The relationship between total suspended matter and sea current for the spread of Chlorophyll-a and fishing area in Jakarta Bay

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Abstract. Jakarta bay is a water with high input load due to activities from the surrounding river estuaries comes from Jabodetabek regions. This activity impacts the availability of Total Suspended Matter (TSM) in Jakarta Bay. The problem comes when the concentration of TSM exceeds the carrying capacity of the water thus encouraging plankton to grow and breed rapidly which has caused eutrophication. This research has three objectives: (1) Analyzing the relationship of TSM and Chlorophyll-a Case 2 (CHL2), (2) Analyzing impacts between sea current with CHL2 distribution, and (3) Analyzing correlation CHL2 distribution with fish catch data. Data collection was conducted on January 2018 until December 2018. Monthly TSM and CHL2 data were obtained through GlobColour data, monthly data on sea currents were obtained through Marine Copernicus data. TSM and CHL2 data were processed using the GIS and time series method to determine distribution area. Furthermore, a regression analysis is used to determine the relationship of TSM and CHL2. The result: Relationship of TSM and CHL2 obtained R = 0.8508 so that there is a strong association between TSM and CHL2; the current pattern in the Jakarta bay strongly affected by monsoon wind, the highest distribution occurs in the NWM, evenly distribution occurs in the transition 1, and SEM, the lowest distribution occurs in the transition 2; the demersal and pelagic fish catch period occurs in the end of transition 2 period where high CHL2 concentration and low sea current velocity make it easier for fishermen to catch the fish.

1. Introduction
DKI Jakarta government in 2004 reported that the water quality of the Jakarta bay has suffered considerable pollution. The current water has eutrophication caused by land pollution, coastal, and marine activities. The worst quality is found in waters close to the coast (5 Km from the coast) and increasingly to the middle (15-20 Km) the quality is improved [1]. High eutrophication has potential to cause Red Tide which is followed by a sudden drop of oxygen. All these conditions are very unfavorable
both ecologically, economically, and aesthetically [2]. Experiment made in the field are relatively expensive and need a long time, in addition it is also difficult to do with the same measurement time, alternative method is needed. One of them is the development of remote sensing technology to extract variable information such as TSM and CHL2 [3]. TSM parameter are used to determine the concentration of suspended materials and CHL2 parameters to determine the concentration of chlorophyll-a needed on the trip. Higher concentrations of chlorophyll-a are present in water characterized by high suspended solids and sea surface temperatures, whereas this water has lower salinity values [3], [4].

Indonesian waters have different water circulation patterns and vary each season [5]. This phenomenon is influenced by the monsoon pattern system. Monsoon is divided into two over the Indonesian region, i.e., the northwest monsoon (NWM) between December and February and the southeast monsoon (SEM) from June to August. The phenomenon of circulation of Indonesian water masses differs between the northwest monsoon and the southeast monsoon. When the northwest monsoon, the mass of water generally flows to the east of Indonesian waters, otherwise when the southeast monsoon, the mass of water from Arafura sea and Banda sea will flow towards west Indonesian waters.

The existence of difference in the supply of water masses causes changes in the condition of the waters which will affect high and low fluctuations in productivity and the distribution of mass of the water [6]. The problems discussed in this paper are as follows: How is the relationship of TSM and CHL2?, how sea currents affect CHL2 distribution?, and what are the consequences for the amount of fish caught in the Jakarta Bay?

2. Data and method

2.1. Data

2.1.1. Study region. The research sites were conducted in the waters of Jakarta Bay at positions 106.6° E – 107.1°E and 05.8°S –6.2°S. The geographical boundary of the west Jakarta bay is bordered by Pasir cape, on the east bordering Karawang cape, and on the north bordering the parts of thousand islands.

![Figure 1](Created using Ocean Data View (ODV) software; bathymetry data from GEBCO).

Jakarta bay is a shallow water with an average depth about 18 m, area of 514 Km², and its shoreline is about 72 Km [7]. The estuarine circulation in Jakarta bay is mainly controlled by monsoon winds and the current pattern is generally influenced by seasonal variations [8].
2.1.2. Gridded observational and reanalysis datasets

This study uses quantitative research methods, a method to provide an overview of an object through certain analytical techniques that are concrete/empirical, objective, measurable, rational, and systematic, and research data in the form of numbers.

The data collected in this study are monthly data on Total Suspended Matter (TSM), Chlorophyll-a case 2 (CHL2), and sea currents. TSM and CHL2 data were obtained through GlobColour products from http://hermes.acri.fr/ with the spatial resolution of 0.04° x 0.04° [9]. Ocean currents data were obtained through Marine Copernicus products from http://marine.copernicus.eu/services-portfolio/access-to-products [10] with spatial resolution of 0.08° x 0.08° (Figure 2). The data analysis was conducted using Monsoon period: The NWM (December, January, February); Transition 1 (March, April, May); The SEM (June, July, August); and Transition 2 (September, October, November).

