__Short Research Article__

Variability in Oceanographic Conditions of Chlorophyll-A and Sea Surface Temperaturein the Waters Around North Maluku

ABSTRACT

The waters surrounding North Maluku possess high fisheries resource potential. The variability of oceanographic conditions, such as chlorophyll-a and sea surface temperature (SST), plays a significant role in determining fish abundance in this region. This study aims to analyze the seasonal variation of chlorophyll-a and SST during 2021 and their impacts on marine productivity. The highest chlorophyll-a concentration occurred in June (0.212 mg/m³), while the lowest value was observed in February (0.103 mg/m³). High chlorophyll-a concentrations in mid-year support optimal primary productivity, whereas low values at the beginning of the year were influenced by the negative phase of the Indian Ocean Dipole (IOD), which reduced upwelling intensity. The highest SST value was recorded in November (30.99°C) and the lowest in August (29.87°C), indicating a seasonal pattern with consistently warm temperatures throughout the year due to the influence of the negative IOD phase. This temperature increase reduced upwelling intensity, thereby decreasing nutrient availability in the surface layer. These variations in oceanographic conditions directly impact the decline in primary productivity, affecting the availability of phytoplankton as the primary food source in the marine food chain. These findings are crucial for supporting the sustainable management of fisheries resources in the waters of North Maluku.

Keyword : Chlorophyll-a, Fish Abundance, Indian Ocean Dipole, Oceanography, Sea Surface Temperature

1. INTRODUCTION

The North Maluku Sea is part of Fisheries Management Area (WPP) 715, known for its high biodiversity and abundance of fishery resources (Albasri and Pratama 2019). The richness of fish resources in this region is supported by its location within the Coral Triangle, a region with the world's highest coral reef biodiversity. Fishing activities in these waters yield various economically valuable pelagic fish, such as tuna, skipjack, and mackerel, as well as demersal fish, which are the primary catch (DKP 2023). This vast potential not only supports the local economy but also makes a significant contribution to national fishery production.

Fish abundance in a particular area is strongly influenced by oceanographic conditions, including chlorophyll-a concentration, sea surface temperature (SST), and salinity (Pratama et al. 2022). According to Gaol et al. (2014) and Setyaningrum et al. (2017), the presence of fish resources in a water body is not only affected by sea surface temperature but also by chlorophyll-a concentration. These oceanographic factors play an important role in determining the distribution and abundance of fish in specific waters

(Saifudin et al. 2014; Wang et al. 2016). Chlorophyll-a, as an indicator of primary productivity, provides phytoplankton, which serves as the primary food source in the marine food chain (Simbolon and Girsang 2009). SST influences fish metabolism, distribution, and migration, making it one of the main factors in determining fish habitats (Azwar et al. 2016).

The relationship between fish abundance and oceanographic conditions is highly interconnected. Optimal environments, such as high chlorophyll-a concentration, suitable temperatures, and stable salinity levels, support marine productivity and fish availability. Conversely, significant changes in oceanographic conditions, such as a decline in chlorophyll-a concentration or an increase in sea surface temperature, can negatively impact fish populations by reducing primary productivity or altering habitat distribution (Sadly and Awaludin 2017). Seasonal dynamics and global climate change also influence these oceanographic factors, making a deeper understanding of their variability essential to support sustainable fisheries.Pratama et al. (2022) successfully modeled the relationship between oceanographic factors, such as chlorophyll-a, sea surface temperature, salinity, and current velocity, and the formation of optimal fish habitats using the Maximum Entropy method. Their findings showed that the combination of these oceanographic factors significantly affects fish distribution and abundance.

Based on this background, it is crucial to analyze the variations in oceanographic conditions, including chlorophyll-a and sea surface temperaturein the waters of North Maluku. This analysis is expected to provide deeper insights into the relationship between oceanographic factors and fish resource abundance in the region. Furthermore, the findings are anticipated to support sustainable fishery resource management, particularly through a better understanding of marine environmental dynamics in the waters around North Maluku.

