Catch Per Unit Effort (CPUE) Dynamic of Scad (*Decapterus* spp) related to Water Parameters in the Banda Sea

Fajar Indah Ningsih[1], Am Azbas Taurusman[2], Budy Wiryawan[3], Prihatin Ika Wahyuningrum[4]
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Abstract — **The lack of data and information concerning the scad fishing grounds in that area restricts the efficiency of fish capture. This research aims to estimate the CPUE of the scad, map the spatial-temporal dynamics of sea surface temperature (SST) and chlorophyll a (Chl-a), and evaluate the SST and Chl-a relationship to scad catch rates in the Banda Sea. The SST and chl-a were obtained from Aqua MODIS satellite imagery over three years (2020-2022), while scad catch data were obtained from the Kendari Fishing Port. Bivariate correlation analysis was used to assess the relationship between SST, Chl-a, and scad catch rates. The results show a fluctuation trend in CPUE (2020-2022), with CPUE values ranging from 53.41 to 354.65kg/trip. The temporal distribution of SST values ranged from 26.91 to 29.42°C, while the Chl-a concentration ranged from 0.20 to 4.8mg/m³. Spatially, it was higher near the shore and lower offshore. A moderate negative correlation (r = -0.464) was observed between Chl-a and CPUE, while SST showed a weak positive correlation (r = 0.101) with the CPUE. This study recommends integrating field data and satellite imagery to accurately estimate the fishing grounds to improve efficiency and sustainable fisheries management in the Banda Sea.**

Keywords— *Banda Sea, Chlorophyll-a, CPUE, Scad (Decapterus spp), Sea Surface Temperature (SST)*

*Corresponding Author:indahningsih@apps.ipb.ac.id

I. INTRODUCTION

The Banda Sea, located within Indonesia's Fisheries Management Area (FMA) 714, is strategically situated between Sulawesi, Maluku, and several surrounding islands, making it an important fishing ground for local communities [25]. The scad (*Decapterus* spp) is among the region's most widespread small pelagic fish species and has considerable economic importance. Scad is an important animal protein source and a primary target in capture fisheries in the area [9][14]. However, intensive fishing targeting this species has led to declining catch yields. According to statistical data of the Kendari Fishing Port, scad landings have decreased over the years, from 9,519.75 tons in 2020 to 8,131.39 tons in 2021, making an 85.42% reduction, before slightly recovering to 8,937.03 tons in 2022 [20]. These catch-yield fluctuations may reflect responses to various environmental and fishing pressure factors [21].

Fishery dynamics are influenced by several factors, including the intensity of fishing activities and environmental conditions such as weather patterns, sea surface temperature (SST), chlorophyll a concentration (Chl-a), and the availability of fish stocks. [8][21]. Unregulated fishing may lead to the overexploitation of scad stocks in the Banda Sea [12]. Consequently, monitoring and regulating fishing activities are crucial to ensure the sustainability of the fish resources.

Fishing grounds are dynamic and may shift based on changing environmental conditions. This unpredictability makes it challenging for fishers to target specific fishing grounds, resulting in variable catch yields [24]. The distribution of scad habitats is closely linked to oceanographic parameters such as SST, Chl-a concentration, salinity, currents, sedimentation, tidal patterns, upwelling events, thermal fronts, and eddies [24]. These parameters are valuable indicators for identifying potential fishing grounds [11].

Purse seine fishers based at Kendari Fishing Port still utilize traditional methods to locate a fishing ground, such as observing seabird behavior, air bubbles, and star patterns. However, these methods are time-consuming and less precise. The habitat of scad is subject to the influence of environmental factors, which lead to variations in population distribution. [23]. Key oceanographic parameters, such as sea surface temperature (SST) and chlorophyll-a (Chl-a), significantly influence fish growth, spawning, metabolism, and migration patterns [17][22]. These parameters can be effectively monitored through in situ

Fajar Indah Ningsih, Study Program of Marine Fisheries Technology, Department of Fisheries Resource Utilization, Bogor Agricultural University, Bogor, 16680, Indonesia. E-mail: indahningsih@apps.ipb.ac.id
Am Azbas Taurusman, Study Program of Marine Fisheries Technology, Department of Fisheries Resource Utilization, Bogor Agricultural University, Bogor 16680, Indonesia. E-mail: azbas@apps.ipb.ac.id
Budy Wiryawan, Study Program of Marine Fisheries Technology, Department of Fisheries Resource Utilization, Bogor Agricultural University, Bogor 16680, Indonesia. E-mail: budywi@apps.ipb.ac.id
Prihatin Ika Wahyuningrum, Study Program of Marine Fisheries Technology, Department of Fisheries Resource Utilization, Bogor Agricultural University, Bogor 16680, Indonesia. E-mail: piwahyuningrum@apps.ipb.ac.id

observations or remote sensing technologies, including satellite imagery, which facilitates the efficient assessment of SST and Chl-a distribution across marine areas [30].

