggests that the high trophic status

in the Cipunagara and Cimanuk estuaries is likely caused by intense anthropogenic activities in the surrounding areas. This condition is supported by the presence of various community activities that potentially generate organic waste, which flows into the water bodies through these two river basins. Such activities include settlements, aquaculture ponds, agriculture, fish landing ports, and fish processing facilities.

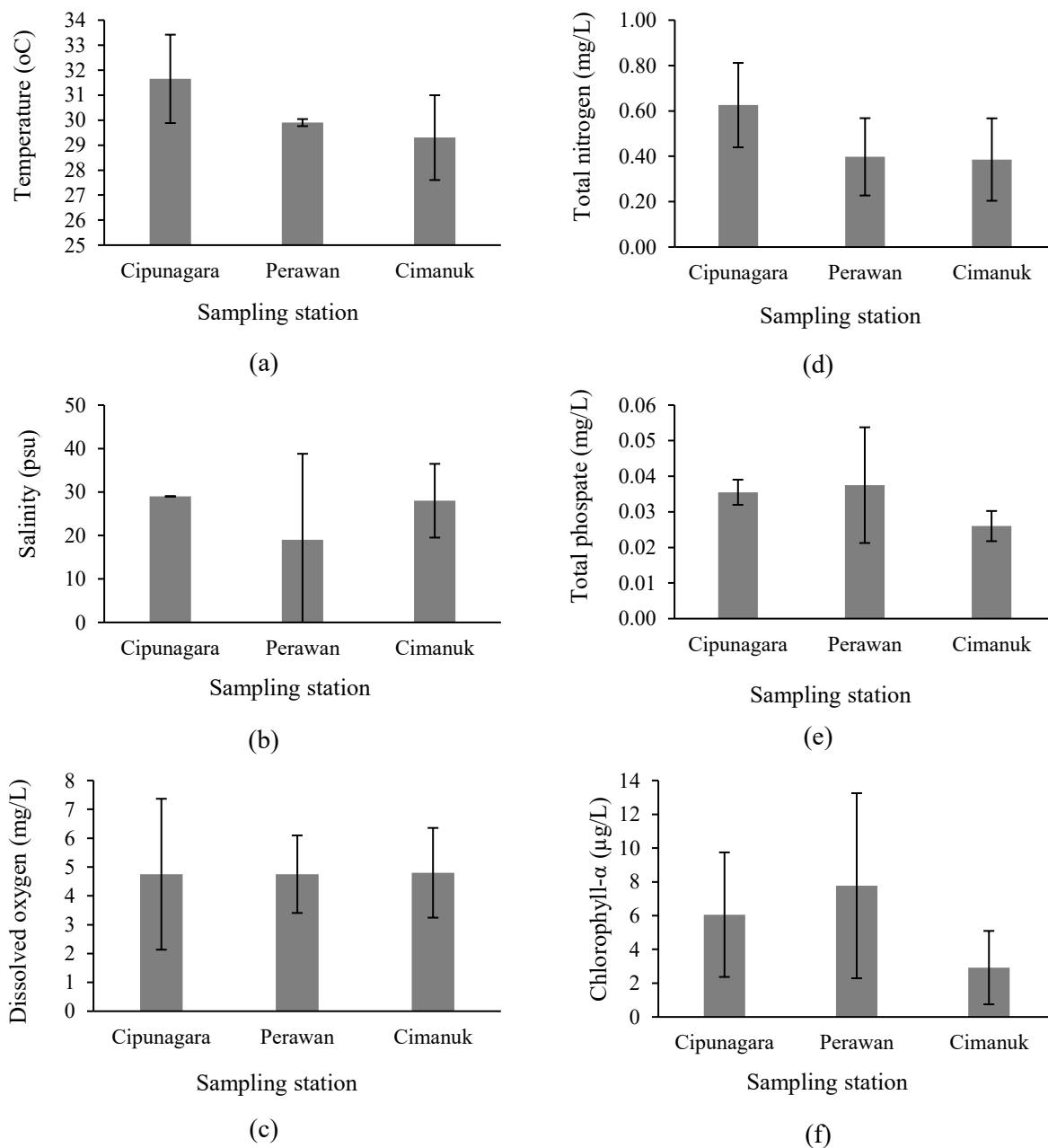


Figure 3. The concentration of water quality parameters in the coastal waters of Eretan. Measurements were conducted based on SNI 8995:2021, which outlines the methods for sampling water for physical and chemical testing.

