The role of water conditions in Jakarta Bay on the sustainability of capture fisheries production

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Abstract. The extensive coastal development in Jakarta is placing significant pressure on the water conditions of Jakarta Bay, which is suspected to have a high correlation with the fish catch yields in the bay. To investigate and analyze this issue more thoroughly, spatial analysis is required, considering the interrelated aspects of water parameters and fishery production. Based on this need, the study formulated the following objectives: 1) To identify trends in the water conditions of Jakarta Bay, 2) To analyze the correlation between fishery production and the number of fishermen, and 3) To analyze the interrelationships among various parameters.This study employs Geographic Information System (GIS) analysis of annual average data on Total Suspended Matter (TSM), Chlorophyll-a Case 2 (CHL2), and Secchi Disk Depth (Z_{SD}) from 2017 to 2022, obtained from GlobColour. Water condition data were analyzed multivariately to determine the correlation between TSM and Z_{SD} with CHL2. Additionally, bathymetry data and Z_{SD} data were used to calculate seawater clarity based on visual percentage to the seabed. Fishery production data and the number of marine fishermen in Jakarta Bay were obtained from KKP statistics and subsequently analyzed to determine their correlation. Finally, all data were analyzed to determine their overall correlation with fishery production. The results are as follows: There is a very high correlation between TSM and ZSD with CHL2, with a correlation value of 0.97 and a TSM and ZSD p-value of <0.05, indicating that both parameters significantly affect CHL2 concentration. The lowest water clarity was found in area G (a hub for industries like textiles, food, chemicals, coal, and metals), with a clarity percentage ranging from 17.97% in 2017 to 21.4% in 2022. The highest clarity was found in area A (characterized by a well-maintaned mangrove forest ecosystem and luxury housing developments), with clarity percentages from 67.62% in 2017 to 54.39% in 2022. The lowest eutrophication indicator was in area D (which is a recreation, tourism, and shopping zone) with an average TSM value of 4.19 g/m3 and CHL2 of 1.86 mg/m3 in 2017, increasing to 4.80 g/m3 and CHL2 of 5.38 mg/m3 in 2022 while the highest was in area G, with an average TSM value of 7.94 g/m3 and CHL2 of 4.39 mg/m3 in 2017, rising to 24.25 g/m3 and CHL2 of 12.33 mg/m3 in 2022. There is a high correlation between fishery production and the number of fishermen, with a correlation value of 0.64, although the p-value of 0.20 indicates that the number of fishermen does not significantly affect fishery productionIn terms of geographical correlation with fishery production, the highest is in area A, with a correlation value of 0.99, while the lowest is in area D, with a correlation value of 0.65. All parameters have varying levels of influence on fishery production, though none are significant.
Key Words: Chlorophyll-a Case 2, GlobColour, multivariate analysis, Secchi disk depth, total suspended matter.

Introduction. The growing population and limited land-based resources make marine and coastal areas, along with their resources, a viable alternative to support current and future national development. In Indonesia, coastal management has become a strategic national issue for three key reasons: (a) the dependence of communities on coastal resources, (b) the fact that most coastal communities are among the poorest in

Indonesia, and (c) the high level of exploitation that threatens the sustainability and livelihoods of coastal communities (Kusumastanto 2003).

Jakarta Bay is a coastal area in Indonesia that faces complex pressures due to its position at the center of Indonesia's economy. Waste disposal can pollute seawater and disrupt marine life by increasing water turbidity, reducing dissolved oxygen levels, and releasing harmful substances. Additionally, waste disposal activities can drastically alter the coastal landscape (Krek et al 2024), decreasing economic value due to reduced fishery productivity and impacting local livelihoods and the regional economic structure. Another issue arises when the concentration of nutrients exceeds the water's carrying capacity, leading to eutrophication. In eutrophic conditions, the increase in nutrient concentrations was followed by an increase in phytoplankton biomass, as observed in Jakarta Bay, from 15.81 μg chl-*a* L^{-1} in 2001 to 21.31 μg chl-*a* L^{-1} in 2019 (Damar et al 2020). Based on the identified problems, this study is designed to address and respond to various emerging issues. The objectives of this study are as follows: 1) to identify trends in the water conditions of Jakarta Bay; 2) to examine the correlation between fishery production and the number of fishermen; and 3) to investigate the interrelationships among various parameters.