As scad populations continue to decline due to intense fishing pressure, obtaining accurate and reliable data is essential to support the sustainability of fish stocks and fishing activities. A comprehensive understanding of the relationship between population dynamics and environmental factors, particularly through *Catch Per Unit Effort* (CPUE) trends, is key to optimizing scad utilization in the eastern waters of Southeast Sulawesi. Integrating field data with satellite remote sensing imagery offers a practical approach for identifying fishing grounds and assessing SST and Chl-a concentrations [26]. This research aims to investigate the CPUE of scad and to map the spatial-temporal patterns of SST and Chl-a in the Banda Sea.

II. Method

A. Data Types and Sources

This research employed field observations and remote sensing data acquired via Aqua MODIS satellite imagery. Two primary categories of data were collected:

(a) Catch Data: Scad (*Decapterus* spp) catch data, including fishing trip duration, fishing grounds, vessel names, and gross tonnage, were obtained from purse seine logbooks recorded at the Kendari Fishing Port for the years 2020–2022. This data provided the basis for calculating the study period's Catch Per Unit Effort (CPUE)

(b) Oceanographic Data: Oceanographic parameters, specifically Sea Surface Temperature (SST) and Chl-a concentration, were obtained from the NASA Ocean Color website (http://oceancolor.gsfc.nasa.gov). These data were derived from Level-3 satellite imagery provided by the Aqua MODIS sensor, with a spatial resolution of 4 × 4 km, covering the period from 2020 to 2022.

B. Data Collection Techniques

Data collection was divided into two key components: catch data of scad and Aqua MODIS imagery data collection.

(a) Data on scad catch were recorded from the fishers' logbooks of the purse seiner. This data were compiled into a monthly time series, including catch yields, fishing effort, fishing trip duration, and fishing location. The monthly catch data were then averaged for analysis.

(b) Aqua MODIS Data Collection: Satellite imagery from Aqua MODIS was selected for this study, ensuring minimal cloud cover for accurate data. The images used were Level-3 composite satellite imagery, providing monthly average SST and Chl-a concentration values. These images were obtained from the NASA Ocean Color website, offering a spatial resolution of 4 × 4 km.

C. Data Analysis

Data analysis was conducted in three main steps: CPUE analysis, spatial and temporal analysis, and correlation analysis.

(a) CPUE Analysis: The first research objective involved calculating Catch Per Unit Effort (CPUE) by identifying catch yields and fishing effort data from the monthly logbook entries. Monthly CPUE values were computed and analyzed to identify temporal variations across the study period (2020–2022).

$$\mathrm{CPUE}_i = \frac{\mathrm{C}_i}{\mathrm{F}_i} \tag{1}$$

(b) Chl-a concentrations were analyzed using the Aqua MODIS satellite imagery. The data were categorized by seasonal periods, specifically the west and east monsoon seasons, to identify how environmental factors influence fishing

(c) Correlation Analysis: After calculating CPUE and analyzing spatial-temporal dynamics, statistical methods were employed to assess the correlations between SST, Chl-a concentration and scad catch rates. Bivariate correlation tests were used to determine the strength and significance of these relationships.

$$r = \frac{n\sum \mathrm{XY} - (\sum \mathrm{X})(\sum \mathrm{Y})}{\sqrt{[n(\sum \mathrm{X}^2) - (\sum \mathrm{X})^2][n(\sum \mathrm{Y}^2) - (\sum \mathrm{Y})^2]}} \tag{2}$$

III. Results and Discussion

A. General Overview of the Research Location

The Kendari fishing port, located in Kendari City, Southeast Sulawesi, is a Type A fishing port under the jurisdiction of the Directorate General of Capture Fisheries, Ministry of Marine Affairs and Fisheries of Indonesia. Kendari fishing port plays a vital role in the local economy and fisheries development, offering a range of facilities to support fish landing, storage, processing, and marketing activities. These facilities benefit multiple fishing fleets, including trawlers, shrimp trawlers, purse seines, hand lines, and gill nets. The port is crucial to the regional economy, functioning as a hub for fish production, resource monitoring, supporting maritime operations, and facilitating the pre-production, production, and marketing of fishery products.