2. MATERIALANDMETHODS

This study was conducted using secondary data processing, including satellite imagery data on chlorophyll-a, sea surface temperature (SST), and salinity throughout 2021. Chlorophyll-a and SST data were downloaded from the website www.oceancolor.gsfc, while salinity data were obtained from https://marine.copernicus.eu/. The imagery data were downloaded in Non-Conformance (.nc) format. Subsequently, the data underwent several processing procedures.

The process began with data extraction using the SeaDAS 7.5.3 application, followed by spatial clipping to focus on the study area. After the clipping process, the data were exported into a tab-delimited text format (.txt). The .txt files were then processed using Microsoft Excel to remove unnecessary or irrelevant data and to correct for cloud cover issues.

The cleaned .txt data were further processed using ArcGIS software to perform advanced processing, such as data interpolation using the Inverse Distance Weighted (IDW) method. The IDW interpolation method is advantageous due to its adjustable characteristics, allowing for the restriction of input points used in the interpolation process. Additionally, this method facilitates the removal of points that are distant from samples or have low to no spatial correlation (Pasaribu and Haryani 2012).Once the interpolation process using IDW was completed, raster data for the oceanographic parameters were obtained. These raster data were then used to create map layouts, which facilitated the analysis of spatial distribution.

3. RESULTS AND DISCUSSION

3.1 Chlorophyll-aVariation in the Waters Around North Maluku

The monthly average variations in chlorophyll-a concentration in the waters around North Maluku during 2021 are shown in Figure 1. The average chlorophyll-a concentrations from January to December were 0.145 mg/m³, 0.103 mg/m³, 0.131 mg/m³, 0.147 mg/m³, 0.172 mg/m³, 0.212 mg/m³, 0.207 mg/m³, 0.187 mg/m³, 0.136 mg/m³, 0.157 mg/m³, 0.162 mg/m³, and 0.141 mg/m³, respectively. The highest chlorophyll-a concentration occurred in June, with a value of 0.212 mg/m³, while the lowest concentration was recorded in February at 0.103 mg/m³.

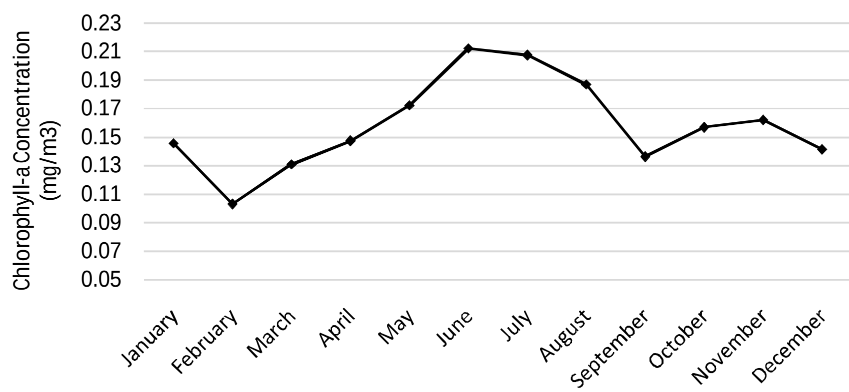

Figure 1. Monthly average fluctuations in chlorophyll-a concentration in the Waters around North Maluku

Figure 1 shows significant seasonal variations, where chlorophyll-a concentrations tend to increase in the middle of the year (May to August) and decrease at the beginning and end of the year (December to February). The rise in chlorophyll-a concentration from June to August indicates that this period was marked by relatively optimal primary productivity in 2021, supporting the abundance of phytoplankton, which forms the base of the marine food chain. This condition is typically followed by an increase in the abundance of pelagic fish such as skipjack tuna, due to a significant positive correlation between chlorophyll-a concentration and skipjack tuna catch production (Pratama et al., 2022). Conversely, the low chlorophyll-a concentrations at the beginning of the year may indicate oceanographic conditions that are less favorable for primary productivity.