Direct field measurements tend to be expensive and time-consuming. Additionally, simultaneous measurements are challenging, necessitating alternative methods. One such method is the use of remote sensing technology to extract information about variables affecting primary fertility, such as total suspended matter (TSM) and chlorophyll-*a* Case 2 (CHL2). Several studies related to TSM and CHL2 have been conducted by previous researchers, including Budhiman (2005), Hunter (2006), Sulaiman et al (2006), Gohin (2011), Wouthuyzen et al (2011), Ambarwulan et al (2012), Hermawan et al (2012), Dsikowitzky et al (2018), Wouthuyzen et al (2018), Akbar et al (2020) and Damar et al (2020). Additionally, research has been conducted using Secchi disk depth (Z_{SD}), a method for measuring water clarity through the visibility of a Secchi disk submerged in water. This variable can be measured in turbid waters, although different approaches are needed (Lee et al 2015; Bowers et al 2020). These studies have provided a solid foundation for understanding the dynamics of TSM, CHL2, and Z_{SD} in various waters, but further research is needed to understand the specific conditions in Jakarta Bay and their implications for local fishing activities. By understanding the trends in water conditions and their impact on fishery production, this study aims to make a significant contribution to more sustainable coastal resource management and support government policies in improving the welfare of coastal communities and maintaining the sustainability of marine ecosystems.

Material and Method

Description of the study sites. The research was conducted from January to June 2024 in the waters of Jakarta Bay. It is located between longitudes 106.6°E and 107.1°E and latitudes 05.8°S and 6.2°S. The western boundary of Jakarta Bay is bordered by Tanjung Pasir, the eastern boundary by Tanjung Karawang, and the northern boundary by the Thousand Islands.

Jakarta Bay features a gentle bathymetry and shallow depths resulting from prolonged and continuous sedimentation. This sedimentation mainly occurs at the mouths of rivers along the bay, such as the Cisadane River in the west and the Citarum River in the east (Rositasari et al 2017). In the coastal areas, the bay's bathymetry is relatively shallow, with depths between 1 and 6 meters, gradually increasing to over 50 meters in the open sea (Figure 1).

Regarding its utilization, the water quality of Jakarta Bay plays a crucial role in supporting fishery production and the sustainability of coastal communities. Good water conditions enable local fishermen to achieve sustainable fish catches and support the local economy through stable income and food security for coastal communities.