B. Monthly CPUE of Scad (*Decapterus* spp)

The analysis of monthly CPUE values for two consecutive years (2020 to 2022) indicated that the highest average CPUE was observed in March at 354.65 kg/trip, while the lowest occurred in July at 53.41 kg/trip. The monthly total production is illustrated in Figure 1.

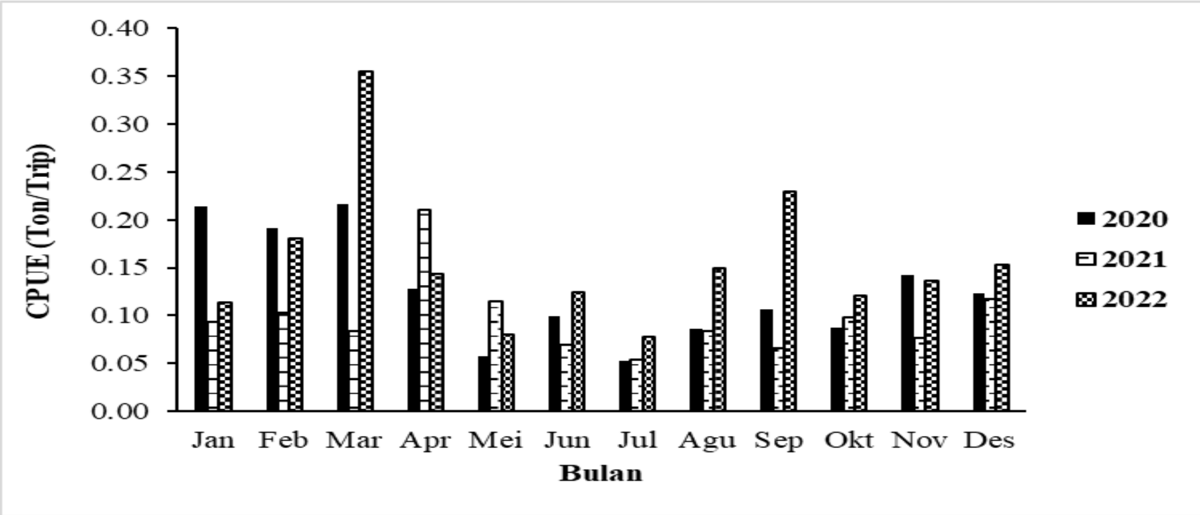

Figure. 1. Monthly CPUE of Scad (*Decapterus* spp) in the Banda Sea during 2020 - 2022

The research findings showed a declining trend in CPUE values from 2020 to 2022. The highest CPUE values in 2020 were recorded between January and March, whereas in 2021, the peak occurred in April, and in 2022, it occurred in March. The lowest CPUE was observed in May 2020, June 2021, and May and July 2022. These months mark the transition period from the west to the east monsoon season, when the waters tend to experience rougher conditions, leading to reduced catch yields due to fewer fishing trips. According to [3], wave heights in the Banda Sea reach their peak during the east monsoon season, particularly in June and July. [13] further confirmed that the highest wave heights in the Banda Sea occur between June and August, ranging from 3.51 to 6.72 meters.

C. Temporal Distribution of SST (°C) and Chl-a (mg/m^3) in the Banda Sea

The results of SST observations for 3 years (2020 – 2022) showed significant fluctuations in sea surface temperature, and SST from 2020 to 2022 ranged from 26.91 to 29.42°C. The highest SST value is found in December at 29.42°C, while the lowest SST value occurs in August at 26.91°C. The temporal distribution of SST over 3 years is presented in Figure 2.