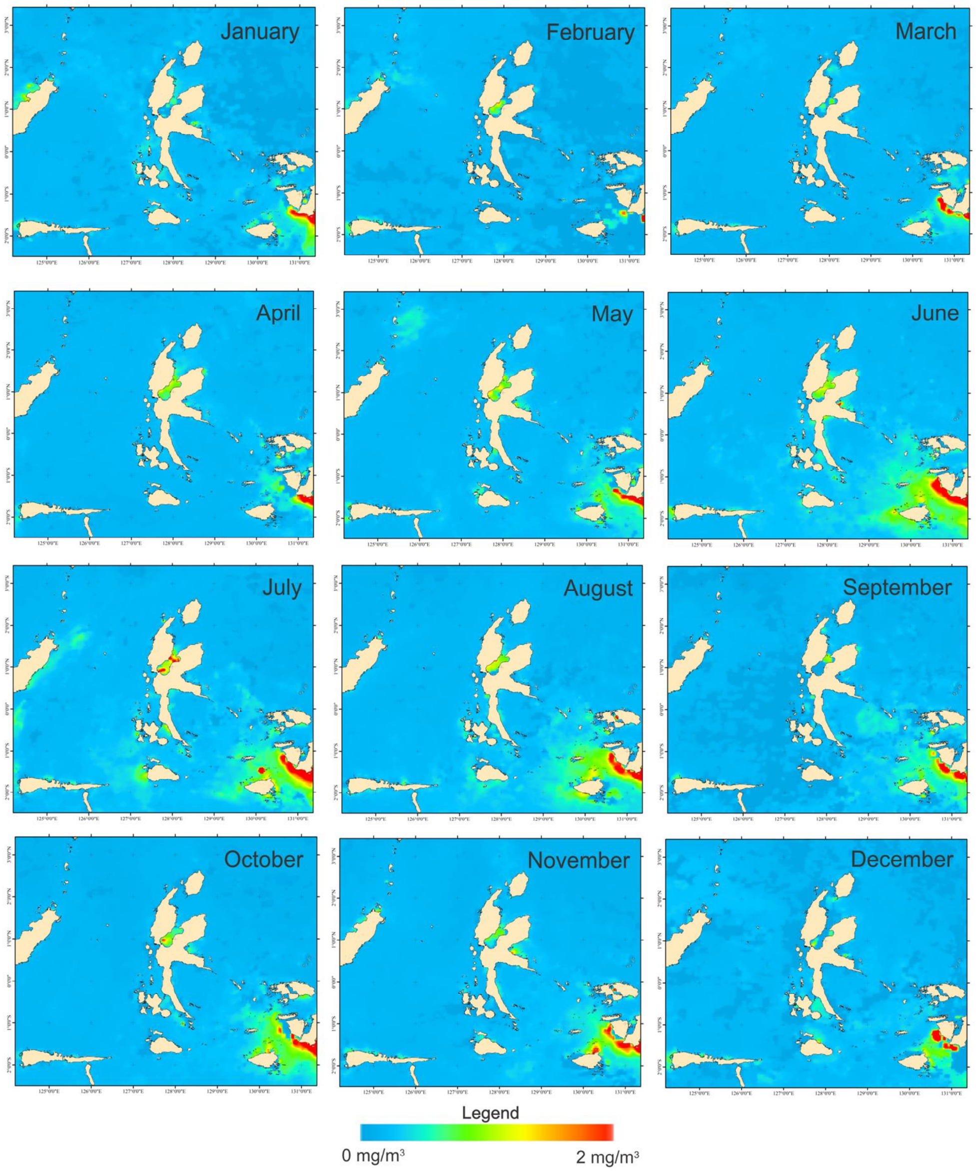

Figure 2. Spatial map of chlorophyll-a concentration distribution in the waters around North Maluku.

Based on the spatial and temporal distribution map of chlorophyll-a concentration in Figure 2, it can be observed that coastal areas or waters near the land tend to have higher chlorophyll-a concentration values. This aligns with the findings of Nurani et al. (2021), which state that waters near the land will have higher chlorophyll-a concentrations compared to waters farther from the land.