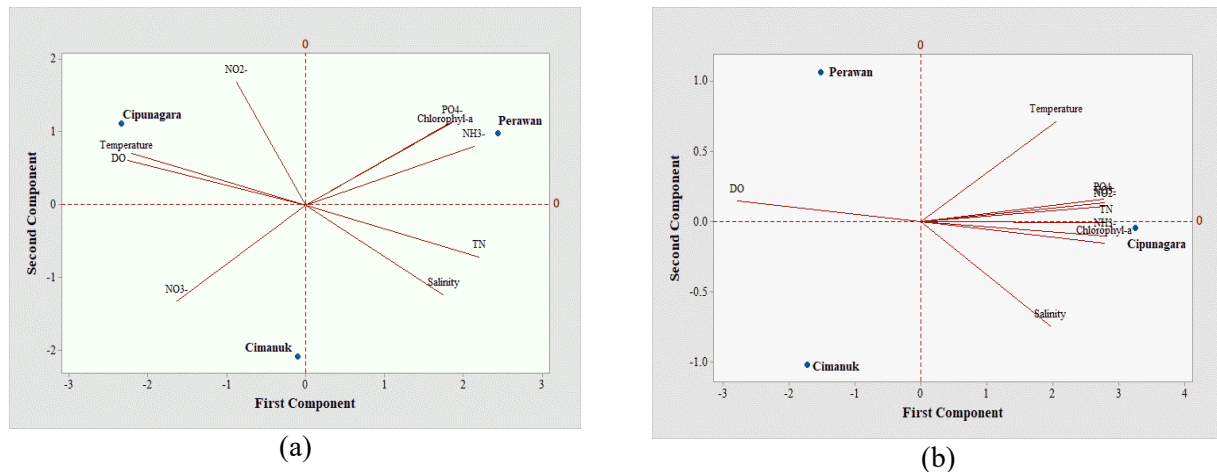


Figure 4. Principal component analysis in dry season (a) and rainy season (b)

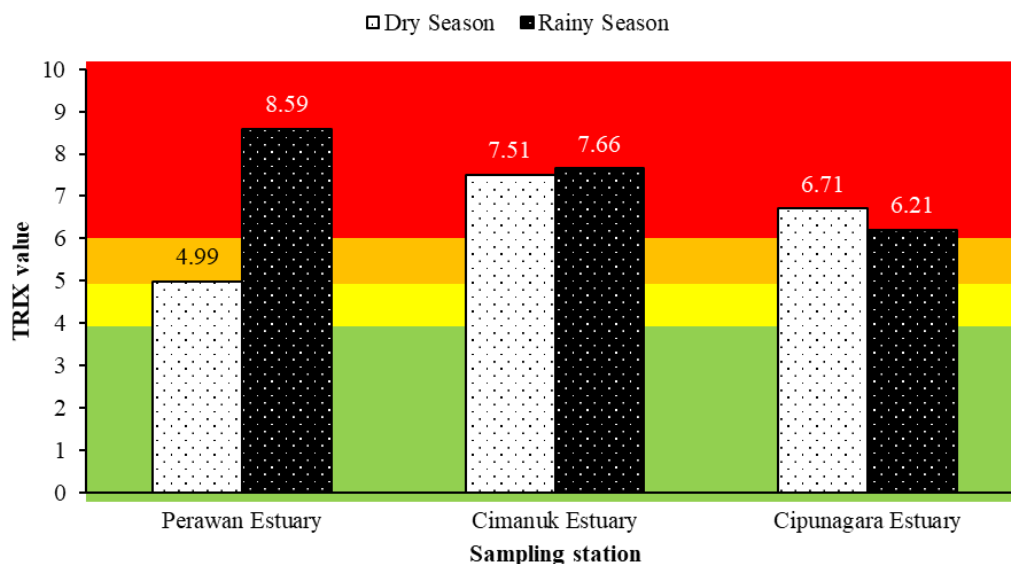


Figure 5.TRIX index in the coastal waters of Eretan. Trophic status based on Vollenweider *et al.*, (1998): green-oligotrophic (0-4), yellow-mesotrophic (4-5), orange-eutrophic (5-6), and red-hypertrophic (6-10).

Additionally, this section suggests that rivers flowing into the Eretan coastal waters are suspected to contain high concentrations of pollutant loads. This is supported by previous research, which indicates that the Cipunagara River tends to be heavily polluted, with a pollution index value reaching 21.82 (Juwana & Nugroho, 2020). Additionally, this condition is reinforced by the increasing trend of accretion occurring annually in the downstream area of the Cimanuk River, indicating a high pollution load entering the water from land-based sources (Nur *et al.*, 2020). Meanwhile, the Cimanuk River tends to exhibit a pollution status ranging from lightly to moderately

polluted, with a pollution index value reaching 8.56 (Ginastiar, 2023). Therefore, comprehensive monitoring is necessary to provide an accurate picture of the current conditions of the watershed. The impacts of excessive nutrient levels in water can negatively affect water quality, leading to deterioration and influencing the survival of aquatic biota. Such conditions may result in low dissolved oxygen (DO), making it more difficult for biota to survive, which could eventually force them to migrate to other areas. Meanwhile, other biota that tend to remain may adapt to the new conditions. However, if eutrophication becomes extremely high, it can cause mass mortality due to

the toxicity from low oxygen levels (Damar *et al.*, 2012; Owa, 2013).

The pollutant load that accumulates at river mouths originates from the surrounding areas, which directly contribute to the increased concentration of organic material, particularly from terrestrial regions. This organic material is naturally formed from the decomposition of animals and plants that enter the water body. However, anthropogenic activities play a significant role in the increased accumulation of these materials. This can include domestic waste, which generally does not undergo wastewater treatment, whether in the form of greywater or blackwater (Adyasari *et al.*, 2021). Agricultural activities around the study area, primarily rice fields and fish ponds, are suspected to contribute to the increase in organic materials such as nitrogen, phosphate, and even pesticides used during the farming process. The feed used in fish ponds typically contains high levels of nutrients, which tend to remain as sediment (Fried *et al.*, 2003). This suggests that human activities in the coastal area are likely contributing significantly to the eutrophication process. Therefore, managing human activities, especially in controlling wastewater discharge directly into the water, is essential.

CONCLUSION

The main water quality parameters tended to differ in each season. The trophic status of Eretan coastal waters ranges from 4.99 to 8.59, so it has a mesotrophic to hypertrophic status. Muara Perawan tends to have major changes in trophic status. This relatively high status is thought to be influenced by anthropogenic activities around the coastal area. Immediate management efforts are needed to control wastewater that enters directly into water bodies.

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