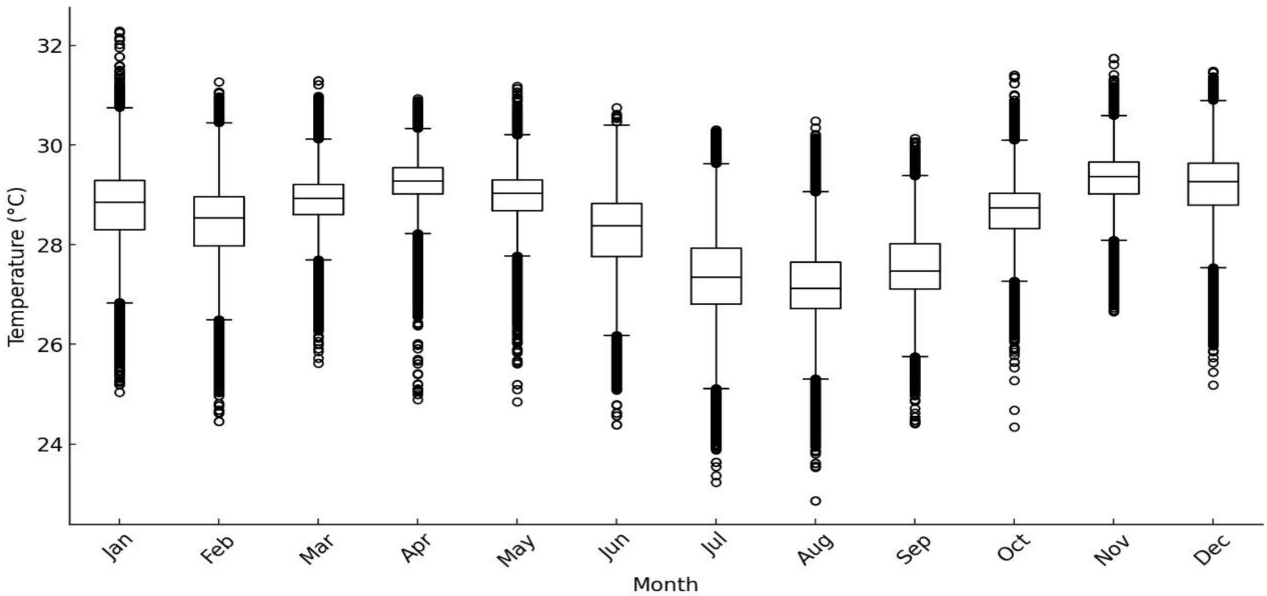

Figure. 2. Temporal Distribution of SST (°C) in the Banda Sea during 3 Years (2020 – 2022)

The results of the observation of Chl-a concentration for 3 years (2020 – 2022) showed significant fluctuations; the Chl-a from 2020 to 2022 ranged from 0.20 mg/m³ to 0.48 mg/m³. The highest Chl-a value was found in Juny at 0.48 mg/m³, while the lowest Chl-a value occurred in December at 0.20 mg/m³ mg/m³. The temporal distribution of Chl-a over 3 years is presented in Figure 3.

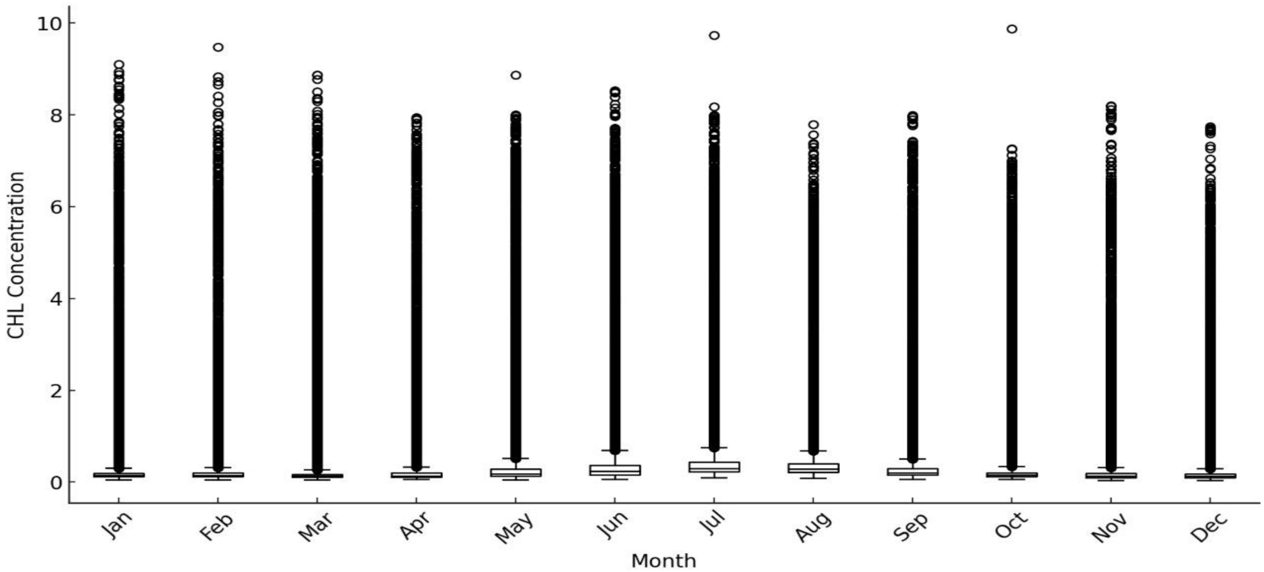

Figure. 3. Temporal Distribution of Chlorophyll-a (mg/m³) in the Banda Sea during of 3 Years (2020 - 2022)