The average distribution of chlorophyll-a values this year tends to be low. According to the Dipole Mode Index (DMI) from the Meteorology, Climatology, and Geophysics Agency (BMKG), a negative IOD phase occurred in June 2021, characterized by a DMI value of less than -0.4. BMKG also predicted that the negative IOD phase would persist until November 2021. This phenomenon leads to an increase in sea surface temperature, which in turn reduces chlorophyll-a concentrations. According to Nurani et al. (2021), low chlorophyll-a concentrations in a body of water can result from the negative phase of the Indian Ocean Dipole (IOD), which decreases upwelling intensity. Upwelling is the process where cold, nutrient-rich water rises from the ocean depths to the surface, typically enhancing primary productivity in the waters. Without sufficient upwelling, nutrient availability in the surface layer decreases, reducing the growth of phytoplankton, which is the primary component of chlorophyll-a.

The IOD itself is an ocean-atmosphere phenomenon occurring along the equator that affects the climate of countries surrounding the Indian Ocean (Saji et al., 1999). With the decrease in chlorophyll-a concentrations, primary productivity in the waters becomes lower because phytoplankton, the primary producer in the marine food chain, cannot develop optimally. This directly impacts the availability of food for zooplankton and other organisms that serve as prey for fish. Consequently, fish abundance in the waters also declines due to the reduced food supply. Small pelagic fish, such as mackerel and anchovies, are highly dependent on phytoplankton abundance since they are directly or indirectly at the base of the food chain starting with phytoplankton. The decline in small fish populations also affects predator fish at higher trophic levels, such as tuna and skipjack.

3.2 Sea Surface Temperature Variation in the Waters Around North Maluku

The fluctuations in the average sea surface temperature in the waters around North Maluku in 2021 are shown in Figure 3. The monthly average sea surface temperatures for January, February, March, April, May, June, July, August, September, October, November, and December are 30.43°C, 30.27°C, 30.73°C, 30.68°C, 30.31°C, 30.06°C, 29.89°C, 29.87°C, 29.93°C, 30.82°C, 30.99°C, and 30.29°C, respectively. The highest value was recorded in November at 30.99°C, while the lowest value occurred in August at 29.87°C.

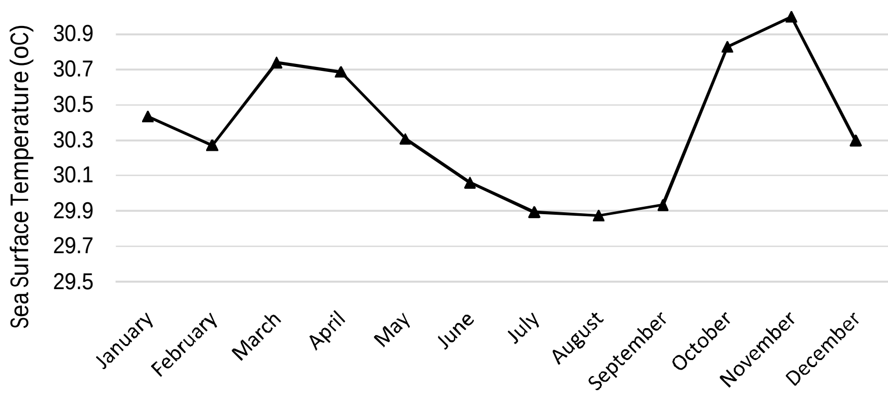

Figure 3. Monthly average fluctuations in sea surface temperature in the waters around North Maluku

Based on Figure 3, it is evident that sea surface temperature (SST) ranges from 29.87°C to 30.99°C throughout the year. SST tends to be higher in October and November, with values reaching 30.82°C and 30.99°C, respectively. Meanwhile, the lowest SST values occur in July and August, at 29.89°C and 29.87°C, respectively. Overall, the temperature pattern indicates that these waters remain relatively warm year-round, with a slight temperature decrease during mid-year (eastern season) and an increase towards the end of the year (western season).