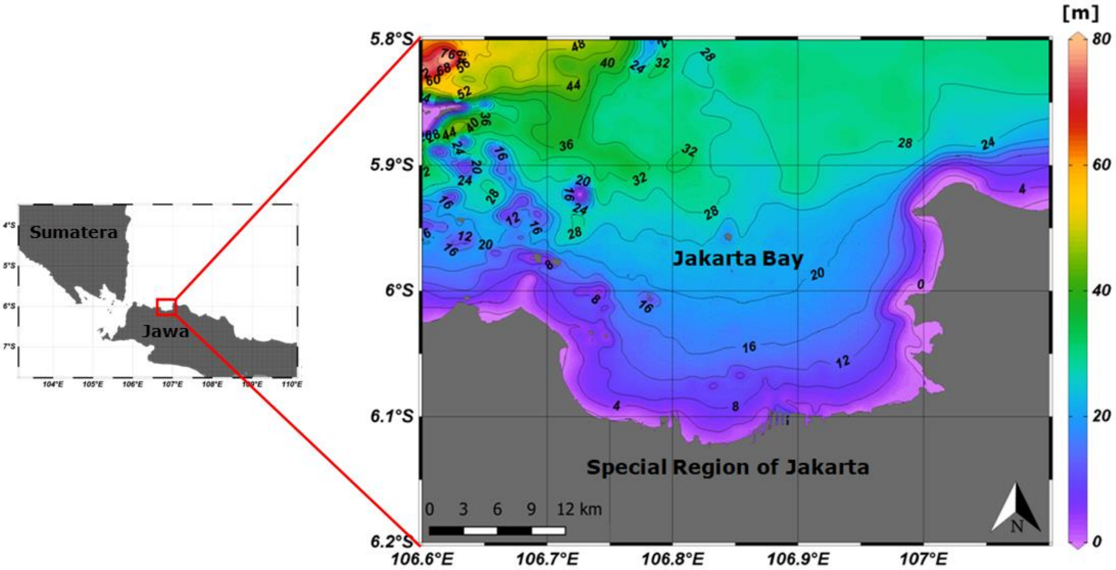


Figure 1. Research area and bathymetry of Jakarta Bay (Data source: GEBCO 2013).

Availability of data and analysis. This research employed a quantitative research method using observational data available from 2017 to 2022. The observation data collected for this study include monthly data on TSM, CHL2, and Z_{SD} parameters obtained from the GlobColour product available at https://hermes.acri.fr/. The spatial resolution of these parameters is 0.04° per data (Figure 2).

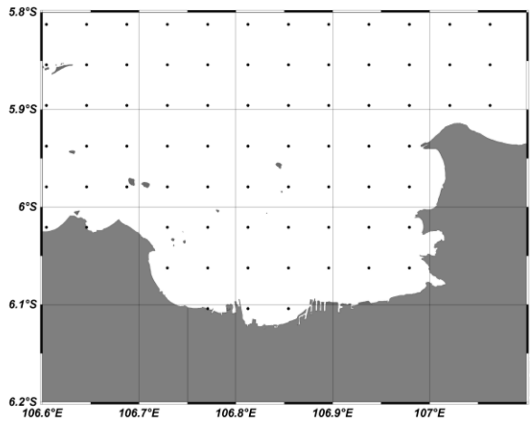


Figure 2. Research data available in the Jakarta Bay area (black dots).

The available data are averaged annually to determine annual changes in Jakarta Bay's water conditions. Water turbidity conditions are assessed by calculating the clarity percentage from the water surface to the seabed using the formula:

$$C = \frac{Bt(i) - Z_{SD}(i)}{Bt(i)} \times 100$$

where: C = the clarity percentage (%);
Bt(i) = bathymetry (m);
Z_{SD} = Secchi disk depth (m).

Multivariate analysis with a confidence level of 95% or with a significance level of $\alpha = 0.05$ was further conducted to determine the relationship between water conditions using TSM and Z_{SD} data with CHL2 conditions as an indicator of phytoplankton abundance in the water. Rencher (2002) stated that in multivariate linear regression analysis, there are independent variables (also known as predictors or explanatory variables) that influence dependent variables (also known as response variables or outcomes). Its primary goal is to understand the complex relationships between these variables simultaneously.

Fishery production data and the number of marine fishermen in Jakarta were obtained from Ministry of Marine Affairs and Fisheries (KKP) statistical data from the website https://statistik.kkp.go.id/home.php, which were then subjected to correlation analysis to measure the strength of the relationship between the two variables and determine its quantitative form. Subsequently, correlations were conducted between fisheries and water quality from the west to the east sides of Jakarta Bay (Figure 3). This was done to understand what water conditions correlate highly with fisheries production in Jakarta.