Based on the extraction of temporal distribution data for SST and Chl-a, variations in SST within the Banda Sea in 2020 showed that the highest temperature occurred during the west monsoon in December at 29.42°C, while the lowest temperature was recorded during the east monsoon in August at 26.91°C. [15] also reported that the lowest SST in the Banda Sea occurred in August, while the highest average SST was observed in November. This finding is consistent with the study by [18], which demonstrated that SST distribution during the east monsoon is generally lower than during the west monsoon. The average monthly distribution of Chl-a in 2020 ranged from 0.20 to 0.48mg/m³. The lowest Chl-a concentrations were observed during the west monsoon, with a gradual increase starting in the east monsoon. [10] found that the highest average Chl-a concentrations occurred during the east monsoon, while the lowest concentrations were recorded at the end of the second transition season in November through the early first transition season in March. [6] reported that the highest variations in Chl-a concentration occurred from April to August.

The SST distribution in 2021 and 2022 showed a similar trend. The highest SST in 2021 occurred in December at 29.06°C, while the lowest was observed in August at 27.45°C. In 2022, the highest SST was recorded in December at 29.42°C, while the lowest occurred in August at 27.22°C. The highest Chl-a concentration in 2021 was recorded in July at 0.44 mg/m³, while the lowest concentrations ranged from 0.23 to 0.26mg/m³ from December to February. Similarly, in 2022, the highest Chl-a concentration was observed in July at 0.44mg/m³, but there was a significant decline compared to the previous year, with values ranging from 0.20 to 0.27 mg/m³ during the west monsoon (December to February).

Annual variations in SST and Chl-a concentrations are suspected to be influenced by the El Niño Southern Oscillation (ENSO) phenomenon. According to [6], high Chl-a concentrations in the Banda Sea during the east monsoon are associated with the La Niña phenomenon, characterized by decreased sea surface temperatures. ENSO events have implications for cooler sea conditions in Indonesia [7], increasing chlorophyll-a levels and significantly enhancing marine productivity [4].

D. Spatial Distribution of SST (°C) and Chl-a (mg/m³) in the Banda Sea

The spatial distribution of SST during the west monsoon from 2020 to 2022 is shown in Figure 4, indicating SST values ranging from 24.64 to 31.15°C. The highest SST concentration (31.15°C) was observed in the northwest to northeast areas of the Banda Sea in December, while the lowest SST (28.90°C) occurred in the eastern to western areas in February. The Chl-a concentrations from 2020 to 2022 ranged from 0.048 to 4.5mg/m³. Fluctuations in Chl-a concentrations during the west monsoon averaged around 0.24mg/m³. The highest concentrations were found in the western to southwestern areas of the Banda Sea in February, while the lowest concentrations were dispersed throughout offshore regions in December.