Figure 2. Spatial resolution of TSM and CHL2 data (left); ocean current data (right).

2.2. Methods

Data were collected from January 2018 until December 2018. raw data that contains Geographic Information System (GIS) is converted into ascii format using ODV software. The data is distributed on a monthly basis. TSM data with g/m³ units, CHL2 with mg/m³ units, and data u (zonal) and v (meridional) in ocean currents presented in the form of current velocity vectors (m/s) [11]. TSM concentration level refers to The Ministerial Decree of Environment No. 51 of 2004 about raw water quality for port water Table 1, CHL2 concentration level refers to classification level of chlorophyll-a Table 2.

| Concentration (g/m³) | Classification |
|----------------------|----------------|
| < 20                 | Low            |
| 20 – 80              | Moderate       |
| > 80                 | High           |

Furthermore, the classification of CHL2 concentration is shown in Table 2 as follows:

| Concentration (mg/m³) | Classification |
|-----------------------|----------------|
| 0,01 – 0,5            | Low            |
| 0,501 – 1,0           | Moderate       |
| 1,01 – 1,5            | High           |
| >1,5                  | Very High      |
Data is displayed using time series maps. Furthermore, data correlation between TSM and CHL2 was used using Pearson analysis. Weighting method is using with 4 scores to assess the level of productivity area. Score 0 = no observation in this region, score 0.1-1.0 = very low, score 1.1-2.0 = moderate, score 2.1-3.0 = high, score 3.1-4.0 = very high. Furthermore, the productivity area was analyzed for three months with current data to see the effect of ocean currents in each monsoon on productivity area. The fish catch data collected from Ministry of Marine Affairs and Fisheries in Nizam Zahchman fishing port and Muara Angke fishing port in the year 2018.

3. Results and Discussion

3.1. Results

3.1.1. TSM (g/m$^3$) concentrations in the Jakarta bay. The 3 years average of monthly TSM concentration in the Jakarta bay on 5.93°S – 6.08°S latitude can be seen in Figure 3.

![Figure 3](image)

**Figure 3.** Average of TSM concentration characteristics in Jakarta Bay

In Figure 3, a characteristic image of TSM is presented in the Jakarta Bay where it appears that TSM variability has a very high concentration in the 5.93°S – 6.08°S latitude then its concentration decreases toward the open sea throughout the year. High TSM concentrations play a role in relation to the quality of the waters where the waters will be easier to bind pollutant chemicals from outside the water system so that the water become turbid water.

The distribution of TSM concentrations from the coast to the open sea is also influenced by marine physical factors which is ocean currents. The lowest TSM distribution occurs on April and October 2018 which occurs at Transition 1 and Transition 2 while the highest TSM distribution occurs on February and December which occurs at Northwest monsoon.

3.1.2. CHL2 (mg/m$^3$) concentrations in the Jakarta bay water

The 3 years average of monthly CHL2 concentration in the Jakarta bay on 5.93°S – 6.08°S latitude can be seen in Figure 4.
In Figure 4, a characteristic image of CHL2 is presented in the Jakarta bay where it appears that CHL2 variability has a very high concentration through the year then its concentration decreases toward the open sea. TSM parameters provide nutrients from inorganic materials as a support for the abundance of CHL2 concentrations, beside that the abundance of CHL2 is also influenced by sea currents that move plankton to get its food. The highest CHL2 distribution occurs on February 2018 which occurs at Northwest monsoon.

3.1.3. The relationship between TSM and CHL2 concentrations. The result from the regression equation that CHL2 concentration in Jakarta bay is

\[
\text{CHL2} = -0.218 + 0.374\text{TSM}
\]  

Concentration with \( R^2 = 0.819 \) so the value of R is 0.908. From the r table with df = 94 and significance 5\%, obtained results in R table = 0.1689. So, R table < R It can be concluded that TSM parameters have a strong relationship with CHL2 parameters.

3.1.4. Sea Current in the Jakarta bay. The currents observed in the Jakarta bay are classified as surface current because of the shallow depth of Jakarta Bay (about 18 m average depth). The average of velocity and direction of sea current throughout in 2018 can be seen in Figure 5.
The impact of sea current on the CHL2 distribution in the monsoon season is shown in Figure 6.