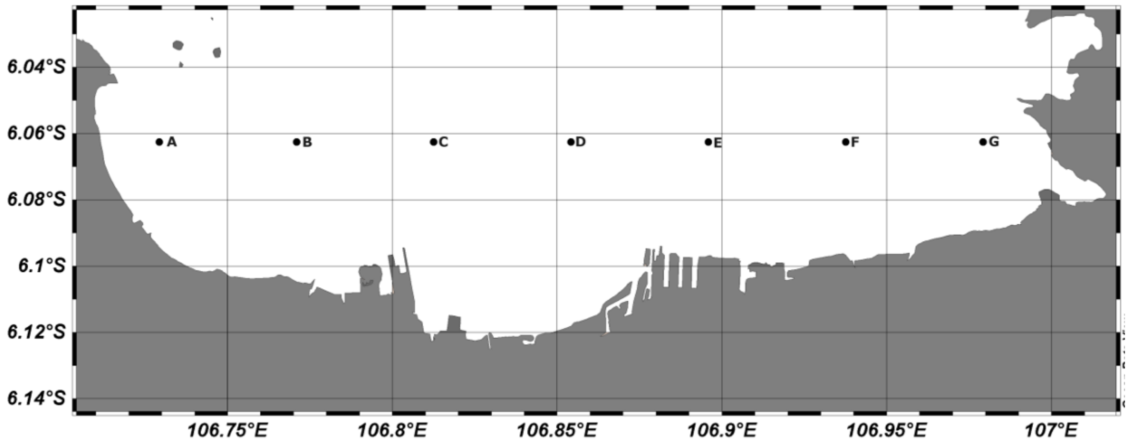


Figure 3. Analysis of data from the western to the eastern side of Jakarta Bay.

Each region of Jakarta Bay from point A to G is noteworthy for discussion due to being the estuary of various types of coastal land uses. Point A is a region that represents waters originating from luxury residential areas with mangrove conservation areas there, point B represents the region from a fishing port with a river mouth planted with mangroves, point C represents the region from a ferry terminal with predominance of residential and commercial land use, point D represents the region from the tourism location of Ancol beach, point E represents the region from the container port activity center and industrial area of Tanjung Priok, point F represents the region from land use dominated by residential areas, warehouses, and fish ponds, and point G represents the region from gas-fired power plant activities, industrial areas, and mangrove forests.

Results. Based on average values from 2017 to 2022, Jakarta Bay waters exhibit high eutrophication indicators, characterized by consistently high CHL2 concentrations (> 5 mg m^{-3}) along the coastal sides of Jakarta Bay. This is also driven by high TSM content and low Z_{SD} values (Figure 4).

The highest concentration of TSM (> 20 g m^{-3}) is found in the eastern region of Jakarta Bay, while the lowest concentration is in the central area with concentrations < 5 g m^{-3}. The low Z_{SD} values in the areas near the coast indicate high water turbidity in those regions. Furthermore, the relationships between variables were calculated using multivariate analysis, with the results shown in Table 1.

Table 1

Multivariate analysis of TSM and ZSD variables on CHL2

Regression statistics		*Coefficients*	
Multiple R	0.972239	Intercept	3.89E+00
Adjusted R^2	0.94388	TSM	2.21E-01
Significance F	3.43E-51	Z_{SD}	-2.51E-01
P-value			
TSM		1.39E-39	
Z_{SD}		9.10E-22	

