Variability of chlorophyll-a concentration relation to fish catch of Indian mackerel in West Halmahera waters

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Abstract. The presence of chlorophyll-a is an indicator of water fertility, where the high chlorophyll-a content will be followed by the presence of zooplankton which will then affect other aquatic organisms that form the food chain. The interaction of chlorophyll-a concentration on the presence of mackerel in West Halmahera waters is unknown, so this study was carried out with the aim of examining the relationship between chlorophyll-a concentration in West Halmahera waters and mackerel catch. The use of experimental fishing methods from May to July 2020 and non-linear regression analysis and Generalized Additive Model (GAM) are expected to provide an overview of the relationship between the two research variables. The results showed that the distribution of Indian Mackerel was more in coastal areas with a chlorophyll-a concentration distribution of 0.18 - 0.39 mg/m³ which played a major role in determining the variability of the quantitative distribution of mackerel (α < 0.05) and positively correlated with a value of r = 0.819 and these results supported by predictions using GAM, where the potential fishing area for mackerel in West Halmahera waters is at a chlorophyll-a concentration value of about 0.2 - 0.4 mg/m³.

1. Introduction
West Halmahera Waters belonging to the AIRLINDO area adequately have various biological resources, including fish which consists of both pelagic and demersal fish [1]; [2]; [3]. Fish is one waters’ biological resource utilized not only as food resources but also developed into trading commodity to improve people’s welfare, especially fishermen. Small pelagic fish is considered as one important economic resource and ecologically as one main component in various marine ecosystems [4]; [5]. Small pelagic fish types are various, including Indian Mackerel (Figure 1) considered as the neritic resource since dominantly spread in the surrounding coastal areas.

Figure 1. Indian mackerel (Rastrelliger kanagurta)
Its abundance availability and wide spread make Indian Mackerel become a quite fluctuating neritic resource and commonly influenced by the waters’ biophysical conditions, such as chlorophyll-a concentrations. To optimize the Indian Mackerel utilization and management sustainability, the information related to the waters’ biophysical conditions are greatly important to figure out [6, 7] since Indian Mackerel will choose the environments of biophysical conditions with optimum chlorophyll-a concentrations for living and growing. Nababan (2008) in [8] stated that the chlorophyll-a concentrations indicate the existence of phytoplankton as in food chain, phytoplankton is the food producer for higher tropic organisms.

Chlorophyll-a concentrations are known as the phytoplankton’s photosynthetic pigments in which those pigments are considered as the index to the waters’ biological productivity level [5]. Thus, knowledge on chlorophyll-a concentrations is greatly required to predict the abundance availability and wide spread of Indian Mackerel in West Halmahera Waters that this research is conducted to figure out the variability of chlorophyll-a concentrations in West Halmahera Waters related to the distributions of Indian Mackerel.

2. Materials and Method
The research data were collected from May to July 2020, in the form of data related to the capturing result of Indian Mackerel, capturing position with the experimental fishing method utilizing the purse seine and gill net capturing devices in West Halmahera Waters (Figure 2). The secondary data were in the form of chlorophyll-a concentrations downloaded for the Aqua satellite using the MODIS NASA sensor).

![Figure 2. Research location](image)

The data were then analyzed to determine the relationship between chlorophyll-a and capturing result using the Pearson correlation analysis with the mathematical model.

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r_{xy} = \frac{\sum xy}{\sqrt{(\sum x^2)(\sum y^2)}}
\]

where: \( r_{xy} = \) correlation coefficient between variable \( x \) and \( y \), \( \bar{x} = \) deviation from mean for chlorophyll-a variable value, \( \bar{y} = \) deviation from mean for \( y \) variable value

The analysis was then conducted using the Generalized Additive Model with R version 4.0.2 software. GAM is a non-linier model used to figure out the correlation between \( \mu \) response variable (number of Indian Mackerel capturing result) and predictor variable (chlorophyll-a concentrations), formulated with the mathematical equation [9]; [5]:
G(\mu_i) = \alpha_0 + s_1 (\text{Const. chl-a}) + \varepsilon

where: \ g = \text{spline smooth function,} \ \mu_i = \text{response variable,} \ \alpha_0 = \text{constant coefficient,} \ s_n = \text{smoothing function from predictor variable and} \ \varepsilon = \text{error standard.}

3. Result and Discussion

3.1. Capturing result
Indian Mackerel type is included into 5 small pelagic fish types dominating the capturing result of the purse seine and gill net ships in West Halmahera Water during this research was conducted starting from May to July 2020, with the capturing result for 68 trips as shown in Figure 3.

Figure 3 shows that the Indian Mackerel capturing result during May, June and July 2020 tended to increase with the number of production in each month respectively by 590.00 kg, 912.40 kg and 1,179.90 kg with the total and average capturing result per month respectively by 2,682.30 kg and 894.1 kg/month.