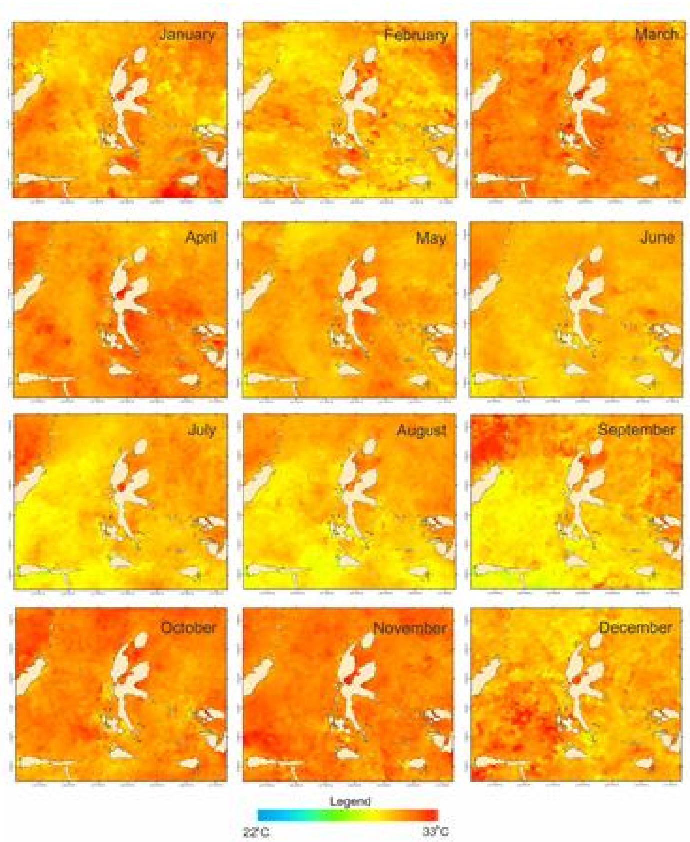

Figure 4. Spatial map of sea surface temperature distribution in the waters around North Maluku.

Based on the temporal spatial map of sea surface temperature (SST) in the waters around North Maluku shown in Figure 4, the average SST in 2021 is considered high. This elevated SST distribution is attributed to the negative IOD phase and La Niña phenomenon (BMKG, 2021). During the negative IOD phase, waters tend to warm compared to other phases (Malau et al., 2021). The negative IOD phase increases SST in the eastern Indian Ocean (including Indonesia and Australia), leading to an intensification of downwelling. Downwelling is the sinking of warm, nutrient-poor water, which hampers the distribution of nutrients from deeper layers to the surface. This phenomenon is suspected to contribute to the elevated SST in the waters around North Maluku during the eastern season. The IOD phase (positive/negative) in a region can be identified using the Dipole Mode Index (DMI), which is the difference in sea surface temperature anomalies between the Western Tropical Indian Ocean (WTIO) and the Southern Tropical Indian Ocean (STIO).
Similar to the decline in chlorophyll-a concentration, an increase in SST also negatively affects fish abundance in the waters. Warmer temperatures tend to reduce the intensity of upwelling, the process by which nutrient-rich water rises from the ocean depths. With reduced upwelling, the amount of nutrients in the surface layer decreases significantly. As a result, primary productivity, marked by phytoplankton growth at the base of the food chain, also declines. Phytoplankton plays a crucial role as a primary food source for zooplankton, which, in turn, serves as food for various fish species.

4. CONCLUSION

The seasonal variation in chlorophyll-a concentration and sea surface temperature (SST) in the waters around the Halmahera Sea, North Maluku, exhibited significant patterns throughout 2021. The highest chlorophyll-a concentration was recorded in June (0.212 mg/m^3), indicating optimal primary productivity driven by increased phytoplankton growth. Conversely, the lowest chlorophyll-a concentration occurred in February (0.103 mg/m^3) due to the negative Indian Ocean Dipole (IOD) phase. The negative IOD phase reduces upwelling intensity, thereby limiting nutrient availability in the ocean's surface layer. The SST pattern revealed the highest temperature in November (30.99°C) and the lowest in August (29.87°C). Elevated SST was influenced by the negative IOD phase, which caused an increase in downwelling intensity, reducing the distribution of nutrients from the deeper ocean layers to the surface.

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