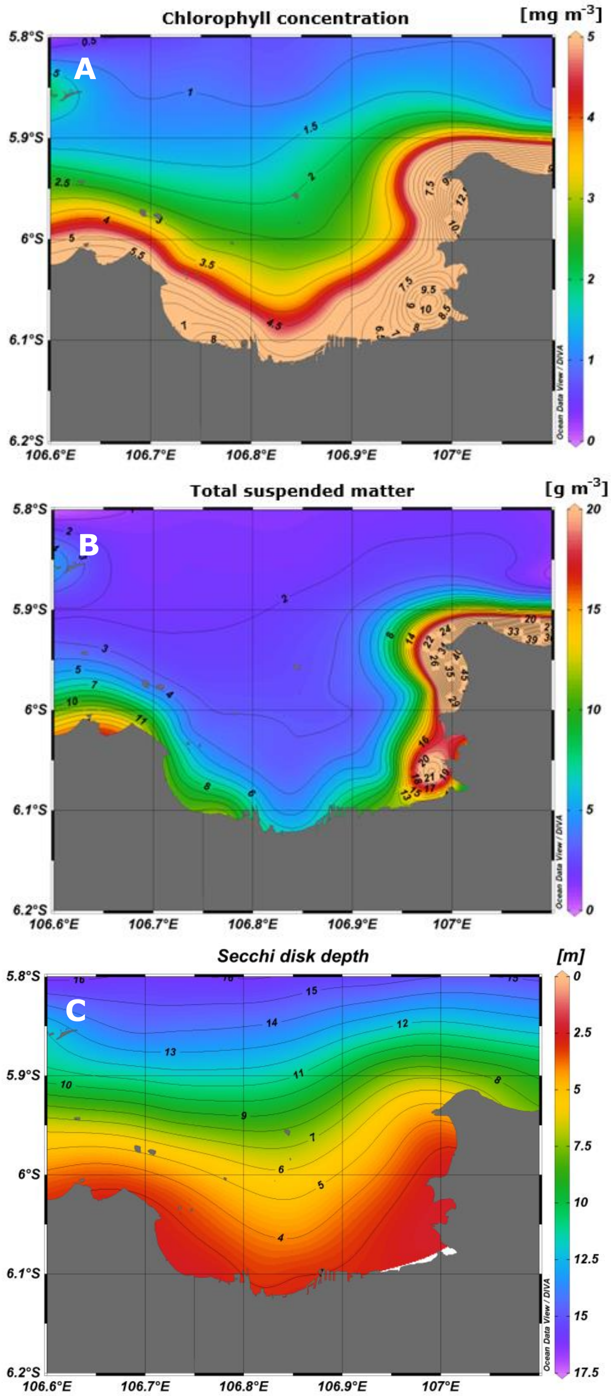


Figure 4. The average values of A). CHL2 (mg m^{-3}), B). TSM (g m^{-3}), and C). Z_{SD} (m) in Jakarta Bay waters.

The Multiple R value of 0.972239 indicates that the correlation between the variables TSM and Z_{SD} with CHL2 is very high. The adjusted R^2 value of 0.94388 indicates that the prediction model will accurately produce new CHL2 data from the TSM and Z_{SD} values. The significance F value < 0.05 means that there is a significant effect of TSM and Z_{SD} on CHL2. The p-values for TSM and Z_{SD} < 0.05 mean that the TSM and Z_{SD} values significantly affect CHL2. The coefficients resulting from this analysis are shown in the following equation:

$$CHL2 = 3.89E+00 + 2.21E-01*TSM - 2.51E-01*Z_{SD}$$

To analyze these three parameters in more detail, the Jakarta Bay area was divided from west to east, marked by points A-G. The results of the analysis were then correlated with fishery production and the number of fishermen to examine the correlations.

Water clarity. This calculation was performed on each side of the waters from various different years. This was done to determine the water turbidity in the observation area. The results of the percentage clarity calculation from the sea surface to the seabed can be seen in Figure 5.