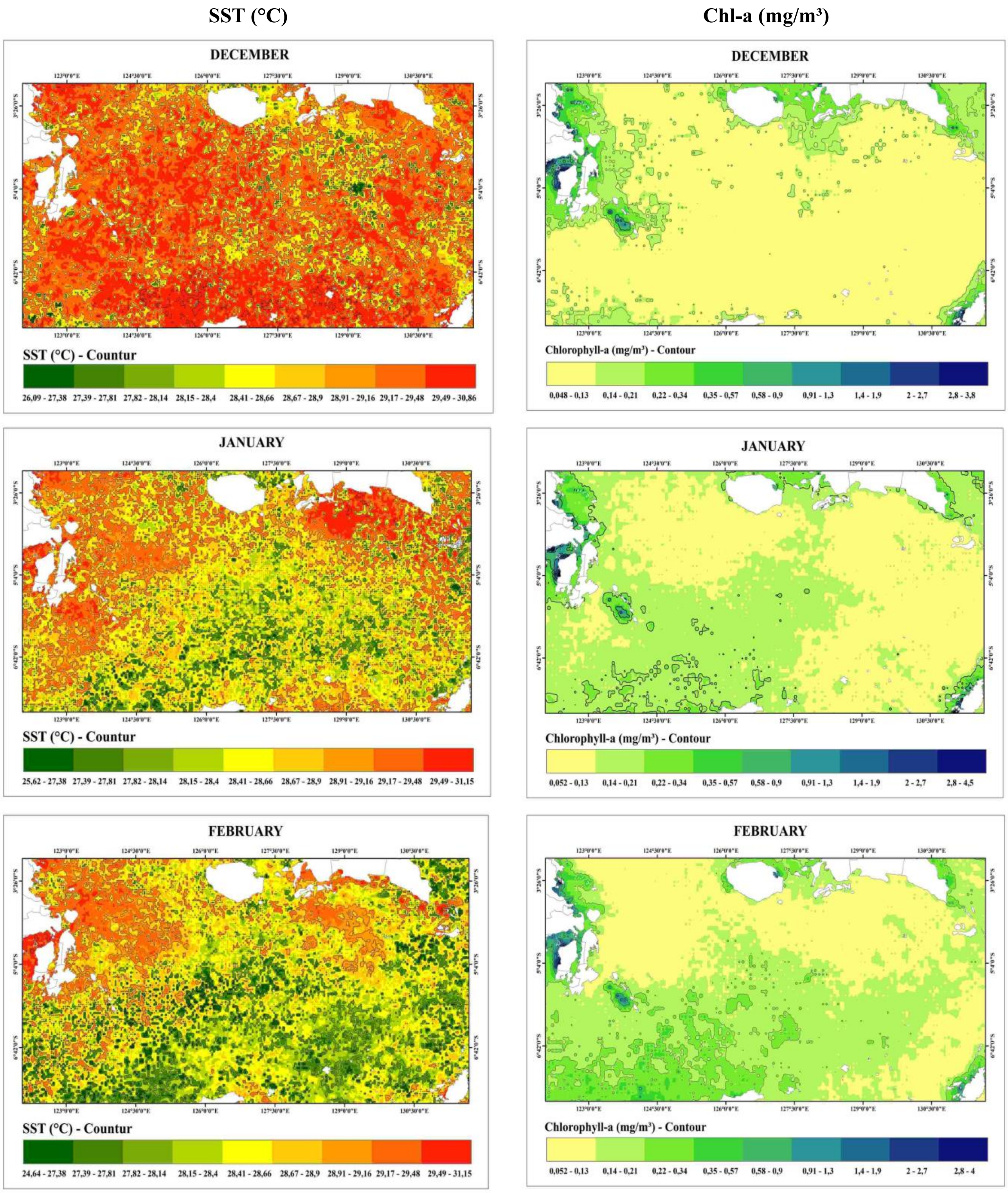

Figure. 4. Spatial Distribution of SST (°C) and Chlorophyll-a (mg/m³) in the Banda Sea during the West Monsoon

The spatial distribution of SST during the east monsoon from 2020 to 2022 is presented in Figure 7, showing SST values ranging from 24.5 to 30.86°C. The lowest SST concentration (27.19°C) was recorded in the eastern waters of the Banda Sea in August, while the highest SST (28.90°C) occurred in the southwest area in June, with an average SST of 29.05°C. Chl-a concentrations from 2020 to 2022 ranged from 0.1 to 6.7 mg/m³. Chl-a concentrations increased significantly in the northern, eastern, and southern areas of the Banda Sea. The average concentration during the east monsoon reached approximately 0.41mg/m³. The highest concentration (0.45mg/m³) was recorded in July, while the lowest (0.38mg/m³) occurred in June in the southwestern waters of the Banda Sea.