Figure 5. Chart of monthly sea current velocity and direction in Jakarta Bay

Figure 6. Sea current characteristics during NWM season (a), transition 1 season (b), SEM season (c), and transition 2 season (d) that affects CHL2 distribution
In NWM season, sea currents are influenced by the monsoon system which drives the mass of water towards the south east so that it "traps" CHL2 in the east of the bay of Jakarta. While during the SEM season, the wind blowing from the opposite direction pushes the mass of water and CHL2 to the northwest to the north away from the bay of Jakarta. In the transitional season, weak sea currents cause the distribution of TSM from river mouths in the bay of Jakarta to cause CHL2 gathering in areas close to the river mouth [8]. Current velocity plays a role in increasing CHL2 concentrations in the Jakarta bay. The high current velocity in the western season (January & December) causes a decrease in the average CHL2 concentration in the Jakarta Bay. This is due to the lack of disturbance of the island in the middle to the east of the Jakarta bay. While in the east monsoon, high current speeds actually increase the CHL2 concentration due to the many disturbances of the island in the middle to the west of the Jakarta bay. Low current speeds in the transition seasons increase CHL2 concentrations in the Jakarta bay.

3.1.5 *Fish catch in the Jakarta bay.* Demersal fish in the Jakarta bay are only caught on November and December 2018 with the number of catches is shown in Table 3.

| No. | Type of Fish | Month    | Catch Weight (kg) |
|-----|--------------|----------|-------------------|
| 1   | Red Snapper Fish | November | 43                |
|     |               | December | 1,994             |
| 2   | Stingray      | November | 209               |
|     |               | December | 16                |
| 3   | Swordfish     | November | 95                |
|     |               | December | -                 |
| 4   | Black Pomfred | November | 9,986             |
|     |               | December | 25,016            |
| 5   | Fish Ariidae  | November | 17,782            |
|     |               | December | 27,980            |

The demersal fish catch period in the Jakarta bay occurs on November and December 2018 (the end of transition 2 period) where high CHL2 concentration and low sea current velocity make it easier for fishermen to catch the fish. Pelagic fish in the Jakarta bay mostly caught on November and December 2018 with the number of catches is shown in Figure 7.

![Figure 7. Pelagic Fish Catch in Jakarta Bay.](image-url)
Same case with demersal fish, pelagic fish catch period in the Jakarta bay mostly occurs on November and December 2018 (the end of transition 2 period).

3.2. Discussion
The bathymetry in Jakarta bay has a role in supporting productivity in the Jakarta bay. Higher sea depths in the open sea area make the distribution of productivity at sea level decrease due to the decrease of TSM materials from sea surface to the sea floor, different depth in shallow regions that make productivity of the water is higher [4].

The CHL2 parameter has a fluctuating annual concentration distribution. This is mostly influenced by the concentration of suspended material (TSM) in the Jakarta bay. The more suspended material coming out of the river mouth, the higher the concentration of CHL2 in Jakarta Bay. This result is reinforced by the research of [13] which said that the fluctuation of the different chlorophyll-a content in the Jakarta bay is closely related to the phosphate content in the region.

Current direction which is moved by monsoon wind system. This results in the distribution of the direction of the current. During the NWM, ocean currents are regulated by the monsoon wind system and the coriolis force which pushes water masses towards the southeast and east so that they "trap" CHL2 in the east of Jakarta bay. While during the SEM, winds that spin from opposite directions push air masses and CHL2 to the northwest and west away from the Jakarta bay. In the transitional season, weak ocean currents cause no TSM distribution from river mouths in Jakarta Bay which causes CHL2 coordination in areas close to river mouths.

The fish catch is not available monthly but it can be seen that the high CHL2 concentration in the Jakarta bay correlates also with the weight catch of Black Pomfred and Fish Ariidae compared to other demersal fish such as red snapper fish, stingray, and swordfish. The highest catch in November then decrease on November are Bali Sardinella, long Jawed Mackarel, and Barred or Spanish mackerel fish. The fish float and Tuna fish shows an increasing trend which allows the number of catches can still be increased in the following month.

4. Conclusion
Characteristic of CHL2 and TSM is presented in the Jakarta Bay has a similar pattern that is very high concentration in the Latitude 5.93° S – 6.08° S then its concentration decreases toward the open sea throughout the year. It can be concluded that TSM parameters have a strong relationship with CHL2 parameters. The current pattern in the Jakarta bay strongly affected by monsoon wind. In NWM season, due to the current direction caused TSM and CHL2 distribution trapped in the east region of Jakarta bay so the highest distribution of TSM and CHL2 occurs, changes in current direction and current velocity in transition 1 season causing the distribution of TSM and CHL2 move leaving the Jakarta Bay, the same case occurred in SEM season, the occur of a decrease current velocity causes a lack of TSM and CHL2 distribution on transition 2. The demersal and Pelagic fish catch period in the Jakarta bay occurs on November and December (the end of transition 2 period) where high CHL2 concentration and low sea current velocity make it easier for fishermen to catch the fish, that the high. The CHL2 concentration in the Jakarta bay correlates with the weight catch of demersal fish (Black Pomfred and Fish Ariidae) and pelagic fish (Bali Sardinella, long Jawed Mackarel, and Barred or Spanish mackerel fish).

5. References
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