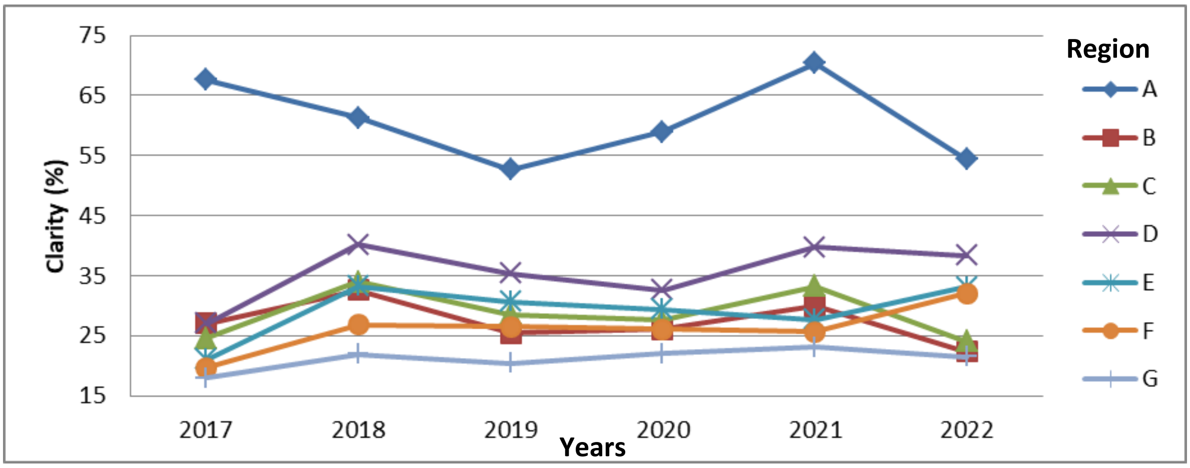


Figure 5. Percentage of water clarity in Jakarta Bay waters.

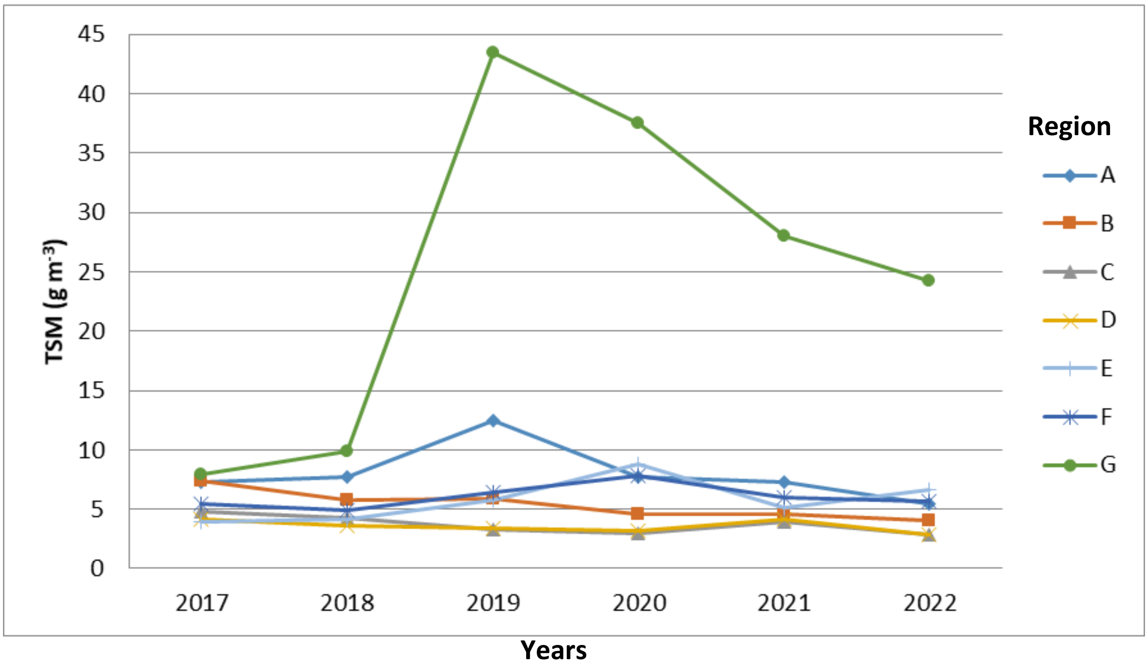
It is known that area A has a higher percentage of clarity compared to other areas, indicating that the water conditions in area A are clearer than in other areas. The ranking of areas from the highest to the lowest water clarity is A, D, E, C, B, F, and G. Changes in water clarity can affect the overall aquatic ecosystem, particularly fish populations and fishing patterns. Some fish species benefit from increased water clarity, which allows them to hunt more effectively due to better visibility. However, other species that rely on more turbid environments experience population declines as their habitats change (Bunnell & Poole 2021). Further research is needed to determine the causes of the differences in clarity trends in different areas of Jakarta Bay.