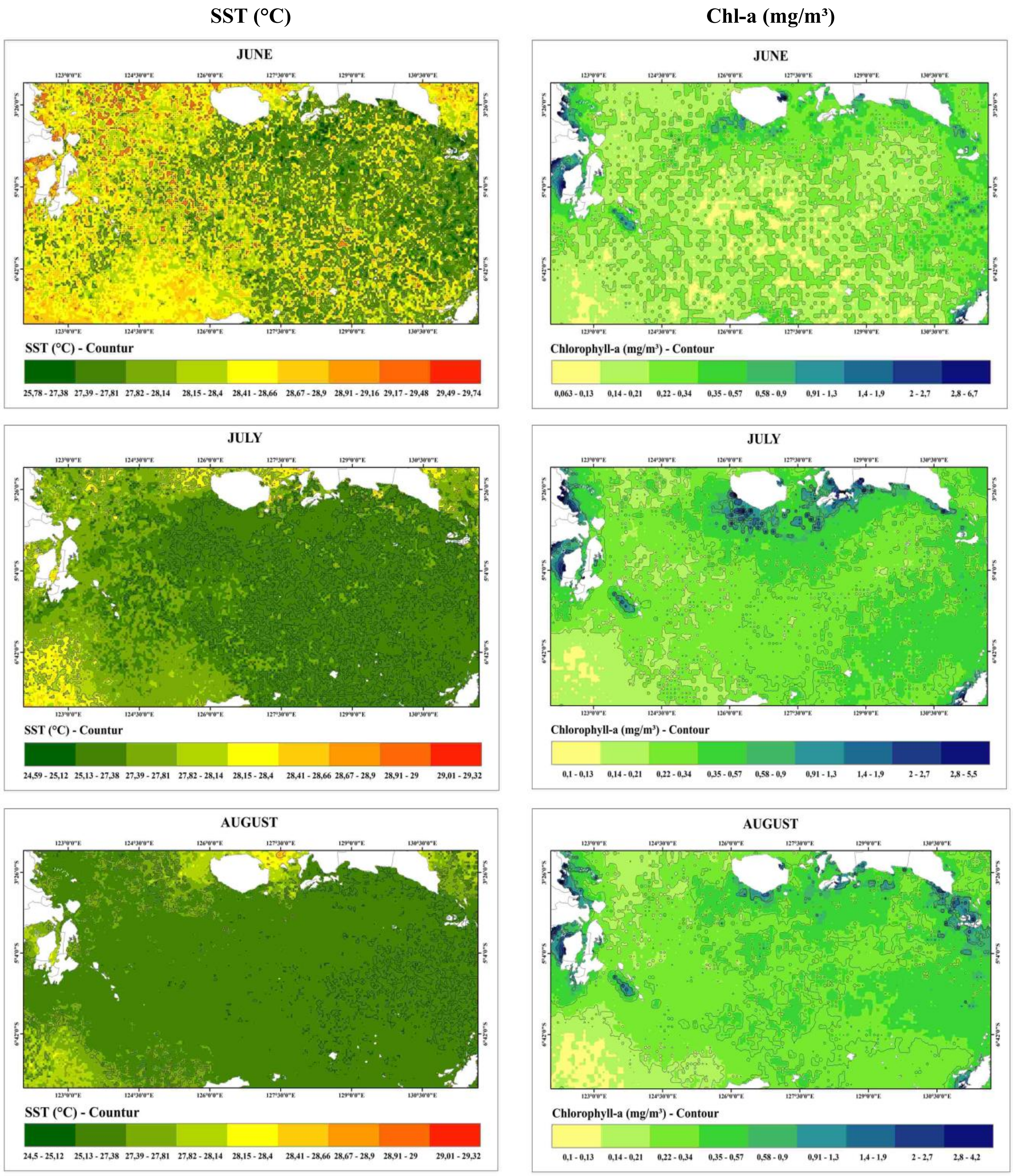

Figure. 5. Spatial Distribution of SST (°C) and Chlorophyll-a (mg/m³) in the Banda Sea during the West Monsoon

Observations from Aqua MODIS satellite imagery, processed and visualized as spatial distribution maps, suggest that seasonal variations in SST and Chl-a concentrations are likely influenced by the upwelling phenomenon driven by monsoonal winds. [19] reported that the lowest average SST in the Banda Sea during the east monsoon coincided with an increase in Chl-a concentration, indicating the occurrence of upwelling. The upwelling phenomenon during the east monsoon is caused by the southeast monsoon winds, which transport cold air masses from the Australian mainland, resulting in a temperature drop of approximately 4°C. This phenomenon is followed by increased Chl-a concentration and marine productivity [28]. Similar conditions were reported by [29], who found that the peak upwelling in the Banda Sea occurs during the east monsoon in August. High Chl-a concentrations were observed from the east monsoon through the early part of the second transitional season [16].

E. Relationship Between SST (°C) and Chl-a (mg/m³) with Scad (*Decapterus* spp) CPUE

The correlation diagram between SST, Chl-a, and CPUE values shows a decline in CPUE between May and October, ranging from 0.08 to 0.10kg/trip, in parallel with decreasing SST and increasing Chl-a concentrations. Conversely, from November to April, CPUE values increased to 0.12 to 0.17kg/trip, coinciding with rising SST and decreasing Chl-a concentrations.