3.2. Chlorophyll-a daily fluctuation
Chlorophyll-a concentrations or photosynthetic pigment of phytoplankton is the index to the waters’ biological productivity level in which chlorophyll-a is the depiction of phytoplankton biomass [10]. The distribution condition of chlorophyll-a concentrations can be correlated with the fish production, that is, possibly depicting the capturing area’s productivity level [5]. The distribution of chlorophyll-a concentrations in the research area can be seen that in May, the value of chlorophyll-a concentrations in the northern part and some of southern part were quite high and approximately of above 0.3 mg/m$^3$. In June, the high chlorophyll-a concentrations tended to be in the southern part of the research area with the same value. In July, the highest value was in southern part, yet the value tended to decrease and below 0.3 mg/m$^3$, however, in some research points, the value was higher than 0.3 mg/m$^3$ (Figure 4).

The daily fluctuation of chlorophyll-a concentrations can be seen in Figure 5, in which the condition of chlorophyll-a concentrations was adequately fluctuating in the research location in May, June, and July 2020, with the value of respectively 0.19-0.39 mg/m$^3$, 0.20-0.32 mg/m$^3$ and 0.18-0.38 mg/m$^3$, while the monthly average value was respectively 0.20 mg/m$^3$, 0.27 mg/m$^3$ and 0.29 mg/m$^3$. Gower in [10] stated that a water area had a certain range in which fish are gathering to physiologically adapt to the other factors, such as temperature, current, and salinity which are more appropriate to what fish wanted, yet the availability of chlorophyll-a concentrations of above 0.2 mg/m$^3$ indicated that the availability of plankton is adequate to maintain the fish living sustainability which is economically important.
3.3. Relationship between chlorophyll-\(a\) concentrations with capturing result

Indian Mackerel is pelagic fish which existence is influenced by the food chain processes and indirectly by the availability of phytoplankton. The fluctuation graph of Indian Mackerel and chlorophyll-\(a\) concentrations can be seen in Figure 6.
Figure 6 shows the daily fluctuation of Indian Mackerel capturing result and chlorophyll-a concentrations during May to July 2020. It was proven that when the Indian Mackerel capturing result increased, the condition of chlorophyll-a concentrations also increased and if the chlorophyll-a concentrations decreased, the Indian Mackerel production trend also decreased. The correlation analysis result between chlorophyll-a and Indian Mackerel capturing result, it was shown that the chlorophyll-a concentrations in West Halmahera Waters were closely related to the oceanographic conditions, that is, chlorophyll-a concentrations, with the determination coefficient value ($r^2$) of 0.6709 or individually of 67.09%. The existence of Indian Mackerel was influenced by chlorophyll-a concentrations. The correlation coefficient resulted from the data analysis was 0.819. It means that the relationship of both variables was very strong with positive correlation value, that is, if chlorophyll-a concentrations increased, Indian Mackerel capturing result also increased as seen in the linear trend line presented in Figure 7.

The result of the other research conducted by [9] showed that chlorophyll-a in Maluku Sea had a close relationship with the chlorophyll-a of about 0.042-0.78 mg/m$^3$, [13] stated that the fluctuation of chlorophyll-a in Java sea waters was about 0.22-1.15 mg/m$^3$ and significantly influenced the small pelagic fish capturing result (Isnawarti, 2008), while the chlorophyll-a in Pangkep regency Waters was about 0.2086 -7.4654 mg/m$^3$ and 0.20 - 0.40 mg/m$^3$ [14]. The monthly average value of chlorophyll-a concentrations of more than 2.0 indicated the adequate existence of plankton to maintain the fish life sustainability, especially the small pelagic fish [11].

Figure 7. Relationship of chlorophyll-a concentrations with Indian mackerel capturing result.
The result of analysis conducted using the Generalized Additive Model explained that chlorophyll-a concentrations in the potential capturing area during May to July 2020 of West Halmahera Waters had the value of about 0.2 - 0.4 mg/m$^3$ (Figure 8 and Figure 9). Furthermore, the analysis result of cross correlation between chlorophyll-a concentrations and number of Indian Mackerel capturing result was presented in Figure 10, in which time leg or correlation distance happened in trip 67. This test result was strengthened with the descriptive analysis in Figure 11, showing that the Indian Mackerel capturing result had just significantly increased in trip 67 although the values of chlorophyll-a concentrations and Indian Mackerel capturing result had been high in the previous trips.

![Figure 8](image1.png)  ![Figure 9](image2.png)  ![Figure 10](image3.png)

**Figure 8.** Influence of chlorophyll-a on Indian mackerel distribution  
**Figure 9.** Relationship of indian mackerel distribution with chlorophyll-a  
**Figure 10.** Cross correlation between chlorophyll-a and Indian mackerel capturing result
Figure 1. Chlorophyll-a shows a significant influence in Trip 67

4. Conclusion
Variability of chlorophyll-a concentrations during the research ranged from 0.18 to 0.39 mg/m$^3$ and has a very strong relationship with the Indian Mackerel capturing result of 0.819 with the determination coefficient value ($r^2$) of 0.6709 and the result was supported with the prediction using GAM, in which the potential area to capture the Indian Mackerel was in West Halmahera Waters with the chlorophyll-a concentrations value of about 0.2 - 0.4 mg/m$^3$.

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