The dynamics of TSM and CHL2. The dynamics of TSM and CHL2 were calculated based on the observation areas and are displayed in Figure 6. The expected results of this calculation are the characteristics of TSM and CHL2 concentrations in the observation areas to determine which area has the highest eutrophication indicator.

TSM is often considered a triggering factor for eutrophication because it can carry nutrients that promote excessive algal growth. Additionally, TSM can affect light penetration, thereby altering the structure of phytoplankton communities (Cloern 2001). Based on this condition, the area with the highest TSM concentration was area G, while the lowest concentration was found in area A. This is directly correlated with water clarity in Jakarta Bay (Figure 6A). From these findings, it can be concluded that high TSM concentrations are likely influenced by different typical coastal activities. High industrial activity leads to increased TSM concentrations, which can be followed by an increase in phytoplankton biomass, as shown in Figure 6B.

Nontji (2005) found that the CHL2 concentration in the Java Sea ranges between 1 and 3 mg m^{-3}. Meanwhile, Damar et al (2020), in their research found that an increase in CHL2 concentration in Jakarta Bay from 15.81 to 21.31 μg L^{-1} could be followed by an increase in plankton biomass in this area. Assuming that the unit μg L^{-1} is equivalent to mg m^{-3}, the CHL2 concentration throughout Jakarta Bay is very high. The tendency for an increase in phytoplankton biomass is most likely in area G in 2019. The ranking of areas from the highest to the lowest water productivity is G, A, F, B, D, C, and E.

A



B

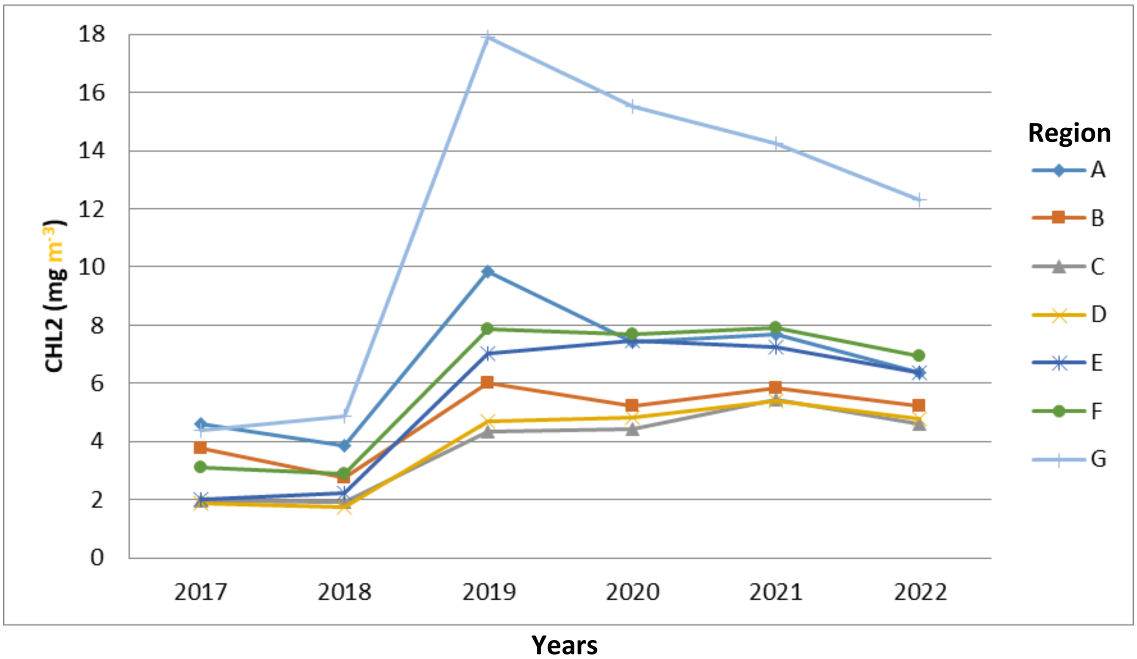


Figure 6. Dynamics of (A) TSM and (B) CHL2 concentrations in the observation area.