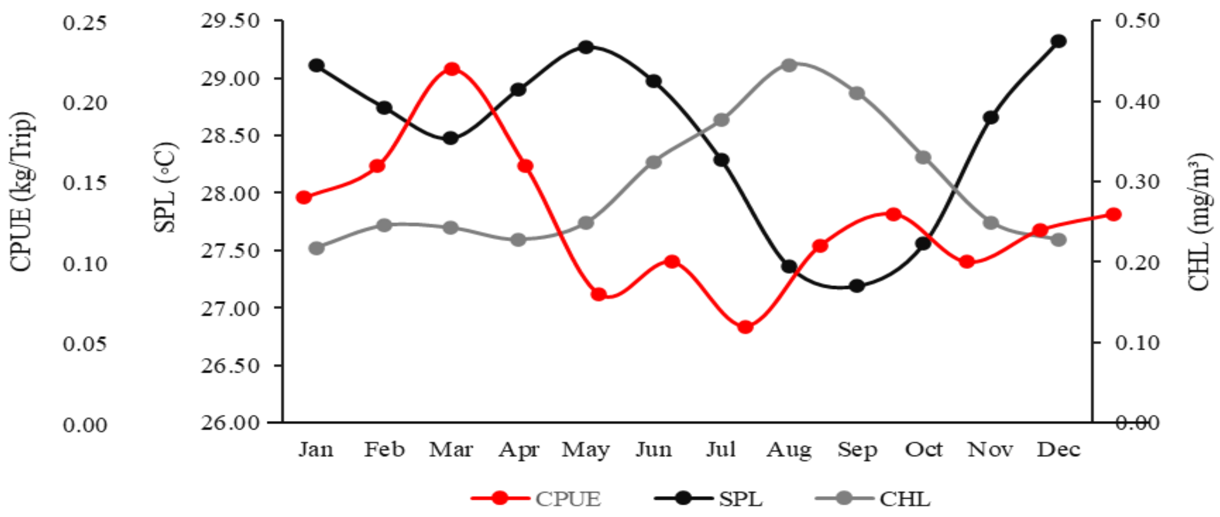

Figure. 6. Temporal Correlation Diagram of SST (°C) and Chlorophyll-a (mg/m³) with CPUE of Scad (*Decapterus* spp)

The relationship between SST and the CPUE of scad shows that the sea surface temperature ranged from 27.19 to 28.90°C. Within this range, SST remains within the optimal temperature conditions for aquatic organisms (between 18 and 30°C). Pearson correlation analysis indicated a weak positive relationship between SST and CPUE, with a coefficient of 0.382 and a significance value of 0.220. An increase in SST resulted in higher catch rates, which contradicts the findings of [2] that rising SST negatively affects catch yields. Figure 10 shows a positive correlation between SST and CPUE, indicating that catch yields increased alongside rising SST. This observation aligns with [18], who found that a rise in CPUE accompanied an increase in sea surface temperature. Fluctuations in SST are critical factors that stimulate and determine the aggregation and grouping of fish, as variations in temperature directly impact catch productivity. Each fish species has a specific temperature range required for survival and growth [31].

The correlation coefficient between Chl-a concentration and CPUE indicates a moderate negative relationship of -0.709, with a significance value of 0.10. This suggests that CPUE decreases as Chl-a concentrations increase. Conversely, lower Chl-a levels are associated with higher CPUE values. This finding contradicts the study of [5], which revealed that increasing Chl-a concentrations positively affect scad CPUE. [27] also highlighted that Chl-a concentration significantly influences the catch of small pelagic fish, including scad. The highest CPUE values corresponded to Chl-a concentrations of 0.24mg/m³, while average Chl-a concentrations in the Banda Sea ranged from 0.22 to 0.45mg/m³. The Chl-a concentrations above 0.2 mg/m³ indicate the presence of sufficient phytoplankton and the related food web to support commercially viable fisheries operations, while SST on the CPUE of scad has no effect at 0.382, which means weak positive.

IV. Conclusion

Based on the data processing and analysis, the conclusion is as follows:

a) CPUE Decline and Seasonal Variability. Catch per unit effort (CPUE) exhibited a progressive decline across the study period, with annual ranges narrowing from 53.41–216.44 kg/trip (year 2020) to 78.24–354.65kg/trip (year 2022). Intra-annual patterns showed consistent seasonal peaks in March–April (210.00–354.65kg/trip) and minimums in July (53.41–78.24 kg/trip), suggesting thermal or prey-driven migration influences.

b) Environmental Drivers.
- Sea Surface Temperature (SST): Displayed inverse seasonal dynamics, peaking at 29.42°C (December 2022) during west monsoon periods and troughing at 26.91°C (August 2020) in east monsoon phases. Coastal zones maintained elevated SST compared to offshore regions.
- Chlorophyll-a(Chl-a): Demonstrated complementary seasonality to SST, with maximal (0.48 mg/m³, June 2020) aligning with east monsoon upwelling and minimal (0.20mg/m³, December 2022) during stratified west monsoon conditions. The spatial distribution of SPL and chlorophyll-a tends to be higher in areas close to the mainland and lower in offshore areas.

c) Bivariate analysis identified a moderate negative correlation between Chl-a and CPUE (r = -0.464), implicating prey dispersion or habitat compression mechanisms in productive waters. The weak SST-CPUE relationship (r = 0.101) suggests thermal thresholds within the observed range (26.91–29.42°C) do not directly limit scad availability.

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