The dynamics of capture fisheries production and the number of marine capture fishermen. These dynamics were analyzed using correlation analysis. The correlation results between fisheries production and the number of fishermen are shown in Table 2.

The Multiple R value of 0.60544 indicates that the correlation between the number of marine capture fishermen and capture fisheries production is high. The adjusted R^2 value of 0.20820 indicates that the number of capture fishermen does not accurately predict fisheries production data. The significance F value > 0.05 means that there is no significant effect of the number of fishermen on fisheries production. The p-value for the number of fishermen > 0.05 means that the number of fishermen does not significantly affect capture fisheries production. Based on this, a correlation calculation was carried out between water conditions and capture fisheries production and the number of capture fishermen.

Table 2
Correlation between capture fishery production and the number of marine capture fishers

Regression statistics		*Coefficients*	
Multiple R	0.60544	Intercept	-330423.89
Adjusted R^2	0.20820	Fishermen	0.20041
Significance F	0.20279		
	P-value		
Fishermen		0.20280	

Discussion. Fisheries production tends to impact the surrounding water conditions. However, the specific characteristics of the water that have the highest correlation with fisheries production can be analyzed using multivariate statistical analysis. The correlation between fisheries production, the number of fishermen, and water conditions in areas A-G can be seen in Table 3.

Table 3
Multivariate analysis of fishery production, number of fishers, and water conditions

	Regression statistics						
	A	*B*	*C*	*D*	*E*	*F*	*G*
Multiple R	0.996625	0.823721	0.800987	0.653023	0.658324	0.793216	0.882764
Adjusted R^2	0.966309	-0.60742	-0.7921	-1.86781	-1.83305	-0.85404	-0.10364
Significance F	0.122853	0.759353	0.790733	0.918818	0.915849	0.80051	0.652874
	P-value						
	A	*B*	*C*	*D*	*E*	*F*	*G*
Intercept	0.083951	0.898485	0.786252	0.752372	0.637523	0.6924	0.946657
Fishermen	0.095724	0.605538	0.552489	0.586143	0.547015	0.525442	0.606865
Z_{SD}	0.426807	0.544721	0.568789	0.956536	0.941432	0.94442	0.532826
TSM	0.071274	0.980089	0.921571	0.855473	0.801079	0.629031	0.466799
CHL2	0.087354	0.944748	0.814102	0.910534	0.816466	0.716447	0.441351

The Multiple R values in areas D and E indicate a strong relationship with fisheries production, while in areas F, C, G, and A, they indicate a very strong relationship. The highest adjusted R^2 value is in area A, meaning that the measurement parameters in area A very accurately predict fisheries production data. The significance F value > 0.05 means that there is no significant effect of the number of fishermen, Z_{SD}, TSM, and CHL2 on fisheries production. The p-value > 0.05 means that there is no significant effect of the number of fishermen, Z_{SD}, TSM, and CHL2 on fisheries production. However, from the results in area A, it can be concluded that the number of fishermen and the TSM value have a higher influence on fisheries production compared to other parameters.

Conclusions. This study has successfully documented the water areas that have a high correlation with marine capture fisheries production. High CHL2 concentration is greatly influenced by TSM and ZSD. Although water conditions and the number of fishermen do not have a significant effect on fisheries production. Area A, with good clarity conditions and high CHL2 and TSM concentrations, has been proven to have a very high correlation with fisheries production in Jakarta. These results can serve as input for further research in area A.

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Conflict of interest. The authors declare that there is no conflict of interest.

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